Pluralism and Complexity

Tolerance and Dialogue in Economics and Other Empirical Sciences

Alessandro Vercelli

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Pluralism in economics is the view that modern approaches to studying economic phenomena are too restrictive. It is an important issue within the development of the discipline as many approaches that were once deemed to be outside the mainstream have now become part of the consensus, for example, game theory, behavioural economics, and information economics. *Pluralism and Complexity* explores the philosophical background to pluralism and shows how this can be applied to modern economics. It examines key moments like the Keynesian Revolution and the New Classical counter-revolution to show how different 'epistemic visions' arise from fundamentally different ways of handling and simplifying complexity. Examining the history of aggregate economic analysis, this book argues that the propagation of a dogmatic view of science by political and self-interested elites creates a severe deficit of pluralism in macroeconomic research and offers suggestions for reversing this dangerous trend in economics and beyond.

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For Francesco

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Preface

1. The first motivation that prompted me to write this book is the deep-seated conviction that there is a conspicuous deficit of pluralism in macroeconomic research and in the usual way of teaching it, as well as in several mainstream business and policy applications. A similar deficit of pluralism has been denounced by researchers working in other scientific disciplines: not only in social sciences but also in natural sciences, including medical sciences, environmental disciplines, and fundamental physics. This deficit of pluralism in evidence-based research has huge scientific and policy implications that must be urgently tackled. Although many authoritative voices and grassroots initiatives have recently addressed this issue stigmatising it with growing frequency and alarm, the awareness of its epistemic and pragmatic consequences is still insufficient. In addition, the occasional countermeasures taken at the local level have been so far insufficient to create an influential movement of opinion able to reverse this negative trend. The causes of the systematic undervaluation of the crucial role of pluralism are multiple and complex. In particular, an instrumental use of science by self-interested decision-makers thrives on the misleading myth that updated science agrees on a unique interpretive and pragmatic message. This dogmatic view of 'science' is propagated with increasing vigour by mass media, political institutions, and self-interested consultants facilitating an instrumental use of empirical science. It is thus important to clarify that this distorted view does not reflect what science should be and usually is. Though the backbone of my analysis is pluralism in economics, I insert its discussion in the frame of a broader investigation on pluralism in empirical science. My preliminary definition of scientific pluralism is an attitude of active tolerance for alternative theories, models, methods, and interpretations focusing on the same empirical evidence. Notice that my initial definition of pluralism remains willingly somewhat fuzzy to

avoid rigid demarcation lines that would impair the analysis of the evolution of pluralism in economics and other empirical disciplines. The analysis of pluralism as a field of study did not yet reach a stage suitable for a more formal analysis.

2. Most economists pay lip service to pluralism but look scarcely motivated to implement a workable version of it in practice. Researchers usually avoid any explicit attack against pluralism, probably because of its evident nexus with liberty and democracy, two basic values of modern society that few economists would dare to question. It is obvious to anyone that democracy would be meaningless without political pluralism, and that pluralism in economics is a fundamental pillar of political pluralism. However, several mainstream economists did not hesitate to assert, at least in private, that there is only one relevant distinction in economics, the distinction between 'good' and 'bad' economics. The criteria for this distinction are then usually set according to a rigidly monist vision of updated Science that tends to exclude a priori the scientific character of alternative approaches. Of course, even this sort of fundamentalist monism cannot exclude a certain degree of pluralism to the extent that it can be somehow encompassed within the mainstream paradigm itself. Researchers sharing the same vision may interpret and assess the empirical evidence in different ways. As for theory, significant internal divergences may branch in different variants of the same approach. A case in point is the bifurcation between the *monetary* business cycle models (Lucas 1981) and the *real* business cycle models (Kydland and Prescott 1982). This split remained internal to the general vision of New Classical economics because the two branches shared analogous assumptions and a similar methodological approach, apart from the conspicuous exception of the causal direction between money and income. As for the heterodox economists, they often endorse pluralism but not always conceive it as an end in itself. Some of them waive the flag of pluralism to defend the advocated heterodox approach from the intolerance of the mainstream school but then do not hesitate to assume a position of similar intolerance not only against the mainstream school but also against alternative heterodox schools.

This book advocates pluralism as a crucial requisite of sound science and – indirectly – of liberty and democracy. I hope that my analysis may help to find some suggestions to reverse the ongoing trend. This endeavour is huge and calls for systematic initiatives meant to substantiate tolerance and dialogue on scientific issues and their policy and social consequences. This requires a broad consensus on the foundations and goals of scientific pluralism.

The approach worked out in this book refers mainly to the epistemic foundations of the principal schools of macroeconomics and their coevolution with the history of facts. I believe that a similar approach could be pursued also in other subfields of economics and could as well be adapted to different social sciences and, possibly, to some controversial areas of natural sciences, including medical and environmental research.

3. In all scientific disciplines, different 'visions' emerge and persist evolving through time. These scientific visions are often mutually inconsistent and lead to diverging interpretations of the empirical evidence. The understanding of the crucial role of epistemic visions should not lead to scepticism or relativism, as some philosophers and scientists asserted or feared, but only to the awareness that the search for truth is influenced by the point of view of researchers. The critical pluralism advocated in this book does not rule out a comparative appraisal of the existing epistemic approaches, and their interpretation of the empirical evidence. Therefore, I will do nothing to conceal my methodological and interpretive preferences, but I will avoid any specific emphasis on them. I will try hard, instead, to understand the alternative points of view under investigation to the best of my capabilities, running the risk of being accused of relativism or eclecticism, attitudes that I don't endorse. Critical pluralism rejects active intolerance, namely acts or words, expressing prejudicial opposition to different points of view and advocates active tolerance, welcoming any opportunity of learning from different points of view. This open-minded attitude should aim at establishing a constructive dialogue between interlocutors entertaining different views. One advantage of the suggested definition of pluralism in terms of tolerance is that it builds a robust bridge with the political meaning of pluralism. This link may help us clarify the interaction between scientific and political pluralism. If all epistemic visions were actively tolerant of alternative visions and open to dialogue, pluralism would be easy to implement. Unfortunately, this is not the case. This explains why it is so difficult for genuine pluralists to promote and implement their points of

view. As is well known, the tolerance for intolerants is bound to increase the power of intolerance. This vicious circle may end only when tolerance is completely defeated, even if some (limited) tolerance were retained for cosmetic reasons. To build genuine tolerance, people of good will must work hard in relatively quiet periods through routines and institutions that try to build and consolidate mutual understanding among people avoiding any element that can trigger uncontrollable tensions. Unfortunately, it is very difficult to build trust while it is very easy to destroy it. What is important is thus to keep alive a constructive dialogue between all the virtual interlocutors, while each of them remain open to the possibility of learning something significant from their opponents.

I discuss pluralism in this book as the object of a specific field of study. Often the word pluralism has been used simply in a descriptive sense to designate a plurality of alternative models or theories on the same issues in a specific situation, or to advocate its normative value. What we need is much more. First, we need a systematic study of the interactions between different forms of approaches referring to the same issues and their normative implications. Second, we have to study causes and effects of different varieties of pluralism on the evolution of science and its influence in society. Since the topic of pluralism as an autonomous field of study is exceedingly broad and articulated, my investigation is necessarily limited in many directions. First, although several arguments discussed in this book could be applied to most empirical sciences, I developed them mainly in reference to *aggregate economics* and its microfoundations. A further limitation was the focus on the fight for hegemony between the most influential schools of thought recognised by the Academia and governments. Therefore, I excluded almost completely from my analysis all the schools that have been considered heterodox by the ruling élites. This is a huge limitation. Heterodox schools are often very influential, much beyond what is usually recognised. The case of Marxism is particularly significant. But also other heterodox schools (such as the Austrian, the Institutionalist, and Neo Ricardian schools) continue to have a significant impact. I recognise the depth of these lacunae. However, if the approach introduced in this book will stand up to the critiques of my readers, a similar approach may be extended to heterodox economics. In addition, a similar approach may be applied with adaptations to more restricted topics referring to particular authors, historical periods, geographic areas, epistemic constructs, and so on.

4. In this book, the main focus of the arguments has been directed to a particular aspect: the relation between pluralism and complexity. This choice narrows the scope of analysis but is far from arbitrary because a basic causal divergence of scientific paradigms in empirical sciences depends on the different approach towards complexity. Therefore, I am going to discuss the impact on pluralism of the main dimensions of complexity:
   (i) *Dynamic dimension*: the dynamic behaviour of a system is conditioned by the internal connections among the parts and the external connections with the environment. Complex dynamics depends crucially on the non-linearity of the system's connections.
   (ii) *Structural dimension*: the structural complexity of a system depends on the number and heterogeneity of the constituent parts, the levels of their internal organisation, and the nature of their horizontal and vertical links.
   (iii) *Irreversibility of time*: the complex dynamics of the system is signalled by the sensitivity of its behaviour to the direction of time.
   (iv) *Evolutionary dimension*: the complexity of an evolutionary system depends on the process of irreversible structural change that combines the structural, dynamic, and temporal dimensions of complexity listed before.
   (v) *Random dimension*: complex systems are often characterised by a random component that jeopardises the understanding and predictability of their behaviour.

   Each dimension of complexity may raise serious problems to the analysis of a system behaviour, problems that require appropriate methodological devices and countermeasures some of which I will discuss in this book, in particular in Chapter 12. The different solutions pursued are a crucial source of scientific pluralism.

5. So far, I made explicit reference mainly to economics. However, it is easy to find similar problems in all evidence-based sciences. This led me to extend my investigation to philosophy of science and physics, the scientific discipline that has been often considered by

philosophers and economists as the paradigmatic empirical science. Most economists share a sense of mistrust for arguments referring to philosophy of science because of its alleged sterility, and arguments referring to physics because of the risk of misleading analogies. Some exclude any sort of comparison between different disciplines for their alleged incommensurability. However, as for philosophy of science, all the great economists have been exceptions: Hume, Smith, Mill, Marx, Marshall, Schumpeter, Keynes, and Lucas are significant examples. This is true also in physics as in the case of Kepler, Galileo, Newton, Mach, Boltzmann, and Einstein. In both physics and economics, all the initiators of scientific schools have always shown a strong interest in philosophy of science because their new visions were first reconceptualisations of existing theories that were bound to raise time-honoured philosophical issues. My investigation on pluralism focuses mainly on the initiators of scientific traditions and thus on their struggle to build a coherent interaction between scientific and philosophical visions. As for the nexus between economics and physics, we can learn a lot from analogies and differences, if we always keep in mind the intrinsic limits of this sort of comparison.

6. I adopted in this book an evolutionary approach to scientific pluralism focusing on issues based on the relationships between the scientific visions of researchers, their implementation through models, and the research programmes providing the guidelines for model building. The three polarities of this interaction evolve to adapt to the structural changes in the issues investigated and in the available tools box. New models are built to answer new research questions posed by the evolving subject matter and seek to answer better the extant research questions. This process of innovation may lead to the revision of the research programme or its substitution with a new one believed to be more coherent, more up to date, or just more efficient. The scientific vision itself, which is usually more persistent than specific research programmes, slowly evolves to adapt to a new epistemic and pragmatic environment. This approach is not new. As we will see in Chapter 4, philosophy of science has recently developed different variants of an evolutionary approach to history of science. By discussing some of them, I will clarify the specificity of my approach. My analysis will focus on some details of the grand evolutionary tree of Western thought that

grew from the robust roots implanted in the classical period of Ancient Greece about 2500 years ago. Though the pre-Socratic philosophers, who put the early seeds of the process, rejected the traditional polytheism of traditional culture to find a unifying principle (*arché*) ruling the cosmos, they introduced a new form of pluralism consistent with evidence-based science and critical philosophy. This seminal 'critical pluralism' found its early full-fledged form with Socrates finding its emblematic expression in the early dialogues written by his pupil Plato. Within the complex evolutionary tree of Western thought, I will limit my analysis to the specific path of critical pluralism, the vital lymph that gave a crucial contribution to the fecundity and resilience of its amazing growth. After the foundational period of Ancient Greece, I do not need to investigate how critical pluralism survived and evolved in the next two millennia, plagued by wars, invasions, and ideological and religious conflicts. I resume my sketchy narrative from the Renaissance period when critical pluralism revived with the renewed passion for the classical civilisation. The vital lymph of critical pluralism nurtured the 'scientific revolution' that broke down in the late Renaissance and started the Modern Era of western thought. In the same period, also the new science of political economy started an evolutionary path that I briefly reconstruct from the point of view of pluralism.

Structure of the Book

The book is articulated in four parts. Part I sketches the early evolution of critical pluralism in epistemology and empirical science since its birth in Ancient Greece (Chapter 1), its crucial development during the Scientific Revolution (Chapter 2), and in its aftermath (Chapter 3). This part contributes to clarify the approach to pluralism pursued in this book, in the light of the recent influential contributions of post-positivist epistemology (Chapter 4). In Part II, the focus shifts to aggregate economic analysis. Chapter 5 deals with the early evolution of political economy. I select a few authors and schools of thought who had a significant influence on the subsequent policy of governments. Chapter 6 sketches the evolution of aggregate economics since the beginnings of the Marginalist Revolution in the 1870s. The change of name from Political Economy to Economics reflected a change of skin by a discipline that narrowed the scope of its analysis and the variety of its methods. The success of the new vision did not occur unchallenged. At the turn of the century, harsh methodological disputes divided the emergent field of economic studies (Chapter 7). This affected the evolution of the analytic models, in particular the General Equilibrium model (Chapter 8). Part III deals with an era characterised by dramatic political upheavals, great economic crises, the catastrophic impacts of two WWs and then the urgency of the massive post-war reconstruction. In such a period, the conflict between different schools of thought in economics became inevitably much harsher also within democratic societies. This led to the Keynesian Revolution starting in the 1930s (Chapters 9 and 10), and then to the New Classical Counter-revolution since the early 1970s (Chapter 11). In Part IV, I sketch a path towards a workable form of critical pluralism that might contribute to invert the current trend characterised by a growing deficit of pluralism. To this end, the focus reverts on the epistemological issue of complexity (Chapter 12). Chapter 13 discusses different varieties of decision theories under uncertainty from the point of view of their ability to deal with complexity. The constructive approach suggested in this book is based on a suggested taxonomy of scientific visions meant to clarify their peculiarities and relations (Chapter 14). This contributes to clarify the process of coevolution of economic systems and economic visions (Chapter 15). Finally, the last chapter provides some ideas about how to implement a workable form of critical pluralism in the light of the preceding analysis.

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Tables and Figures

Abbreviations

Classical:	mainstream school of political economy since Adam Smith until the Marginalist Revolution
classical:	mainstream school of aggregate economics criticised by Keynes (1936)
CW:	*The Collected Writings of John Maynard Keynes*, Edited by Elizabeth Johnson, Donald Moggridge, Published by the Royal Economic Society, Cambridge University Press
CWM:	*Collected Works of John Stuart Mill*, Edited by Jean O'Grady, John M. Robson. London: Routledge
GE:	General Equilibrium
GT:	General Theory (see Keynes 1936)
KE:	Keynesian economics
QTM:	Quantity Theory of Money
TP:	Treatise on Probability (see Keynes 1921)
Nc:	New classical
NcE:	New classical Economics
NCS:	Neoclassical synthesis
NK:	New Keynesian
RBC:	Real business cycles
REH:	Rational Expectations Hypothesis
SEP:	*The Stanford Encyclopedia of Philosophy*, Edited by Edward N. Zalta
VAR:	vector autoregression

PART I

The Epistemic Foundations of Pluralism

1 *Rationality and Pluralism*
Genesis and Coevolution

Carlo Rovelli:[1] *it is easier to understand ideas by starting with the roots from which they have grown, and an important number of the ideas which turned out to be effective for understanding the world originated over two thousand years ago. If we briefly retrace their birth, they become clearer, and the later steps turn out to be simpler and natural.*

Xenophanes:[2] *But as for certain truth, no man has known it, nor will he know it [. . .] And even if by chance he were to utter the perfect truth he would himself not know it. For all is but a woven web of guesses.*

The concept of reason has always played a crucial role in Western thought. I assume that reason is the faculty to appraise rationality, while the latter designates the desirable features of arguments and actions to reach a certain goal. In science and epistemology, few scholars dared to question the authority of reason. This is true not only of rationalists who put reason above any other authority, but also of empiricists, who always asserted the ultimate authority of experience. However, under the same name, believers in reason happened to worship different gods. This often jeopardised the possibility of a constructive dialogue between different visions. Often, what was rational for one stream of thought was irrational for another. In this chapter, I will try to clarify the most important dimensions of rationality to make possible a constructive dialogue between different visions. To this end, this chapter aims to provide a brief reconstruction of the early evolution of the concept of rationality in Western thought. The starting point is the observation that the different notions of rationality have a common root in the Greek concept of *logos* (Section 1.1). This concept focused on the paradox of change that found divergent early

1 Rovelli (2017, 1).
2 Xenophanes, in the translation of Popper (2012 [1998], 51).

solutions in the teaching of Heraclitus and Pythagoras (Section 1.2). The discovery of irrational numbers in the fifth century BCE by the Pythagoreans was a crucial turning point that redirected the evolution of rationality concepts (Section 1.3). Delving deep into the logical implications of the problem of change, the Eleatic School of Parmenides and Zeno denied the possibility of authentic change (Section 1.4). In Section 1.5, I analyse how the atomists, under the lead of Democritus, reversed the argument of Parmenides suggesting a solution that was going to influence philosophy and physics for many centuries up to contemporary research. Under the stimulus of these hot debates, the ancient logicians clarified that a fundamental requisite of epistemic rationality is the logical consistency of arguments that must comply with the law of non-contradiction (Section 1.6). In Section 1.7, I discuss how dialectic extends epistemic rationality to the dialogic interaction between different subjects. Since its early stages, dialectic branched into two different directions that have diverging implications for the issue of pluralism (Section 1.8). In Section 1.9, I distinguish sharply the *critical* dialectic of Socrates as represented in the early dialogues of Plato from the *teleological* dialectic of Plato's later political dialogues. In the final section. I discuss the problematic links between two different visions of rationality: extension of true knowledge or potential of learning. As we will see in the following chapters, this dichotomy plays a crucial role in many empirical sciences, including economics, and underlies two opposite views of scientific pluralism.

1.1 The Origin of the Concept of Rationality

The extraordinary achievements obtained by pre-Socratic thinkers have a strong link to pluralism. In about two centuries Greek philosophy and science developed from the path-breaking original stage of Thales (c.624–c.545 BCE) to the sophisticated complexity of Plato (c.424–347 BCE) and Aristotle (384–322 BCE) that continued to exert a great influence on the successive evolution of human knowledge. We can explain the rapid growth and prolific flourishing of this evolutionary tree only by appealing to exceptional conditions favouring the cross-fertilisation of theories and approaches. First, the Greek civilisation flourishing in the same period was nurtured by an interacting plurality of small political and cultural entities (city-states or *poleis*) mutually connected by an easily navigable sea, the same conditions that in the same period favoured the development of market relations and the early diffusion of money. In addition, the Greek city-states established on the eastern part of the Aegean Sea entertained systematic relations with the great empires of the East that in certain fields – such as mathematics, geometry, and astronomy – were rapidly shifting the frontier of knowledge. The systematic exchange of ideas was a powerful stimulus for the establishment of high-level schools of thought such as the Milesian School in Miletus and the Pythagoreans in Samos. When the Persians invaded the Greek city-states of western Anatolia in the middle of fifth century BCE, this produced a diaspora of many scholars who established their schools in safer areas – mainly in Athens and southern Italy.[3] In this period, the Greek Schools of thought entertained strong mutual interactions that stimulated the rapid development of their teaching.[4] All these unprecedented conditions kindled a sustained lively dialogue within and between the different schools of thought that contributed to their flourishing, rapid evolution, and remarkable achievements. As we will see, similar geopolitical conditions favourable to pluralism stimulated subsequent periods of exceptional creativity in science and art. A case in point is Renaissance leading to a deep renovation of art and science.

Since the beginning of the sixth century BCE, pre-Socratic philosophers started a tradition of thought meant to propose an approach to knowledge and ethics alternative to the traditional wisdom of early Greek culture. While the tradition based on myths was highly suggestive but fragmentary and subject to countless variations and interpretations, pre-Socratic philosophers rejected the traditional theology of Homer and Hesiod looking for a unifying 'origin' or 'principle' (in Greek *arché*) capable of accounting for the ultimate design of the world (*cosmos*). The first attempts pursued by Milesian philosophers focused on some substance assumed to pervade the entire world. Thales (c.624–545 BCE), the founder of the Milesian School, maintained that the ultimate substance is water. Anaximander (610–545 BCE), a pupil of Thales who became his successor, held a more sophisticated view asserting that the material world is composed of a boundless and formless substance, dubbed *apeiron*, that originates the world's

[3] For example, Pythagoras in Croton, and Parmenides in Elea.

[4] Apart from the partial exception of the Pythagorean School, these schools succeeded in developing a strong identity without resorting to any sort of paralysing dogmatism.

elements (water, earth, air, fire) and rules their motion and change.[5] His successor Anaximenes (585–526) did not accept the idea that a boundless and formless substance could explain movement and change. This is likely to be the main reason why Anaximenes replaced the *apeiron* with *air* as basic *arché* of the world. The influence of air on crucial everyday phenomena such as weather, seasons, and agriculture looked much more intuitive and concrete in a mainly agricultural society.[6]

The Milesian School conceived the world as an ordered and stable building (*cosmos*) and investigated not only the nature of its constitutive material but also its construction plan conceived as invariant. Heraclitus (c.535–c.475 BCE) was the first philosopher who reacted against the naturalist approach of the Milesian School and started the influential tradition of thought based upon the concept of *logos*. He maintained that the basic element of the world is fire, but this assertion should not be interpreted as a naturalistic claim like those of the Milesian School but as a suggestive metaphor of the ubiquitous change that characterizes the *cosmos*. He wanted to emphasise that the world is not composed of invariant things but of processes that continuously change. In his opinion, change depends on the conflict between opposites that characterises all processes. Their unity he called *logos*. This new way of conceiving the *arché* of the cosmos started a tradition that had a great impact on the evolution of Western thought. His conception of *logos* sprang from the creative and unifying power of language that may capture the hidden unity underlying the plurality of phenomena. The *logos* provided the fundamental bridge between sound arguments and the true structure of the world. According to Heraclitus, everything is in constant flux, and every changing object contains at least one pair of opposites.[7] However, in his view, a process

[5] The concept of *apeiron* witnesses the progressive emergence in pre-Socratic philosophy of a bold capacity of abstraction. This is confirmed by other innovative ideas entertained by Anaximander. In particular the idea that the earth is suspended in space has been considered by philosophers and scientists a first fundamental step in abstract thinking. Popper, for example, argued that this idea 'is one of the boldest, most revolutionary, and most portentous idea in the whole history of human thinking' (quoted by the eminent physicist Rovelli (2023 [2007] 60) who shares the same judgement).

[6] See Popper (2012, 15–16.)

[7] For example, according to Heraclitus, 'the road up and the road down are the same thing' and this provides an example of unity of opposites. Heraclitus also

undergoing change persists despite the coexistence of opposite tendencies. This is because, according to Heraclitus, the unifying force of the universe is the hidden harmony of opposed forces 'due to recoil and tension, as in the bow or the lyre'.[8]

1.2 Reason and Change: Heraclitus and Pythagoras

Heraclitus's conception of reason (*logos*) raises the 'problem of change' that became the crucial problem of Greek natural philosophy deeply affecting all its branches, including cosmology, physics, and logic. Heraclitus's universal flux is the continuous change of the cosmos' constituent parts. The trouble is that we can consistently say that one thing changes only if, notwithstanding the change, it keeps its identity. Heraclitus's solution is that the constituents of the cosmos are not 'things' that change but processes in continuous flux whose structural features remain invariant through time and space. According to the famous metaphor of the river, we cannot swim in the same river: this is an illusion, a mistaken abstraction from reality. All things are like fire. A flame may look like a thing, but we know that it is not a "thing" but a process.' All single processes merge in the global process of change within which all the oppositions interact and converge towards a unity. What Heraclitus means by unity of opposites is not clear. However, in a few fragments he seems to evoke a rudimentary concept of equilibrium as balance of opposite forces. The nexus between reason and equilibrium is much more evident in an alternative, broadly contemporaneous, interpretation of *logos* as the ultimate *arché* of the world, that of Pythagoreans. The origin of the concept of rationality as *logos* has been often associated with the teachings of Pythagoras (c.570–c.495 BCE). He was a generation senior to Heraclitus, but our first-hand knowledge of his thought is very limited because none of his writings survived and subsequent references are unreliable and contradictory.[9] According to the early tradition, 'Pythagoras was primarily a figure of religious and ethical significance, ... for whom number and cosmology primarily had significance in this religious and moral context' (ibidem). It is not clear if his subsequent fame as mathematician

refers to opposites as a basis for change: 'cold things grow hot, hot things grow cold, a moist thing withers, a parched thing is wetted' (DK B126).

[8] I adopt here the translation by Popper (1945, 15.)

[9] See Huffman (2018).

and cosmologist was really deserved or just the consequence of a posthumous glorification by his numerous pupils and followers. We do not know for sure whether Pythagoras himself used the word *logos*, but we find this concept in a pivotal position in the surviving works and fragments of his followers in the fifth and fourth centuries BCE, in a meaning quite different from that of Heraclitus. The influence of Pythagoreans on the history of philosophy and science cannot be exaggerated: 'Pythagoras exceeded all the other pre-Socratic schools both in the number of his followers and in the continuity of his doctrine. Indeed, Pythagoreanism was the only strain of Presocratic thought to survive, albeit in much-modified form, until the end of antiquity' (Zhmud, 2014, 88). What was common to Pythagoreans before Plato[10] was the conviction that numbers reveal the foundations of both the celestial and earthly worlds. This is usually recognised by ancient sources. For example, Aristoxenus – a philosopher of Pythagorean education who became an influential pupil of Aristotle – asserted that 'Pythagoras more than anybody else seems to have valued the science of numbers and to have advanced it, separating it from the merchants' business and likening all things to numbers.' As Pythagoras asserted, '... number contains all things ... and there is a ratio to each other between all the numbers'.[11] This fragment confirms the crucial role of numbers in Pythagoras's metaphysics, and that this is linked to the early Pythagorean belief in the existence of an exact ratio between all of them. This conviction is likely to come from the fact that the calculus of the ratio (*logos*) of rational numbers is a process that converges towards an exact value that represents the equilibrium of this epistemic process. While in Heraclitus the coincidence of opposites provides the ultimate foundations for the unity of the universe, in the early Pythagorean tradition such a unity is retrieved by the principle of non-contradiction guaranteed by rational ratios interpretable as stable equilibrium states. As is well known, the etymology of both rationality and reason, as well as that of other related words (such as

[10] Pythagoras did not found a philosophical school characterised by some precise doctrine, but a community (*hetaireia*) with religious, political, and ethical goals. The members of the community practiced different disciplines including mathematics, astronomy, music, medicine, and athletic and military training. I am here exclusively interested in the mathematicians that became increasingly influential in the history of philosophy and science.

[11] Fragment 23 quoted in Zhmud (2012, 96).

ratiocination, rationale, and reasonable) comes from the Latin word *ratio*, whose original meaning is that of division between two integer numbers. The Latins translated with the word *ratio* the Greek word *logos* having in mind the Pythagorean view of rational numbers. Greek philosophers eventually managed to unify under the term *logos* a series of attributes that in Greek mythology were associated to different gods: not only reason, rationality, but also word, proportion, and law.[12] This polysemous word evolved in a particularly pregnant concept of reason branching in different directions that deeply affected religion, metaphysics, science, theory of music, visual arts, and architecture.

Since Heraclitus and early Pythagoreans, the concept of *logos* plays the crucial role of revealing the hidden unity of the *cosmos* underlying the apparent plurality of processes, relations, and things. From then on, rationality has been associated in formal and empirical sciences with logical consistency as required by the law of non-contradiction. In religion, the *logos* became the matrix of the monotheist god exercising the supreme power of generating and ruling the cosmos. In early Christian theology, the *logos* came to designate the divine reason generating the world, and giving it form, order, and meaning. The concept of *logos* came to play the role of arch stone in the Greek building of culture and civilisation. In metaphysics, the concept of *logos* combined its multiple meanings with the pre-Socratic effort of reducing the essence of the world to a single principle. In science, the concept of *logos* provided the rational foundations for warranted knowledge (*episteme*) that distinguishes science from lower-rank forms of knowledge, such as myth or mere opinion (*doxa*).

The concept of *logos* has a different focus in different streams of thought. The Pythagorean tradition deeply affected, through the philosophy of Plato and Aristotle, the mainstream views of rationality in logic and science.[13] However, the Heraclitan tradition did not disappear. In particular, the link between interacting opposites and change played a crucial role in subsequent dialectic to explain structural change in evolutionary and complex dynamics. Similarly to the Heraclitan tradition, the relationism of the ongoing research in

[12] The concept of *logos* as reason is deeply related to the verb 'to say': *logos* is something that may be said by a rational speaker.

[13] In the Middle Ages, the Pythagorean inspiration of quadrivium education (based upon arithmetic, geometry, music, and astronomy) was universally recognised.

quantum physics denies the existence of 'things' and maintains the ubiquity of relational processes (see, e.g., Rovelli 2017). In addition, the ontological suggestions of the ambiguous but suggestive idea of coincidence of opposites continued to exert a deep influence in many fields, including religion, metaphysics, and science.[14]

1.3 The Discovery of Irrational Numbers

Pythagoreans connected the concept of *logos* with formal and empirical sciences maintaining that numbers reveal the essence of reality. This belief in mathematics was shared by the two main components of the Pythagorean fraternity: the mystic branch and the branch of *matematikoi*. However, the consistency between their beliefs was deeply questioned in consequence of the discovery of irrational numbers by one of its mathematical members (probably Hippasus of Metapontum, c.530–c.450 BCE) that not all numbers are rational because for some of them the assertion that they have a common unit of measure implies a contradiction. In particular, he demonstrated that '… if the hypotenuse of an isosceles right triangle was indeed commensurable with a leg, then one of those lengths measured in that unit of measure must be both odd and even, which is impossible' (Kline, 1990, 33). This shocking discovery deeply questioned the identification of the concept of *logos* with the ratio of numbers and had a far-reaching influence on the evolution of philosophy and science. Pythagorean mathematicians termed the ratio of incommensurable magnitudes *alogos* in the sense that it is inexpressible and thus irrational.[15] Hippasus's discovery posed many serious problems to Greek mathematics and philosophy that went well beyond the theory of numbers. In particular, it refuted

[14] The idea of coincidence of opposites played a crucial role in eastern religions and esoteric disciplines such as alchemy. Moreover, we can detect a significant influence also on Christian theology. Christian philosophers, such as Nicolaus of Cusa, interpreted the coincidence asserted in the Gospels of the two substances of Jesus ('son of God' and 'son of man') in terms of coincidence of opposites.

[15] The depth of the crisis triggered by the discovery of irrational numbers by the Pythagorean mathematician Hippasus of Metapontum stimulated the flourishing of suggestive legends. According to one of them, his fellow Pythagoreans threw him overboard for having sunk the traditional doctrine that we can reduce all phenomena to whole numbers and their ratios (Kline, 1990, 32). A different tradition maintained instead the more plausible story that the Pythagorean community of Croton exiled Hippasus for this revelation.

the traditional assumption that arithmetic and geometry are inseparable, and that numbers played a crucial foundational role for both, and the cosmos itself.[16] However, after the initial shock, the mathematicians realised that they could not ignore irrational numbers but had to include them in the corpus of mathematics. They started to include crucial irrational numbers such as the ratio π of a circle's circumference to its diameter, the golden ratio φ that played a crucial role in visual arts and architecture, and then the square root of all natural numbers. The new vision of mathematics shifted from the numerical approach of arithmetic focusing instead on geometry as the ultimate foundational discipline. Since geometry focuses on continuous magnitudes, it offered the only method that could consider incommensurable ratios without approximation. Geometric magnitudes varied continuously while numbers jumped from one value to another.[17] This explains why Plato, who was on this point in syntony with the Pythagorean School,[18] asserted an ontology based on geometry and wrote on the door of Academia that access was denied to pupils ignorant of geometry. Archytas of Tarentum (428–350) who was a friend of Plato, and Eudoxus of Cnidus (390–337) who was his pupil, found a more general escape from the crisis of irrational numbers by proposing a new theory of proportions applicable both to commensurable and incommensurable quantities. The crisis of irrationals affected not only the evolution of mathematics but also of philosophy and science.

[16] The divorce between mathematics and geometry was fully reconciled only two thousand years later when Descartes and Fermat provided the foundations of Analytic Geometry (see Chapter 3).

[17] See Kline (1990, 48.)

[18] Aristotle asserted that the philosophy of Plato was heavily influenced by the teachings of the Pythagoreans. However, this influence has never been explicitly recognised by Plato himself or by his pupils who emphasised instead his influence on the evolution of Pythagorean mathematics and metaphysics (Zhmud, 2013). It is likely that Aristotle, who explicitly criticised the Pythagoreans, was pushed to conflate Plato's and Pythagorean views to mark the independence of his own thought from Plato. Whatever was the actual direction of mutual influence, we may detect a significant and progressive convergence between Platonic dialogues and Pythagorean themes and views. According to Kahn (2001), Plato's middle dialogues, including *Meno*, *Phaedo*, and *The Republic*, have a strong 'Pythagorean colouring', while his last few dialogues (particularly *Philebus* and *Timaeus*) are altogether Pythagorean in character.

1.4 Mathematics and Epistemic Visions

According to the Pythagoreans, mathematics revealed the metaphysical structure of reality. Applied to astronomy, the numbers represented the perfection of celestial movements, while applied to music and visual arts, they captured rationality also in earthly empirical domains. Plato, writing after the discovery of irrational numbers, asserted the primacy of geometry on the foundational issues of mathematics and metaphysics. Euclid's *Principia of Geometry* reflected the Pythagorean side of Platonic metaphysics. Aristotle restricted the empirical scope of mathematics (both arithmetic and geometry) to the perfection of celestial movements denying its relevance for the imperfect earthly world. This point of view dominated science in the Middle Ages, inhibiting the application of mathematics to earthly physics. The revival of the Pythagorean approach by the Italian Renaissance and then its application to physics by Copernicus, Kepler, Galileo, and Newton played a crucial role in inspiring the Scientific Revolution.

Greek mathematics progressively broadened the concept of rationality including new crucial dimensions. A further meaning (and use) of rational numbers is measure. If we choose a rational number as a unit of measure, we can express and compare the quantitative measure of a certain attribute in different objects. This is not only important for obvious practical reasons that merchants knew very well but also for deeper conceptual reasons. In Greek thought a measure is also a focus point of view. Not by chance, the famous assertion by the Greek sophist Protagoras (485–415 BCE) that 'man is the measure of all things' was so striking that Athenians accused him of impiety. In his dialogues, Plato criticised Protagoras for his relativism, interpreting his thesis as one of incommensurability of individual 'wisdoms' preventing a common discovery of truth:

> how, my friend, was Protagoras so wise that he should consider himself worthy to teach others and for huge fees? And how are we so ignorant that we should go to school to him, if each of us is the measure of his own wisdom? (Plato, Theaetetus, 161B)

In other words, Plato maintained that the incommensurability of different epistemic and moral views ('wisdoms') is inconsistent with rationality (*logos*). The link between rationality and commensurability remained deeply entrenched in Western thought for many centuries and is still a very influential belief. The thesis of incommensurability of theories advanced by Feyerabend (1924–1994) and more cautiously by Kuhn (1922–1996) in the 1960s has been sharply rejected by many critics as irrational, or in any case as inconsistent with sound rationality.[19] A further attribute of rationality deriving from its origin is precision; in the case of rational numbers their ratios are precise (or exact). Philosophy of science traditionally distinguished between exact sciences (mathematics, logic, and possibly physics) and lesser sciences deprived from exactness. Only with the emergence of Post-Positivism, many scientists and philosophers questioned the traditional distinction between exact and non-exact science. However, no one would dispute that precision is an important virtue in language, science, and technology. In the case of irrational numbers, instead, we can only approximate the 'true' value of their ratios as the limit to which tends our calculation. This observation immediately suggests a further link between rationality and knowledge: the discovery of truth through rational learning. This is altogether evident in the case of the traditional notion of truth as correspondence between an object and its epistemic image. By analogy, rationality came to designate the capability of grasping, or at least progressively approaching, objective truth. The logical meaning of rationality provides the foundations for a further link with the concept of solution of an equations system, that is the set of values of the unknown variables for which all the equations of the system are true. In addition, the concept of solution corroborates the semantic link between rationality and determinacy, a concept close but not overlapping with that of precision mentioned before.

1.5 Parmenides and Zeno

What is common in pre-Socratic philosophy is the search for a fundamental principle capable of unifying the world and to assure the consistency of its epistemic representations. In a very influential philosophical poem written at the beginning of the fifth century BCE,[20] Parmenides of Elea maintained an extreme form of monist ontology arguing that the ultimate essence of reality is a unified and unchanging

[19] See Sections 4.4 and 4.5.

[20] Plato dated the birth of Parmenides to 515 BCE, while Diogenes Laertius suggested an earlier birthdate (around 540 BCE.)

singular entity,[21] a metaphysical point of view that exerted a deep and lasting influence in history of philosophy and science. He was the first to base his worldview on an axiomatic-deductive method as he started the argument from an axiom that he believed unquestionably: only what is can truly be. From this premise Parmenides derives a few conclusions: (i) the non-existing cannot be, (ii) therefore the void, interpreted as nothingness, cannot be; (iii) the world is thus full, namely it is a continuous block without any internal division; (iv) since the world is full, motion is impossible.[22] Parmenides's view of a 'block universe' introduced a hierarchy between two levels of reality: its *essence* characterised by unity, eternity, and incorruptible perfection, and its *appearance* characterised by a plurality of imperfect material things subject to change and corruption. At the same time, this ontological point of view introduced a 'mirror' epistemic hierarchy between genuine knowledge justified by reason (*episteme*), and mere opinion (*doxa*) conditioned by ostensible sense experience. According to Parmenides, true knowledge that must assert certain and demonstrable truths is limited to invariant properties.[23] No one ignores the paradoxes that Parmenides's pupil Zeno (c.495–c.430) worked out to defend the point of view of his master on the illusory character of change. These paradoxes reveal particularly well the difficulty of reconciling the concept of reason (*logos*) with a rational understanding of movement and change. In this view, change and motion are illusory appearances because reality is in its essence unchanging, motionless, and eternal. The contrary opinion entertained by human beings is because they rely on fallible senses rather than on reason. For example, according to the paradox of Achilles and the tortoise,[24] the fast-running Achilles will never catch the slowly crawling tortoise because,

[21] This was the interpretation of his followers and early critics, in particular Plato and Aristotle. The correct interpretation of Parmenides' philosophical vision is still very controversial.

[22] I follow here the insightful reconstruction of Popper (2012, 135).

[23] This point of view favoured in the ancient world the adhesion to the Ptolemaic view of the universe while inhibiting the acceptance of the heliocentric view, notwithstanding the latter provided better observational results.

[24] According to Plato (*Parmenides* 127a to 128e), Zeno (490–430 BCE), was a pupil of Parmenides and accompanied the master when he visited Athens. Zeno brought a book of paradoxes defending the philosophy of his master. Four of the ten Zeno's paradoxes focus on the illusion of change. I refer here only to the most famous of them: the Achilles and tortoise paradox.

before reaching it, he must run through all the places where the tortoise has been after the start of the run. The trouble, according to Zeno, is that these places are in principle an infinite number and this prevents the completion of Achilles's attempt in a finite time, whatever their relative velocity. The paradox is generated by the introduction in the argument of the ambiguous dichotomies between infinite vs finite and continuous vs discontinuous. These dichotomies emerge whenever we address a process of change, but their meaning is unclear. Aristotle provided an early influential solution based on the distinction between potential and actual infinity. In his view, Zeno made the mistake of assuming that, to reach the tortoise, Achilles had to go through an infinite number of actual steps in a finite time, while this sequence is only potential so that Achilles does not need to exhaust this potential infinity in its actual process. Aristotle's treatment of the paradox became the generally accepted solution until the late nineteenth century.[25] For almost 2000 years, almost all scholars entertained this point of view, also because it was consistent with the Church's doctrine that only God is an actual infinity. In this period, most philosophers such as Berkeley and Kant, and mathematicians such as Gauss and Poincaré, distinguished carefully between actual and potential infinities and abstained from the use of actual infinities. A different solution, often called standard solution, emerged only in the middle of nineteenth century with the help of set theory as developed by the formalist theory of mathematics established by Dedekind and Cantor. Differently from that of Aristotle, this solution does not deny Zeno's concept of actual infinite but reverses its link to potential infinite. As Cantor maintains, 'each potential infinite ... presupposes an actual infinite' (Cantor, 1887).[26]

Not all the schools of mathematics accept the standard solution implied by the axioms of mathematical formalism. For example, the intuitionist and constructivist schools reject the Standard solution and suggest new escapes. The nonstandard and the smooth infinitesimal

[25] Aristotle's concept of movement as actualisation of a potentiality generated a new apparent paradox since movement seems to be at the same time potential and actual. In this view, however, the process of actualisation of the potential movement does not lead to an actual infinity as assumed by Zeno.

[26] Cantor asserts that the finite line on which Achilles and the tortoise run is abstracted at any particular time from an actual infinite continuum. This leads to the so-called standard solution of the paradox (Dowden, 2009).

analysis have recently explored new promising escapes (see Dowden, 2009 for more details). However, these sophisticated solutions too turned out to be controversial as they generate new paradoxes.

Summing up, Zeno's paradoxes of change exerted a deep influence on both Plato and Aristotle extending through them the influence of Parmenides until contemporary philosophy and science. Suffice it to say that, according to Popper, Einstein's theory of general relativity is inspired by a worldview that is closely reminiscent of the block universe of Parmenides (Popper, 2012), and that Zeno's paradoxes are still puzzling physicists in the quantum theory (ibidem). As Russell asserted, 'Zeno's arguments, in some form, have afforded grounds for almost all theories of space and time and infinity which have been constructed from his time to our own.'[27]

So far, I have discussed the simplest case of change, namely the motion along a line, showing that in this simple case we find already a host of unsettled mathematical and philosophical problems. In this book. I will consider less simple dynamic processes, such as non-linear and complex dynamics, structural change, and evolutionary processes. I will resume the discussion started in this section where these problems will emerge and require a further investigation. What we have seen so far shows that, by reacting creatively to the problems emerging from history of thought and society, the classic notion of human rationality proved able to extend its reach to areas that seemed to lie outside its boundaries. However, each extension forces us to take into due account higher levels of complexity and a growing plurality of possible interpretations.

1.6 The Genesis of Atomism

Democritus of Abdera (460–370 BCE) suggested a different solution to the problem of change that became very influential in philosophy and science. Democritus accepted most of Parmenides's arguments, but rejected the idea that change is an illusion because the empirical evidence proves that change exists. If motion is real, we must refute the existence of a unique indivisible Parmenidean block, and to accept the existence of many indivisible blocks, or atoms, whose shifting configurations explain quantitative and qualitative changes. This

[27] See Russell (1914, 178).

approach must assume the existence of the void that separates the atoms and is something real, and not mere nothingness as Parmenides assumed.[28] Parmenides's ontological monism is thus substituted by the dualism between atoms and void. All the qualities of objects are simply sensations produced by the different configurations of the atoms in the void.[29] Atomism was soon adopted by natural scientists as a sound foundation of change. Its influence, temporarily eclipsed by the hostility of both Plato and Aristotle, was revived by Epicurus (341–270 BCE). Atomism was basically a determinist theory. However, Epicurus introduced the *swerving* of atoms (in Latin *clinamen*) to allow for occasional random changes that may justify free will. Atomism was eventually eclipsed by the hostility of the Church that found more congenial the metaphysical doctrines of Plato and Aristotle and their finalistic implications. The modern revival of atomism was promoted by Newton in his works on optics and chemistry (Bobzien, 2020, 15–19). Notwithstanding the growing importance of atomism in the nineteenth century in progressive theories such as chemistry and kinetic theory of gases, atomism was still considered with scepticism by leading scientists and philosophers (such as Mach) until the end of the nineteenth century and beyond. After Newton, atomism had to adapt to new observations inconsistent with the original version (such as the discovery of molecules, new elementary particles, duality with waves, and electromagnetic fields).[30] Only in 1905, Einstein published an article on Brownian motion that established atomism on solid evidential ground. The emerging quantum physics revived atomism merging it with an idea of universal change closer to Heraclitus than to Democritus.[31] The revival of atomism exerted also a deep methodological influence in social sciences, and specifically in economics, corroborating the idea that the scientific approach to social phenomena required appropriate microfoundations in the behaviour of individuals, the 'atoms' of society, an attitude that Menger called with the

[28] Plutarch clarified that according to Democritus and Epicurus the void 'has a certain physics and a substantiality of its own' (Rovelli (2017, 73).

[29] The argument developed by Democritus against Parmenides's philosophy has been considered as the first falsification based upon a deductive system (see Popper, 2012, 137).

[30] 'The introduction in physics of fields and their growing importance in contemporary research is not necessarily inconsistent with atomism because fields are conceived as "granular"' Rovelli (2017)..

[31] See Popper (2012, 184).

suggestive name of methodological individualism. Not by chance, the philosophical approach pursued to this end – utilitarianism – was deeply influenced by the atomist philosophy of Epicurus.

1.7 Classical Logic

The deep link between rationality and *logos* is particularly evident in the case of logic, as is suggested also by its etymology. The early Greeks conceived it as a formal discipline aimed to assure the correctness of arguments (*logoi*) and thus their compliance with rationality. The main criterion of logical consistency is the absence of formal contradictions. This was already clear in the fragmentary and unsystematic early contributions of Sophists who cultivated the art of defending or attacking a thesis by means of arguments. In a dispute opposing incompatible theses, the typical Sophist argument against the opponent's thesis pointed out the presence of a logical contradiction forcing its rejection. In the pluralist Socratic version of rational argumentation, all the interlocutors participate in the research of truth through a sequence of questions and answers to discover the contradictions in their theses and reach more robust conclusions. Plato provided simple rules for *dialectical arguments* to guarantee their consistency and their ability to converge towards truth. However, the first to develop logic as a rigorous discipline was Aristotle, who systematised much of the fragmentary achievements of his predecessors and developed them in many fruitful directions. His logic was the main source and reference in teaching and research from the fourth century BCE to the nineteenth century CE. The early followers of Aristotle collected the bulk of his logical works in what they called the *Organon* or 'tool', a title chosen because they considered logic as a fundamental instrument of philosophy, including natural philosophy (that today we call science).[32] The only serious rival to the Aristotelian logic as developed by the

[32] According to the traditional list, the *Organon* contains the following books *Categories*, *De Interpretatione*, *Prior Analytics*, *Posterior Analytics*, *Topics*, and *Sophistical Refutations*. We may find further logical insights and discussions in other works of Aristotle. In particular, *Metaphysics Γ* discusses the foundations of logic from the metaphysical point of view focusing on the principle of non-contradiction. Aristotle considers the principle of non-contradiction a metaphysical principle underlying the discipline of logic. The traditional arrangement of the books within the *Organon* is not chronological nor Aristotle's own (see Bobzien, 2020).

Peripatetic School was the logic developed by the Stoic School. The main exponent of this school, Chrysippus of Soli (c.280–207 BCE), developed a different approach to logic that became mainstream in the Hellenistic period. The Aristotelian approach was concerned with the logical relations between terms, and it was thus close to modern predicate logic and set theory. The Stoic approach developed instead an early version of propositional logic that was rediscovered by Frege in the mid nineteenth century exerting in this new form a strong influence not only on logic but also on modern analytic philosophy. The two schools developed separately in the wrong conviction that they were inconsistent, a conviction reinforced by their conflicting metaphysics. These different approaches started to be combined in terminology and theory only in the second century CE by scholars such as Galen and Apuleius who wrote in Latin. Notwithstanding these and other scattered attempts at a synthesis, between the third and sixth century CE, Stoic logic eventually faded into oblivion until it was rediscovered in the nineteenth century in the wake of the revival of propositional logic. The Aristotelian logic was in its turn largely forgotten in the late classical period until the sixth century when Boethius translated Aristotle's *Organon* (except *Posterior Analytics*) into Latin, making it available to scholars of the medieval period.

In both Aristotelian and Stoic approaches, logical consistency was praised as the fundamental requisite of sound argumentation. Aristotle asserted In Book Γ of the *Metaphysics*, that the principle of non-contradiction is 'the most certain of all principles'.[33] This principle was later called law of non-contradiction. It is difficult to find a justification of the principle (or law) of non-contradiction in ancient logic because it was considered as self-evident.[34] Even the arguments advanced by Aristotle stopped short of any convincing proof. A strong argument was first formulated by medieval logic based on the principle that 'from contradiction, anything [follows]',[35] a principle that is often summarised with the acronym ECQ (from the Latin *ex contradiction*

[33] The medieval logicians used in Latin the same expression, arguing that the law of non-contradiction (LNC) is *firmissimum omnium principiorum* (see Priest et al., 2018a, 1).

[34] This point of view is still entertained by important contemporary logicians such as Davidson.

[35] This principle was usually expressed in Latin: '*Ex Contradictione Quodlibet [sequitur]*' from which the acronym ECQ.

quodlibet). This assertion was then considered compelling and implicit in classical logic according to which from a contradiction one can prove any sort of statement, even an absurd statement. However, only by the 1930s did the ECQ become the main argument for the prohibition of contradictions in a deductive system. According to the modern language of logic, a logical consequence relation is *explosive*, namely violates ECQ, if the alleged truth of a contradiction entails the truth of any arbitrary conclusion.[36] Not only classical logic but also most 'non-classical' logic, including intuitionist logic, is explosive in this sense. This radical form of indeterminacy, usually called *trivial* by logicians, is bound to destroy the foundations of whatever form of rational discourse.

1.8 Rationality and Dialectic

So far, I did not make explicit the nexus between argumentation and epistemic subject that enunciates it. This becomes necessary in dialectic as soon as one considers a dialogue (or conversation) between two or more interlocutors. The word comes from the Greek roots *dial-* (across) and *logos* (in the original sense of spoken or written interchange of ideas),[37] and indicates any kind of conversation between two or more interlocutors. In Greek philosophy, dialectic (διαλεκτική) is a particular form of dialogue opposing theses and antitheses to refute one of them or to obtain a sound synthesis. Following the diffusion of Plato's *Dialogues*, the so-called Socratic Method suggested a more specific meaning of dialectic.[38] In this view, dialectic aims to make explicit a conflict of different fundamental theses on some significant philosophical issue to discover and eradicate the contradictions and reach the truth. In the dialectic method as practiced early by Plato, the removal of a contradiction detected in an argument is a progressive step towards a more coherent and general argument. In subsequent dialogues, Plato based the steps of this progression on the synthesis

[36] See Priest et al. (2018b, 1).

[37] Also in this case, the word *logos* assumes all the semantic overtones connected to the concept of reason: concept of.

[38] Plato was not the inventor of dialectic as he learned much of its motivations and techniques from his master Socrates, who in his turn developed a particular version of the argumentative techniques worked out by the Sophists and pre-Socratic philosophers.

between two opposite theses, a solution that became paradigmatic in later dialectic (as in Fichte or Hegel). Greek scholars distinguished Dialectic from Eristic and Rhetoric. Eristic (from *Eris*, the ancient Greek goddess of discord) aims to dispute in the most effective way a specific argument, regardless of its truth. Rhetoric is the art of persuasion and focuses on the techniques that speakers or writers use to convince a specific audience in a specific situation. Differently from Logic, Rhetoric is concerned not only with the correctness and adequacy of logical arguments but also with the emotions that they may arouse. According to Socrates and Plato, Rhetoric – like Eristic and differently from Dialectic – is not a legitimate art of reasoning because it aims to exploit the emotive reactions of the interlocutors for the sake of winning an argument regardless of its truth. Therefore, they criticised the Sophists because they taught for money the deceptive techniques of Eristic and Rhetoric. According to Aristotle, instead, Rhetoric – differently from Eristics – is a legitimate art that aims to train orators, lawyers, and political leaders to increase the effectiveness of their arguments. Rhetoric in the Aristotelian meaning became, along with grammar and logic, one of the three liberal arts taught in medieval universities as part of the so-called *trivium*.

Summing up, according to the Greek wisdom, the crucial difference between logic and dialectic is that while logic arguments are in principle impersonal and timeless, dialectic arguments unfold in a specific succession according to the effective interactions between the interlocutors. Therefore, the process of progressive elimination of errors confers to a dialectical argument a dynamic nature of gradual approximation to truth.

1.9 Critical and Teleological Dialectic

We find in Plato's dialogues different versions and uses of dialectic.[39] We must discriminate between them because they have completely different implications for scientific pluralism. To clarify this point I must distinguish two opposite ideal types of dialectic that may be found in Plato's dialogues. We find the best illustration of the first type of dialectics in the first dialogues – such as *Apology*, *Crito*, and the *Euthyphro* – where Plato is still under the overwhelming influence of

[39] See, e.g., Popper (1945).

Socrates not only in the epistemic use of dialectic but also in the contents of arguments. I call *critical* this type of dialectic.[40] Socratic dialectic is a method to search with a group of interlocutors the best possible answer to an important question. Socratic dialogues convey a captivating image of philosophical research as a progressive commitment to which all the potential interlocutors are called to contribute. The Socratic approach is an early example of what I am going to call critical pluralism, because its role is that of seeking truth taking into account the limits of individual knowledge.[41] According to Socrates, wise persons do not pretend to know what they do not know.[42] The awareness of ignorance is the mainspring of learning to reduce ignorance, of prudence in action to avoid unjustified risk bearing, and of wisdom in judgment to avoid superficial appraisals.[43] In each stage of the dialogue, the answers based on contradictory assumptions or leading to inconsistent consequences are discarded. In this way, the dialectical technique selects an argumentative path robust enough to build up a satisfactory answer to the over-arching initial question. To this end, Socrates insists on the crucial importance of an open-minded cooperation in the search for truth between willing interlocutors. To each of them Socrates attributes equal rank and authority as participants in the process of 'refuting and being refuted'. In particular, he does not aim to lecture the other interlocutors to persuade them of a

[40] Socrates practiced this sort of dialectic. This is confirmed by other pupils (such as Xenophon) and the fragments of other contemporary witnesses.

[41] As Kraut observes, one of the deepest methodological convictions of Socrates (confirmed by Plato in *Meno*, *Theaetetus*, and *Sophist*) is that 'in order to make intellectual progress we must recognize that knowledge cannot be acquired by passively receiving it from others: rather, we must work our way through problems and assess the merits of competing theories with an independent mind' (Kraut, 2017, 25).

[42] I could have mentioned the famous paradox 'I know that I know nothing' often attributed to Socrates. However, this formulation is likely to be apocryphal. In Plato we find less paradoxical, but not less significant, assertions such as the following: 'I am wiser than this man, for neither of us appears to know anything great and good; but he fancies he knows something, although he knows nothing; whereas I, as I do not know anything, so I do not fancy I do. In this trifling particular, then, I appear to be wiser than he, because I do not fancy I know what I do not know.' (Plato, 1997, 21d)

[43] Socrates was particularly interested in ethical questions such as: 'What is impiety?' (e.g., in *Euthyphro*), 'what is justice?', 'what is courage?' The same method, however, can be used to find the best possible answer to scientific questions as Plato showed in other dialogues.

preconceived truth.[44] The wisdom of this genuinely pluralistic method is difficult to understand and practice. Many critics lamented the negative and inconclusive character of this sort of dialectic.[45] The accusation of idle scepticism was often repeated also by famous philosophers such as Hegel. However, this criticism misses the constructive role of Socratic dialectics. The selection of most robust arguments to answer the original question, or to reach the truth, is a fundamental instrument of rational learning. In addition, Socratic dialectic provides the basic support of a democratic society that requires the continuous practice of critical pluralism to survive and thrive.

Plato did not endorse the criticism of inconclusive scepticism addressed against Socrates. However, we find in some later dialogue (such as the *Republic*, the *Statesman* and the *Laws*), a teleological view of dialectic aiming to grasp the ultimate truth on the issue under investigation.[46] In this view, the discovery and eliminations of contradictions guides the intellect to ascend from sensible impressions to intelligible concepts and then to increasingly general ideas until it reaches a direct grasping of the 'first principle':

> And so with dialectic; when a person starts on the discovery of the absolute by the light of reason only, and without any assistance of sense, and perseveres until by pure intelligence he arrives at the perception of the absolute good, he at last finds himself at the end of the intellectual world ... (Plato *Republic*, VII, 533 c–d).

The *Republic* is a turning point in Plato's dialogues. Plato abandons the Socratic idea of equal authority attributed to all the interlocutors by establishing instead a clear hierarchy between his avatar Socrates and the other interlocutors. This is consistent with the utopic blueprint of the Platonic republic that deviates significantly from the principles of democracy maintained in Socratic dialogues. Plato abandons the unprejudged pluralism that is the salt of democracy and argues that only philosophers know the right answer to the relevant questions. We call

[44] He makes clear that '... it is not from any sureness in myself that I cause others to doubt: it is from being in more doubt than anyone else' (*Meno* in Plato, 1997, 80c).

[45] This criticism is raised also by Socrates's interlocutors (see, e.g., *Meno* in Plato 197, 80c).

[46] Plato expresses this view of dialectic in the book VII of the *Republic* where he derives from the myth of the cavern the ideal education system that the Republic should adopt.

this *teleological* dialectic. In this case, the dialogue aims to persuade all the interlocutors of a specific truth that was already entertained by the leading interlocutor before beginning the conversation. What is puzzling is that also in the teleological dialogues Plato designates Socrates as the protagonist of the conversation, but his traditional role of gadfly is now distorted in a role of pundit that the real Socrates has always rejected. For this reason, a few philosophers did not hesitate to accuse Plato of betrayal of his master Socrates (see in particular Popper, 1945). How can we explain this disguised reversal of Socrates's pluralism by a rigorous philosopher such as Plato? A possible answer is that Socrates was critical of the degeneration of democracy occurring in contemporaneous Athens, but never deflected from his democratic ideals deeply rooted in critical pluralism and always entertained the hope that the shortcomings of democracy could be corrected. This did not prevent the democratic leaders led by Aneto to put him to death in 399 BCE on charges of corrupting the young and introducing new gods. However, as a matter of fact, Socrates never played the role of corruptor that presupposes a hierarchy between teacher and pupils that he always rejected. In addition, his critical pluralism was inconsistent with the unexamined acceptation of the authority of new gods. The process of Socrates and its tragic outcome convinced Plato that democracy necessarily degenerates into tyranny. To avoid that, he eventually advocated what he believed to be the only possible remedy: to concentrate all the power in the hands of enlightened philosophers. Unfortunately, after many centuries we know that an elitist regime of this kind would be unable to establish or defend a genuine democracy. In addition, the blueprint of its constitution, largely inspired by that of Sparta, was full of unacceptable prescriptions violating basic human rights.[47]

In this view, dialectic is thus not an instrument facilitating the convergence towards an unknown truth in a fragmentary, unsystematic but genuinely undogmatic way, but the only instrument that may assist in the construction of a general unifying view. The critical (or Socratic) version of Plato's dialectic compares with genuine respect the plurality of points of view and the necessity of a frank discussion meant to find their shortcomings and to select the best for the issue investigated. The teleological version of Plato's dialectic tends instead

[47] See, e.g., Popper (1945).

towards a comprehension of the issue under investigation that includes within an increasing generality the preceding stages of understanding. This point of view jeopardises pluralism because it tends to encompass all the possible points of view within the 'final' (or 'absolute') point of view. We find an updated version of critical dialectic in what Kant called transcendental dialectic that leads to unsolvable antinomies revealing the limits of reason. Critical dialectic has often been rejected for its alleged negative nature. For example, Aristotle criticised Plato's dialectic for being merely destructive and being thus unable to improve our knowledge. Hegel (1974 [1817]) resumed Aristotle's criticisms against the dialectic method of Plato that in his opinion engages only with specific philosophical claims and is unable to get beyond scepticism. He extended the same criticisms against Kant's dialectic claiming that it leads to scepticism or nothingness.

1.10 The Early Evolution of Rationality

In this chapter, I tried to sketch a few crucial steps of the seminal evolution of rationality in western thought, namely the set of qualities that characterise genuine and reliable knowledge as well as the process of approaching truth. I argued that the original meaning of reason is rooted in the concept of *logos* and its evolution since ancient Greek thought.[48] In the preceding sections, we have reviewed different notions of rationality. Reflecting on them, we are led to distinguish two different basic notions that have quite different implications. According to the first vision, the crucial characterisation of rationality is the extension of true knowledge of the epistemic subject while, according to the second vision, the essence of rationality is the process of learning converging towards the truth. These two views are not necessarily incompatible. We extend knowledge through learning, while learning requires an apt background of knowledge. Exceptions to this widespread belief are extreme forms of Rationalism assuming that our knowledge is innate, a view entertained by philosophers such as Plato, Descartes, and Leibniz. However, they do not deny that

[48] After the discovery of irrational numbers, the scope of mathematics was broadened to embrace also irrational numbers. In the field of logic, the scope of rationality was stretched to encompass dialectic and rhetoric (Priest et al., 2018a). In empirical science, there was a progressive use of paradoxes, originally introduced by Greek philosophers to stimulate a deeper and sounder knowledge.

learning plays a crucial role as they admit that innate knowledge must be unlocked by experience or deduction. Their point is that the experience cannot produce sound knowledge without the crucial support of reason. This belief often leads to a reductive conception of learning constrained by rigid rules of induction. On the other hand, radical empiricists claim that all knowledge derives from experience. In other words, rationalists and empiricists have a different conception of learning and its interaction with pre-existing knowledge. However, neither of them denies the crucial role of learning in the acquisition of rational knowledge. And thus, what is more important for rationality: learning or knowledge? This is a typical chicken-or-egg question that requires the integration of both points of view. Nevertheless, the way to look at this problem has huge consequences for pluralism. The primacy of knowledge may easily lead to dogmatic claims that demotivate learning and repress pluralism. On the contrary, the awareness of ignorance shifts the focus of rationality towards the necessity of learning from other people to reduce ignorance. This is the great lesson that we must draw from Socrates. This is what science requires to continue its amazing evolution towards a better understanding of the world. And this implies a crucial propulsive role for critical pluralism. Occasionally, science endorses the unquestionable truth of a corpus of knowledge slowing down, blocking, or distorting its evolution and derailing its epistemic role and social function. This pathology of science is always signalled by the repression of pluralism.

2 *Science and Epistemology from the Scientific Revolution to the Enlightenment*

> *Hamlet:*[1] *there are more things in heaven and earth, Horatio, than are dreamt of in our philosophy.*
>
> *Francis Bacon:*[2] *there are Idols which have immigrated into men's minds from the various dogmas of philosophies, and also from wrong laws of demonstration. These I call Idols of the Theatre, because in my judgment all the received systems are but so many stage plays, representing worlds of their own creation after an unreal and scenic fashion.*

It is usual to classify scientists and natural philosophers active since the late Renaissance in two groups of researchers characterised by alternative visions and methods: on one side the empiricists (in particular British empiricists such as Bacon, Newton, Locke, and Hume) and on the other side the rationalists (in particular the Continental rationalists such as Descartes, Spinoza, and Leibniz).[3] Since the early seventeenth century, these conflicting research programmes spread in all European countries. In the renaissance period, Empiricism was advocated as a revolutionary manifesto against the mainstream scholastic tradition that was then ruling in the academia and in the official culture. Seventeenth-century rationalists reacted against the uncritical confidence in induction shown by the empiricists and emphasised the crucial role played by reason in sound epistemic processes. In this chapter,

[1] Shakespeare, Amleth, Act 1 Scene 5, First Folio (1623). Philosophy included natural philosophy, that is emerging sciences.

[2] Francis Bacon *Novum Organon* (1620, Book I, Aphorism XLIV).

[3] The epistemological stance of natural philosophers is usually much more subtle and complex than the above ideal-typic classification suggests. For example: 'Locke rejects rationalism in the form of any version of the Innate Knowledge or Innate Concept theses, but he nonetheless adopts the Intuition/Deduction thesis with regard to our knowledge of God's existence. Descartes and Locke have remarkably similar views on the nature of our ideas, even though Descartes takes many to be innate, while Locke ties them all to experience' (Markie, 2017, 9).

I refer to some disputes between these two scientific visions that affected their coevolution. I suggest a preliminary definition of an ideal type of these diverging research programmes in terms of the relation between sense experience on one side, and the active role of intellect on the other.[4] Both research programmes believed in the crucial role of apt simplifications to understand reality notwithstanding its complexity. But they pursued two different strategies of epistemic inference. According to the down-top empiricist strategy, the elementary bricks of the building of knowledge are specific empirical observations that are combined by induction to raise the building of knowledge culminating in universal laws. According to the top-down rationalist strategy, the construction of knowledge starts from a minimum number of basic true propositions (called postulates or axioms) established by rational insight, usually called *intuition*, from which all the other true propositions are derived by *deduction*. Second, according to the view of uncompromising rationalists, true knowledge is innate; namely, it is not only a priori, as it precedes and makes possible experience, but is intrinsic to our rational nature.[5] The empiricists objected that a priori intuitions and concepts are unreliable unless they ultimately derive from sense experience. If this derivation is not possible, wisdom suggests suspending the judgement.

I start my narrative from the Italian Renaissance in art and science that reflected the emergence of the New Renaissance Vision of the

[4] The categories of Empiricism, Rationalism, and all the other broad categories ending in -ism, must be used with extreme caution. We should be aware, in this as in similar cases, that we cannot find a single scholar fitting exactly into an ideal type of this kind. The role of these categories is thus similar to that of useful conventions such as the meridian of Greenwich or the Equator to evaluate the longitude and latitude of a certain specific object on the globe. The combined use of these two conventional references defines where the object under investigation is located in the globe. In the case of a system of thought, this way of defining its position and evolution in the manifold of ideas is much more difficult because its features are multidimensional, qualitative, and subject to various interpretations. We should thus never use the -ism categories as labels for appraising the position of a single thinker or scientist, and we should never use them with emotional overtones as a substitute of detailed arguments.

[5] Plato presents in the dialogue *Meno* an early version of the innate knowledge thesis in the form of knowledge by recollection. Noam Chomsky argues along similar lines in presenting what he describes as a 'rationalist conception of the nature of language' (Chomsky, 1975, 129). However, 'Chomsky gives us a theory of innate learning capacities or structures rather than a theory of innate knowledge' (Markie, 2017, 20.)

world paving the way to the Scientific Revolution (Section 2.1). A new sophisticated form of Empiricism, as advocated by Bacon in England, played a crucial role as a methodological and institutional driving force (Section 2.2). The new context encouraged the modern revival of the heliocentric hypothesis (Section 2.3). Galileo and Huygens greatly contributed to the successful spreading in different European countries of the New Renaissance Vision of natural science based on the systematic mathematisation of the empiricist approach (Section 2.4). Since the middle of eighteenth century, Newton became the paradigmatic exemplar of eminent scientific achievement; I limit the analysis of his pathbreaking contributions to a few methodological aspects that impinge on scientific pluralism (Section 2.5). In the seventeenth and eighteenth centuries, a few eminent philosophers and scientists reacted against the unilateral views of many leading empiricists vindicating the critical role of reason. Descartes and Leibniz played a crucial role in this creative revival of Rationalism influencing many subsequent developments in science and philosophy (Section 2.6). Hume brought to the extreme consequences the theses of British Empiricism preluding to its subsequent decline, opening new, more sophisticated vistas (2.7).

2.1 The Genesis of the Scientific Revolution: Leonardo and the Renaissance

As is usual with the labels that designate broad historical processes, the concept of Scientific Revolution is rather ambiguous in its content and timing. According to the prevalent view, its time boundaries go from the first half of the seventeenth century to the end of eighteenth century. However, as all revolutions, this one too had a long and significant incubation started in the period of early Renaissance that triggered a rapid transition period. This Renaissance Vision exhibits the following main characteristics:

(i) *Individualism*: a new view of individuals as autonomous persons, entitled to reason and act according to their own principles and goals.
(ii) *Freedom of thought*: rejection of the unscrutinised authority of previous scholars – including scholastic philosophers, Aristotle, and Plato – as well as powerful institutions, including religious and political authorities. In this view, the individuals should accept

only the authority of sense experience through systematic observation and experimentation interpreted in the light of reason.

(iii) *Mathematisation of science*: crucial role of mathematics and geometry in the interpretation of the empirical evidence. In the new view, this principle, traditionally applied only to celestial phenomena, has to be extended also to terrestrial phenomena.

(iv) *Pragmatism*: systematic linking of theory and praxis reflected in a growing interaction between science and technology.

The Renaissance Vision is stimulated by the revival of the Greek thought accompanied by the rediscovery and unprecedented diffusion of important Greek original texts.[6] The new worldview emerges and gradually spreads during the Renaissance. We cannot find a more emblematic early exemplar than Leonardo da Vinci (1452–1519) who illustrates the crucial link between the mindset of Italian Renaissance and the Scientific Revolution. The characteristics listed here describe well Leonardo's vision. His *Vitruvian Man* is often taken as the symbol of the new humanistic anthropology. His freedom from the received wisdom was a constant in his life facilitated by his lack of formal education and his complete reliance on persisting self-instruction. Leonardo's manuscripts document his commitment to the direct observation of nature and systematic use of the experimental method.[7] One significant example that illustrates at the same time the first three points is the direct study of the human anatomy through the dissection of cadavers, practice that violated the severe prescriptions of the Church. As for the role of formalisation, he maintained, 'No human investigation can be considered true science, if it does not pass through mathematical demonstrations.'[8] Leonardo follows and extends here a recent tradition spreading in Italy in visual arts. The most striking example is the discovery and practice of perspective in painting conceived as a mathematical structure underlying the visible forms of the earthly world. In particular, I have to mention Piero della Francesca who, building on the recent pioneering contributions of Filippo Brunelleschi and Leon Battista Alberti and his deep self-

[6] As is well known, this is related to the sixteenth-century attempt, particularly promoted by the Republic of Florence aiming to become the New Athens, of overcoming the schism between Orthodox and Catholic Church.

[7] Leonardo da Vinci (2019 [1510]).

[8] Leonardo da Vinci (1996, 3, my translation).

thought knowledge of geometry and mathematics, contributed to the theory of perspective and implemented some of the best early examples.[9] The influence of the Pythagorean tradition revived in visual arts was even more pronounced in music where this influence had never been lost. The importance Leonardo gave to the link between science and technology underlies and animates all the intriguing manuscript of the *Codex Atlanticus*.[10] Leonardo da Vinci was not the only one to pursue the ideals of the emerging New Renaissance Vision in Renaissance Italy. The same vision was entertained by a growing number of architects, scientists, and engineers, in Italy and then in all of Europe.[11]

2.2 The Revival of the Geocentric Hypothesis: Copernicus and Kepler

I cannot refer to the cohort of forward-looking Renaissance scientists without starting from Nicolaus Copernicus (1473–1543). He studied in Italy where he absorbed the new scientific vision influenced by the revival of the Pythagorean philosophy. Shortly before 1514, he began to revive the ancient idea that the earth revolves around the sun. Copernicus spent the rest of his life seeking a mathematical proof of the heliocentric theory. He eventually published the results of his investigation in 1543, the year of his death. The Copernican revolution was the first step of the Scientific Revolution in astronomy that occurred in the following century. Copernicus presented his version of the heliocentric theory as the revival of the Pythagorean research programme pursued by the late Plato.[12] The attunement of

[9] Albrecht Dürer contributed to spread this approach in Northern Europe after his visit to Italy. We find also a new systematic use of Greek and Roman mathematical proportions, such as the golden section in visual arts and architecture, a fashion favoured by the discovery in the Monte Cassino abbey in 1414 of the famous *Treatise* by the Roman architect Vitruvius (c.80 BCE–c.15 BCE). Leonardo took the *Vitruvian Man* as a symbol of his own vision.

[10] Leonardo da Vinci (2019 [1510]).

[11] Limiting my examples to the personal friends of Leonardo, I can mention his teacher Paolo Dal Pozzo Toscanelli cosmographer and mathematician, the influential polymath Gerolamo Cardano, and father of modern accounting Luca Pacioli who apparently plagiarised some mathematical contributions of his friend Piero della Francesca (and so doing popularised his ideas).

[12] Copernicus (1543) cited various Pythagoreans as predecessors of his heliocentric model. Instead, after a cavalier citation of Aristarchus of Samos in the first

Copernicus's heliocentric theory to the spirit of Renaissance explains not only the timing of its revival but also its immediate success and influence. After all, Copernicus failed to demonstrate its empirical superiority over that of the mainstream geocentric system. A few decades later, Tycho Brahe (1546–1601) implemented a dramatic improvement in the empirical evidence. This Danish nobleman-turned-astronomer dedicated his life to extending the tables recording astronomical observations. To this end, he built better instruments of observation, such as a sophisticated sextant,[13] and used them to register a growing quantity of astronomical data that paved the way for the subsequent epoch-making advances of astronomy. He also tried to improve the interpretation of the data by suggesting a new theoretical framework – the Tyconic system – that combined the heliocentric and geocentric systems. This system aimed to combine the computational and mathematical advantages of the Copernican system with the traditional interpretation of the Sacred Scriptures and mainstream physics.[14] The Tyconic system succeeded to become for a while a competitive alternative to the geocentric and heliocentric systems but the rapid progress of the heliocentric system implemented by Kepler and Galileo rapidly reduced its appeal.[15] The ingenious Tyconic system eventually became a paradigmatic exemplar of misleading eclectic theory. However, the tables of his astronomical observations gave a great acceleration to the progress of astronomy. The first astronomer who exploited Brahe's data was Johannes Kepler (1571–1630) who worked as his assistant in Prague since 1600. After Brahe's untimely demise, the Emperor Rudolf II appointed Kepler his successor as imperial mathematician with the task of completing and updating the astronomical tables that Tycho Brahe had compiled. Kepler published

edition, he cancelled also this reference from subsequent editions, although Aristarchus had developed in the fourth century BCE the most famous heliocentric model of the antiquity. This neglect may be related to the fact that Aristarchus' work was based on a non-Pythagorean perspective distant from Copernicus's view.

[13] These instruments were the best available before the imminent invention of the telescope.

[14] He assumed that the earth does not move, while the sun, the moon, and the stars orbit around it; at the same time, he assumed that the planets orbit around the sun.

[15] The empirical evidence on the earth's movement was inconsistent with the Tyconic system.

the new tables with the name of *Rudolfine tables* in 1627. This updating allowed him to improve the empirical fit of the heliocentric theory by replacing the circular orbits made arbitrarily complex by alleged *epicycles* with much simpler elliptical trajectories. This crucial innovation allowed him to formulate his celebrated laws of planetary motion. As is well known, the first law asserts that the orbit of a planet is an ellipse with the sun at one of the two foci. The second law provides a geometrical description of the reason why a planet travels faster when is closer to the sun, showing that a line segment joining a planet and the sun sweeps out equal areas during equal intervals of time. The third law asserts that the square of the orbital period of a planet is directly proportional to the cube of the semi-major axis of its orbit.[16] These insightful mathematical laws inspired the spectacular advances of the heliocentric theory along the seventeenth century.[17] Initially, however, their success was controversial because the predictions drawn from these laws remained less accurate than those derived from the geocentric theory.[18] Only after the publication of Newton's *Principia* did most astronomers start to recognise the superiority of the heliocentric theory. The complex corpus of Kepler's contributions was the typical expression of a transition phase as it mixed different visions, methods, and sources of inspiration. The derivation of the laws from the accurate data gathered by Brahe was a remarkable achievement that science historians exalted as an exemplar of successful induction. However, his metaphysical intuitions and theological convictions played a crucial role in their genesis and elaboration. In his first published book *The Cosmographic Mistery* (1596),[19] Kepler suggested that we could comprehend the distance between the six known planets in terms of the five Platonic solids, enclosed within a sphere that represented the orbit of Saturn. In his view, the specific arrangement of the Platonic solids reveals God's design underlying the structure of the universe. In addition, he believed that the Pythagorean research

[16] This law implies that the farther a planet is from the sun, the longer is its orbit, and vice versa.

[17] Kepler published his three laws between 1609 and 1997 [1619].

[18] The mistakes for the location of the planets could be as big as a fourth of the width of the Moon.

[19] This was the first accomplished defence of Copernicus's heliocentrism. This book attracted the attention of a few leading astronomers including Brahe who called him in Prague as his assistant.

programme on 'universal music' could be a fundamental way of access to understand the structure of the universe. He published the first two laws in the summary of his astronomical views in *New Astronomy* (1609), and the third law ten years later in his theory of the music of celestial spheres, *The Harmony of the World* (1997 [1619]).[20] In these books, Kepler rooted his research programme in the tradition started by Pythagorean mathematicians as developed by the late Plato. He believed that the results of his own research, particularly the three laws of planetary motion, revealed the wisdom of God as a sublime geometer.[21]

2.3 Bacon and the Golden Age of British Empiricism

The new vision of the world emerging during the Renaissance promoted a new vision of science characterised by individualism, freedom of thought, mathematical formalisation, and technological pragmatism. These points clearly emerge in the works of Renaissance scientists, but they were not yet consistently coordinated within a comprehensive scientific vision. Francis Bacon (1561–1626) provided a general framework that endowed the emerging sciences of apt philosophical foundations. Bacon identified in history three periods of scientific revolution: the one that flourished in ancient Greece, its revival in classical Rome, and finally the new revival initiated in Europe in his own time.[22] In his opinion, the latter adopted a new methodology that he aimed to specify in his later works. To this end, Bacon published in 1620 the 'New Instrument of Science' (*Novum Organum* in Latin) aiming to update and renovate the traditional methodology of empirical science based on the 'old' *Organum* of Aristotle. In it, Bacon rejected the Aristotelian and scholastic philosophy of science and suggested a new approach based on inductive reasoning aiming at

[20] The original title of this book published in Latin was *Harmonices Mundi*.

[21] Kepler's inspiration was not Pythagoras's numerology, as adopted by his school before the discovery of irrational numbers, but the subsequent resetting of the Pythagorean research programme by Plato, Eudoxos, and Euclid in terms of ontological primacy of geometry. Consistently with this vision, Kepler abandoned the original Pythagorean tuning that relied on rational numbers and adopted geometrically supported musical ratios to relate musical consonance and angular velocities of the planets.

[22] Bacon IV ([1901], 70ff).

empirical generalisations justified by painstaking observation of the relevant events[23]:

> Those who have handled sciences have been either men of experiment or men of dogmas. The men of experiment are like the ant, they only collect and use; the reasoners resemble spiders, who make cobwebs out of their own substance. But the bee takes a middle course: it gathers its material from the flowers of the garden and of the field, but transforms and digests it by a power of its own. Not unlike this is the true business of philosophy; for it neither relies solely or chiefly on the powers of the mind, nor does it take the matter which it gathers from natural history and mechanical experiments and lay it up in the memory whole, as it finds it, but lays it up in the understanding altered and digested.

This suggestive metaphor became an influential manifesto for the new science. It shows also that Bacon's Empiricism tried to find a middle way between pure Empiricism (the ant) and pure Rationalism (the spider) emphasising the necessity of combining observation and experiment with the independent constructive power of the mind (the bee). In his opinion, differently from the opinion of radical empiricists, the human mind is neither a *tabula rasa* on which sense experience writes its findings, nor a simple mirror of empirical reality. The trouble is that our mind reflects nature like a crooked mirror because of a series of distortions that he called 'idols' (transient and misleading images of the truth). He distinguished four kinds of idols: (1) 'idols of the tribe', prejudices common to the whole human race such as the anthropomorphic analogies; (2) 'idols of the cave', prejudices peculiar to individuals due to their limited knowledge; (3) 'idols of the market place', prejudices created by social interaction; and (4) 'idols of the theatre', false notions spread by various schools of thought. I limit myself to go a bit deeper in the fourth category of idols '... which have immigrated into men's minds from the various dogmas of philosophies, and also from wrong laws of demonstration'.[24] Bacon is particularly concerned with three kinds of idols of the theatre affecting three classes of philosophers. Bacon stigmatises the Rational School of philosophers

[23] Bacon (1620, Book I, Aphorism 95).

[24] Bacon (1620, Book I, Aphorism 44). Bacon explains why he related these Idols to the Theatre: 'because in my judgment all the received systems are but so many stage plays, representing worlds of their own creation after an unreal and scenic fashion' (ibidem).

that 'snatches from experience a variety of common instances, neither duly ascertained nor diligently examined and weighed, and leaves all the rest to meditation and agitation of wit'.[25] Bacon maintains that Aristotle himself is the most eminent example of this sort of idol. Bacon stigmatises also the 'Empirical' philosophers 'who, having bestowed much diligent and careful labour on a few experiments, have thence made bold to educe and construct systems, wresting all other facts in a strange fashion to conformity therewith.' As examples, Bacon mentions the alchemists. Finally, he mentions the class of superstitious philosophers '. . . who out of faith and veneration mix their philosophy with theology and traditions'. Bacon mentions Pythagoras and Plato as examples of this idol arguing that from 'this unwholesome mixture of things human and divine there arises not only a fantastic philosophy but also an heretical religion'.[26] Bacon introduces a rigid demarcation between sound science based on empirical evidence, and pseudoscience deviating from sound inductive principles, such as alchemy, astrology, and theology. This resetting of the method of sound science became rapidly mainstream in the post-Baconian period. We see this new tendency in Galileo who builds the foundation of his cosmology on the concrete science of mechanics rather than on the fashionable metaphysical theory of matter. Although Newton wrote extensively on theological and alchemic issues that Bacon would have defined pseudoscientific, the change in the concept of science is confirmed by the fact that he kept these interests rigorously secret to keep intact his scientific prestige.

Bacon urges us to 'thoroughly free and cleanse' our mind from the idols to grasp the truth. We must repeat the cleansing regularly to keep our mirror in working order, but the idols tend to reproduce themselves in new forms. In other words, Bacon's theory of idols illustrates the limits of our knowledge and strongly recommends a persistent critical and self-critical attitude. Nevertheless, we have to recognise the active role of our mind because induction, invention, and judgement presuppose its crucial action. In addition, the researcher must confirm or correct the information gained through the senses by a critical use of experiments. Finally, sound science must focus on

[25] Bacon (1620, Book I, Aphorism 63).
[26] This third case implicitly involves Kepler himself and much of Renaissance science.

efficient causes excluding the other forms of Aristotelian causes that are particularly vulnerable to the idols of the mind. The Baconian method requires first systematic observations to gather reliable facts, and then a careful use of induction to generalise these facts as consequences of one or more axioms. The researcher should then reiterate this process until a sufficient variety of facts corroborate a few general laws. Within the Baconian method, induction, thus, plays a role much more crucial than for Aristotle. Bacon did not repudiate Aristotle, but rejected the scholastic interpretation of his philosophy for its emphasis on syllogism, dialectics, and textual hermeneutics rather than on the empirical efficient causes. Bacon is considered the founder of British Empiricism that played a crucial role as a driving force of the Scientific Revolution since the beginning of the seventeenth century until the end of the eighteenth century.[27] Bacon's methodology inspired many working scientists including the famous chemist Boyle (1627–1691), the founder of modern chemistry. The latter, following the suggestions of Bacon in the *New Atlantis* (2018 [1627]), promoted the establishment of the Royal Society of London (1663). This Institution was the first of several national academies that played a crucial role in the subsequent development of science. In the period of Enlightenment, scientific societies and academies largely replaced universities as hubs of innovative scientific research, while universities retained a more conservative attitude. In this way, research emancipated more easily from the influence of traditional scholasticism that was still hegemonic in the universities. The academies extended their reach also to the popularisation of science among an increasingly literate population. The States often supported and chartered academies and scientific societies to obtain the technical expertise required by their growing activity. In the seventeenth and eighteenth centuries, this network of scientific institutions was instrumental in promoting significant advancements in physics and emerging empirical sciences such as biology, medicine, and chemistry.

[27] Bacon builds on a pre-existent empiricist tradition that was particularly influential in Great Britain (Occam and Roger Bacon are well-known examples) and keeps a balanced empiricist position that the following British Empiricists – such as Hobbes, Locke, and Hume – made much more extreme. The breath of his vision explains why his influence extended also to historicist philosophers such as Giambattista Vico (1668–1744).

2.4 The Mathematisation of Natural Philosophy: Galileo and Huygens

Three years after the publication of the *Novum Organum*, Galileo Galilei (1564–1642) published *The Assayer* (1957 [1623]) in which he endorsed a full freedom from received authority and an uncompromising Empiricism based on meticulous observation. To this end, he advocated the systematic use of the experimental method that he practiced with great success. Differently from Bacon, Galileo emphasised the crucial role of mathematics and geometry in the interpretation of empirical evidence, arguing that the grand book of the universe[28]

> cannot be understood unless one first learns to comprehend the language and interpret the characters in which it is written. It is written in the language of mathematics, and its characters are triangles, circles, and other geometrical figures, without which it is humanly impossible to understand a single word of it; without these, one is wandering around in a dark labyrinth

As this famous citation clearly suggests, also Galileo – as Kepler, Copernicus, and many other scholars in European Renaissance – was deeply influenced by the Pythagorean orientation of the late Plato.[29] Differently from his predecessors, however, he based his cosmological insights not on disciplines of dubious scientific rigour (as astrology or proto-chemistry) but on the emerging discipline of mechanics that he contributed to develop. By adopting an approach based on systematic experimentation and careful use of mathematics, Galileo gave a decisive impulse to the Scientific Revolution by providing a few paradigmatic examples of sound science. Many historians of science consider Galileo the greatest scientist of his age.[30] His contributions prepared and anticipated many subsequent advances. In particular, Galileo played after Kepler a key role in the refinement of the

[28] Galileo Galilei (1623, 237–238).
[29] The father of Galileo, Vincenzo Galilei, in his quality of musician (lutenist) and music theorist, exposed the young Galileo to the Pythagorean tradition of *musica universalis*. In particular, Vincenzo Galilei – through systematic experiments implemented on musical instruments – established a non-linear relation between the pitch of a stretched string and the square root of the tension (1985 [1584]). This function is one of the oldest non-linear relations in physics and exemplifies the deep link between mathematics, observation, experiment, and technology (concerned with the crafting of musical instruments).
[30] See, e.g., Einstein (1954, 271).

heliocentric model of the Solar System, paving the way for the grand synthesis of Newton. Moreover, as Einstein recognised (1954), in his *Dialogue Concerning the Two Chief World Systems* (1632), Galileo suggested the basic principle of relativity, according to which the laws of physics are the same in any inertial system moving at a constant velocity. A further feature of Galileo's approach that is highly significant for modern science is the strict link with technology that he systematically cultivated. The development of the experimental method required the invention and continuous improvement of instruments that could facilitate observation. His contributions to the improvement of the telescope played a crucial role in making possible his powerful synthesis of Empiricism and mathematics. This approach inspired many applied scientists of the seventeenth century (including Huygens and Newton).

We find a similar strict link between observation, experiments, mathematics, and technology in another great scientist of seventeenth century, the Dutch polymath Christiaan Huygens (1629–1695). He was a first-rate applied physicist mainly in the fields of optics and mechanics and an innovative astronomer who advanced significantly the design and crafting of telescopes. Through his improved devices, he made a few important discoveries, including that of Titan, the moon of Saturn. Because of his systematic use of mathematics, he is considered the founder of mathematical physics.[31] In addition, Huygens implemented a fecund interaction between science and technology exploiting cleverly their synergies. He studied spherical lenses from a theoretical point of view with the aim of understanding and improving the existing telescopes. He began grinding and polishing his own lenses in 1655 and introduced the first compound multi-lens eyepiece. His most famous invention, however, was the pendulum clock in 1656, which he patented the following year. The determination of longitude in navigation as well as scientific observation in astronomy required accurate timekeeping and this prompted Huygens to design a pendulum clock. His analysis of the pendulum behaviour in his 1673 book *Horologium Oscillatorium* is regarded as one of the most important seventeenth-century works in mechanics

[31] He was also a pioneer of probability theory, writing in 1657 a path-breaking treatise on the subject.

(Huygens, 1934a [1673]). He aimed to combine Galileo's mathematical treatment of phenomena with Descartes's ambition of understanding the ultimate design of nature.[32] He eventually succeeded in clarifying the crucial concepts of mechanics such as mass, weight, momentum, force, and work. This deep and broad vision inspired his first rigorous analysis of a non-linear dynamical system, namely the compound pendulum.

2.5 The Methodology of Newton: Induction, Fallibilism, and Pluralism

At the turn of the seventeenth century, Isaac Newton (1642–1727) was considered as the most influential scientist. He became justly famous for his invention of calculus in the mid 1660s (more than a decade before Leibniz) and for having formulated the theory of universal gravitation in his *Principia* published in 1687. We consider here only a few methodological aspects of these achievements that are significant for the rest of the book. Newton's *Principia* soon became the paradigmatic exemplar of great scientific achievement in physics comparable to that of Euclid's *Elements* in geometry. Only Einstein, after more than two centuries, was able to go beyond the limits of the Newtonian system. The *Principia* brought about an epoch-making change of vision showing that the same force explaining terrestrial gravity keeps the planets in their orbit. This ended the dichotomy, dating back to Aristotle, between celestial and sublunary realms. Galileo anticipated this vision but did not succeed to read in the mathematical language of nature as much as Newton did. Newton himself presented the *Principia* as a novel approach to natural philosophy by implementing a perfected form of Empiricism.[33] At the same time, he explicitly rejected the rationalist approach championed by Descartes and Leibniz that had become influential in the second half of the seventeenth century. Newton rejected their heuristic method based on the formulation of

[32] Though Huygens had begun his research as a follower of Descartes, committed to correct his errors, he eventually became one of its sharpest critics.

[33] He recognised, however, that he could see further than his predecessors because he could mount on the shoulders of giants (such as, presumably, Copernicus, Kepler, and Galileo).

hypotheses weakly corroborated by empirical evidence, testing them to deduce observable conclusions[34]:

> I have not as yet been able to discover the reason for these properties of gravity from phenomena, and I do not feign hypotheses. For whatever is not deduced from the phenomena must be called a hypothesis; and hypotheses, whether metaphysical or physical, or based on occult qualities, or mechanical, have no place in experimental philosophy. In this philosophy particular propositions are inferred from the phenomena, and afterwards rendered general by induction.

This and similar passages suggest that the Empiricism of Newton was more radical than that of Bacon and Galileo. He believed that in contemporary scientific practice the so-called hypotheses go beyond what is authorised by sound induction and are thus unnecessary and misleading. This is the case of the theories put forward by rationalist philosophers such as Descartes and Leibniz. In this mood, the *Fourth Rule of Reasoning*, added in the third edition of the *Principia* (Newton, 1999 [1726]), maintained that,

> In experimental philosophy, propositions gathered from phenomena by induction should be taken to be either exactly or very nearly true notwithstanding any contrary hypotheses, until yet other phenomena make such propositions either more exact or liable to exceptions.

Newton's fallibilist point of view emphasised that the generalisations obtained by induction are usually only approximately true. We should see them as provisional propositions that solicit further observations and experiments to improve the precision of empirical results. This view, whenever experiments and observations are unable to decide a theoretical issue, the latter must remain open. Newton was keenly aware, as he recognised in the so-called *Copernican scholium*, that orbital motions are extremely complex and hence open to multiple competing descriptions. In particular, he was familiar with different approaches (at least seven) to calculating planetary orbits, having all a similar accuracy. All these approaches followed Kepler in using an ellipse to represent the trajectory of planets. Newton's doubts were particularly keen on the vexed issue weather gravitation should be explained by action at a distance or by mechanical processes not yet revealed by facts. One aspect

[34] Isaac Newton (1726, 943 of volume I).

of this new scientific approach, advocated in the preface to the first edition, was his focus on forces acting on atomic particles:

> many things lead me to have a suspicion that all phenomena may depend on certain forces by which particles of bodies, by causes not yet known, either are impelled toward one another and cohere in regular figures, or are repelled from one another and recede (Newton, 1687).

Newton argues that induction is the instrument of selection of the best theoretical option and that in this view mathematics is the handmaid of induction, while according to the Rationalists mathematics is the servant of deduction. To grasp this point, we must understand the crucial role of measurement in Newton's methodology. The *Principia* opens with a section called 'Definitions' that includes Newton's discussion of absolute space, time, and motion by introducing variables such as mass, inertia, and centripetal force. The emphasis in every one of these definitions is on how the designated quantity is to be measured. The most controversial aspect of Newton's method was his insisting that he had established conclusions about the physical features of celestial forces while holding questions about their physical causes in abeyance. This was the core of the complaint by Cartesians that the *Principia* was a work of mathematics, not physics. For similar reasons, in his *Discourse on the Cause of Gravity* (1934b [1690]), Huygens articulated a mixed assessment of the *Principia* (Huygens, 1934b). On the one hand, he accepted Newton's argument that terrestrial gravity is the same centripetal force holding the planets in orbit; on the other hand, he rejected attraction forces acting at distance, and considered Newton as a Geometer rather than a Physicist.[35] The reaction of Leibniz was even more critical. Two years after the publication of *Principia*, Leibniz published the *Essay on the Causes of Celestial Motions* (1689) which offered a revised vortex theory and rejected the notions of absolute time and space defending and updating the relative notions that were previously mainstream.[36]

[35] Huygens had a great admiration for Newton but remained critical of his theory of universal gravitation: 'I esteem [Newton's] understanding and subtlety highly, but I consider that they have been put to ill use in the greater part of this work, where the author studies things of little use or when he builds on the improbable principle of attraction.'

[36] Newton's absolute notion of time and space was fit for his theory and was in tune with the emerging exigencies of international trade and safe navigation. The

The divergent scientific visions of Newton and rationalists is clearly visible also in the calculus priority dispute. Newton did not hesitate to develop a full range of symbols and algorithms for determining what we now call integrals and derivatives, but he always opposed the idea, advocated by Leibniz, of providing foundations for this branch of mathematics based upon mere symbol manipulation. From his empiricist standpoint, Berkeley argued in favour of the superiority of the Newtonian approach to differential calculus criticising the Leibniz approach for its formalism.[37] Newton was fully aware that the priority dispute with Leibniz was involving much more than their personal pride and honourability. Newton confirmed this view at the end of his report on the priority dispute presented as anonymous to the Royal Society that he was then chairing:

> It must be allowed that these two Gentlemen differ very much in Philosophy. The one proceeds upon the Evidence arising from Experiments and Phenomena, and stops where such Evidence is wanting; the other is taken up with Hypotheses, and propounds them, not to be examined by Experiments, but to be believed without Examination.

The outcome of this dispute was different from what both scientists advocated. Applied physics followed more the experimental method of Newton, while the rationalist point of view prevailed in mathematics, geometry, and logic. This conflict evolved into a persistent divergence between English science associated with the Royal Society and the group that had been working with Leibniz since the 1690s, including Johann Bernoulli. The Newtonian theory of gravity was still very controversial when Newton died. In the first edition of the *Principia*, he had left a series of loose ends, but he could correct them only partially in the two successive editions. His followers tried hard to mend them in the eighteenth century. This enterprise took time but turned out to be highly successful. Euler (1736) played a crucial role in turning the three laws of motion into a coherent theory of mechanics. A great contribution came from French mathematicians and physicists who by the middle of the century had abandoned the vision of

new techniques for measuring latitude and longitude aimed to coordinate space and time according to a common framework.

[37] A recent study argues that the Leibniz's approach to calculus was free of contradictions and was sounder from the point of view of modern mathematics (Katz and Sherry, 2012).

Descartes in favour of that of Newton.[38] Clairaut (1713–1865) successfully predicted the month of return of Halley's Comet in the late 1750s greatly contributing to the acceptation of Newton's theory of gravity.[39] In the end, it was Laplace (1749–1827) who, extending the insightful mathematical contributions of Lagrange (1736–1813), succeeded to implement the research programme outlined by Newton in his *Principia*. Laplace summarised his comprehensive theorising in the four volumes of his *Traité de Mécanique Céleste* published from 1799 to 1805. Newtonian science as systematised by Laplace became the paradigmatic example of excellence in empirical science until Einstein (1879–1955) showed that Newtonian theory was only a limiting case of the theory of relativity. Analogously, Newton had shown in the *Principia* that the theory of local motion under uniform gravity worked out by Galileo and Huygens is a limit-case of his theory of universal gravity. This succession of progressive generalisations seemed to confirm the continuity of scientific progress through accumulation of empirical evidence and theoretical advances. However, this evolutionary process cannot be understood without considering the discontinuous changes of scientific vision that propelled it.

2.6 The Resurgence of Rationalism: Descartes and Leibniz

The modern rationalists adopted the epistemological point of view of Plato and Aristotle based on the distinction between mere opinion (*doxa*) and warranted knowledge (*episteme*) that is the hallmark of rationality. The empiricists claimed instead that sense experience is the ultimate source not only of opinions but also of warranted knowledge. Moreover, the extreme version of Empiricism maintained that in the process of scientific discovery the intellect plays only the passive role of a blank slate (*tabula rasa*), or a mirror reflecting reality (*camera obscura)*. According to this view, 'there is nothing in the intellect that

[38] This conversion was greatly influenced by Voltaire who wrote with Châtelet an influential popularisation of the Newtonian vision arguing in favour of its superiority over that of Descartes (Voltaire and Madame La Marquise de Châtelet (1745 [1738])). This example shows how important may be a change in scientific vision in restraining or promoting a specific research programme.

[39] This and other similar predictions were only approximately correct, leaving space to controversies.

was not before perceived by senses'.[40] The rationalists rejected this point of view claiming that induction is unable to lead to universal laws without the crucial active contribution of the intellect. The empiricists retorted that reason itself was based on previous experience. In this section, I will limit my analysis to a few selected epistemological insights contributed by Descartes and Leibniz.

René Descartes (1596–1650) distinguished himself as a creative mathematician, an insightful 'natural philosopher',[41] and an influential metaphysician. For our purposes, I need to mention only two of his many achievements: his model of rationalist reductionism and his crucial contribution to the foundation of analytic geometry. Descartes agreed with Bacon and Galileo on the necessary rejection of received authorities including that of Aristotle.[42] However, differently from the empiricists, he shared Aristotle's directive principle that certain knowledge 'must necessarily be deduced from first causes [. . .] we must try to deduce from these principles knowledge of the things which depend on them, that there be nothing in the whole chain of deductions deriving from them that is not perfectly manifest' (Descartes, 1985, vol. 1, 179–189).[43] He interpreted the relation between the language of facts and the language of mathematics differently from Galileo. In a letter of 1638 to Mersenne, Descartes criticised Galileo because, 'without having considered the first causes of nature, [Galileo] has merely looked for the explanations of a few particular effects, and he has thereby built without foundations' (Descartes, 1985, vol. 2, 380). He maintained that the ultimate seeds of knowledge are inside our mind.[44] He argued that sound knowledge requires certainty: 'We must occupy ourselves only with those objects that our intellectual powers appear competent to know certainly' (1628,

[40] The Peripatetic School asserted this proposition that was later often repeated by the main exponents of Empiricism such as Aquinas and Locke.

[41] His achievements in physics include the sine law of refraction, an empirical account of the rainbow, and an explanation of the formation of the earth and planets that anticipated the nebular hypothesis.

[42] This freedom of thought could be dangerous also in Descartes's France as in Galileo's Italy. In 1624 the French Parliament had passed a decree forbidding criticism of Aristotle on the pain of death.

[43] On this crucial point, Aristotle followed his master Plato. In *Theaetetus* and in *Meno*, Socrates suggests that reliable knowledge is '*orthos doxa*' for which one can provide a *logos*.

[44] He was thus closer to Plato, who believed in innate ideas, than to Aristotle, who asserted that, before experience, our mind is a blank slate (tabula rasa).

Rule II, 1).[45] In his celebrated *Discourse on Method* (2008 [1637]) he adopted an attitude of "systematic doubt", namely the suspension of judgement, until the truth is not fully grasped, to avoid the persistence of false beliefs. He advocated this form of methodical 'scepticism', to find the way to defeat systematic scepticism. He argued that the solutions to philosophical and scientific problems cannot be found by relying on the empirical evidence alone, as empiricists did, but only through rational reflexion. To doubt is to think and thinking proves the existence of the thinker: '*cogito ergo sum*'. According to Descartes, this unquestionable truth provides the ultimate foundations for certain knowledge, upon which he struggled to build his philosophical system. However, the goal of certain knowledge may be sought only at a heavy cost. Descartes's arguments had to be derived from basic rational principles, but deductions of any appreciable length must rely on our fallible memory. Therefore, the syllogisms on which complex deductions are based are themselves subject to error. Notwithstanding these shortcomings, Descartes's subjectivist turn in metaphysics had a deep influence on successive European philosophy. In mathematics, Descartes was particularly famous for having devised the so-called Cartesian coordinates that favoured the development of 'analytic' geometry. The latter played the role of a rigorous bridge between geometric entities and algebraic equations, making possible the reformulation of problems initially posed in the language of geometry as equivalent problems of algebra or vice versa. This terminated the traditional systematic primacy of geometry over the other areas of mathematics that had been established by Pythagoreans, Plato, and Euclid after the discovery of irrational numbers.[46] The step forward in the use of analytic methods proved to be crucial in many scientific fields because the geometric approach

[45] The other rules are the following: (1) accept nothing as true that is not self-evident, (2) divide problems into their simplest parts, (3) solve problems by proceeding from simple to complex, and (4) recheck the reasoning. These rules are a significant manifesto for the reductionist method.

[46] After two millennia of geometry primacy, this became possible only after algebra had been significantly developed by Islamic and Indian mathematicians. The immediate predecessor at the end of the sixteenth century was the French mathematician François Viète (1540–1603) who introduced the first systematic algebraic notation and developed powerful general algebraic methods for solving algebraic equations. Descartes and Fermat independently founded analytic geometry in the 1630s by generalising and improving Viète's approach.

is more powerful to solve specific problems while algebra is more powerful for other problems. The complementary use of both methods made possible crucial advances, such as the elaboration of calculus by Newton and Leibniz.[47] As this example shows, the invention of analytic geometry played a crucial role in the Scientific Revolution favouring the mathematisation of physics.

The contraposition between Descartes and Newton influenced the conflict between Empiricism and Rationalism that characterised philosophy. The same conflict reverberated from philosophy to science. Descartes was also an excellent scientist who influenced the practice of science in France and elsewhere for a few decades. Descartes's vision greatly influenced the philosophy of logic and mathematics paving the way for the far-reaching Kantian synthesis and its subsequent evolution in the post-Kantian thought. His approach was for a while particularly influential also in physics (vortex theory) but by the end of the century, it succumbed to that of Newton.

Gottfried Wilhelm Leibniz (1646–1716), along with Descartes and Spinoza, is considered one of the great seventeenth-century advocates of Rationalism. Similarly to Descartes, Leibniz assimilated and updated a few principles of the scholastic tradition. In particular, he agreed with the latter that the only way to work out sound arguments must apply reason to first principles rather than to the empirical evidence:

> The senses, although they are necessary for all our actual knowledge, are not sufficient to give us the whole of it, since the senses never give anything but instances, that is to say particular or individual truths. (Leibniz (1996 [1704]), Preface, 150–151)

However, following Aristotle, Leibniz stressed the importance of empirical observation and induction in empirical science. For this reason, he exhorted the scientists to base their theories on systematic observations and experiments, urging them to distinguish sharply between scientific and metaphysical points of view. Leibniz insisted, however, that induction is insufficient to guide our intellect, claiming against empiricists that 'nothing is in the intellect that was not first in

[47] Both used coordinates to develop notations that expressed the ideas of calculus in full generality and led naturally to differentiation rules and the fundamental theorem of calculus (connecting differential and integral calculus).

the senses, except the intellect itself' (Leibniz, 1996 [1704]).[48] In other words, understanding presupposes an active role of the intellect that involves the systematic use of logical inferences and categories of thought such as causality that we cannot derive by mere induction. The most original and influential contribution of Leibniz was his fruitful exploration of the potential of logic in philosophic and scientific arguments. In particular, he believed that, by reducing human reasoning to some sort of logical calculation, we could overcome many differences of opinion:

> The only way to rectify our reasonings is to make them as tangible as those of the Mathematicians, so that we can find our error at a glance, and when there are disputes among persons, we can simply say: Let us calculate [calculemus], without further ado, to see who is right. (Leibniz, 1685, The Art of Discovery, quoted by Wiener, 1951)

To this end, Leibniz introduced the so-called *calculus ratiocinator*, which foreshadowed symbolic logic, classical decision theories, and the universal Turing machine that underlies computer architecture. Leibniz reached in his unpublished writings a level of sophistication in logic that only Frege equalled 200 years later (Russell (1946). In addition, Leibniz's modern interpreters emphasise that he anticipated subsequent research streams, such as fractal geometry, algorithmic information theory, and cybernetics. Finally, Leibniz anticipated Einstein by arguing, against Newton, that space, time, and motion are relative, not absolute: 'As for my own opinion, I have said more than once, that I hold space to be something merely relative, as time is, that I hold it to be an order of coexistence, as time is an order of successions.'

The persisting influence of Leibniz is still visible even at the frontier of quantum physics. For example the recent contributions of Smolin to quantum gravity are explicitly based on a revival of Leibniz's methodological principles (see Smolin, 2014 [2013], 2019).

2.7 Hume and the Crisis of Enlightenment Epistemology

Hume (1711–1776) continued the tradition of British Empiricism as developed by Bacon, Newton, Hobbes, and Locke. His radical

[48] Leibniz (1996 [1704] Book II, Ch. 1, §2): 'Nihil est in intellectu quod non fuerit in sensu excipe: nisi ipse intellectus').

Empiricism reached extreme conclusions that most readers interpreted as radical scepticism. According to Hume, experience is not only the source of all ideas, but also the ultimate determinant of their content. In his opinion, even our most abstract ideas – such as cause and substance – draw their content by the experiences generating them. Thus, the initial disagreement between rationalists and empiricists about the source of our ideas led to one about their content: '... the rationalist/empiricist debate ultimately concerns our position in the world, in this case our position as rational inquirers. To what extent do our faculties of reason and experience support our attempts to know and understand our situation?'[49] To answer this question, Hume constructed critical arguments with the declared intention of undermining the unjustified presumption of reason, as conceived by rationalist philosophers:

> When we entertain, therefore, any suspicion that a philosophical term is employed without any meaning or idea (as is but too frequent), we need but inquire from what impression is that supposed idea derived? And if it be impossible to assign any, this will confirm our suspicion (Hume, 1748, Section II, 30).

At the same time Hume exposed the intrinsic weaknesses of the inductive method on which empiricists crucially relied, opening the way to more robust versions of both Empiricism and Rationalism and to more convincing syntheses between the two scientific visions.[50] Against Rationalists, Hume rejected the existence of innate ideas, positing that all human knowledge derives solely from experience. Intuition and deduction can provide us with knowledge of necessary truths such as those found in mathematics and logic. However, Hume, differently from Descartes, argued that this sort of knowledge cannot play the role of reliable knowledge of the external world but only of the relations between our own ideas. However, Hume also argued that there is no way to provide an unconfutable rational justification for scientific inductive reasoning. We can draw sound inferences from experience only if we presuppose that the future will resemble the past, but we cannot ground this assumption on prior experience alone. This radical criticism of induction shows not only the limits of reason applied to

[49] Markie (2017, 33).

[50] He inspired in particular the far-reaching Kantian synthesis between Empiricism and Rationalism (see Section 3.1).

empirical arguments but also the limits of experience in the absence of supporting rational priors, soliciting a synthesis between experience and reason. Hume applied in particular this argument to causality that – according to Aristotle and the scholastic approach – constituted the hallmark of deep and sound knowledge: 'true knowledge is causal knowledge'. According to the epoch-making objections by Hume, we are unable to find in the experience the required link of necessity between cause and effect, as we can only observe a 'constant conjunction' of events:

> . . .we may define a cause to be an object followed by another, and where all the objects, similar to the first are followed by objects similar to the second . . . (Hume, 1748, Section VII, Part 2, 87)

This assertion challenged the scholastic and rationalist models of knowledge based on causality, but stimulated constructive reactions that eventually led to more sophisticated models of causality. Hume's approach stimulated the emergence of the concept of empirical correlation underlying the birth of modern statistics. If causality is nothing but association of observations, this does not stop our investigation: a natural step forward would be to measure the extent of this association and its persistence through time. This is what the statisticians started to do at the end of nineteenth century as soon as the dogma of determinism started to crumble. The influence of Hume's criticism of causality went much beyond causality as it deeply affected the subsequent evolution of philosophy and methodology.[51]

[51] See De Pierris and Friedman (2018, 1).

3 Science and Epistemology Since Kant

William Whewell:[1] *The Senses place before us the Characters of the Book of Nature; but these convey no knowledge to us, till we have discovered the Alphabet by which they are to be read.*

Werner Heisenberg:[2] *The positivists have a simple solution: the world must be divided into that which we can say clearly and the rest, which we had better pass over in silence. But can any one conceive of a more pointless philosophy, seeing that what we can say clearly amounts to next to nothing?*

The crisis of Enlightenment epistemology, clearly exposed by Hume in mid eighteenth century, solicited a plurality of reactions. The first and most far-reaching came by Kant (Section 3.1). His new critical paradigm was a turning point leading to the transition from the scientific visions of Enlightenment to a plurality of new scientific and philosophical visions. The influence of Kant took divergent forms in different countries. While in Germany the traditional Historicism blended mainly with Idealism, in Great Britain a different form of Historicism (Evolutionism: as Historicism) blended with a revised form of Empiricism often called Positivism.[3] In both cases, the emphasis on history aimed to provide new foundations to the idea of progress in science and politics. The German idealists reacted mainly to Kant's thesis that reason tends to slip into unsolvable antinomies as soon as it

[1] Whewell (1967 [1840], vol. 1, xvii). [2] Heisenberg (1971, 213).

[3] The philosophical vision of 'Positivism' was introduced by Auguste Comte (1798–1857) in his influential *Course in Positive Philosophy* (published between 1830 and 1842). Comte reappraised the principles of Empiricism in a sanguine way emphasising the progress of natural science and advocating the extension of the positive method to the general science of society that he called sociology. Comte's positivism (similarly to traditional Empiricism) asserted that we can obtain warranted (or 'positive') knowledge exclusively upon the empirical evidence received from the senses.

is disconnected from experience. They claimed instead that reason can resolve these antinomies by a creative act that overcomes the opposition of reason and experience into a new synthesis. This view interprets the unfolding of history as a dialectical process driven by reason. In particular, the German Idealism culminating with Hegel subsumed science's evolution under the categories of idealist dialectics (see Section 3.2). In the same period, a different philosophical stream, dubbed Positivism by Comte, reacted differently against the alleged scepticism of British Empiricism. Comte's Positivism endorsed a few convictions that reflect the spirit of the time. First, Comte (1830–1842) gave a crucial role to history of science as an interpretive clue of science and society. Second, he advocated a teleological view of history that motivated a strong faith in the progress not only of science, but also – through science – of society. Third, he emphasised that the crucial target of science is prediction because action crucially depends on it. This view, which will be very influential also in the successive forms of Positivism, reflected the increasing link between science and technology.[4] In the same period, also natural sciences started to show a new interest in the long-run evolution of Nature. Eminent scholars – such as the palaeontologist Cuvier, the geologist Lyall, and the zoologist Lamarck – contributed to increase the interest in the long-run history of the biosphere. Building on systematic painstaking observations, Darwin suggested in 1859 a far-reaching theory of biological evolution that slowly conquered the consideration of his contemporaries (Section 3.3). In the same period, physics itself introduced the arrow of time with the second law of thermodynamics first formulated by Carnot in 1824. In the second half of the nineteenth century, the Austrian polymath Mach suggested an influential view of the new advances of science and their close interaction with epistemology (Section 3.4). This approach influenced the establishment of the Vienna Circle as the hub of different traditions of thought sharing a common trust in science and mistrust in traditional metaphysics. In particular, the Circle promoted the synthesis between the positivist method of natural

[4] In later life, Comte developed a 'religion of humanity' for positivist societies aimed to fulfil the cohesive function once held by traditional religion. Comte's methodology and humanitarian ideals had an influence not only in France, but also in other countries such as Brazil and Great Britain where Comte influenced in particular John Stuart Mill, Harriet Martineau, and George Eliot. Mill recognised the influence of the first Comte but rejected his late humanitarian 'religion'.

sciences and the formalist approach of exact sciences. This synthesis that many scholars called ‘Logical Positivism’, dominated philosophy of science for a few decades (Section 3.5). After WWII, the shortcomings of logical positivism became more evident triggering a process of decline that paved the way to the emergence of a different vision of science often dubbed post-positivism (Section 3.6).

3.1 Kant and the Decline of Enlightenment

At the turn of nineteenth century, Immanuel Kant (1724–1804) played a crucial role in redefining the plurality of scientific visions. Hume’s criticism of induction and causality ‘interrupted [his] dogmatic slumber and gave [his] investigations in the field of speculative philosophy a completely different direction.’ (Kant 1983).[5] The new direction mentioned by Kant is that pursued in the ‘critical period’ of his thought that led to the publication of the three *Critique* books that express his mature system of thought: *Critique of Pure Reason* (published in 1781; second revised edition in 1787), *Critique of Practical Reason* (1788), and *Critique of Judgement* (1790). In these three masterpieces, Kant implemented a paradigm shift based on a network of related conceptual innovations that deeply influenced the foundations of subsequent philosophy and science. I mention here only some of his epistemological insights, focusing mainly on the *Critique of Pure Reason*. In this book, Kant advocated a ‘Copernican revolution’ in epistemology aimed to shift the focus of thinking from objective reality to the epistemic subject. What he called ‘critical philosophy’ aimed at a systematic exploration of the inherent limits of knowledge and its relational nature. One of the main goals of his approach was that of determining the conditions under which scientific knowledge is possible. To this end, he discriminated the legitimate forms of investigation, such as those pursued by natural sciences, from those that he considered illegitimate, such as those carried on by traditional metaphysics. The outcome of this investigation superseded the traditional opposition between Empiricism and Rationalism because ‘thoughts without [empirical] content are empty, perceptions without concepts

[5] Kant defended Hume’s arguments from a series of superficial rebuttals that missed his points. In his opinion, the weak step of his argument lies in the wrong characterisation of the role of human intellect that implies a distorted view of the nature of experience.

are blind' (Kant 1999 [1781/1787]). In this view, the mind receives and works out the perceptions of external phenomena, but their comprehension requires the active intervention of our mind.[6] Our observations are confined to *phenomena*, namely the relations between things in themselves (*noumena*) and the epistemic subject. The characteristics of phenomena are thus theory laden as they depend on the structuring role of the intellect. Kant maintains that the mind is much more than an empty container that receives data from outside, as radical Empiricism pretended. The epistemic subject must order the sensorial signals in the mind through cognitive concepts such as time, space, and cause. The critical approach of Kant removes the opposition between Empiricism and Rationalism from the centre stage of epistemology that it occupied since the Scientific Revolution, initiating a new phase characterised by a more complex interaction between different dimensions of knowledge. In the *Critique of Pure Reason*. Kant revived dialectic focusing on its critical role. While dialectic represented for Plato a crucial source of rational knowledge, it represented for Kant an emblematic case of the limits to reason. He adopted a diminutive view of traditional dialectic as deceptive 'Logic of Appearance'. However, he emphasised the critical role of what he called 'transcendental dialectic' as it aims to keep reason within its limits to avoid unsound conclusions and metaphysical dogmatism. Reason has an intrinsic tendency to move beyond ('transcend') the realm of experience but so doing remains trapped in unsolvable antinomies.[7] Kant's transcendental dialectics revives in different form the critical spirit of Socrates's dialectic.

Many interpreters see Kant as the emblematic philosopher of the late Enlightenment. In the three *Critiques*, Kant tried to defend the Enlightenment from the growing criticisms that were paving the road to its decline. Kant was keenly aware of the deep tension between the irrepressible critical attitude of rational individuals and the required interpersonal rationality of the community. Kant discussed this issue in

[6] Kant articulated human rationality into two faculties: understanding and reason. The process of understanding uses concepts to organise our experience. Reason coordinates the concepts of understanding to achieve higher and higher levels of conceptual unity. This process leads reason to produce transcendental ideas, or concepts that go beyond the world of experience.

[7] Senses are less likely to err, 'not because they always judge correctly, but because they do not judge at all' (see Kant (1999 [1781/1787], 208.)

connection with the crisis of the Enlightenment. In the famous essay 'What Is Enlightenment?' published in 1784, Kant defended the deepest aspirations of the Enlightenment by arguing that

> Enlightenment is the human being's emergence from his self-incurred immaturity. Immaturity is the inability to use one's own understanding without the guidance of another [. . .] *Sapere aude!* [Dare to be wise!] Have courage to make use of your own understanding! Is thus the motto of Enlightenment (Kant, 1784, 8:35)

Kant did not share the fashionable contemporaneous critiques of Enlightenment for its alleged negative attitude and vindicated its persistent validity. He was, however, concerned with the possible destructive effects of Enlightenment on public morals and social order in consequence of its usual individualistic misinterpretations. Kant recognised that a merely individualistic interpretation of the rejection of any authority could fragment social cohesion and morality. In his late works, primarily in his three famous *Critiques*, Kant undertook the titanic task of suggesting a conception of reason that would provide solid foundations to social cohesion and morality without jeopardising the unbounded freedom of individuals required by reason. To this end, Kant clarified in the *Critique of Pure Reason* that

> Reason [. . .] cannot restrict the freedom of critique through any prohibition without damaging itself and drawing upon itself a disadvantageous suspicion. For there is nothing so important because of its utility, nothing so holy, that it may be exempted from this searching review and inspection. [. . .] On this freedom rests the very existence of reason, which has no dictatorial authority, but whose claim is never anything more than the agreement of free citizens, each of whom must be able to express his reservations, indeed even his veto, without holding back

In other words, Kant conceives of reason as the only authority that a free individual must follow to orientate their epistemic and practical behaviour.[8] In the Kantian philosophical system, the primacy of practical reason does not undermine the autonomy of pure reason. Reason is the necessary arbiter between truth and error and thus the fundamental guide of knowledge, learning, and rational action. On the other

[8] In the language of Kant, reason is the only form of unconditional (or non-heteronomous) authority that may guide our thinking and acting (see Williams, 2018).

hand, the principle of seeking unity in experience is a crucial regulative principle of reason. Kant is aware that the critical role of reason and its unifying function are in principle conflicting. The critical role tends to destabilise and fragment whatever unity reason has succeeded to build. Kant recalls on this purpose the biblical story of the Babel tower. God punished the arrogance (*hubris*) of the builders by interrupting the mutual understanding of individual languages to make impossible the necessary coordination of their efforts to build the tower. The tension between the critical and unifying requisites of epistemic reason cannot find a solution within pure (epistemic) reason itself. Kant suggested a way out from this impasse by asserting that the Categorical Imperative is not only the supreme principle of practical reason but also indirectly of pure (epistemic) reason. According to Kant, the general adoption of the Categorical Imperative guarantees the independence of practical reason of particular interests and individual cognitive inclinations. Unfortunately, its general adoption does not seem to be implementable in the real world.

The influence of Kant has been wide and long lasting, stimulating the genesis and development of a variety of schools of thought. These include German Idealism, logical positivism, phenomenology, existentialism, linguistic philosophy, structuralism, post-structuralism, and deconstructionism. In what follows, I will consider only some of these research programmes that I consider particularly important for the theme of pluralism.

3.2 Hegel and Teleological Dialectic

Although most scholars maintain today that Kant's late contributions provided the most influential thought system in modern philosophy, few readers acknowledged their full importance soon after their publication. In that era of epochal transition, cultural and philosophical trends were moving away from his thoughtful critical defence of Enlightenment. However, the Kantian synthesis did not fail to attract some of the most brilliant young German philosophers (including Fichte, Schelling, and Hegel), but they soon detached themselves from Kant's vision towards radical forms of idealism. For our purposes, it is sufficient to discuss briefly some features of the philosophical system elaborated by Friedrich Hegel (1770–1831), the most influential representative of German Idealism. I cannot ignore him because the influence of his historical vision went much beyond philosophy extending also to the evolution of science and epistemology. I will focus exclusively on his dialectical method that he regarded as the backbone of his philosophical system.[9] He related this 'speculative mode of cognition' to the traditional meaning of dialectic as a method of philosophical argument that leads opposing positions towards the truth. However, he criticised Plato's version of dialectic, claiming that it is unable to go beyond scepticism and cannot generate more than approximate truths.[10] Hegel suggested a new form of dialectical method that aimed to reach a general synthesis of partial truths.[11] He was initially influenced by Fichte who had suggested that we can encompass Kant's antinomies within a more general and comprehensive synthesis. To this end, Fichte introduced the iconic triad thesis–antithesis–synthesis that in popularisations became the hallmark of dialectic. Hegel, to whom this triad has often been attributed,[12] criticised its mechanical use by Fichte.[13] However, he implemented a similar teleological method arguing that contradictions eventually find a synthesis that preserves what is still valid in the preceding stages of the dialectical progression while moving beyond their limitations. Hegel adopted this approach to work out a new vision of nature, knowledge, and history in which the dialectic progression plays a crucial role. According to Hegel, this progression leads from the initial state of self-alienation of human beings to their self-realisation as free and equal citizens. Hegel asserted that the purpose of dialectic is 'to study things in their own being and movement and thus to demonstrate the finitude of the partial categories of understanding'.[14] In his view, any stage of history is characterised by internal contradictions that eventually sublate in a stage that preserves what is still valid in the

[9] Hegel (1977 [1807]).

[10] This criticism is clearly focused on the critical dialectic of the Socratic dialogues and cannot be extended to the teleological dialectic of the late dialogues of Plato. On the contrary, Hegel revives and develops the spirit of Plato's teleological dialectic (see Popper, 1945).

[11] Hegel (2010 [1812, 1813, and 1816], 33).

[12] In the preface to *Phenomenology*, Hegel derides explicitly the 'mechanical formalism' of the triad thesis–antithesis–synthesis introduced by Fichte and accepted by other philosophers, including Schelling.

[13] He addressed the same criticism against Kant without compelling arguments.

[14] Hegel (1807, note to §81).

preceding stage while moving beyond its limitations.[15] The new stage starts a successive phase of the evolutionary process. The succession of stages so conceived does not iterate, as in Fichte, the same mechanical triad but adapts to the empirical evidence of history to represent its complex evolution.[16] According to Hegel, his own version of the dialectical method leads to increasingly universal concepts, and ultimately drives to the 'Absolute', which is the final all-encompassing concept in the subject matter under investigation. Hegel's dialectical logic, differently from formal logic, depends on semantic components as well as subject-matter specificities. The concept of contradiction is essentially heuristic and does not involve a genuine logical contradiction. Therefore, we should not confuse in the subject matter the 'necessity' of the dialectical progression with logical necessity. The dialectical progression is a sort of organic succession where its stages follow one another as bud, blossom, and fruit.[17]

The interpretation of Hegel's thought has always been highly controversial. Most contemporary philosophers followed the lead of Schelling (1775–1854) who interpreted Hegel's idealist philosophical system as a return to what Kant had criticised as dogmatic metaphysics. According to this interpretation, Hegel aimed to offer a metaphysical view of God as Absolute Spirit, namely the ultimate reality that we could know through pure thought processes. This interpretation may find textual support in the writings of Hegel, particularly in his later contributions. He asserted, for example, that philosophy 'has no other object but God and so is essentially rational theology'.[18] However, Hegel's metaphysical approach did not underplay the crucial importance of human history that in his view actualises the mind of God through the actions of human beings. Thus, in Hegel's view, the evolution of human consciousness progressively realises God's self-consciousness and perfection. Therefore, the self-actualisation of the Absolute Spirit encompasses both the subjective life of human beings and their historically determined actions.[19] An important consequence

[15] Sublation is the usual translation into English of the German word *aufhebung*.

[16] Hegel does not always follow the textbook triadic paradigm articulated in thesis, antithesis, and synthesis 'because the method or progression is driven only by the subject matter itself'.

[17] Hegel himself used this metaphor.

[18] Hegel (1998, I: 101).

[19] In contrast to the British subjective idealism as epitomised by Berkeley, Hegel inherited from the pantheistic tradition of German culture the belief in the

of Hegel's specific approach to metaphysics leads to a systematic concern for human history in all its concrete details, a concern that appealed also many non-idealist philosophers and scientists, contributing to keeping alive his thought in successive waves of resurging interest. However, the specific role of history in his thought has been particularly controversial. The principal criticism of Hegel's 'historicism' focused on its teleological approach.[20] Hegel's historical idealism rapidly declined in Germany after Hegel's death but revived in new forms later and elsewhere.[21]

A few interpreters of Hegel's thought considered reductive the standard interpretation because it plays down his several insights in specific areas including science, logic, aesthetics, politics, and law. Since 1970, some interpreters of Hegel's idealism emphasised an alleged continuity with the 'critical philosophy' of Kant.[22] This new view of Hegel's idealism, often called 'post Kantian', sees within the fog of Hegel's metaphysics a critical philosopher in disguise that aimed to extend Kant's critique. For example, Hegel criticised Kant's thesis that we cannot know the world in-itself as radically sceptical and maintained instead that the reason of the epistemic subject is the same underlying the inner rationality of the external world. Hegel's response to the alleged scepticism of Kant is thus based on a radical change in the concept of reason.[23] In this view, Hegel rejected the traditional

existence of an external world conceived as objectified and evolving divine spirit. Thus, he subsumed in his philosophical system the 'objective' idealism that had already inspired German historians who reconstructed the evolution of social life and philosophical thought in terms of historically determined cultural structures (namely, worldviews or *weltanshauungen*).

[20] See in particular Popper (1945).

[21] In Great Britain, for example, the Idealist School led by Green and Bradley flourished at the end of the century for a brief period. However, at the turn of nineteenth century, Russell and Moore reacted against mainstream Idealism initiating a radically different style of philosophy that they called analytic philosophy. The chasm between the new approach to logic advocated by them and the dialectical logic cultivated by Hegel and his followers was too deep to allow any conceptual compromise. Russell did not hesitate to build a Turk's head that deeply distorted the image of Hegel, discouraging for many decades any possible revival of idealist philosophy.

[22] See, in particular, Pinkard (2014) and Pippin (2019).

[23] Hegel derives his own version of self-driving reason from Kant himself by adopting his notion of concept-creating 'speculative' reason. However, according to Kant, the trouble with self-driving reason is that it tends to produce 'antinomies' consisting of irreconcilable theses and antitheses. In Kant's opinion,

assumption attributed to Kant that reason consists of static universal concepts, and assumed instead that universal concepts are dialectical. The crucial insight of Hegel's dialectics is that concepts 'self-sublate', namely cancel and preserve themselves in a higher synthesis. In this view, we may find in Hegel a critical kernel concealed within a pre-Kantian shell.[24] How can we explain this apparent incongruence of Hegel's philosophical system? Hegel grew up in the period of the surging German Romanticism characterised by the '*Sturm und Drang*' and fervid hope in political revolution, but he wrote his major works in the period of restoration. It is not surprising that his works reflected the sudden change of worldview (*zeitgeist)*, of the late Hegel's era, repressing his earlier motivations and achievements. The trouble is that – according to Schopenhauer, Wittgenstein, Popper, and many other critics of German Idealism – Hegel often used dialectics, in particular the dialectical principle of the coincidence of the opposites, as a device to convince the interlocutors of self-serving truths. What is important for our purposes is that even the most sympathetic interpretations of Hegel's philosophical system cannot ignore the dogmatism of his teleological historicism, which is inconsistent with a sound theory and practice of scientific pluralism. This is because Hegel's teleological historicism assumes that the latest synthesis is necessarily more comprehensive than the previous theses and antitheses. This assumption would not necessarily imply the impossibility of an alternative competing synthesis, but Hegel seems to reject this residual margin of possible pluralism by assuming that the ultimate authority

to avoid these destructive contradictions, we should not apply to the world of experience any reason's conclusion that is not within the scope of our understanding. On the contrary, Hegel objected that the Kantian antinomies reveal the dialectical nature of reason that may supersede contradictions by generating increasingly comprehensive concepts. Therefore, we should not repress reason within the narrow scope of understanding but adopt a more comprehensive and constructive concept of reason supported by his version of the dialectical method.

24 Popper maintained that Hegel used dialectic to reverse the meaning of Kant's teachings (as the late Plato did with Socrates): 'Hegel never attempted to refute Kant. He bowed, and twisted Kant's view into its opposite. This is how Kant's "dialectic", the attack upon metaphysics, was converted into Hegelian "dialectic", the main tool of metaphysics' (Popper, 1945, 252). In my opinion Popper is substantially right but plays down the insights that we may find in the applications of Hegel's historicism to specific subject matters.

for deciding truth is the Sovereign. This irremediably clashes against the ultimate foundations of science.

3.3 Darwin and the Genesis of Evolutionism

We cannot understand the evolution of pluralism in the last two centuries without discussing the genesis of biological evolutionism and its rapid diffusion in the second half of the nineteenth century. This new scientific vision was an epistemic revolution that had a deep impact not only in biology but also in epistemology and many natural and social scientific disciplines. I focus in this section on the theory of biological evolution as worked out by Darwin (1809–1882) in his masterpiece *On the Origin of Species* published in 1859.[25] As is usual with any new idea, we can find a long list of predecessors starting from Ancient Greece (Anaximander, Empedocles, and, in a sense that I will specify later, Aristotle himself). We find this tradition evolving in Classical Rome (Lucretius and Cicero), revived by the early fathers of the church (in particular Origen and Augustin), as well as by medieval Islamic philosophers (in particular Ibn Khaldūn). For our purposes, it is sufficient to mention a crucial idea of Aristotle that influenced not only medieval scholastics but also the debate on Darwinism itself. Aristotle in *Historia animalium* classified living beings according to the so-called ladder of life, a progressive hierarchy that starts from the simplest organisms and proceeds step by step towards a greater complexity of structure and function.[26] Aristotle claimed that this ladder represents the teleological order of nature but he did not go significantly beyond its static representation. In the period of Enlightenment, we find a few limited hints to an evolutionary theory of biological species in authors such as Buffon (1707–1783) the greatest naturalist of his time, Diderot (1713–1784) the co-editor of the *Encyclopédie*, and Erasmus Darwin (1731–1802). the grandfather of Charles Darwin who was an esteemed physician and naturalist. However, the first full-fledged theory of biological evolution was suggested by the French naturalist Jean-Baptiste Lamarck (1744–1829) in his path-breaking *Philosophie Zoologique* (Lamarck, 1984 [1809]).

[25] As is well known, this theory was first exposed by two independent contributions of Darwin and Wallace (1823–1913) published in 1858. From now on, I will focus exclusively on the theory of Darwin.

[26] This idea was mentioned in Latin with the expression "*scala naturae*".

In this work, he explained the 'transmutation of species' by combining a force driving organisms up the ladder of complexity with a force adapting them to local environments through the use and disuse of biological characteristics and the inheritance of acquired traits. However, the first force remains mysterious,[27] as it looks more like an alchemic influence than to a rigorously natural cause. In his view, biological evolution leads to a process of *orthogenesis*, namely a progressive process to which, however, he did not provide any rigorous evidential support. The theory of Lamarck was heavily criticised by contemporary naturalists (such as Cuvier) for the weakness of the evidential support. These severe criticisms inhibited further attempts of suggesting a sound theory of biological evolution for many decades. Darwin was able to make respectable his own version of the theory of biological evolution mainly by providing a great wealth of accurate observations and by applying a cautious inductive method to data gathered and interpreted in a very careful way. Notwithstanding all these efforts, Darwin found difficult to overcome the initial hostility. Even Darwin's friends and early mentors (such as Whewell and Lyell) remained unconvinced by his theory of natural selection. In the end, after a lively debate that raged over many decades, many scientists eventually accepted Darwin's vision of biological evolution as an established network of facts. Nevertheless, the laws of evolution that Darwin drew from his painstaking observations remained highly controversial for almost another century until the convergence with Mendel genetics, the systematic use of mathematical models and a wealth of new compliant observations enabled evolutionary biologists in the 1930s and 1940s to construct the modern Darwinian synthesis (often called 'the second synthesis').

In this section, I mention briefly the foundations of the theory of evolution as suggested by Darwin himself. First, in contrast with the literal interpretation of the *Genesis* and Aristotle's tree of life, he maintained that all species have descended from common ancestors. As for the *Homo sapiens*, Darwin just hinted at his descent from the common ancestor in the *Origin*, but he fully argued this thesis in a subsequent book *The Descent of Man* (published in 1871). He explained the branching pattern of evolution by focusing mainly on the interplay between random modifications and natural selection. He maintained

[27] This assumption recalls Aristotle's ladder of life.

that the struggle for existence had an effect like the artificial selection involved in selective breeding. The deliberate exploitation of selective breeding of animals and plants was a well-established practice started in the prehistory and progressively refined by the evolution of agriculture and husbandry. Robert Bakewell (1725–1795) had established selective breeding as a scientific practice during the British agricultural revolution in the eighteenth century. This gave a convincing support to Darwin's extension of the process of selection from its intentional artificial variety to the unintentional natural mechanism:[28]

If feeble man can do much by his powers of artificial selection, I can see no limit to the amount of change, to the beauty and infinite complexity of the co-adaptations between all organic beings, one with another and with their physical conditions of life, which may be affected in the long course of time by nature's power of selection. (Darwin, 1859, 109)

Darwin explained nature's power of selection by combining Malthus's insights on life struggle with the well-known, but not yet scientifically investigated, laws of genetic inheritance:

As many more individuals of each species are born than can possibly survive; and as, consequently, there is a frequently recurring struggle for existence, it follows that any being, if it vary however slightly in any manner profitable to itself, under the complex and sometimes varying conditions of life, will have a better chance of surviving, and thus be naturally selected. From the strong principle of inheritance, any selected variety will tend to propagate its new and modified form (Darwin, 1859, 59)

All the basic statements of Darwin's theory of evolution are empirical statements verifiable or falsifiable according to the tradition of British Empiricism. So, why even his learned friends who had shared with him the basic principles of biological evolution did not feel like providing an open endorsement to his full-fledged theory? First, most readers felt uneasy about the expression 'natural selection' that seemed to attribute an anthropomorphic intentionality to nature.[29] Most reviews, including many favourable ones, maintained that Darwin's explanation could account for the varieties of the same species but not for the

[28] Darwin always denied that his own notion of natural selection had this sort of implications, contrasting it sharply and consistently with artificial selection.
[29] Wallace himself preferred the more traditional expression of 'survival of the fittest'.

evolution of the characteristics that differentiate humans from their nearest relatives. The second main obstacle to the acceptation of Darwin's theory was strictly related to the first one. Most Darwin's contemporaries – including his sympathetic friends Lyell, Herschel, and Whewell – had an essentialist view of species, while Darwin explicitly rejected it, stigmatising '... the vain search for the undiscovered and undiscoverable essence of the term species'.[30] In his opinion, the organisms that we classify as species are merely the most recent and evident stages of a slow and gradual evolutionary process. Finally, we can find one important source of misunderstanding in the random nature of Darwin's natural selection theory. Its principles are based on mere 'tendencies' and 'frequencies' rather than deterministic causes as respectable science was still requiring. 'Privately, Darwin learned, Herschel had referred to his theory as 'the Law of higgledy-piggledy', presumably a reference to the significant role played in its key principles by chance and probability'.[31] The later neo-Darwinian synthesis that combined Darwin's ideas with Gregor Mendel's (1822–1884) genetics fully supported also this aspect of Darwin's theory. However, as for chance variations, Lamarck had already advanced before Darwin a causal explanation that is recognised today as particularly insightful. Lamarck interpreted the variations of organisms as a response to a structural change of the environment, a change that living species themselves may induce. This explains his forward-looking concern for environmental issues. However, we can get similar results through the two-step Darwinian selection theory distinguishing a first stage characterised by chance variations of a certain group of living beings unrelated to their adaptive requirements, and then a second stage characterised by the differential persistence of those variations according to their adaptive capabilities. It is not clear, however, if in Lamarck the process is purely evidential or has some teleological overtones. Darwin certainly rejected the idea that God directly rules evolution. This raised the criticisms of traditionalist Christians (including his own wife) but did not prevent the acceptation of his theory by younger and more open-minded members of the Church on the argument that the laws of evolution were set by God. Darwin avoided as much as possible the use of the word evolution that suggested to his contemporaries the idea of a pre-established orthogenesis. However,

[30] Darwin (1859, 485). [31] Lennox (2019, 11).

the permanence of adaptive traits seems to imply some sort of progressive improvement in the adaptation to natural environment. On the other hand, we learned from the recent ecological disruptions that the improved adaptation foreshadowed by Darwin could be only local, short-lived and eventually inconsistent with long-term survival. Darwin and his most faithful followers seemed uncertain whether the process of biological evolution complies with a week form of teleological progress or not. In any case, a correct interpretation of the empirical evidence implies that, even if we find a progression in some sense in the past, we cannot project its persistence in the future.

The theory of natural selection had to be developed by Darwin and his nineteenth-century followers without the support of a valid theory of heredity. The subsequent discoveries in classical genetics made possible a new, more sophisticated and compelling, version of biological evolution theory since the mid twentieth century. Later, the emergence of molecular genetics provided sounder foundations for evolutionary developmental biology. These scientific advances did not reject the basic Darwinian two-stage approach but allowed its progressive refinement. We know that genotypes can slowly change by random genetic drift, and that natural selection remains the primary explanation for adaptive evolution. These innovations confirm the wisdom of the Darwinian cautiousness on the application of whatever notion of progress to evolutionary biology in the absence of compelling empirical evidence.

3.4 From Mach to the Vienna Circle

In the second half of the nineteenth century, the progressive separation from the encompassing framework of natural philosophy of new scientific disciplines (such as chemistry, psychology, and sociology) changed the relation between philosophy and science. Some philosophers drew the conclusion that the progressive hollowing up of the content of philosophy had determined its irreversible demise. This prediction turned out to be wrong. However, to survive, philosophy had to change its role. There are at least two fields that science could not subtract to philosophy: *ethics* because science aims to be value free, and *science* itself because its general implications for the biosphere must be assessed from a perspective broader than that of specific scientific disciplines.

An important novelty in the scientific field was the establishment of psychology as a sound empiricist science. Among the founding fathers of experimental psychology, I must mention for their significant impact on the history of science and epistemology two German scholars: Gustav Fechner (1801–1887) and Wilhelm Maximilian Wundt (1832–1920). Fechner published in 1860 *The Elements of Psychophysics*, an influential essay in which he provided solid foundations to experimental psychology by developing a method for 'measuring' psychical phenomena (Fechner1948 [1860]. In particular, he found a logarithmic relation between the intensity of senses stimulation and its psychic consequences. The successful application of this experimental method to the external physical world and the inner psychological world transformed the perception of the relation between experience and mind as dual aspects of the same reality. Wundt pursued the research programme of Fechner and established psychology as an autonomous academic discipline. He founded the first laboratory of experimental psychology that brought about a host of followers and stimulated lively controversies that challenged the traditional role of philosophy. The most important controversy developed about the soundness of the 'thesis of psychologism'. According to the latter, we should reduce to psychology the activity of the mind, including logic and epistemology. This issue was the object of a harsh dispute that raged mainly in German-speaking countries, especially from 1890 to 1910. This *Psychologism dispute* was strictly related to the *Method dispute* in economics that I am going to discuss in Section 3.5.2.

In German-speaking countries, the Austrian polymath Mach (1838–1916) was the most influential representative of the transition from the traditional science of Enlightenment to the modern science of the twentieth century. In particular, he combined Fechner's psychologist methodology with Darwin's evolutionary theory applying to physics this new scientific vision. He wrote extensively on history of science eventually holding the Chair for the Philosophy of the Inductive Sciences at the University of Vienna (1895–1901). As Leibniz and Descartes, Mach criticised the epistemological foundations of Newton's absolute space and time and advocated a relational vision of space, time, and movement. The young Einstein recognised Mach's influence and considered him as the philosophical forerunner of relativity theory. Mach was also an innovative empirical physicist and held the chair of physics in Prague from 1867 to 1895. In particular, he was the first to study systematically supersonic motion and to explain the Doppler Effect. He interacted with the contemporaneous technological advances in a proactive way. For example, he started to study supersonic motion to cope with the unexpected consequences produced by the new bullets reaching supersonic speed. He also devised a simple apparatus that demonstrated that the Doppler effect of sound is real. As epistemologist, he was one of the first scholars who understood the far-reaching implications of the new scientific disciplines burgeoning in the second half of the nineteenth century, in particular Darwinism and experimental psychology. He understood that the new disciplines displaced the Newtonian mechanistic paradigm of the universe and called for a new scientific vision: 'the foundations of science as a whole, and of physics in particular, await their next greatest elucidations from the side of biology'.[32] He gave important original contributions also as an experimental psychologist. The most important is the discovery of what physicists now call Mach bands that show that our sensations are biased representations of objective phenomena because our senses unconsciously pre-process information before sending it to the brain. This experimental observation falsifies the belief of naïve empiricists (such as Locke) who equate the intellect to a clean slate (*tabula rasa*). Mach explains the distortions of perception in terms of evolutionary theory. In his opinion, the same process that drives biological evolution underlies perception and drives science itself. In his view, at the basis of all evolutionary processes is the process that brings back environmental disturbances into equilibrium. Following this scientific vision, he inspired the *gestalt* theory founded in the early twentieth century and foreshadowed the theory of neural networks that was developed only after WWII. Sensations are not simply raw experiences, but the interaction with previous experience to implement the process of adaptation of the human beings to a continuously changing environment. However, while Darwin's theory conceives of natural selection as a process that does not have a given end, Mach supported the teleological German tradition in the anti-metaphysical version of Haeckel. In his view, science is part and parcel of biological evolution: 'Science has taken over the task of replacing tentative and unconscious adaptation by a faster variety that is fully conscious and methodical'.[33] To do so, science must be economical to provide the most convenient means

[32] Mach (1959 [1897], Preface to 1st Edition).

[33] Mach (1976, 361.)

for our adaptation: 'The economical role of science is to allow us to understand and react to nature prior to experience; just as a new-born chicken knows what to do as soon as it is hatched due to its accumulated memory'.[34] Mach pursued the unity of science to provide a single orientating perspective. This may be done only by building up a more general approach avoiding any sort of reductionist approach. The search for a wider unity in science does not cloud Mach's commitment to pluralism deeply rooted in his evolutionary perspective. Scientific progress needs variation to update the necessary selection to new facts. In his view, it is better to tolerate what may seem blatant error to the ruling mainstream view rather than losing precious variations which might prove fruitful later in different circumstances or following a sudden change in scientific gestalt.

Mach greatly contributed to spread in Vienna and in the German-speaking world an intellectual climate of open and constructive dialogue between scientists of different disciplines.[35] In addition, Mach's ideas on the unity of science directly inspired the realisation of the monumental *Encyclopedia of Unified Science*, the most important common enterprise started within the Vienna Circle, an initiative that propagated the ideas and goals of logical positivism in the following decades (see next section). His epistemological pluralism inspired the constructive non-parochialism of the Vienna Circle and deeply affected the pluralism of many of its exponents. In addition, Mach's radical anti-metaphysical empiricist attitude, which was not so widespread in the German tradition as in the Anglo-Saxon world, contributed to shape the uncompromising Empiricism of logical positivism. On the other hand, the logical side of this school of thought had different origins in sharp contrast with Mach's psychologism.

3.5 Logical Positivism

The far-reaching impact of Darwinism on the vision of natural history produced a reaction against its alleged 'materialism' that took different forms. In the Anglo-Saxon philosophy, it brought about a revival of German Idealism in a watered-down version that became hegemonic at the turn of the century but failed to exert a significant influence on

[34] Pojman (2019, 24).
[35] Not by chance, the first name of the Vienna circle was "Mach *Verein*".

science itself.[36] In England, the belated success of idealist philosophy at the turn of the century prompted the spirited reaction of a few young philosophers active in Cambridge, including Moore (1873–1958), Russell (1872–1970), and Wittgenstein (1889–1951). Something similar happened in Oxford, involving Ayer (1910–1989) and Ryle (1900–1976). These anti-idealist philosophers soon became highly influential in the philosophy of science, implanting the early roots of 'analytical philosophy'. Russell and Moore led a reaction against idealism centred on the characteristic ambiguity of its language. The demystification of the idealist language followed two different but complementary ways: Russell used the instrument of symbolic logic that he had contributed to develop, while Moore reported scientific language to common language. In 1922 the Austrian physicist Schlick, who was the successor of Mach in the chair of philosophy at the University of Vienna, established in Vienna the so-called *Vienna Circle* with the aim of connecting the emerging analytical philosophy with the Empiricism of contemporary science.[37] The Vienna Circle was by no means a homogeneous and static school of thought. It was rather a sort of intellectual hub aiming to favour a constructive dialogue between philosophers of different extraction and scientists active in different disciplines.[38] A fundamental inspiration for the members of the Vienna Circle was the proposal, already advanced by Leibniz, of translating the philosophical problems into the rigorous language of formal logic. The members of the Vienna Circle attempted to combine the criterion of verifiability with the 'method of logical analysis' and create, on this basis, a unified scientific paradigm embracing both natural and social sciences.[39] The circle published the journal *Erkenntnis* (1930–1939) and held a number of congresses and conferences in different countries. By the late 1930s, the leading

[36] Among the most influential exponents of British idealism, I can mention Green and Bradley.

[37] The Vienna Circle published its manifesto in 1929, *The Scientific World View*.

[38] The inner core of the circle included Neurath, Hahn, Waismann, Gödel, Kaufmann, Kraft, and Feigl. Many distinguished guest speakers participated in its initiatives including Frank, Hempel, and Ayer. In 1926, Carnap accepted the invitation to become a member of the circle and rapidly became a leading figure.

[39] By 1930, the Vienna circle had established institutional links with other groups such as the Berlin Society for Empirical Philosophy, the Münster School of Logic, the Lvov-Warsaw School, the Cambridge Analytical School, the Uppsala School.

representatives of the Vienna Circle had to flee from Germany and Austria to escape the Nazis persecutions and established abroad, particularly in the USA and in Great Britain. Notwithstanding this diaspora, the interaction between the old members did not stop and remained in the 1950s and 1960s a leading driving force of philosophy of science.

It is usual to associate the prevailing view of the Vienna Circle with 'logical positivism' (also called 'neopositivism' or 'logical empiricism'). Logical positivism has never been a doctrine or a set of doctrines but rather a complex and articulated movement in continuous evolution. Since I cannot reconstruct this evolution in short space, I limit myself to sketch a fuzzy contour of the research programme of its members, First, we can detect a main common motivation in the reaction of logical positivism against any form of philosophy that may encourage the irrationalism underlying the shocking events of WW1, WW2, the turbulent interwar years, and then the Cold War years. This motivation led them to implement a new style of philosophy aiming to shield individuals and society from all forms of conceptual 'degeneration'. The idea is that of building up a sort of 'scientific philosophy' that should adopt the same standards of rigour of science while coordinating the efforts of increasingly fragmented and heterogeneous scientific disciplines for the improvement of the human condition. The first component of this research programme is the updating of anti-metaphysical positivism in continuous dialogue with the evolving scientific disciplines. The second component is the defence and valorisation of scientific reason against all the irrational drives of modern societies considering the recent advances in logic and mathematics. The synthesis between the empiricist and analytic components is first realised through a so-called 'linguistic turn', namely by choosing the analysis of language as a common critical space capable of implementing a 'new enlightenment'. Its exponents resumed Leibniz's idea of the crucial foundational role of formal logic, drawing direct inspiration from Frege's logical foundations of mathematics as developed at the beginning of the century by Russell and Wittgenstein. These path-breaking pioneers had used logic to clarify the foundations of mathematics, while logical empiricism follows them in the attempt of using the language of symbolic logic to clarify other fundamental philosophical issues. To this end, logical positivism assumes a particularly radical version of anti-metaphysical position by arguing that the metaphysical statements made by philosophers such as Hegel, Schelling, and Nietzsche are not just false, but meaningless. They shared Kant's assertion that truth can be known either by analysing the meanings of words or by observing the features of phenomena; they merged these two paths by arguing that a statement is meaningful only if there were a possible experience that would show that the statement is true. The principle of *verifiability* aimed thus to classify all non-analytic sentences in two categories: meaningless propositions such as those of metaphysics, and meaningful propositions such as those of genuine science. They used this principle as a criterion of demarcation between science and pseudoscience.

The verifiability criterion has strong implications for the issue of pluralism. Most logical positivists are committed to pluralism within genuine science, but not at all outside its alleged strict boundaries. There is thus a tension between an area of tolerance and one of intolerance whose relative scope strictly depends on the definition of genuine science and the verifiability criterion of demarcation. However, notwithstanding reiterated efforts, no one succeeded to provide sound foundations to the demarcation principle. In addition, following Mill, the logical positivists based verification on inductive inference without succeeding to overcome Hume's destructive criticisms.

3.6 The Decline of Logical Positivism

The complex evolution of logical positivism was characterised by a series of inner tensions. First, we may identify a basic tension between the role of experience and that of reason relying upon extreme variants of the two polarities, namely verifiability and symbolic logic. The linguistic turn was not sufficient to overcome the tension between the two polarities so conceived. The logical empiricists soon discovered that the ideal language worked out by their approach had a very limited extension that excluded also terms, such as dispositional terms, routinely used by science itself. After heroic but unsuccessful efforts by philosophers of the standing of Carnap, they concluded that to extend the scope of their approach they had to relax the strict requirements adopted so far. This determined a significant evolution of logical positivism in the second phase of its parabola, from the end of WWII to the late 1960s. As for experience, they relaxed the criterion of verifiability realising that a theory is a network of terms and propositions that is anchored to the empirical evidence as a whole ('liberalised thesis of Empiricism'). As for reason, the confidence in the normative and heuristic power of logic progressively petered out nurturing two different reactions in the USA and in England. The American branch remained closer to the original idea of an ideal language warranting scientific rigour, but added to the original interest in its syntactic structure and its semantics a new and growing interest in its pragmatic dimension. Under the influence of American pragmatism, the attention shifted progressively towards the role of linguistic actions and their intersubjective and social implications. In England the attention shifted towards the analysis of common language, an approach started by Moore in Cambridge in the 1920s and then developed in Oxford by Austin. In the 1960s, logical positivism was challenged by the so-called post-positivists, in particular Feyerabend, Kuhn, and Lakatos (see Chapter 4). This determined a cognitive turn in analytic philosophy that abandoned the anti-psychologism and the linguistic bias of logical positivism. The latter eventually lost a clear specificity and dissolved within the broader movement of analytic philosophy.

4 *Pluralism and Philosophy of Science*

John Stuart Mill:[1] *When [a scholar] persuaded himself that he can work out the final truth on any subject, exclusively from his own sources, he is apt to lose all measure or standard by which to be apprized [. . .]*

Lee Smolin:[2] *it is the interests of the scientific community as a whole to encourage the widest diversity of approaches consistent with the evidence in hand … it is competition among diverse viewpoints and research programs that drives the progress of science.*

As we have seen in the preceding chapter, logical positivism aimed to realise a synthesis between the authority of reason as emblematically represented by the contemporary advances of logic and mathematics, and the authority of nature relying on the empirical verification of significant concepts, laws, and theories. A few philosophers, the most notable of which was Karl Popper, promptly reacted against this new synthesis with forceful critical arguments. However, logical positivism managed to maintain a hegemonic role in the philosophy of science until the early 1960s when a new generation of philosophers – led by Kuhn, Feyerabend, and Lakatos – resumed and developed a systematic critique branching from the path-breaking trail initially trodden by Popper. Although the new school of thought was quite heterogeneous, it came to be called with the collective name of Post-Positivism. The

[1] Mill (1965, 4). The quotation continues in this illuminating way: 'Living only with his own thoughts, he gradually forgets the aspect they present to minds of a different mould from his own; he looks at his conclusions only from the point of view which suggested them, and from which they naturally appear perfect; and every consideration which from other points of view might present itself, either as an objection or as a necessary modification, is to him as if it did not exist [. . .] The natural result of the position is a gigantic self-confidence, not to say self-conceit.'

[2] Smolin (2019, 172). Lee Smolin is a distinguished physicist working at the frontier of quantum gravity.

common inspiration of post-positivists was an investigation of the actual legitimacy of the competing principles of authority – reason and nature – in science. In this chapter, I focus on the implications of Post-Positivism for scientific pluralism. Section 4.1 provides a preliminary discussion of the concept of pluralism by discussing the contribution of an important early advocate, John Stuart Mill. Popper built his vision on Mill's fallibilism but rejected his inductivism (Section 4.2). Feyerabend resumed and extended the Kantian thesis that the interpretation of experience is theory dependent. He developed this thesis in a sceptical direction by asserting the incommensurability of different theories dealing with the same issues (Section 4.3). I discuss then the contributions of Kuhn who worked out the most influential version of Post-Positivism (Section 4.4), and Lakatos who developed Kuhn's and Popper's theses in an original way (Section 4.5). In the last section, I discuss the role of scientific visions in Kuhn and in the current book.

4.1 Pluralism in John Stuart Mill

The thought of John Stuart Mill is located at a crucial crossroads of the themes investigated in this book. Mill was arguably the first philosopher to advocate explicitly epistemic pluralism in a fully articulated manner.[3] The recent debate on scientific pluralism, rekindled and developed by post-positivist philosophers of science, revived his thoughtful foundations of epistemic pluralism. Although Mill's epistemology sounds today somewhat dated and old fashioned, on the contrary his advocacy of liberty of thought in the book *On Liberty* (1864 [1859]) is still fresh and inspiring. We cannot find a better starting point for an in-depth discussion of the role of pluralism in modern scientific thought.[4]

The main thesis of Mill is that we should never repress diversity of thought, and thus also the open and respectful discussion of diverging

[3] We find the best version of his argumentation in the celebrated essay *On Liberty* (Mill, 1864 [1859]).

[4] The main arguments of Mill in chapter 2 of *On Liberty* refer to 'differences of opinion' rather than to differences of scientific theories, methods, and assertions, what we call in this book 'scientific pluralism'. In this section, I limit myself to apply Mill's arguments to 'differences of opinion' in science. This specific focus makes sense, because Mill's fallibilism prevents a crisp demarcation between opinion (doxa) and scientific knowledge (episteme).

theses, because diversity of opinion is 'advantageous, and will continue to do so until mankind shall have entered a stage of intellectual advancement which at present seems at an incalculable distance'.[5] No doubt, the distance from this utopic stage is still incalculable. However, too many people, even leading scientists, believed that we have reached, or we are approaching, the final stage of complete knowledge and universal consensus. In his articulate analysis of the role of pluralism in the current stage of human progress, Mill's argument starts from the obvious observation that any opinion (including scientific theories and assertions) is bound to be either false, or true, or partially true.[6] First, 'the received opinion may be false, and some other opinion, consequently, true' (ibidem). In this case, it is obvious the necessary role of a different point of view to falsify the received theory, a point that will be developed by Popper a century later (see next section). However, even if the received theory is true, a different theory is still necessary because 'a conflict with the opposite error is essential to a clear apprehension and deep feeling of its truth' (ibidem). Otherwise, the true assertion would easily degenerate in a dogmatic formula repeated mechanically without a genuine understanding of its meaning and implications.[7] Nevertheless, Mill does not consider these two extreme cases as the usual ones because in the common case 'the conflicting doctrines, instead of being one true and the other false, share the truth between them' (ibidem). In this usual case, the role of pluralism is particularly compelling because 'the nonconforming opinion is needed to supply the remainder of truth, of which the received doctrine embodies only a part'. Therefore, what are considered – often contemptuously – heretical opinions, in fact, generally are

> some of these suppressed and neglected truths, [. . .] either seeking reconciliation with the truth contained in the common opinion, or fronting it as enemies, and setting themselves up, with similar exclusiveness, as the whole truth. The latter case is hitherto the most frequent, as, in the human mind, one-sidedness has always been the rule, and many-sidedness the exception (Mill, 1864[1859]).

[5] Mill (2002 [1859], chapter 3, paragraph 34). [6] See Macleod (2018, 50).
[7] As Mill brilliantly explains, 'However unwillingly a person who has a strong opinion may admit the possibility that his opinion may be false, he ought to be moved by the consideration that however true it may be, if it is not fully, frequently, and fearlessly discussed, it will be held as a dead dogma, not a living truth' (1864 [1859], XVIII, 243).

This passage confirms that Mill advocates a persistent appreciation of pluralism and of its far-reaching implications for freedom of thought.[8] In this view, even scientific progress loses much of its appeal, as it usually 'only substitutes one partial and incomplete truth for another; improvement consisting chiefly in this, that the new fragment of truth is more wanted, more adapted to the needs of the time, than that which it displaces' (ibidem). Feyerabend, Kuhn, and Lakatos will systematically develop these far-reaching insights (see Sections 4.3–4.5). This view of scientific progress confirms the crucial role of scientific pluralism:

> Such being the partial character of prevailing opinions, even when resting on a true foundation; every opinion which embodies somewhat of the portion of truth which the common opinion omits, ought to be considered precious, with whatever amount of error and confusion that truth may be blended. No sober judge of human affairs will feel bound to be indignant because those who force on our notice truths which we should otherwise have overlooked, overlook some of those which we see' (ibidem).

Mill's pluralism is thus principally founded on incomplete knowledge and fallibilism. The dogmatic prescription that we should instead suppress false opinions presupposes the possibility of demonstrating the infallibility of specific opinions, at least those allegedly corroborated by scientific observation and sound induction. Mill denies this possibility because he rejects any sort of a priori knowledge, while his Empiricism leads him to believe that our opinions, also those supported by the best available scientific knowledge, must remain open to revision in the light of further observations or criticisms. Mill's pluralism is not only motivated by epistemic arguments but also by socio-political worries. Mill believes that the great danger of the contemporary massification of society is conformism, leading to the repression of human energy and creativity.[9] In contrast with the conformist ethos of the Victorian society, Mill encourages the 'Greek ideal of self-development' (1864 [1859], 266). This requires a 'diversity of

[8] Mill laments that this is not the case even in periods of radical change: 'in revolutions of opinion, one part of the truth usually sets while another rises' (ibidem). Kuhn (1962) developed these insights in more detail a century later (see Section 3.5).

[9] Macleod (2018, 50).

character and culture' that provides the engine that drives a nation forward:

> The despotism of custom is everywhere the standing hindrance to human advancement, being in unceasing antagonism to that disposition to aim at something better than customary, which is called, according to circumstances, the spirit of liberty, or that of progress or improvement. (Mill, 1964 [1959], XVIII, 272).

Incomplete knowledge is by no means the only source of pluralism. The contemporaneous polymath Whewell analysed a second one: the different interpretation of the same data. This difference is related to a different vision of induction. While Mill, who was greatly influenced by Comte and early Positivism, tried to minimise subjective influences on the induction process, Whewell emphasised the subjective influences on induction that inevitably led to different interpretations of the same data. Whewell's point of view influenced the position of Post-Positivism that I am going to discuss in the next sections.

4.2 Popper: Critical Rationalism and the Progress of Science

The thought of Karl Popper (1902–1994) is deeply linked, in a significant but contradictory way, to that of Mill.[10] Popper adopted Mill's fallibilism but bluntly rejected his positivist inductivism extending the scope of Mill's pluralism beyond his limits. The main interlocutors of Popper's early works were the representatives of the Vienna Circle whose Positivism was more radical than that of Mill as they denied any sort of meaning to words that are not empirically verifiable. Independently of their wishes, and perhaps awareness, the strict demarcation criterion between science and pseudoscience adopted by logical positivism, namely the criterion of verifiability, did not leave a significant space for theoretical and methodological pluralism.[11] The claim that a non-verifiable statement is altogether meaningless excludes any form of rational defence in scientific discussion. This narrow demarcation criterion was at the centre of the criticisms advanced against logical positivism since the early 1930s. Karl Popper worked

[10] Feyerabend has often emphasised the deep link between Mill and Popper.

[11] The so-called received view that emerged from the Vienna Circle and coalesced into logical positivism entertained an ambiguous attitude towards pluralism.

out the most influential early critique.[12] His first major book (Popper, 1959 [1934]) aimed to be a radical critique of logical positivism, but was published in the Vienna Circle series edited by Frank and Schlick.[13] This book was thus initially perceived as a variant of logical positivism advocating significant corrections to its dominant approach that did not imply its rejection. However, with hindsight, we may credit Popper for having opened a significant breach in the well-defended citadel of logical positivism, a breach that was sufficiently radical and influential to mobilise a sequence of further attacks that eventually led to its decline after WWII. The critical wave originated by Popper mounted after the publication of the English translation in 1958, gathering momentum with the works of Feyerabend, Kuhn, and Lakatos published in the early 1960s (see the next three sections). Popper's criticisms of some of the crucial tenets of logical positivism were in fact quite radical and uncompromising. In particular, he bluntly rejected inductivism, the verification theory of meaning, and the criterion of verifiability as demarcation between science and non-science.[14] In this section, I briefly review the main points of Popper's approach that greatly contributed to support pluralism in science and philosophy.

Popper started his account of scientific discovery from the idea that, contrary to what Empiricism and Positivism maintain, scientific activity does not start from the systematic registration of the empirical evidence that is then generalised through induction into verifiable theoretical statements. He argued that what triggers and motivates scientific research is the exigence of solving specific problems. Therefore, in his view, the positivist myth of 'pure' observation as the starting point and ultimate foundation of theory in empirical sciences is deeply misleading because actual observations are theory laden. This critical observation had a huge impact on the evolution of his thought

[12] Popper pleaded guilty for having killed logical positivism (see Popper, 1986 [1976], section 17, 87–90). This assertion was excessive but not wholly unjustified.

[13] Popper's book was published with the recommendation of Feigl and received highly favourable reviews by Carnap and Hempel, all eminent representatives of logical positivism. The exponents of the Vienna Circle gave more importance to the common anti-metaphysical stance than to its different foundations.

[14] Popper's criterion of falsifiability was not just a different way of defining the common criterion of testability, as some contemporaneous interpreters maintained, but a radically alternative criterion.

and the genesis of post-positivism. Popper rejected the traditional criterion of verification because he agreed with Hume that it is logically impossible to verify a universal proposition by the exclusive reference to experience. Therefore, he replaced verification with falsification emphasising the logical asymmetry between the two criteria: any number of favourable tests is insufficient to verify conclusively a universal law, while in his opinion a single counterexample is sufficient to falsify it.[15] According to Popper, this approach also solves the problem of demarcation between science and 'non-science' (or 'pseudoscience', namely non-science that pretends to be science). According to the criterion of falsifiability introduced by Popper, science does not include metaphysics as well as many disciplines usually considered scientific such as logic, Marxism, and psychoanalysis. At the end of WWII, he published two books that in his intention were showing the fecundity of his epistemological approach also to discuss political issues strictly related to the recent upheavals (Popper, 1944 and 1945). His main critical target was the approach advocated by *Historicism* and its misleading link with *Holism*. According to Popper's idiosyncratic definition, which is much more restrictive than the usual one, *Historicism* consists in the conviction that history unfolds inexorably according to invariant laws towards a determinate end (as in Hegel's dialectic and in the Marxian materialistic offspring). According to Popper, this conviction is not only false, being inconsistent with scientific fallibilism, but also dangerous, especially because it is strictly linked to the belief in social holism. According to Popper's narrow definition, social holism assumes that the behaviour of individuals is essentially conditioned by the social groupings to which they belong. Historicism maintains that these groupings shape the destiny of their members following laws of development independent of individual choices. In his view, the assumptions of historicism and holism have been combined to justify large-scale social planning relying on alleged 'iron laws' of history. Popper argues that this approach is pseudoscientific because there is no way to falsify an alleged historical law before its failure.[16] Moreover, in his opinion, this approach provides the ultimate foundations for different forms of totalitarianism, including those of fascist or Marxian

[15] This is literally true only for a determinist theory. In a probabilistic theory, falsification is much more complex and controversial.

[16] A case in point, according to Popper, is the 'scientific socialism' promoted by Marx and Engels (Popper, 1961 [1944] and 1945).

ascendency.[17] According to Popper, what happens in history is instead the unplannable and unpredictable result of the choices of individuals and their mutual interactions.[18] He advanced a robust argument supporting historical indeterminism and unpredictability: history is deeply influenced by the evolution of human knowledge but 'no society can predict, scientifically, its own future states of knowledge'.[19] Popper founds his critique of *Historicism* upon the ideals of individualism that requires free markets in the pursuance of an open society.[20] He claimed that we may derive long-term unconditional scientific 'prophecies' from conditional predictions only if they apply to systems that are isolated, stationary, and recurrent (like our solar system). In his opinion, such systems are rare in nature and inexistent in human societies. The contrary belief derives from the confusion between scientific laws based upon propositions claiming universal validity, and mere trends expressed by singular existential statements. We can use these trends to improve the conditions of the human lot but only through actions of 'piecemeal social engineering' that are circumscribed to specific problems for a limited space and time.

Popper rarely used the word pluralism in his works. When he used it, he meant ontological pluralism.[21] However, epistemological pluralism plays a crucial role in his evolutionary epistemology. The suggested demarcation based on falsifiability implies the crucial contribution of pluralism to activate an efficient process of falsification: the larger the set of 'potential falsifiers' the higher is the probability of falsification, and thus also more robust the drive towards scientific progress. This idea acquired new content and normative implications as Popper progressively clarified the strict nexus between his epistemology and Darwinism (see, e.g., Popper, 1986, 169). Since his early works, Popper emphasized that, in any stage of science history, we find a plurality of non-falsified theories that claim to solve a certain scientific problem better than the competitors do. He argued that the choice

17 See, for example, (Popper, 1986 [1976], 113).
18 By his own admission, Popper's methodological individualism has been deeply influenced by Hayek.
19 Popper (1961 [1944], vii).
20 Popper argues that totalitarian historicism derives from 'one of the oldest dreams of mankind – the dream of prophecy, the idea that we can know what the future has in store for us, and that we can profit from such knowledge by adjusting our policy to it' (Popper, 1961, 338).
21 See, for example, Popper (1972).

between non-falsified theories should be based on the extension of their 'empirical content', namely their explanatory and predictive power. According to this criterion, we should choose the theory that, in addition to what competing theories explain, also solves some further problems. Popper defines scientific progress as the gradual extension of the empirical contents of the accepted theory in a certain field. After the adoption, since *Conjectures and Refutations* (1963), of Tarski's correspondence theory of truth, Popper qualified scientific progress as a process of convergence towards truth by adopting theories having an increasingly higher degree of empirical content or *verisimilitude*. The introduction in his epistemology of the controversial concept of verisimilitude aimed to mitigate what many saw as the scepticism of his philosophy of science. The significant change of Popper's view on the epistemology of evolution theory had a significant impact on the role of pluralism. This U-turn is candidly recognized by Popper himself:

> I blush when I have to make this confession; for when I was younger I used to say very contemptuous things about evolutionary philosophies. When twenty-two years ago Canon Charles E. Raven ... described the Darwinian controversy as 'a storm in a Victorian teacup', I agreed, but criticized him for paying too much attention to the vapours still emerging from the cup... But now I have to confess that this cup of tea has become, after all, *my* cup of tea; and with it I have to eat humble pie (Popper, 1972, 241.)

In his book *Objective Knowledge. An Evolutionary Approach* (1972), Popper endorsed the Darwinian inspiration of his epistemological theory. In his view, science is an evolutionary process in which new conjectures play a role akin to that of variations in the Darwinian theory of evolution. Scientists select the variations of a certain theory that promise to improve the ability to solve extant, emerging, and future problems. The role of scientific pluralism is implicit in his evolutionary epistemology. Like mutations in biological evolution, the introduction of new conjectures plays a crucial role in the evolution of science as they promote the formulation of more robust conjectures. The trouble with this approach is that, as Popper recognizes, evolutionary theory does not comply with the requisites of what he had called 'good science'.[22] This does not imply that Darwinism is useless for science. Popper emphasizes that Darwinist theory is invaluable:

[22] Popper wrote 'I have come to the conclusion that Darwinism is not a testable scientific theory, but a metaphysical research programme – a possible

I do not see how, without it, our knowledge could have grown as it has done since Darwin ... Although it is metaphysical, it sheds much light upon very concrete and very practical researches. It allows us to study adaptation to a new environment (such as a penicillin-infested environment) in a rational way: it suggests the existence of a mechanism of adaptation, and it allows us even to study in detail the mechanism at work' (Popper, 1986[1976], 171–172).

This view on evolutionism implies that also Popper's epistemology is metaphysical. In fact, he recognizes that when he wrote the *Logic of Scientific Discovery*, his point of view on metaphysics was defective because he 'had not then realised that a metaphysical position, though not testable, might be rationally criticisable or arguable' (Popper, 1986 [1976]). Summing up, Popper, throughout his entire career, rightly advocated an anti-dogmatic approach in science and philosophy that rejects the authority of any a priori principle, including that of reason and induction. According to Popper, any scientific theory is at best a theory not yet falsified but whose doom is inevitably its future falsification. Therefore, any scientific construct and assertion should always be open to serious criticism and shy away from any form of dogmatism. Pluralism came out greatly corroborated from Popper's 'unended quest'.

4.3 Feyerabend: Epistemological Anarchism and Incommensurability

Paul Feyerabend (1924–1994) was an imaginative thinker who exerted a significant influence on philosophy of science in the second half of the twentieth century. He was a sort of postmodern 'gadfly' that played a critical stimulus against received beliefs in history of science and epistemology. As all thinkers with these characteristics, the critical side of his arguments proved to be more effective than his constructive contributions. The evolution of his thought was relentless and spanned an increasingly broad field. Limiting my analysis to the issue of pluralism, it is possible to distinguish three broad phases.

framework for testable scientific theories' (1986, 168). In particular, ' ... Darwinism does not really predict the evolution of variety. It therefore cannot really explain it' (Popper, 1986 [1976], 171).

The first publications are heavily influenced by the approach of Popper who was his teacher at LSE in the academic year 1952–1953. In particular, Feyerabend accepted Popper's radical rejection of inductivism in favour of falsificationism that he interpreted in an increasingly liberalised version, progressively expanding the meaning and role of scientific pluralism. In particular, he developed Popper's idea of a 'pluralistic test model', in which theories focused on the same issue are compared in the light of the available empirical evidence. In addition, he refined Popper's 'contextual' theory of meaning by identifying the meaning of a term or statement with the role played within specific theoretical contexts. He came to the conclusion, foreshadowed by Whewell, that we cannot construct a separate and neutral 'observation-language' within which theories may be tested. This conviction pushed the young Feyerabend to develop a general critique of logical positivism that was then still exerting a strong influence in the US academia where some of its more eminent representatives – such as Carnap, Feigl, Nagel, and Hempel – had moved during the 1930s, and where Feyerabend started to teach in 1958.[23] He focused mainly on the relationship between observation and theory and its impact on scientific evolution. The main target of his criticism was the 'stability thesis' of logical positivism, namely the thesis that the meaning of the terms in the observation-language is invariant to changes of the theory. Feyerabend formulates instead what he called 'Thesis I', arguing that the interpretation of an observation-language is dependent on the theories we use (ibid., 31).[24] Feyerabend emphasised that the methodological 'principle of testability' requires that we encourage the confrontation of as many competing theories as possible interpreting them as alternative descriptions of reality rather than mere instruments of prediction. This approach advocated a radical theoretical pluralism because the evolution of science based on the falsification of competing theories is a function of the number of potential falsifiers, an idea that was already hinted at by Popper. However, in the late 1950s, Feyerabend came to the conclusion that Popper's criticism of logical positivism did not go far enough. His criticisms focused mainly on the normative implications of Popper's epistemology based upon a demanding demarcation criterion specifying

[23] He taught at the University of California at Berkeley.

[24] The Thesis I combined two ideas whose roots can be found in Popper's epistemology: the contextual theory of meaning and scientific realism.

optimal rules and quality standards that he came to consider not less rigid and repressive than those of logical positivists.

In the second phase, started in 1962 with the publication of his influential essay 'Explanation, Reduction, and Empiricism',[25] he struggled to draw all the consequences of his Thesis I by working out a new extreme version of pluralism based on the concept of incommensurability of theories, even of those impinging on the same problems. As he admitted, his arguments for theoretical pluralism had followed so far those of John Stuart Mill (1859), but the concept of incommensurability of theories implied a much more radical form of pluralism. In his view, alternative theories are bound to be incommensurable because the same terms acquire a different meaning in different theoretical contexts. He thus argued that the principle of semantic stability postulated by the received account of reduction, explanation, and confirmation is inconsistent with progress in science.[26] In the end, Feyerabend felt thus compelled to reject any form of scientific methodological rule in science. He also downgraded the significance of evidence-based arguments by arguing that aesthetic, personal, and social factors may have a higher, though often only implicit, impact upon the history of science. His rejection of any form of normative methodology eliminates any sort of rational demarcation criterion. This shocking thesis was fully argued in his famous book *Against Method* (1975 [1965]). The main argument is that we should assure in science, as elsewhere, complete freedom to individuals abstaining from any form of restriction including methodological rules. The only acceptable rule is thus a fully permissive 'anything goes' that characterises his advocated 'Methodological Anarchism'[27]:

One of my motives for writing Against Method was to free people from the tyranny of philosophical obfuscators and abstract concepts such as 'truth',

[25] Feyerabend (1962).

[26] In particular, the procedure of 'theoretical reduction' that plays a crucial role in logical positivism is in fact nothing but the sheer replacement of one theory by another.

[27] Feyerabend did not commit himself to political anarchism and argued that 'Dadaism' would have been a better definition of his own point of view that excludes any form of authoritarian control. His political philosophy focused on democracy by combining libertarianism with social democracy. However, Feyerabend's Dadaism is subject to the tolerance paradox, opening the way to the dictatorship of opportunistic behaviour.

'reality', or 'objectivity', which narrow people's vision and ways of being in the world (Feyerabend, 1999, 179).

In the third phase starting in the late 1970s, Feyerabend extended the reasons for pluralism from science to all forms of cultural traditions and practices. In his book *Science for a Free Society* (Feyerabend, 1978), he maintained that in the absence of a sound scientific method, we are not justified to believe that science is the best way of acquiring reliable knowledge. The incommensurability of scientific theories and cultural traditions led him to a form of radical relativism that he defined as the commitment to treat the other people's beliefs and ways of life as 'true for them' while our own views cannot be more than 'true for us'. Feyerabend argued that the divinisation of science is a threat to democracy and condemned as 'scientist' the increasingly widespread contrary conviction. His critics accused him of being an 'anti-science philosopher'. However, Feyerabend did not take issue against science as such but against intolerant scientism. He advocated instead the ideal of a multicultural free society 'in which all traditions have equal rights and equal access to the centres of power'.[28] On the other hand, to pursue these commendable ideals, it is not necessary to accept his controversial thesis that theories are incommensurable and reject the concept of interpersonal truth.

4.4 Kuhn: Scientific Revolutions and Normal Science

The publication of *The Structure of Scientific Revolutions* in 1962 has been a crucial turning point in the philosophy of science. In this book Thomas Kuhn put forward a new vision of the evolution of natural sciences that was radically at odds with that, still quite influential, of logical positivism. The ensuing revolution in epistemology and history of science led to the era of post-positivism characterised by a more pluralist attitude in epistemology and history of science. Kuhn's new vision of science became immediately influential also because he supported his new epistemological views with insightful reconstructions of important episodes of history of science. Before Kuhn, the history of natural science was concerned mainly with specific discoveries or advances in a particular discipline. Scientists and historians shared

[28] Feyerabend (1978, 9).

the view, promoted by mainstream philosophy of science of positivist ascendency, that natural sciences develop by accumulation of new advances capable of progressively approximating truth by generalising previous results and correcting past errors. In this view, even the greatest scientists may only accelerate scientific progress but cannot significantly influence its direction. The latter is ultimately dictated by the rationality of the scientific method whose tenets are shared by all rigorous researchers. Kuhn takes issue against this influential tradition based on the progressive accumulation of knowledge and suggests a radically different view. In a mature science, maintains Kuhn, scientific progress proceeds by alternating phases of normal science and scientific revolutions. Normal science focuses on the solution of scientific puzzles generated by the ruling vision without questioning its ultimate validity, while a scientific revolution focuses on the most serious anomalies of mainstream research and argues that only a different vision can solve them. In normal science, the researchers ignore the most serious anomalies or elude them by ad hoc explanations. It is only the accumulation of particularly conspicuous and stubborn anomalies that, after a certain threshold, poses a serious problem for the existing vision. Kuhn argues that normal science is conservative and anti-pluralist as the competition between researchers is restricted to circumscribed issues that do not jeopardise the hegemony of the existing mainstream theory, while the revolutionary phase is characterised by harsh competition among different scientific visions and antagonistic disagreement about their relative merits. In Kuhn's view, in a mature science, scientific pluralism revives during scientific revolutions but fades out within normal science. The conservative resistance to the attempted refutation of key theories implies that scientific revolutions cannot materialise except under unusual circumstances. The importance given to scientific visions, that he dubbed with the fortunate name of paradigms, does not question the traditional conviction that the evolution of natural sciences depends mainly on internal factors.[29] Kuhn admitted that also in natural sciences extra-scientific factors

[29] Some sociologists and historians of science drew from Kuhn the conviction that the outcome of a scientific revolution is determined by socio-political factors (Bird, 2018). Kuhn himself repudiated such idea and asserted that in modern science the factors determining the outcome of a scientific dispute, are almost always to be found within science, specifically in connexion with the puzzle-solving power of competing ideas.

might affect the outcome of a scientific revolution but always played down their influence as compared to the influence of internal factors.[30]

Summing up, Kuhn rejected the traditional teleological view of science progressing towards the truth along a steady trajectory. He suggested instead an evolutionary view of scientific progress characterised by structural changes and discontinuity.[31] As in the case of a living species, a theory evolves by adapting to a changing environment. This does not guarantee progress.[32] The new vision becoming mainstream after a revolution does not preserve all the truths accumulated in the preceding periods of normal science. In particular, the new paradigm may become unable to explain one or more phenomena that an earlier paradigm could successfully explain. The frequent instances of so-called 'Kuhn-loss' falsify the traditional cumulative picture of scientific progress.[33] Like Popper and Feyerabend, Kuhn rejected the positivist distinction between the context of discovery and the context of justification (1970 [1962]). As regards the context of discovery, the standard view held that the philosophy of science had nothing to say on the issue of creative imagination. However, Kuhn argued that the usual focus on paradigmatic exemplars in scientific education enables scientists to see by analogy potential solutions to their new puzzles. Also, his account of the context of justification radically diverged from the standard picture. The crucial role attributed to paradigmatic exemplars aimed to play down the role of methodological rules as the key criterion for the acceptance of a proposed puzzle-solution. The perception of similarity cannot be reduced to rules of rationality. This is one of the assertions that led Kuhn's critics to accuse him of irrationalism. However, the denial that some cognitive processes are the mere application of rational rules does not imply that these processes are irrational.

Kuhn's concept of paradigm exerted a great influence on both history of science and epistemology in many disciplines including social

[30] Kuhn (1970a [1962] 152–153). In consequence of Kuhn's position, the relationship between internal and external history of science became a particularly controversial issue on which I will come back later.

[31] Kuhn (1970a[1962], 170–173). He defined himself as post-positivist Kantian (see Horgan, 2012).

[32] Kuhn asserted that science, like life on earth, does not evolve toward anything but only away from something.

[33] See Kuhn (1970a [1962], 99–100). According to Kuhn, evolution in science leads towards a growing specialisation that, however, does not imply progress.

sciences and economics. However, even sympathetic readers pointed out that his book uses this concept in different senses. In the *Postscript* to the second edition (1970), Kuhn admits that an attentive reader may find in his book two different usages of the term paradigm and that we must distinguish them. The first meaning 'stands for the entire constellation of beliefs, values, techniques, and so on' shared by the members of a given scientific community.[34] According to the second meaning, instead, a paradigm is an 'exemplary past achievement' that provides a canon for a community of researchers that share a paradigm in the first sense. Kuhn calls the first meaning sociological, while we could interpret the second one as symbolic (like a banner), or as a standard of scientific rigour shared by a group of researchers. Kuhn conceded that the word 'paradigm' was 'hopelessly overused': 'Like a virus, the word spread beyond the history and philosophy of science and infected the intellectual community at large, where it came to signify virtually any dominant idea'.[35] To avoid confusion, in his later works Kuhn adopted for the first meaning the expression 'disciplinary matrix'.

Although Kuhn applied his approach exclusively to natural sciences, it was not less influential in social sciences. There are primarily two reasons for this. First, Kuhn's picture of science appeared to permit a more liberal and realistic conception of science, a view that fitted social sciences much better than previous alternatives. Secondly, Kuhn's rejection of rigid rules in determining the genesis, quality, and implications of scientific outcomes appeared to justify the investigation of other factors external to science (such as psychological, social, political, and ethical factors) in explaining its evolution. However, according to Kuhn, this analogy should not be overemphasized. Although he did not exclude that the external history of science may occasionally play a role also in natural sciences,[36] he defined his own

[34] Kuhn (1970a [1962], 175).

[35] As Kuhn lamented, 'The low point came during the Bush administration, when White House officials introduced an economic plan called 'the New Paradigm' (which was really just trickle-down economics)' (Horgan, 2012).

[36] For example, 'Kuhn himself suggests in The Structure of Scientific Revolutions that Sun worship may have made Kepler a Copernican and that in other cases, facts about an individual's life history, personality or even nationality and reputation may play a role (1970 [1962], 152–153). Later Kuhn repeated the point, with the additional examples of German Romanticism, which disposed certain scientists to recognise and accept energy conservation, and British social thought which enabled acceptance of Darwinism …' (Bird, 2018, 32).

work as 'pretty straight internalist'. However, Kuhn was not surprised of the extension of his approach to social sciences also because he recognised that history of humanistic disciplines, in particular history of art, had been a crucial source of inspiration. Nevertheless, in his contributions to history of science he insisted on the peculiarities of natural sciences. In his opinion, while competing interpretations of facts play a crucial role in social sciences, in natural sciences we find established interpretive canons of the emerging empirical evidence as pre-condition of normal science. Another reason why a continuous reinterpretation of the empirical evidence is part of human sciences and much less of natural sciences is that social and political systems are themselves evolving in ways that call for new interpretations, whereas the subject matter of natural sciences is perceived as a constant in many significant respects, permitting the establishment of a puzzle-solving tradition.

Kuhn's most evident achievement was his crucial contribution to the decline of the received view of logical positivism. However, in his *postscript* to the second edition of his masterpiece, his replies to the criticisms received after the first edition seem to seek an appeasement with more traditional views by watering down the most original features of his novel approach. Nevertheless, he continued to defend the validity of two of its most radical ideas: the concept of paradigm in the second sense of emblematic exemplar, and the related concept of incommensurability.[37] In what follows I will adopt the first concept but not the second (see Section 4.7).

4.5 Lakatos: Research Programmes and Scientific Rationality

The philosophy of science of Imre Lakatos (1922–1974) is usually interpreted as an attempt to reconcile Popper's and Kuhn's views within a more general and realistic evolutionary perspective.[38] The first important contribution of Lakatos was an imaginative extension

[37] According to Kuhn, incommensurability can be (i) methodological because the methods of comparison and evaluation change; (ii) perceptual/observational because the empirical evidence is theory dependent; (iii) semantic because the languages of theories may not be inter-translatable. We should add that the factors that determine our choices of theory (whether puzzle-solutions or paradigmatic theories) are dependent on our epistemic matrix.

[38] See, for example, Musgrave and Pigden (2016).

of Popper's falsification approach to mathematics.[39] His main thesis was that, in the absence of a rigorous axiomatization, mathematical proofs are conjectures that in principle are falsified by the discovery of a single counterexample. He substantiated his thesis through a detailed 'rational reconstruction' of a few case studies. Lakatos's 'rational reconstructions' apply Popper's theory of scientific rationality to a specific case study interpreting it as a sequence of rational responses to the evolving problem situation. Though this methodology retains a flavour of Lakatos's earlier Hegelian philosophy,[40] it diverges in a radical manner from the historicist tradition by admitting that alternative rational reconstructions are possible because of different conceptions of rationality.[41] Lakatos emphasises that a successful rational reconstruction of a scientific innovation corroborates the idea shared by both Popper and Kuhn that the history of science should focus mainly on the internal factors of change. However, he recognised that there are cases in which we have to supplement the rational reconstruction of history with an 'external history'.[42] He argued, for example, that Mendelian genetics disappeared in Soviet Russia in the 1950s not as a rational consequence of internal factors but because Lysenko, a Stalin favourite, acquired hegemonic status within the world of Soviet biology and persecuted the Mendelians,[43] and encouraged his pupils and followers to apply this approach to specific scientific episodes also in other disciplines (see, in particular, the essays collected in Lakatos and Musgrave (1970), and the case studies in economics discussed in Latsis (1976)). The systematic application of the method of rational reconstructions endowed his approach of an evidence-based support that greatly increased Lakatos's prestige also among scientists.[44]

[39] Lakatos (1976).

[40] Lakatos recollects: 'I was nearly forty when I got into the magnetic field of [Popper's] intellect. His philosophy helped me to make a final break with the Hegelian outlook which I had held for nearly twenty years' (Lakatos, 1978a, 139).

[41] As Musgrave and Pigden maintain, 'For a true Hegelian, everything can, in the last analysis, be seen as rationally required for the self-realisation of the Absolute. Hence all history is 'internal' in something like Lakatos's sense, since the 'cunning of reason' ensures that apparently irrational impulses are subordinated to the ultimate goal of history' Musgrave and Pigden (2016, 8).

[42] Lakatos (1978a, 102.) [43] Ibidem, 114.

[44] The scope of this method should not be overemphasised. Feyerabend based his criticism of the rationalism of Popper and Lakatos by showing that crucial

In a second phase covering the last decade of his life before his untimely death in 1974, Lakatos focused on the history of empirical sciences to detect behavioural regularities in actual scientific practice. According to Kuhn, it is only in periods of 'revolutionary science' that we can detect a lively dialectic between alternative conjectures and systematic attempts of refutation as advocated by Popper. Lakatos amends these views by arguing that the basic unit of appraisal should not be an isolated testable theory, but rather a 'research programme' that generates a succession of testable theories.[45] A crucial reason that motivated Lakatos to modify Kuhn's paradigm analysis is his psychology of discovery that he considered irrational, while his advocated research programme approach adopted Popper's critical Rationalism extending it to sequences of theories. Each theory produced within a research programme exhibits the same 'hard core' of assumptions that cannot be abandoned or altered without rejecting it.[46] The hard core is surrounded by a 'protective belt' of auxiliary hypotheses that play a crucial role in the applications of the theory but may be altered to 'protect' the 'hard core'.[47] When the empirical evidence threatens to falsify a particular theory generated within a research programme, the negative heuristic that presides to its survival deflects the criticisms towards the auxiliary hypotheses that characterise its 'protective belt'.[48] The exponents of the research programme seek a solution to the paradigmatic puzzle (or major anomaly) posed by the indicted theory by following the positive heuristic principles implicit in the 'hard core' of the programme.[49] The positive heuristic consists of a set of suggestions on how to change, or develop, the 'refutable

episodes of history of physics were refractory to any sort of rational reconstruction (Feyerabend, 1975 [1965]).

[45] Popper argued that Lakatos borrowed this idea from his concept of 'metaphysical research programmes', a concept used in his lectures from about 1949.

[46] Lakatos's primary example of a research programme is that pursued by Isaac Newton, with his three laws of motion forming its 'hard core'.

[47] The hard-core theses are usually insufficient to imply empirical consequences. For example, to derive empirical predictions from Newtonian mechanics one needs 'a whole host of auxiliary hypotheses about the positions, masses and relative velocities of the heavenly bodies, including the earth.' This is related to 'Duhem's thesis' (Duhem, 1954 [1904–1905]).

[48] Lakatos (1978, 48.) [49] Ibidem, 50.

variants' of the research programme'. The solution is typically found by modifying the auxiliary hypotheses of the theory. However, the suggested solution can be progressive or regressive.[50] A programme is progressive if the new theory solves the anomalies and brings about new falsifiable predictions. A programme is instead degenerating if the predictions of its theories are falsified or do not extend to novel facts. Though Lakatos defines his approach 'sophisticated methodological falsificationism', the heuristic rules are not universal methodological rules but are rational only to the extent they assure a progression towards better theories. However, this is by no means granted. The auxiliary hypotheses are meant to strengthen the link of the theory with the empirical evidence, but the choice of specific auxiliary hypotheses (often ex post if not ad hoc) is frequently done to protect the theory from falsification. This paradox captures well a fundamental channel of infiltration in science of instrumental rationality.[51] The rejection of a specific theory often does not imply the rejection of the underlying research programme because the latter can come out of the impasse by formulating a new progressive theory. In this view, a scientific revolution occurs when a new progressive programme succeeds to supersede a degenerating one. After the revolution, the progressive research programme acquires hegemonic status though rival research programmes may persist as minority points of view that continue to evolve by seeking to recover hegemony. Therefore, contrary to Kuhn's idea that normal science is driven by a single paradigm, Lakatos rightly argued that, even in the normal periods, the evolution of science is affected by the dialectic between competing research programmes. This approach implies that pluralism plays a role much more important than Kuhn maintained. In addition, Lakatos questions the naïf falsificationism of the early work of Karl Popper by showing that also the greatest scientists

[50] Ibidem, 34.

[51] This view of methodology reflects the influence of his friend and critical interlocutor Feyerabend. After Lakatos's death, Feyerabend wrote that:

> Lakatos realised and admitted that the existing standards of rationality, standards of logic included, were too restrictive and would have hindered science had they been applied with determination. He therefore permitted the scientist to violate them (he admits that science is not 'rational' in the sense of these standards). However, he demanded that research programmes show certain features in the long run – they must be progressive ….' (Feyerabend, 1978).

in their most inspired achievements breached his advocated methodological rules. Lakatos abandons falsifiability as the demarcation criterion between science and non-science, merging it with the distinction between good and bad science[52]:

> The Generalized Demarcation Problem is really the problem of the appraisal of scientific theories ... We are, naturally, assuming a continuous scale whereby the value zero corresponds to a pseudo-scientific theory and positive values to theories considered scientific in a higher or lesser degree.

Based on this criterion, Lakatos's list of pseudoscience broadly overlaps with that of Popper – including metaphysics, Marxism, and Darwinism – but adds a few further examples including neoclassical economics.[53] The generalised demarcation problem does not improve on Popper's simple dichotomy for at least two reasons. First, the interpretation of metaphysics as bad science neglects the late Popper's intuition that metaphysics research programmes such as Darwinism may play a crucial role in sound science. Second, the efforts pursued by the late Popper to provide a measure of good science through the concept of verisimilitude, though unsuccessful, went further than his attempts of appraisal. Lakatos admits, however, that we can seldom assert that a research programme is not scientific. We can only say that it is not looking scientifically 'healthy' and that, for the time being, the prospects for a recovery do not look good. The path of progressive divergence from Popper did not prevent the late Lakatos to stretch to Popper's extreme fallibilism arguing that each theory: '... at any stage of its development, has unsolved problems and undigested anomalies. All theories, in this sense, are born refuted and die refuted'.[54] This extreme version of fallibilism undermines the operational efficacy of Lakatos's generalised demarcation criterion based on lax falsification conditions that are unfit for a sharp competitive appraisal of alternative theories or research programmes. Unfortunately, Lakatos's untimely demise in 1974 left this question unanswered. The implications for pluralism are mixed. The blurred boundary between science and pseudoscience makes it more difficult to exclude a research programme from the club of genuine sciences, but the dialectic within this club becomes opaque.

52 Lakatos in Motterlini (1999, 20).

53 See Latsis (1976).

54 Lakatos (1978a, 4–5).

4.6 Scientific Visions and the Evolution of Science

In what follows, I will use the term paradigm exclusively in the second meaning of Kuhn, to avoid not only confusions between different meanings but also the shortcomings of the first meaning. Kuhn himself recognised in his *Postscript* to the second edition of *The Structure of Scientific Revolutions* (1970 [1962]) that the way in which he had defined the concept in the first edition was intrinsically circular: 'a paradigm is what the members of a scientific community share, and, conversely a scientific community consists of men who share a paradigm'.[55] To escape circularity, Kuhn recognises that we must define paradigms and scientific communities independently. This goes in the direction pursued in this book that aims to define independently schools of thought and paradigmatic matrixes. In addition, to avoid the criticism of adhering to a sort of undifferentiated holism, Kuhn introduces the concept of 'disciplinary matrix' that allows him to articulate the contents of a paradigm in the first sense in a more informative plurality of sociological, psychological, and ethical dimensions. In my suggested approach, instead, a scientific vision escapes circularity simply because it belongs to any single researcher, while a school of thought refers to a group of researchers that have a similar scientific vision. In this view, the definition of a school of thought has the nature of a fuzzy set to which its members belong only to a certain extent. The degree of similarity between scientific visions is a matter of judgment. Researchers themselves evaluate whether the analogies between their contributions grant a feeling of belonging and a promising convergence of synergies to a certain group of researchers. Analogously, an external observer may assess the analogies and differences between the scientific visions of individual researchers. In the next chapters, I will characterise scientific visions through an 'epistemic matrix' that plays a role similar, though more restricted, to that played in Kuhn by his concept of 'disciplinary matrix'. In both cases, the word matrix aims to capture the multidimensionality of criteria that define the worldview of a specific discipline (in the case of Kuhn) or of a specific scientific vision (as defined in this book). In my definition, the adjective 'paradigmatic' is used in a sense analogous to the second meaning of Kuhn, as it describes the canonical features of a certain

[55] Kuhn (1970 [1962]).

scientific vision that plays the role of emblematic exemplar for the practice of good science. Kuhn often describes the great masterpieces of science as paradigms in the second sense or exemplars: cases in point are Ptolemy's *Almagest*, Lavoisier's *Traité élémentaire de chimie*, and Newton's *Principia*.[56] Such texts contain not only the key theories and laws of a certain discipline, but also the emblematic applications of those theories to the solution of important problems, along with the required innovative experimental or mathematical techniques. Something similar we can find in economics. For example, as we will see in the following chapters, Fisher's equation of exchanges was the paradigmatic reference for marginalist monetary economics. Friedman's version of the quantitative theory of money provided the paradigm for modern monetarism. The *General Theory* (GT) of Keynes (1936) was the paradigmatic exemplar of Keynesian macroeconomics, while the essays collected by Lucas (1981) played the same role for New classical Economics.

A crucial difference that distinguishes the approach of this book from that of Kuhn is that, as remarked by Lakatos, a mature science is not usually characterised by a unique scientific vision, not even in the periods of so-called normal science. In these periods, however, according to Kuhn, a scientific vision is usually firmly hegemonic while in the 'revolutionary' periods at least two visions fight strenuously for retaining or conquering a position of hegemony. This view maintained by Kuhn is not even accurate in natural sciences (as is confirmed by physics itself).[57] In any case, the thesis of a monist normal science is particularly misleading in social sciences. The plurality of visions is significant also in normal periods, as I will show in this book. Kuhn maintains instead that the lack of consensus is the hallmark of an 'immature science' in what he calls its 'pre-paradigm' period. Kuhn links pluralism with inefficiency, at least in the activity of puzzle solving, because there is little opportunity for collective progress. On the contrary, I maintain that pluralism is the mainspring of scientific progress also in the periods of normal science. This is particularly true in social sciences where the interaction between internal and external history is especially significant.

[56] Smolin (2008 [2007]). [57] See Chapters 2 and 3.

PART II

Pluralism in Aggregate Economic Analysis

5 Epistemic Visions in Early Political Economy

> *Pierre-Simon Laplace:*[1] *What we know is little, and what we are ignorant of is immense.*
>
> *Adam Smith:*[2] *Every faculty in one man is the measure by which he judges of the like faculty in another. I judge of your sight by my sight, of your ear by my ear, of your reason by my reason, of your resentment by my resentment, of your love by my love. I neither have, nor can have, any other way of judging about them.*

Many people with a superficial knowledge of economics think that macroeconomics emerged from the *General Theory* of Keynes (1936) as Athena from the head of Zeus. This widespread preconception is deeply misleading. Keynes coined the name of macroeconomics to emphasise the novelty of his vision of aggregate economics as compared to previous classical vision of system-wide economics. Keynes founded macroeconomics as an autonomous discipline exactly because he believed that its foundations on classical microeconomics are in principle impossible or misleading. In this chapter, I sketch the evolution of aggregate economics before Keynes. From the sixteenth century to the turn of the eighteenth century this process largely overlaps with the process of gestation of economics as a scientific discipline since the main themes discussed by the early economists – inflation, foreign trade, and development – referred to the economy of an entire nation. In the sixteenth and seventeenth centuries, the arguments relied mainly on unsystematic observations and elementary causal associations not yet framed within a sound theoretical structure. This is the case of the early proponents of the mercantilist and monetarist doctrines (see

[1] Fourier (1831 [1829]) comments: "This was at least the meaning of his last words, which were articulated with difficulty."
[2] Adam Smith (1984 [1759], Part 1, Section 1, Chap. 3).

Sections 5.1 and 5.2). Mid -eighteenth-century French Physiocrats were the first economists who elaborated an analytical framework to study the economy as a whole by building on the analogy between circulation of wealth and circulation of blood in the human body (Section 5.3). In the same period, Adam Smith took inspiration from the Newtonian model of celestial mechanics to work out a different unifying principle based on the gravitation of prices and quantities exchanged towards their equilibrium values in a competitive market (Section 5.4). At the turn of the nineteenth century, Bentham transformed the traditional utilitarianism in a more sophisticated framework of decision theory to be applied also to economics (Section 5.5). The Classical school of political economy elaborated and refined Smith's conceptual model. Say introduced the law of markets, usually called Say's law, which will play a crucial role in the evolution of mainstream macroeconomics (Section 5.6). From the analytical point of view, a significant progress occurred mainly in the theory of value as developed by Ricardo and Stuart Mill. Ricardo focused on the short period and included in the core of his theory the interaction between functional distribution of income and value theory (Section 5.7). Marx's vision was much wider than that of contemporary economists focusing not only on the theory of labour value but also on the circulation of capital, its accumulation, and the evolution of the capitalist system. The influence of this broad scientific vision on the evolution of aggregate economics has been vast but only partially recognised (8). In the final section, in the light of the preceding historical sketch, I discuss a few aspects of the early branching of political economics in a plurality of scientific visions.

5.1 Mercantilism and State Dirigisme

In Western Europe, the emergence of economics in the modern era was fragmented in a plurality of contributions to specific policy issues as experienced in different countries. The contributors supported the interests of disparate stakeholders by using a variety of media such as pamphlets, journal articles, and brief documents as instruments aiming to convince decision-makers, usually the sovereign and their councillors. They could not refer to established theories, which in the field of economics were then missing, and adapted their arguments to their perception of the local problems and their urgency. We find thus dissimilar approaches in different countries. In most cases, the arguments relied mainly on direct observation, as was obvious in a period dominated by scientific Empiricism, which however remained casual and unsystematic. Nevertheless, we can find a few similar arguments for problems observed in all, or most, countries. I must mention here two of the problems that were particularly pressing in many European countries: the persisting inflation started in the sixteenth century and the disequilibria in international trade. The reflexions on these two problems planted the seeds of the two most important early economic theories: the mercantilist theory and the Quantitative Theory of Money.

By the sixteenth century, monarchical absolutism prevailed in much of Western Europe and solicited the emergence of a constellation of doctrines and practices that promoted governmental control of a nation's economy to increase its power in the harsh economic and political competition with the rival national powers. The advocates of these influential doctrines were subsequently called mercantilists.[3] In the early seventeenth century, the so-called 'Dutch puzzle' greatly stimulated the influence of Mercantilism. Although the Dutch Republic was a tiny recently established country,[4] it had succeeded in rapidly becoming the wealthiest and most powerful country in Europe.[5] Its amazing performance was particularly puzzling because Netherlands had a small population, and virtually no natural resources, including land, timber, and precious metals. The mercantilists explained the Dutch power by focusing on its prosperous international trade boosted by its colonies that were scattered all over the globe. In their view, the consistent commercial surplus made possible for many years by the Dutch colonial empire and the control of international maritime commercial routes allowed the accumulation of precious metals deemed indispensable to a nation's wealth and power. Therefore, mercantilists

[3] Adam Smith (1776) was the first to introduce the collective name of mercantilism to designate this school of political economy, the first to become influential in the modern era.

[4] This country had come into existence in the 1580s after a revolt against its Spanish Hapsburg rulers. Though its inhabitants were at the beginning no more than 1.5 million, it controlled a worldwide network of naval trade routes through powerful trading companies: the Dutch East India Company and the Dutch West India Company.

[5] This small country managed to build a colonial empire that stretched across the globe, from Nagasaki to New Amsterdam, from the Arctic Circle to South Africa.

encouraged colonialism as a vent for exports and a source of cheap and abundant raw materials but strongly discouraged manufacturing in colonies that would compete with domestic exports. The mercantilist policies were dirigiste and enforced the principle that the mother country must subject international trade to sovereign monopoly. At home they encouraged austerity and saving to favour a surplus in the trade balance and the ensuing accumulation of capital. This provided a favourable climate for the early development of merchant capitalism. Among the main seventeenth-century mercantilists I mention Antonio Serra in Italy, Thomas Mun in England, and Jean-Baptiste Colbert in France.

Antonio Serra in his *Short Treatise on the Wealth and Poverty of Nations* (Serra, 2011 [1613]), analysed the causes of the shortage of coin in the Kingdom of Naples. To this end, he was the first to analyse in some depth the determinants of the balance of payments and its components (goods, services, and capital movements). He concluded that the shortage of coin in the Kingdom of Naples was due to a persistent deficit in the balance of payments. He advocated measures of active encouragement of exports to solve the problem. Analogously, Thomas Mun (1571–1641) – successful British merchant and Director of the East India Company – argued, in *A Discourse of Trade, from England unto the East Indies* (1621), that the net outflows and inflows of gold depend on the balance of payments, which includes the balance of trade and capital transfers. Therefore, the State cannot check the net outflow of gold by restricting its movements as many commentators advocated. In other words, he claimed that the observed trade mechanisms of species flows was a 'natural law' that could not be disabled by royal dictation but only bended in the right direction by encouraging exports and discouraging imports. Mun also recognised that a policy of rising prices as advocated by earlier mercantilists (such as Malynes and Misselden) for their alleged stimulus to industry, could decrease the competitiveness of exports.[6] Similar ideas were promoted in practice by Jean-Baptiste Colbert (1619–1683), First Minister of State under the rule of King Louis XIV from 1661 until his death, who aimed – in his words – to provide the monarch with the funds he

[6] English mercantilists were often private businessmen who sought to influence the government by publishing pamphlets for or against some parliamentary act in which they had a vested interest. Their arguments were based on their life experience and conversations in coffee shops and palace foyers.

needed for 'order and glory'. In particular, he recommended the establishment of colonies, the improvement of the quality and efficiency of domestic manufacturing, the rationalisation of internal transportation, the expansion of the shipping industry, rigorous budgetary control, and the full employment of the labour force. Colbert pursued the 'universal rule' of controlling the economy and the fiscal system so that enough money could circulate in every corner of the country, giving all French citizens the opportunity of making profits and paying taxes. Taxation should 'increase the cash available for general commerce by attracting cash from other countries, keeping it inside the kingdom, and hindering its export, thus giving men the means to profit from it' (Cole, 1939, 340).

5.2 Monetarism: Inflation and Economic Activity

Some mercantilists, in particular Mun, were aware of the contradiction between the potential stimulus of inflation on industry and the likely hindrance on exports, but they failed to find a solution to this puzzle. In the same period, an alternative theory emerged that denied a persistent positive effect of inflation on economic activity by arguing that the latter does not depend ultimately on money but on labour and entrepreneurship. This point of view was subsequently interpreted as a germ of the Quantity Theory of Money (henceforth QTM).[7] In the sixteenth and seventeenth centuries, a common problem for many European countries was a slow but persisting process of inflation. We can find contemporaneous verbal versions of the QTM as tentative explanations of this process of secular inflation. A certain number of scholars observed that this process followed the discovery of the new world and the ensuing flow in Europe of gold and precious metal. They did not hesitate to interpret the empirical association between these two processes in causal terms. One of the first to maintain this thesis was Copernicus (1517), who was followed – to limit my list only to the most illustrious early scholars – by Jean Bodin (1530–1596) and Bernardo Davanzati (1529–1606). These early contributions were still vague and lacked the fundamental notion of

[7] The reconstruction of its origin and early development is very controversial, also because of the persistent confusion between 'Equation of Exchange' (henceforth EQE) and QTM (a distinction clarified by Fisher in 1911).

velocity of circulation (Roncaglia, 2005). However, in the seventeenth century the monetarist view became common as an argument to refute the policy strategy of the mercantilists who aimed to accumulate gold to increase the prosperity and military strength of a nation. The monetarists argued that the accumulation of gold and other precious metals would just increase inflation without increasing real wealth. Subsequently, liberal thinkers such as Locke and Hume progressively refined the quantity theory and utilised it to attack the interventionist policies advocated by the mercantilists. The most rigorous and influential early version of the QTM was that of Hume (1955 [1752]). In his view, an unexpected increase in the quantity of money may stimulate the real economy but only in the short run; in the longer run, the expansionary effect on the real economy would translate in proportionally higher prices while the economy would gradually recede to the previous level. In this way, Hume solved the puzzle that had embarrassed the most thoughtful mercantilists by explaining that the observed beneficial effects of inflation on industry are only temporary. Hume based his analysis on key concepts that will continue to characterise classical economics in its subsequent versions. First, he asserted that money is neutral in the long run, although it may not be necessarily so in the short run. In this view, the expansionary effect of an increase in money supply is a transitory phenomenon that fades out in consequence of the progressive adaptation of the economic agents to the new circumstances. If one compares long-term positions, nominal prices fully reflect the effects of variations in the quantity of money leading to a dichotomy between the real system and the monetary system (henceforth 'classical dichotomy'). We may consider mercantilism and the QTM as proto macroeconomic theories in the sense that they refer to aggregate quantities that characterise the economy of a nation. Their controversial arguments will continue to animate in updated form the debate in macroeconomics until now. Keynes, in chapter 23 of the *General Theory* (1936, 340), defended some of the insights advanced by the mercantilists: 'the methods of the early pioneers of economic thinking in the sixteenth and seventeenth centuries may have attained fragments of practical wisdom which the unrealistic abstractions of Ricardo first forgot and then obliterated'. An example of wisdom was the effort of keeping down the rate of interest by means of usury laws or the devaluation of currency when it is necessary to restore equilibrium (ibidem). The modern monetarism led by Milton Friedman recognised instead its debt to the lucid analysis of Hume.[8]

5.3 The Physiocrats and the Social Circulation of Wealth

The Physiocrats were eighteenth-century French economists who developed the first theory that described a national economy as an organic system.[9] The unifying principle was the analogy with blood circulation in the human body. François Quesnay (1694–1774), the founding father of the Physiocrats, was a well-trained physician. He was so successful in his profession to become the physician 'in ordinary' to King Louis XV and then a highly esteemed advisor on general policy issues.[10] Quesnay's innovative reflexions on the economy drew inspiration from his medical training. He built his vision on the recent work of William Harvey on the circulatory system of the human body to argue that the circulation of wealth plays a similar role in the economy. He thus analysed 'how money flowed between the three classes of farmers, proprietors, and artisans, in the same mechanical way that blood flows between different organs' and claimed that the farmers ultimately produced the entire surplus added to the nation's wealth. Quesnay published his most important work, the *Tableau économique* (Economic Table), in 1758. This work is the first attempt to describe the flows of value through the entire economy according to a rigorous analytical accounting. It shows how the products of agriculture, which constitute in his opinion the ultimate source of wealth, are distributed among the productive classes of landowners and peasants, and the unproductive classes of manufacturers and merchants. He compares the distribution obtainable in a state of perfect liberty with that obtainable under alternative systems characterised by governmental restraint and regulation to argue that the

[8] The early position paper of his monetarist research programme is Friedman (1956).

[9] The followers of Quesnay called themselves simply 'Économistes'. The current name of Physiocrats, or advocates of physiocracy (in Greek 'government of nature'), was given to them later to avoid confusion with the generic name 'economists' increasingly used by a rapidly growing number of researchers.

[10] Eltis remarked that Quesnay '... published his first article on an economic problem in 1756 when he was 62 years old, and in the following twelve years he produced a series of influential articles and successive versions of his famous Tableau économique' (Eltis, 2000, 1).

violations of the natural order would damage the entire society. In addition, Quesnay used the Tableau économique to show that the private interest of landowners brings about the general interest of society. Several pupils and followers gathered around him, including Mirabeau (1715–1789), Turgot (1727–1781), and Dupont de Nemours (1739–1817). Their influence did not remain confined to France.[11]

Whereas the mercantilists held that the ultimate source of wealth came from the surplus of exchange value obtained by the merchant, the Physiocrats were the first to identify the ultimate source of value with productive labour. For the Physiocrats, however, only agricultural labour created value. Quesnay argued that all non-agricultural labour, including that employed in industry, was just an 'unproductive appendage' to agricultural labour. If we compare the *Tableau économique* of Quesnay with the *Wealth of Nations* of Smith, it is immediately evident that the former reflected the stage of development reached by France that was still overwhelmingly agrarian, while the latter was in tune with the Industrial Revolution that was then going on in Britain. This explains why Smith, rather than Quesnay, was subsequently seen as the founding father of *political economy*. From the epistemic point of view, however, the credentials of Quesnay are comparable to those of Smith. The *Tableau économique* vividly captures the autonomy of the economic system, and thus also of economics. We find in his approach many methodological anticipations of macroeconomics. First, the analytical-accounting approach refers to broad functional aggregates. Second, the economic system is described by a model of 'circular flow' representing the aggregate flows of money, goods, services, and productive factors.[12] This approach provided the foundations of the national accounts systems,[13] and thus also of applied macroeconomics. We find in his writings early versions of the multiplier that will play a key role in Keynesian macroeconomics (Eltis, 2000, 1). Leontief

[11] When Smith was in France (as personal tutor to the stepson of Charles Townshend) he visited Quesnay in 1956 and intended to dedicate to him his masterpiece.

[12] The idea of the circular flow was already present in the work of Richard Cantillon.

[13] Richard Stone developed the system of national accounts which is now used internationally.

said that he took inspiration from Quesnay while he elaborated the input-output table for the USA in 1941 (ibidem).

5.4 Smith and Market Gravitation

From the pre-Socratic philosophy to the Scientific Revolution, science was part of philosophy. The Scientific Revolution started a process of progressive autonomisation of specific sciences that involved first astronomy and physics, and then in sequence all the other natural sciences. As for social sciences, the process started later and was more laborious. The first social science that conquered a certain degree of autonomy was political economy since the second half of the eighteenth century.[14] A scientific discipline becomes autonomous when its practitioners, after a period of search for empirical regularities, identify a unifying principle that internalises most of the critical causal factors. Most founding fathers of political economy defined their approach in reference to Newton's world system that during all this period played the role of paradigmatic exemplar of successful science, inspiring not only the evolution of natural sciences but also the genesis of social sciences. Newton himself advocated the application of his method to moral philosophy, a branch of knowledge that partially overlapped with what we call today social sciences. For example, in the last paragraph of *Opticks*, Newton asserted that 'if natural Philosophy and all its Parts, by pursuing this Method,[15] shall at length be perfected, the Bounds of Moral Philosophy will also be enlarged'.[16] Newton's exhortation to apply his method to emerging sciences was very influential in the genesis and early development of many fields such as physiology, medicine, and – indeed – political economy.[17]

[14] As Mill asserted, 'Adam Smith and the political economists universally, both in France and in England; Bentham, and all thinkers initiated by him, had a full conviction that social phaenomena conform to invariable laws, the discovery and illustration of which was their great object as speculative thinkers' (Mill, 1998 [1865]). Indeed, the economists mentioned by Mill have been deeply influenced by the extraordinary success enjoyed in the eighteenth and nineteenth centuries by Newtonian physics. The nature of this influence, however, is highly controversial.

[15] Newton exposes his methodology as going from 'phenomena of motions' to 'the forces of nature', in order to deduce other phenomena from these forces.

[16] Newton (1979 [1704], query 31, 4, 405).

[17] In particular, it inspired a long list of eminent scholars active in the eighteenth century burgeoning social sciences such as Hutcheson, Turnbull, Hume, and

Restricting our focus on the social scientists and following the chronological order, we have to consider first the influence of Newton on Hume was ambivalent on Newton's achievements and their utility for moral philosophy. He asserted that Newton was the 'greatest genius' that 'ever arose for the ornament and instruction of the species', but he questioned the 'usefulness to the Public' of his world system, and the soundness of his method implicitly tainted in metaphysical convictions.[18] The subtitle to Hume's influential *Treatise of Human Nature* presented it as an *Attempt to Introduce the Experimental Method of Reasoning into Moral Subjects* (1739–1740). His introduction to this book finishes with the following sentence:

> Where experiments of this kind are judiciously collected and compar'd, we may hope to establish on them a science, which will not be inferior in certainty, and will be much superior in utility, to any other of human comprehension (Hume, 2000 [1739–1740], 6).

Hume advocated the very ambitious project of providing the outlines of a 'science of man' meant to play a foundational role for all sciences, including Newton's *Philosophia Naturalis* itself. However, Hume maintained that Newton's method is not satisfactory for the science of man. Hume praised Newton's approach for his commitment to experimental method and fallibilism, but claimed that his use of the inductive method was insufficiently rigorous for at least two reasons: the systematic introduction of invisible causes such as forces and gravitation itself, and his too-easy generalisation of sensible experience into general principles. He disliked, in particular, the controversial rule 4, added for the third edition of *Principia*:

> In experimental philosophy, propositions gathered from phenomena by induction should be considered either exactly or very nearly true notwithstanding any contrary hypothesis, until yet other phenomena make such propositions either more exact or liable to exceptions. (Newton, 1999 [1687], 796)

Smith in Scotland; Bentham and his followers in England; Say, St Simon, and Comte in France. However, different scholars interpreted Newton's method in disparate ways.

18 Hume was well acknowledged with Newton's method; for example, in his *Enquiry Concerning the Principles of Morals* (1751), finishes the section on justice by appealing to 'Newton's chief rule of philosophizing' (Hume, 1998 [1751], 98).

In addition, Hume was sceptical about the systematic use in science of mathematics, particularly in the case of its advocated extension to moral philosophy.[19] Summing up, Hume's crisp refusal to consider general principles that go beyond the specific empirical evidence made his approach a better fit for the study of specific regularities, such as the correlation between money and prices, rather than for providing a unifying framework for economic research. It was Adam Smith who first played this role by drawing inspiration from a more sympathetic interpretation of Newton's world system. In the case of Smith, the reference to Newton stimulated the search in economics of its 'final scientific constitution'.[20] Smith was the first to find a compelling unifying principle for political economy, a principle similar to that of general gravitation that managed to coordinate the complex interactions occurring within the market. Adam Smith was particularly successful in showing the analogy between the tendency towards equilibrium in a competitive market and Newtonian gravitation in celestial mechanics. As in the solar system, also in the case of a competitive market, the force of attraction that leads towards equilibrium is exerted, so to say, 'at distance', owing to the ubiquitous mediation of money between the economic actors. Smith had a deep knowledge of Newton's world system and his method. Smith's essay on astronomy, which he wrote prior to 1758 (Smith, 1982, 103), probably while he was studying at Oxford, gives an important background to understanding Smith's relation to Newton. In the *History of Astronomy*,[21] Smith appraises 'the superior genius and sagacity of Sir Isaac Newton' that 'made … the greatest and most admirable improvement that was

[19] One of the reasons is the ubiquitous presence in history of concomitant causes: 'No questions in philosophy are more difficult, than when a number of causes present themselves for the same phaenomenon, to determine which is the principal and predominant. There seldom is any very precise argument to fix our choice, and men must be contented to be guided by a kind of taste or fancy, arising from analogy, and a comparison of similar instances' (Hume, 2000 [1739–1740], 3.2.3.4n71).

[20] According to Mill, a scholar establishes the scientific constitution of a science by 'discovering or proving, and pursuing to their consequences, those of its truths which are fit to form the connecting links among the rest: truths which are to it what the law of gravitation is to astronomy' (Mill, 1998 [1865]).

[21] The full title of this essay is 'The Principles Which Lead and Direct Philosophical Enquiries; Illustrated by the History of Astronomy', a title that explicitly emphasises its methodological focus.

ever made in philosophy' (Smith, 1982, 98).[22] Qualified interpreters of Smith's contributions recognised the significant influence of Newton on Smith. For example, Skinner (1979, 110) maintained that Smith's economics 'was originally conceived in the image of Newtonian physics'. Analogously, Blaug argued that both key concepts of Smith's celebrated monographies, sympathy in the *Theory of Moral Sentiments* (1984 [1759]) and self-interest in the *Wealth of Nations*, 'must be regarded as deliberate attempts by Smith to apply this Newtonian method first to ethics and then to economics' (1992 [1980], 52).[23] We may argue that both sympathy, through psychology, and self-interest through the market, exert in different social contexts gravitation tendencies affecting individual behaviour.

As we have seen in Section 2.5, Newton advocated a scientific vision apt to implement a progressive approximation to reality propelled by the systematic use of his analytic-synthetic method combining induction and deduction. The effective implementation of this approach left open many interpretations. In addition, notwithstanding his reticence on the subject, Newton's heterodox theological convictions could have influenced his most audacious rational conceptualisations, such as the idea of distant action, and the assumption of absolute space and time. Smith perceived the deep analogy between Newtonian theory and the unifying force of a competitive market towards equilibrium. In particular, he did not shy from exploiting Newton's hidden theological metaphors by famously exalting the providential invisible hand of the market leading the economic agents toward the best possible mutual coordination. Smith defined philosophy as 'the science of the connecting principles of nature' (Smith, 1982, 45). In his view, Newton discovered that 'Having thus shown, that gravity might be the

22 Smith is reported to have lectured that 'the Newtonian method is undoubtedly the most Philosophical, and in every science whether of Moralls or Naturall philosophy' (quoted in Montes, 2008). In his *History of Astronomy*, Smith asserted that Newton made 'the greatest discovery that ever was made by man, the discovery of an immense chain of the most important and sublime truths, all closely connected together, by one capital fact, of the reality of which we have daily experience' (Smith, 1982, 105).

23 Blaug argued that Smith 'had a naive view of what constituted Newton's method' (1992 [1980], 53). Montes (2008) argued instead that Smith was a knowledgeable and sophisticated interpreter of Newton's method. In my opinion, Smith had a sufficiently deep understanding of the scientific vision and method of Newton to draw significant insights for his path-breaking approach to political economy.

connecting principle which joined together the movements of the Planets, he endeavoured next to prove that it really was so' (Smith, 1982, 98). Smith's use of might in this quotation is not casual. For Smith science is an open-ended process of successive approximations, which is consistent with Newton's methodological legacy. Although the laws of motion and universal gravitation became Newton's best-known discoveries, he warned against using them to view the Universe as a mere machine, as if akin to a great clock. He said, 'So then gravity may put the planets into motion, but without the Divine Power it could never put them into such a circulating motion, as they have about the sun'.[24]

5.5 Say and the 'Loi des débouchés'

Smith exerted a great influence on the subsequent generations of economists. It became usual to group the first two generations of his closest followers – including Malthus, Ricardo, Say, James, and Stuart Mill – under the collective name of *Classical economists*. However, although all of them shared a Smithian inspiration, the differences between their scientific visions were huge and kindled harsh controversies.[25] We easily recognise a kinship in their theories and policy implications, such as the adhesion to the labour theory of value and a common interest for the economic development of national economies, both traits inherited from Adam Smith. However, they pursued these common interests in diverging scientific directions with different policy implications. An important component of mainstream classical thought did not derive from Smith but from Jean Baptiste Say (1767–1832) who was the most influential early follower and populariser of Adam Smith in France and in the Continent. Ricardo maintained that 'Say was the first, or among the first, of Continental writers who justly appreciated and applied the principles of Smith, and has done more than all other Continental writers taken together to recommend that enlightened and beneficial system to the nations of Europe' (Say, 1964 [1803], ix). His influence was by no means restricted to the

[24] Newton, Isaac (1782, 436–437).

[25] Their divergences are particularly marked if we include within the group of classical economists also Karl Marx (see Section 5.9). However, Marx introduced the name *Classical economics* to distinguish his own position from this form of insightful but misleading 'bourgeois economics'.

Classical school as Walras's appreciation confirms: 'Jean-Baptiste Say … est, après Adam Smith, le nom plus illustre de l'Économie Politique' (Walras, 1874, 8). His main work, the *Traité d'économie politique* (1964 [1803]), was a systematic exposition of Smith's work that took account of the French physiocratic tradition. He managed to express Smith's main contents in a more readable language. It was extensively adopted as a textbook of political economy and was soon translated in many languages. Some of the readers found the contents shallow and scarcely original. This was not the opinion of Ricardo who commended Say's work for having 'enriched the science by several discussions, original, accurate, and profound' (*ibidem*). The most original and influential of his contributions was the so-called Say's law or *law of markets* (called by him *lois des débouchés*) that excluded the possibility of a general glut. Say's law immediately became a fundamental pillar not only of Classical economics but also of most successive variants of mainstream macroeconomics. Marx, who coined the category of Classical economics, put Say in a different category that he dubbed with the derogatory name of 'vulgar economics'. According to Marx, vulgar economists restrict their analysis to the appearance of the capitalist process without seeing the underlying contradictions, involved by the process of generation, distribution, and accumulation of surplus (Marx, 1968, 500–502). Marx argues that vulgar theory focuses on the sphere of exchange where 'Freedom, Equality, Property and Bentham reign supreme; exchange appears as between 'equivalents', governed entirely by competition on the market (see Baradwaj, 1990). There is an unexpected convergence between these criticisms of Marx and those of Walras (1874). In the second lecture Walras criticises Say for his naturalist point of view and his motto '*Laissez faire; laissez passer*', both derived from the Physiocrats. According to Walras, the ultimate motivation of this approach and its wide success is rooted in its simplistic refutation of the socialist doctrines as artificial blueprints while they should be criticised from the point of view of utility and justice. I discuss here only Say's main contribution that will play a significant role for what follows in this book: 'Say's law'. The usual formulation of Say's law is that adopted by Keynes (1936) in its rejection: 'supply creates its own demand'. In all its formulations, Say's law excludes the possibility of a crisis determined by insufficient aggregate demand or 'under-consumption'. The original foundation suggested by Say is almost tautological: 'products are paid for with products' (1803, 153). It was not by chance that Say's law was first formulated by a French economist. Say had in mind the physiocratic circuit implying that the flow of exchange value made possible by the matching of demand and supply maintains its pressure, or in hydraulic terms its flux, throughout all the system of blood circulation.[26] Supply and demand are two symmetric sides of any transaction and thus equalise in equilibrium in any transaction and in their aggregates. Say's law emphasizes that the production of commodities having an expected exchange value paid an equivalent income to the suppliers of the inputs of capital, labour, and land used to produce these commodities. Therefore, a growing supply of output increases in the same measure the income necessary to assure the vent for those products. In terms of the physiocratic metaphor, the circulation of blood in a healthy body tends to keep the same pressure in each part of its circuit notwithstanding external shocks. In a money economy, however, the circulation of the exchange value depends on money as a means of exchange that separates elementary transactions into two parts: the sale of a good for money and the use of money to buy the desired good. The trouble is that the two parts of each monetary transaction are in principle separated from the temporal and spatial points of view. This greatly increases the range of possible exchanges and thus the flexibility of market relations but makes possible disequilibrium within a certain spell of time and spatial area. However, if we do not take account of disequilibrium and a host of further complications, Say's law excludes the possibility of a general excess of aggregate supply: 'a glut can take place only when there are too many means of production applied to one kind of product and not enough to another' (Say, 1964 [1803], 178–179). This point of view explains a general crisis as a mismatch between the structure of aggregate demand and aggregate supply. The Scottish economist James Mill (father of John Stuart Mill) soon introduced in his own work Say's law (Mill, 1808) writing that the 'production of commodities ... is the one and universal cause which creates a market for the commodities produced'. His close friend

[26] When the eminent physiocratic economist Dupont de Nemours complained that Say insufficiently acknowledged the achievements obtained in political economy by the Physiocrats, he replied that he had learned to think from Quesnay and his followers, but that it was in Smith that he had learned to seek the causes and the effects of social phenomena. This reply is fully consistent with the idea that Say's law drew inspiration from the physiocratic view of the circulation of wealth.

David Ricardo (1817) adopted Say's law enthusiastically while Malthus rejected it. Most classical economists sided with Say and Ricardo paving the way for the neoclassical and New classical orthodoxies.

Say's law is one of the most influential ideas emerged within classical political economy. It plays the role of a powerful bridge between the Physiocrats' Tableau Économique and GE theory. Say's law is a fundamental divide between mainstream macroeconomics and critical macroeconomics. The opposite interpretations of its meaning and implications constitute a main obstacle to tolerant pluralism in macroeconomics. As Foley puts it:

> A willingness to deny or criticize Say's Law is one of the hallmarks of economic heterodoxy, and an important token by which the orthodox recognize the heterodox. For the orthodox theorist the denial of Say's Law (in whatever version happens to be dominant at the moment) is a sure sign of the heterodox theorist's confusion and incompetence. To the heterodox theorist the acceptance of Say's Law is an instance of orthodoxy's blindness to reality, and fetishized attachment to absurd abstractions (Foley, 1985, 183).

5.6 David Ricardo and Income Distribution

The adoption or rejection of Say's law has significant implications for economic policy. Its supporters usually interpreted it as a proof of the efficient self-regulation of competitive markets providing the necessary foundations to a policy of laissez faire. The belief in the self-regulation of markets tended to reduce the scope of political economy to the study of phenomena under the control of the market. Malthus, who rejected Say's law, criticised the emerging narrow view of political economy and advocated a broader scientific vision able to keep economic theory in touch with politics and ethics. Ricardo's point of view was narrower than that of Smith and Malthus not only for his adhesion to Say's law but also because he was particularly focused on the short period. However, he struggled to include the interaction between functional distribution of income and value theory into the core of economic theory. In the introduction to the third edition, Ricardo claimed that: 'To determine the laws which regulate this distribution is the principal problem in Political Economy' (Ricardo, 1821, Preface). The point of view maintained by Ricardo on the theory of value and distribution was clearly divergent from that of Malthus but its exact nature, and the implications of their divergence, have been quite controversial. I limit myself to discuss one aspect of the ongoing debate focusing on the determination of money wages. The point of view of Malthus is altogether clear. The law of population assures that the equilibrium value of money wages is that of subsistence in the biological sense of the words since endogenous countervailing movements of the population would eliminate whatever deviation from equilibrium. As for the viewpoint of Ricardo, we may distinguish on this point three main interpretations: the fix-wage approach, the new view, and the so-called alternative interpretation (see Stirati, 2010). The fix wage interpretation, mainly associated with the names of Kaldor (1956) and Pasinetti (1974), borrows from Malthus the assumption that wages tend to be at their natural subsistence level. The employment is determined by the ratio between the wage fund and the natural wage (Kaldor, 1956) as full-employment equilibrium. The New view – usually associated with the work of Hicks and Hollander (1977), Samuelson (1978), and Casarosa (1978) – maintains that the wage rate is determined by 'supply and demand'. The equilibrium rate tends to the subsistence rate only in the stationary state towards which the economy tends in the very long run. According to the New view, before reaching this state, the wage rate is determined by 'supply and demand' that fix the market price of labour. Hicks and Hollander (1977) attribute to Ricardo a decreasing demand schedule for labour based on decreasing marginal productivity. Since this assumption implies the interdependence among economic variables, this category of interpretations tends to reduce the divergence between classical and neoclassical theories undermining the interpretation of Ricardo as a 'surplus theorist'. This is instead the opinion entertained by the third interpretation that claims that for Ricardo there is no demand curve for labour inversely related to the wage. Therefore, we do not find a tendency towards the full employment of labour. In particular, the introduction of machinery and changes in the composition of demand and output might create persistent unemployment. The natural wages depend on the level of subsistence, but the latter depends also on the customary living standards and the specific institutions of the country. The short-term deviations from the natural rate depend on the relation between demand and supply that is affected by any factor that can influence the bargaining position of the parties. In his introduction to the works of

Ricardo, Sraffa (1951) inclined towards this alternative interpretation. He advocated a return to this sort of Classical approach to distribution because he saw its advantage 'as being the absence of a mechanical or "natural" determination of distribution, a determination, that is, independent of the actions undertaken by the parties' (Stirati, 2010, 10). This scientific vision inspired the research programme of the so-called Neoricardian Economics suggested and pursued by Sraffa (1960) and Garegnani (1984). The conflict between the continuity and discontinuity in successive research programmes has often marked a crucial divide between different scientific visions. We will see, for example, in the next chapter that Jevons will emphasise the discontinuity and incompatibility between the Classical and neoclassical schools, while Marshall will insist on the continuity and complementarity between them.

5.7 Marx and Aggregate Analysis

Any study on the genesis of macroeconomics cannot ignore the contributions by Marx to its early development. His influence on the evolution of economics went much beyond what is generally recognised. Many economists who took inspiration from some of his insights and were critical of his political or philosophical ideas preferred to leave out, or play down, their source to avoid prejudicial hostility. In addition, the economists who recognised some sort of inspiration from Marxian ideas diverged significantly in their interpretation of the common source and in the advocated research programme. In this section, I limit myself to a brief assessment of the position of Marx in the evolutionary tree of aggregate analysis. Among the many branches, two of them immediately capture our attention by being particularly extended and ramified. One starts from Marx's theory of labour value and derives its social and economic implications, including the theory of exploitation and the unequal distribution of surplus. This branch ramifies further into economic and political theory including those referring to different varieties of socialism and communism. The second main branch provides the foundations for his theory of circulation, accumulation, and evolution of capital. For lack of space, in this section, I focus exclusively on the second branch whose influence on the evolution of macroeconomics has been vast. This branch drew inspiration from Quesnay's *Tableau* as a starting point for the theory of circulation as developed in volume 2 of the *Capital*, in particular for working out his celebrated reproduction schemes. As Eltis remarks,

> Marx, who according to Schumpeter derived his fundamental conception of the economic process as a whole from Quesnay, called it 'an extremely brilliant conception, incontestably the most brilliant for which political economy had up to then been responsible' (Eltis, 2000, 1).

The influence of Quesnay on Marx goes much beyond the second volume of the *Capital*. His analysis of the evolution of forms of circulation that provides the ultimate foundations of his theory of capitalism in book 1 of the *Capital* shows a strict conceptual link with Quesnay's circular flow. There is a difference, however, of the utmost importance for our theory of epistemic visions in aggregate analysis. Marx managed to combine Quesnay with Hegel to provide a sketch of the evolution of capitalism, a sketch that provides the vertebral column of his vision. This approach inspired many insights that influenced also non-Marxist macroeconomics: in particular, the critique to Say's law, the critique of the QTM, and the growing importance of money and credit in modern capitalism. As for Say's law, he understood its crucial importance in determining the theoretical and policy implications of political economy:

> No one can sell unless some one else purchases. But no one is forthwith bound to purchase, because he has just sold . . . If the interval in time between the two complementary phases of the complete metamorphosis of a commodity becomes too great . . . their oneness asserts itself by producing a crisis (Marx, 1967, 113–114).

Marx clarifies what is the historical and logical source of the possibility of a general glut, a source that rejects all the versions of Say's law that exclude this possibility. In a barter economy characterised by the direct and contemporaneous exchanges between goods Ci-Cj, each transaction can be seen by both traders as demand or supply while their exchange value is identically equal.[27] The aggregate of the exchange value of all demands or all supplies in a certain spell of time and in a certain geographic area must always be equal. This is the only case in which Say's law is true. Note that if all the exchanges are voluntary,

[27] We have to assume that the two symmetrical exchanges are simultaneous to exclude unexpected events such as the deterioration of the commodities exchanged. Unity of time and space is a usual characteristic of barter.

each of them is bound to increase the utility of the traders because each of them disposes of the good in possession if and only if they receive a preferred good in return. However, as is well known, this technology of exchange is very inefficient because it is limited to the rare case in which two would-be traders having symmetrical preferences manage to meet, what Jevons called 'double coincidence of wants' (Jevons, 1875, chapter 1, paragraphs 5–6). In other words, each trader could further improve utility by acquiring other goods from traders who are not interested in keeping them at their disposal. This limit is overcome by introducing money, a commodity that is accepted by all the potential traders. The typical exchange may now be expressed by Ci-M-Cj. The exchange may happen even if j is not interested in Ci, because in this case i sells his good to whomever is interested to buy it and then may obtain Cj from j in exchange of money. Therefore, money articulates the transaction in two parts. The mediation of money introduces a temporal and spatial gap between the two parts of each transaction. This implies that within given temporal and spatial boundaries the possibility of a disequilibrium between aggregate demand and supply cannot be ruled out a priori. With this reasoning, Marx systematises previous critiques to Say's law that pointed out the possibility of a disequilibrium between aggregate demand and supply and thus also the possibility of a crisis. According to Marx, however, it is not sufficient to recognise the possibility of a general glut, as some previous economists had done, without explaining the conditions of its actual occurrence. Stopping here one may convey the wrong idea that it 'is therefore accidental whether or not crises occur and consequently their occurrence is itself merely a matter of chance' (Marx, 1968, 212). According to Marx, we cannot explain actual crises if not in terms of behavioural regularities of specific subjects within a historically determined mode of production.[28]

5.8 The Branching of Economic Visions

In this section, I sketched a bird's-eye view reconstruction of the genesis and early development of aggregate economic analysis. I chose just a few photograms drawn from the actual historical process so that in my sketch its continuity is almost completely lost. Also, the

[28] See Foley (1985, 190).

variety of scientific visions is grossly understated. Notwithstanding these limits, a rushed inspection of the selected photograms could be sufficient to support a few general assertions that question some widespread prejudices.

First, we must reject the assertion that macroeconomics was born in 1936 with the publication of the *General Theory*. This assertion is deeply misleading, unless we restrict the meaning of the word macroeconomics to the specific version of aggregate analysis advocated by Keynes. On the contrary, we should recognise that the genesis of macroeconomics largely overlaps with that of economics, while what we call today microeconomics had a laborious gestation in the period that goes from Bentham to the Marginalist Revolution. Only after microeconomics pretended to exert a dominant influence on aggregate economics that the latter fought back to keep its autonomy. As we will see in Chapter 9, the birth of Keynesian macroeconomics is the fruit of a rebellion against the growing hegemonic pretences of microeconomics, a rebellion prompted by the Great Depression. Second, as is typical of an evolutionary tree, a growing plurality of scientific visions developed through time. This plurality does not depend only on the continuous adaptation of economics to the structural evolution of capitalism, but also on the plurality of interpretations of the nature and implications of its evolving stages. Also in this case, we should never abuse collective labels suggesting homogeneous groupings of different economists. We have seen, for example, how different are the scientific visions of Smith, Malthus, Say, Ricardo, Marx, and Stuart Mill, although they are often grouped under the same label of Classical school. In the next chapters, we will see that the marginalist economists of the first and second generation are not less heterogeneous. Third, at a higher level of abstraction, we can group all these different economic visions into two broad camps. One category believes in the superiority of free markets, adopts Say's law, believes in the QTM, and abhors the intervention of the State in the economy, advocating laissez faire and free trade. As far as this chapter is concerned, we find in the first category the monetarists, the Physiocrats and – to some extent – the Classical economists in the strict sense. In the second category, we find the economists who emphasize the limits to the self-regulating power of the markets, reject Say's law and the QTM, and advocate, in specific circumstances, the intervention of the State in the economy. In this category, we find the mercantilists

Malthus, Marx, and Keynes. In both categories, the differences between their exponents' visions are huge. Any classification of scientific visions must respect the hierarchical complexities of the progressive branching of plural visions. Finally, we must emphasize that the political implications of a certain theory or scientific vision are far from univocal. We should thus be very careful in making simple associations between theories or schools of thought and policy or political positions.

6 *The Marginalist Revolution*

> *John Stuart Mill (*1848*):*[1] *Happily, there is nothing in the laws of Value which remains for the present or any future writer to clear up; the theory of the subject is complete.*
>
> *W Stanley Jevons (1871):*[2] *In matters of philosophy and science, authority has ever been the great opponent of truth. A despotic calm is the triumph of error; in the republic of the sciences sedition and even anarchy are commendable … In science and philosophy nothing must be held sacred. Truth itself is indeed sacred, but where is the absolute criterion of truth?*

The translation in analytic terms of Smith's vision of competitive markets took almost one century and required a reconceptualisation of the hard core of political economy. This found a first controversial accomplishment with the so-called *Marginalist Revolution*. According to the usual opinion, the main revolutionary leaders have been Jevons, Walras, and Menger with their seminal contributions published in the 1870s. All of them rejected the scientific vision of the Classical economists. They rejected the labour theory of value – put forward by Smith and elaborated by his early followers – suggesting a radically different theory of value based upon marginal utility. Jevons, Walras, and Menger independently worked out similar versions of the new value theory. However, they pursued different research programmes and had a different impact on contemporary and subsequent generations of economists. The fortune enjoyed by these trail-blazing economists followed different temporal and spatial paths. Jevons had an immediate, though controversial, impact in Britain but did not have much time to refine and propagate his ideas because of his untimely

[1] Mill (1848, Ch. III.1). [2] Jevons (1871, 266).

death in 1884.[3] Walras had the time to establish a school, the Lausanne School, which attracted first-order mathematically oriented followers (such as Wicksell, Pareto, Barone, and Antonelli). However, his influence remained limited until the 1930s (see Chapter 8).[4] Menger's more accessible contribution was instead immediately successful in Austria and then gradually extended his influence in other German-speaking countries. Since his first work published in 1871, he advocated a specific research programme (often called Austrian economics) that had a significant influence on the methodological vision of subsequent aggregate economics (see Chapter 7). The influence exerted by Jevons, Menger, and Walras was strictly interlinked. However, I prefer to discuss separately the genesis and evolution of their contributions aiming to capture as far as possible the peculiarities of their scientific vision and of their impact on economics. In this chapter, I focus on the Marginalist Revolution mainly from the point of view of the genesis of modern microeconomics recognising the path-breaking role played by Jevons.[5] I start the analysis from Smith showing that the non-utilitarian and antireductionist explanation of individual behaviour sketched in the *Theory of Moral Sentiments* was radically different from that of modern microeconomics, However, in the *Wealth of Nations* Smith clarified how a competitive market determines a progressive convergence of self-interested individual behaviours towards an optimal equilibrium foreshadowing modern microeconomics. The second section focuses on the crucial role played by Jeremy Bentham and John Stuart Mill in transforming traditional utilitarianism in a more operational theory of economic decisions. In the hands of Jevons, utilitarianism was transformed into an analytic decision theory (Section 6.4). In the Section 6.5 I examine how Walras developed

[3] Marshall is often classified as a second-generation marginalist. I argue in the next chapter that this definition is misleading.

[4] In English-speaking countries, the first translation of Walras's masterpiece appeared only in 1954. From that date, his influence rapidly increased, making his approach to GE the crucial reference of mainstream economics and macroeconomics.

[5] In Chapter 7, I focus on the methodological revolution started by first-generation marginalists. The crucial role was played by Menger who triggered an extensive methodological dispute in German-speaking countries. In Chapter 8, I focus on Walras as initiator of the great tradition of GE theory.

the first sketch of a General Equilibrium Theory (GET) focusing on the strategic interactions of self-interested individuals, a theory that generalises Jevons's theory of self-interested behaviour. Section 6.6 investigates the impact of the marginalist 'insurrection' led by Jevons on the genesis of modern microeconomics. Section 6.7 digs deeper on the relationship between the evolution of value theory and the genesis of microeconomics. In the concluding remarks I discuss how the Marginalist Revolution completed the gestation of mainstream microeconomics with the aim of providing effective foundations to the whole of economic theory.

6.1 Smith's Institutional Assumptions

The tension between microeconomics and macroeconomics did not originate in reaction to the birth of Keynesian macroeconomics, as many believe and some scholars asserted.[6] Such a tension started to become apparent in consequence of the gradual emergence of microeconomics within the Classical school but became a crucial issue only with the Marginalist Revolution when microeconomics sought to occupy a hegemonic position within *political economy* transforming it in a reductionist *economics*. Before this radical change of paradigm, the tension between the individualist and social dimensions of a market economy was epitomised by the dichotomy between use value and exchange value. Use value expressed the specific utilitarian relation between consumers and specific goods, while the exchange value expressed the relevant social relations between traders mediated by money. The Classical school did not neglect the role of use value but focused mainly on the social side of value through the theory of labour value. By adopting the labour theory of value, the Classical economists aimed to shift the enquiry on the causes of wealth towards the real economy rather than on the accumulation of precious metals over-emphasised by the mercantilists. Moreover, the Classical economists rejected the idea of the Physiocrats that only the agricultural labour could create value. In their opinion, the prosperity of a country depends in all the fields of human activity on the quality

[6] See, for example, Lucas (1981).

of the productive effort, the division of labour, and the functional distribution of income. In this view, the prosperity of a country depends thus on the behaviour of the economic agents considering their social relations. This is the main topic discussed by Smith in his first major work *The Theory of Moral Sentiments* published in 1759 that made him famous and paved his brilliant academic career. His approach was radically different from that of modern microeconomics. Modern microeconomics is the offspring of a particular stream of moral theory, namely utilitarianism, in the operational version worked out by Bentham and Mill, then adapted to economic behaviour in analytic form by the marginalists. In *The Theory of Moral Sentiments* Smith expressed his own system of moral. Smith followed his teacher Hutcheson and his friend Hume in tracing moral judgment, ultimately, to feelings. He focused on sympathy, described as arising when we imagine how we would feel in the circumstances of others. In his opinion, this is the key to understand what keeps together a community. Smith stresses the constitutive role of sociality and the crucial role of history that affect the moral judgement of individuals. He aimed to provide a standard of moral judgment that is valid in a community (Sen, 2009, 125). The 'chief part of human happiness,' for Smith, comes from the consciousness that we are 'beloved' (1759, 41). The search for feelings we can share – for mutual sympathy – is a basic human drive that leads to the rise of morality.

According to the traditional reading of Smith's major works, there is a radical conflict between the theory of moral behaviour worked out in *The Theory of Moral Sentiments* and that asserted in *The Wealth of Nations*. At first sight, this opinion seems justified because the earlier book emphasises the role of sympathy for others, while the latter book focuses on the role of self-interest. However, the hypothesis of a radical change of view is inconsistent with the documented fact that Smith considered the first book as his main achievement and continued to update it until his death. In the light of recent scholarship,[7] we can understand the nexus between the two masterpieces by starting from their common

[7] Ekelund and Hebert (2013, 105) notice that self-interest is present in both works and that 'in the former, sympathy is the moral faculty that holds self-interest in check, whereas in the latter, competition is the economic faculty that restrains self-interest.'

epistemological inspiration deeply influenced by his study of the Newtonian system.[8] In *The Theory of Moral Sentiments*, in a community, sympathy plays a role similar to that of gravitation in the solar system keeping the parts together within an ordered whole. Sympathy is an antidote to the centrifugal forces of individualism and self-interest seeking for a balance that permits a community to survive, prosper, and evolve. Smith focuses on the process of mutual emotional adjustment that produces the convergence towards the same moral principles. The main motivation underlying the mutual emotional adjustment is the desire of receiving the approval of the other members of the community, a motivation that presupposes a rich network of personal relations. In *The Wealth of Nations*, the shift of emphasis from sympathy to self-interest may be explained in terms of the ongoing change in the historical circumstances. The process of convergence towards a common attractor is implemented within the ruling institutions. Smith takes into account the deep transformations brought about by the ongoing industrial revolution and the growing role of competitive markets.[9] The application to the emerging capitalism of his previous model of moral behaviour had to face a crucial problem. The rapidly growing extension of the markets was then substituting in the economy the previous personal relations with impersonal relations mediated by money and credit. In other words, Smith's *Theory of Moral Sentiments* applies to pre-capitalist communities characterised by direct personal relations, but not to the emerging impersonal market relations mediated by money. The concept of sympathy is applicable only to community relations and not to market competition. As Smith emphasized in a much-quoted passage: 'It is not from the benevolence of the butcher, the brewer, or the baker that we expect our dinner, but from their regard to their own self-interest. We address ourselves not to their humanity but to their self-love, and never talk to them of our own necessities, but of their advantages' (Smith, 1976, 1st chapter). In a competitive market, the coordination between the actions of the individuals could not rely any more on their mutual

[8] This influence is clearly documented by his *History of Astronomy* (see Section 5.4).

[9] In his lectures on jurisprudence, Smith reconstructs the genesis and evolution of different institutions such as property, contract, marriage, and punishment.

sympathy (or benevolence) that would require the dominance of direct personal relations. In the emerging institutions of capitalism, the coordination between self-interested actors relies in principle on the competition between them. The impersonal market gravitation of demand and supply substitutes the personal gravitation of sympathy. In both cases the coordination obtained is an unintended result of economic agents actualised by an 'invisible hand'. As for the consistency of the two books, we should not forget that communities and markets coexisted under early capitalism. What is missing in Smith, but is still missing today, is an in-depth general analysis of the interaction between communities and markets in evolving capitalism.

Let us sum up, the theory of individual economic behaviour worked out by Smith anticipates in part that of modern microeconomics but is quite different in method and implications. Smith's theory is antireductionist and always aware of the complexity of human behaviour. In particular, Smith was not utilitarian and not even consequentialist. We can see an analogy as far as the explanation of economic coordination in a competitive market is concerned. In addition, Smith's theory does not imply that a workable market coordination is an optimal equilibrium. Personal choices are heavily constrained by institutions that can prevent the individuals to implement their optimal choices. This is true in particular for the State. Smith argues that, even when the intentions of the government are good, State's interventions may worsen the actual performance of the economy unless there are sound reasons otherwise. Smith aims to limit the activities of governments also for moral reasons because he considers crucial for the development of personal virtue that people have plenty of freedom to act on their own. In addition, he is suspicious of large-scale plans implemented by the State also for epistemic reasons because he argued for the crucial role of local knowledge.

6.2 Bentham and the Genesis of Utilitarian Microeconomics

Smith provided early conceptual foundations for political economy building them on the key argument that a competitive market is characterised by a tendency towards an optimising equilibrium, a tendency that plays a unifying role similar to that of Newtonian gravitation in celestial mechanics. This far-reaching insight gave birth to a long-lasting research programme that branched in different directions. The main branch gave birth to the influential school of 'Classical Economics' that provided the mainstream vision of political economy for much of the nineteenth century, at least until the early 1870s when a conceptual revolution started to implement a new vision that came to be called marginalist (or neoclassical) economics. To understand this transition, I must mention the crucial role that utilitarianism played in shaping and transforming the mainstream vision of political economy at the turn of the eighteenth century. Jeremy Bentham (1748–1832) played a crucial role in the adaptation of utilitarianism to economics. He built on the core ideas and terminology of preceding British utilitarian thinkers (such as Shaftesbury and Hutcheson) a systematic doctrine that exerted a wide influence on moral, legal, political, and economic theories. Its hedonist rhetoric that did not hesitate to summon the authority of Epicurus may look today démodé but its theoretical contents proved to be much more robust than many critics believe. In particular, Bentham played a crucial role in the transformation of the traditional utilitarian moral philosophy in an operational theory of economic decisions paving the way to emerging microeconomics. Although individuals are only able to grade pleasures and pains in a qualitative order, Bentham aimed to work out the foundations of a 'felicific' calculus able to measure and compare the net effects on happiness of alternative acts. In his opinion, this approach could explain the choices of individuals and guide the elaboration of reforms able to increase the happiness of people. Bentham was particularly influenced by philosophers with a deep interest in economics. He acknowledged the influence of Hume and Smith. From Hume, Smith derived radical Empiricism and a strict anti-metaphysical stance. From Smith, Hume drew the principle that individuals act in their own interest of which they are the best judges: 'Every man is, no doubt, by nature, first and principally recommended to his own care; and as he is fitter to take care of himself than of any other person, it is fit and right that it should be so' (Adam Smith, 1959, chapter 2). The following famous passage expresses well Bentham's hedonism in normative and causal arguments:

Nature has placed mankind under the governance of two sovereign masters, pain and pleasure. It is for them alone to point out what we ought to do, as well as to determine what we shall do. On the one hand the standard of right and wrong, on the other the chain of causes and effects, are fastened to their throne. They govern us in all we do, in all we say, in all we think: every effort we can make to throw off our subjection, will serve but to demonstrate and confirm it (Bentham, 1996 [1779], chapter 1.I).

Bentham applied his utilitarian theory mainly to jurisprudence and institutional reform, extending its reach only occasionally to economics. However, his approach deeply influenced Classical economists – in particular, James Mill, Ricardo, and Stuart Mill – and paved the way towards the Marginalist Revolution implemented by Jevons, Walras, and Edgeworth. According to John Stuart Mill, Bentham became particularly influential not because of its depth or subtlety,[10] but for its straightforward approach that aimed to implement in social sciences the inductivist method of natural sciences:

He introduced into morals and politics the habits of thought and modes of investigation that are essential to the idea of science; and the absence of which made morals and politics, as physics had been before Bacon, a field of interminable discussion leading to no result. It was not his opinions but his method that constituted the novelty and the value of what he did . . . (Mill, 1838, 4).

One should not play down the novelty of this methodological advancement and its impact on the evolution of political economy.[11] Differently from Smith, Bentham was an uncompromising reductionist. First, he reduced the relevance of choices to their consequences (consequentialism). In addition, he evaluated each action's consequences exclusively in terms of pleasure and pain (hedonism). Then, he decomposed any complex decision, as well as the underlying concepts and problems, in elementary components to seek to compare the utilitarian consequences

[10] Mill asserts that Bentham 'was not a great philosopher but was a great reformer in philosophy' (Mill, 1838, 4).

[11] Mill stressed convincingly the novelty of this methodological advancement: 'The application of a real inductive philosophy to the problems of ethics is as unknown to the Epicurean moralists as to any of the other schools' (Mill, 1838, 8).

of each possible alternative. Bentham's analytical approach, or 'method of detail', breaks every question into pieces before trying to answer it. Bentham (i) separates the wholes into their parts; (ii) resolves abstractions into the component things; (iii) and then breaks groupings into the component individuals (Mill, ibidem).[12] This atomistic approach, typical of the utilitarian tradition started by Epicurus, was not yet the formalised analytic approach pursued by modern microeconomics but paved the way for its emergence.

Bentham's classical utilitarianism was further developed by John Stuart Mill (1961), the son of his friend James Mill, educated according to rigid utilitarian principles. He introduced a hierarchy of pleasures as evidenced by his famous assertion that 'it is better to be Socrates "dissatisfied" than a fool "satisfied"'.(Mill, 1861). In addition, differently from Bentham, he emphasized the effectiveness of internal sanctions: guilt and remorse play a crucial role in regulating our actions. Most interpreters, however, tend today to play down the divergences between Bentham's and Mill's utilitarianism and focus on the substantial convergence of their normative visions. Both relied on utility measures to attack traditional ideas, policies, and institutions that were justified by arguments founded on tradition and natural order. Mill followed Bentham's lead but reacted to what he considered his excessive reductionism by introducing a few fundamental qualifications that make more complex the analysis. This correction was certainly commendable from the point of view of moral philosophy, but the higher complexity of his approach slowed down its application in modern microeconomics. If we compare the contents of Mill's *The Principles of Political Economy* (1871 [1848]), the most influential manual of political economy in Anglo-Saxon countries until the end of the century and beyond, with his *Utilitarianism* (Mill, 1998 [1861]), the major treatise on utilitarian thought of the mid nineteenth century, we see that they remain quite distant. Utilitarianism provides not much more than a vague scenario to the economic arguments. Utility enters the stage as protagonist only when Mill speaks of the use value of goods. This occurs only in the third

[12] To this end, he distinguished between different measurable determinants of utility, such as its 'intensity', 'duration', 'certainty or uncertainty', and its 'propinquity or remoteness'.

book on value theory that follows the first chapter on production and the second book on the distribution of income. At this stage, utilitarianism is still unable to provide a unified theory of value and markets.

6.3 The Emergence of Utilitarian Marginalism

At the stage of development reached by political economy at the time of Smith, the causal explanation of market gravitation was still very imprecise and essentially qualitative. In such a situation, utilitarianism played the role of instrument to articulate better the causal explanation of economic behaviour. The authors who accomplished the decisive steps towards the birth of modern microeconomics were Jevons, Walras, and Menger in the early 1970s. Jevons's explanation of exchange value in terms of marginal utility firmly rooted mainstream economic value in utility theory (Jevons, 1871). At the same time, the theory of exchange became prominent also for explaining the other compartments of economic activity. Walras contributed to the change of paradigm working out a GE model extending the logic of exchange to all the articulations of economic activity, including production (Walras, 1874). Finally, Menger (1871) provided explicit methodological foundations for a theory based rigorously on methodological individualism. To do so, he decoupled pure economics from history, ethics, and other social disciplines with which political economy had been so far strictly linked. This approach completed the gestation of modern microeconomics endowing it of a crucial foundational role. This trajectory of mainstream economics towards the primacy of microeconomics had serious epistemic costs that many economists did not accept, determining a fracture between pure economic theory on one side, and history, ethics, and social relations on the other.

In the introduction to his path-breaking masterpiece, Walras recognised Jevons's priority in his application of marginal utility theory to the pure theory of exchange and the analysis of its implications for the theory of labour market, rent, and capital (Walras, 1874, vii). In particular, he asserted that Jevons's *exchange equation* lying at the foundation of his mathematical treatment of exchange theory was 'rigorously identical' to the *condition of maximum satisfaction* that plays the role of starting point of his own theory. The so-called law of demand and supply receives for the first time a fully rational explanation.

6.4 Jevons and the 'Marginalist Insurrection'

William Stanley Jevons (1835–1882) was a brilliant and original polymath who contributed significant works in different fields. After two years of study of natural sciences at the University College of London, pecuniary constraints forced him to accept a job as metallurgical assayer for the new mint in Australia. When he came back, he completed his postgraduate studies integrating his scientific interests with a systematic study of moral sciences. He then published influential books in the fields of logic, philosophy of science, and economics. He was immediately successful, especially as an applied economist. In particular, he wrote a path-breaking book *The Coal Question* (1865), whose theses are still debated in energy and ecological economics.[13] Also his contributions in the field of money have been quite influential. In his *Money and the Mechanism of Exchange* (1875) he introduced the often-quoted definition of the basic function of money as that of solving the structural constraints of barter requiring the so-called double coincidence of wants:

> The first difficulty in barter is to find two persons whose disposable possessions mutually suit each other's wants. There may be many people wanting, and many possessing those things wanted; but to allow of an act of barter, there must be a double coincidence, which will rarely happen (Jevons, 1975, 3–4).

Jevons wrote also authoritative essays in the field of logic and philosophy of science. In particular, he published in 1874 *The Principles of Science* where he criticised the inductivism of Mill with arguments later developed by Popper.[14] We are here interested mainly in his seminal

[13] Although Jevons argued that technological innovation can make possible the exponential growth of available resources, the non-renewable nature of some of them – such as coal – confirmed Malthus's belief in the existence of intrinsic limits to growth: 'in a mine there is no reproduction, and the produce once pushed to the utmost will soon begin to fail and sink towards zero. So far, then, as our wealth and progress depend upon the superior command of coal we must not only cease to progress as before – we must begin a retrograde career' (Jevons, 1865, 201). In addition, Jevons pointed out that, contrary to the expectations of most experts, the growing efficiency in the use of a natural resource is likely to incentivise further its consumption. This so-called Jevons paradox proved far-reaching and is still an important reference for resource and ecological economics.

[14] See Section 4.2.

book *The Theory of Political Economy*, a book in which he introduced the first analytic theory of value based on marginal utility.[15] In this theory, which started the Marginalist Revolution, he argued that the theory of Political Economy: 'as it deals throughout with quantities ... must be a mathematical science in matter if not in language' (Jevons, 1871, viii). He profited of his own first-hand knowledge of natural sciences to make clear that the theory of Political Economy 'presents a close analogy to the science of Statical Mechanics' (ibidem). Jevons did not refer to celestial mechanics as Hume and Smith did, but to applied mechanics: 'the Laws of Exchange are found to resemble The Laws of Equilibrium of a lever as determined by the principle of virtual velocities' (ibidem). The specific focus on equilibrium did not intend to downgrade the importance of dynamics: 'I believe that dynamical branches of the Science of Economics may remain to be developed, on the consideration of which I have not at all entered' (ibidem, viii–ix).[16] The marginalist economists aimed to adopt the utilitarian approach to solve the alleged contradiction between utilitarianism and economic value. Jevons criticised the labour theory of value put forward by the Classical economists to explain relative prices asserting that this doctrine 'cannot stand for a moment being directly opposed to facts' (ibidem). He claimed to have solved the problem by explaining not only use value but also relative prices in utilitarian terms arguing that value depends solely on the marginal utility of the goods exchanged (Jevons, 1871, 160). According to his view, labour affects relative prices only because it acts on supply that 'affects the degree of utility, which governs value, or the ratio of exchange' (ibidem). Therefore, the value of labour 'must be determined by the value of the produce, not the value of the produce by that of the labour' (ibidem, 160–161). This new vision of value theory became rapidly the germ of a new orthodoxy endorsed also by most other first-class economists such as Walras, Pareto, and Menger.[17]

[15] He had anticipated this theory in the book *A General Mathematical Theory of Political Economy* (1866) that Fisher defined as the start of mathematical economics (Fisher, 1892, Appendix III, 109).

[16] Later on, Jevons himself started to explore a dynamic theory of business cycles by correlating them to sunspots. This theory has always been quite controversial becoming the paradigmatic example of a purely exogenous theory of business cycles.

[17] Jevons became aware only in 1878 that Gossen had anticipated him in a forgotten book published only in German in 1854. Jevons recognised the

As soon as we compare the structure of Mill's *Principles of Political Economy* (1871 [1848]) with the structure of Jevons's *Theory of Political Economy* (1871), we can immediately appreciate how innovative was the work of Jevons. In Mill's successful treatise, the first of the five books deals with production, the second with distribution, discussing both issues at the level of macroanalysis. Only in the third book *on Exchange* Mills discusses the theory of value accurately circumscribing its scope:

> It is evident that, of the two great departments of Political Economy, the production of wealth and its distribution, the consideration of Value has to do with the latter alone; and with that only so far as competition, and not usage or custom, is the distributing agency.

Even in this part of the book, the role of utility and what we would today call microeconomic theory is extremely limited. The two remaining books deal with the *progress of society, production and distribution* (Book 4), and *the influence of government* (Book 5). Overall, utilitarianism plays a role that does not go beyond that of background scenery for value theory but never becomes protagonist of the plot. Analogously, what we call today microeconomics does not play any significant role in the argument. In Jevons's classic, on the contrary, utility plays from the very beginning the role of protagonist of the theory. In the preface he makes clear that he treats economy as a calculus of pleasure and pain and that his suggested mathematical treatment of value permits the transformation of economic theory in a mathematical theory like that of natural sciences. Jevons saw his pure economic theory as a mathematical development of Bentham's utilitarianism and never worked out a full-fledged GET. The main critiques of the economists pointed out the impossibility of comparing and summing up the utility of different subjects jeopardising the viability of the felicific calculus. Pareto, following Edgeworth, showed a way to circumvent the difficulty that most mainstream economists soon adopted (see next chapter). On the other hand, the theory of value based – at least in the long run – on costs of

priority of Gossen in the second edition of his masterpiece published in 1879 (p. xxxviii): 'Gossen has completely anticipated me as regards the general principles and method of the theory of Economics. So far as I can gather, his treatment of the fundamental theory is even more general and thorough than what I was able to scheme out.'

production survived the Marginalist Revolution in different variants that I will discuss later.[18]

I am not interested here in the details of Jevons's epistemic vision but only in the discontinuity from the previous mainstream epistemic vision in economics. Jevons emphasised the radical structural change implemented by his suggested theory of value that he did not hesitate to describe as a genuine scientific revolution. In the same mood, he underlined the obstacles encountered to overturn the epistemic vision of the *Ancien Régime* dominated by Classical economics. Jevons emphasised that to obtain acceptance of his new ideas he had to struggle against the mainstream conviction that the science of political economy had already acquired a nearly perfect form.[19] He lamented in particular that Mill himself went so far to assert that 'there was nothing in the Laws of Value which remained for himself or any future writer to clear up' (Mill, v–vi). This unwise claim by Mill clearly confirms how difficult it is to practice consistently pluralism also for one of the most sincere and sophisticated advocates (see Chapter 4). The hostility Jevons perceived against his novel ideas was certainly distressing to the point that he felt the need to observe that:

> in the other sciences this weight of authority [such as that of Mill] has not been allowed to restrict the free examination of new opinions and theories; and it has often been ultimately proved that authority was on the wrong side (Jevons, 1871, vi).

The economists often advocate pluralism to defend their own original theories but are much less keen to praise pluralism when alternative theories are under scrutiny. That is why Jevons (1871, 267), having in mind mainly Stuart Mill, denounced 'the too great influence of authoritative writers in Political Economy'. He rightly protested 'against deference for any man being allowed to check scientific inquiry. Our science is becoming far too much a stagnant one, in which opinions rather than experience and reason are appealed to' (ibidem). Jevons's denunciation of what Kuhn (1970 [1962]) a century later described as 'normal science' and its dogmatic resistance against innovation justifies his effort of implementing a scientific insurrection that initiated what will be subsequently called 'Marginalist Revolution'. Jevons saw his own decisive contribution to the marginalist insurrection as 'a positive

[18] See in particular Section 7.1. [19] Jevons (1871, v).

service to break the monotonous repetition of current questionable doctrines, even at the risk of new error' (ibidem).

6.5 Theory of Value and Marginal Utility

The most striking innovation of the early marginalists was the unification of the theory of value under the paradigm of marginal utility. The latter seemed to be able to dispose of the previous dichotomy between use value and exchange value, as well as between short-run market prices affected by subjective utility and long-run natural prices that depended on production costs and the gravitation of competitive markets. Smith explicitly denied the possibility of explaining exchange value in terms of utility alone. Otherwise, he contended, since water is more useful than diamonds, its relative value should be higher. Therefore, he asserted that the demand and supply mechanism could only contribute to explain short-term market prices. A few economists who were close to the Classical school, such as Say and Lauderdale, argued that utility underlies a long-run mechanism of demand and supply capable to explain natural exchange values. However, they were not fully consistent in their arguments and failed to convince the leaders of the Classical school. For example, Ricardo maintained:

> Say acknowledges that the cost of production is the foundation of price, and yet in various parts of his book he maintains that price is regulated by the proportion which demand bears to supply. The real and ultimate regulator of the relative value of any two commodities is the cost of their production, and not the respective quantities which may be produced, nor the competition amongst the purchasers (Ricardo, 1817, 231).

Analogously, Mill rejected the idea that utility, or the mechanism of demand and supply ruled by utility, could explain long-run exchange values. Therefore, he denied the alleged shortcomings of the Classical school (see the epigraph to this chapter). One of the reasons for the weakness of the utilitarian approach to exchange value before the Marginalist Revolution resided in its inability to build a clear analytical link between subjective utility and scarcity that was usually conceived as objective (as in the case of works of art). However, building on the early insights of seminal authors such as Galiani and Condillac, a few economists in France (Auguste Walras,[20] Cournot, and Dupuit), in Germany (Gossen), and in Great Britain (Senior and Whately) struggled to explain exchange value connecting subjective utility with subjective scarcity, preparing the terrain for the Marginalist Revolution. They argued that their suggested approach was superior to that of the Classical school: 'It is not that pearls fetch a high price because men have dived for them; but on the contrary, men dive for them because they fetch a high price' (Whately, 1832, 253). This alternative approach to exchange value progressively conquered a growing number of followers but remained in the vague until the leaders of the Marginalist Revolution (Jevons, Walras, and Menger) succeeded to establish a rigorous mathematical link between marginal utility, subjective scarcity, and exchange values.

Jevons announced his crucial advances towards a value theory based exclusively on marginal utility (which Jevons called 'final degree of utility') in an 1862 lecture (whose abstract was published in 1866). Jevons framed his theory in a model of pure exchange of two commodities between two agents and argued that, 'The ratio of exchange of any two commodities will be the reciprocal of the ratio of the final degrees of utility of the quantities of commodity available for consumption after the exchange is completed' (Jevons, 1871, 95). Jevons believed that bilateral exchange would offer the key for the correct analysis of general multilateral exchange. Therefore, he tried to reduce multilateral market exchange to bilateral exchange by assuming the existence of 'trading bodies' (Jevons, 1871, 88–90) that play the role, so to say, of 'representative agents' engaged in bilateral exchange.[21] This device is obviously inconsistent with rigorous methodological individualism. Jevons's claim that he had succeeded in providing a general theory of value based upon subjective marginal utility is questioned by his inability of consistently extending to the whole market his suggested solution for the restricted case of bilateral exchange. He failed to extend his pure exchange bilateral equilibrium to multilateral equilibrium because of his defective theory of

[20] Auguste Walras was the father of Léon Walras.

[21] Ten years later, Edgeworth (1881) argued that the progressive increase of the number of traders gradually restricts the indeterminacy of exchange ratios characterising bilateral exchange. The pure concept of perfect competition requires thus an infinite number of price-taker traders.

exchange and production.[22] Jevons argued that in equilibrium the marginal utility of consuming a good must be equal to the marginal disutility of producing it, and that this condition determines the quantity of goods produced.[23] In his opinion, the ensuing supply of goods determines their marginal utility that determines their exchange value.[24]

As for the contemporaneous contribution of Menger (1871) to marginal value theory, his literal analysis of the market process was conceptually superior to that of Jevons and inspired the innovative research of highly talented followers such as Böhm-Bawerk and Wieser starting the influential and long-living Austrian School. Menger emphasised the crucial role of methodological individualism as inspiration for the advocated marginalist approach:

> Value is therefore nothing inherent in goods, no property of them, but merely the importance we attribute to the satisfaction of our needs, that is, to our lives and well-being, and in consequence carry over to economic goods as the exclusive causes of the satisfaction of our needs (Menger, 1871, 116).

On the other hand, the literary language of Menger limited the scope of his analysis preventing a full-fledged coverage of the complex interdependence of competitive markets. Notwithstanding all his influence in German-speaking countries, Menger's masterpiece published in 1871 was still a transition contribution towards full-fledged microeconomics. Menger did not accept the hedonic conception of utilitarianism and explained diminishing marginal utility in terms of subjective prioritisation of possible uses.

Walras's GE model was a conspicuous step forward in mathematical economics that significantly broadened the scope of the Marginalist Revolution extending its influence for many future generations to come. His theory of value based on subjective scarcity (*rareté)* was more insightful and far-reaching than that of Jevons and Menger, let alone the other predecessors including his

[22] In particular, he was unable to construct the familiar 'supply and demand' theory with variable output levels.

[23] In other words, in his view, the quantity of a good produced is determined by the intersection of a downward-sloping marginal utility of consumption curve and an upward sloping marginal disutility of labour curve.

[24] This is the famous Jevons's 'catena' (Jevons, 1871, 165) that Marshall rescued from the analytical point of view by reversing its order, at least in the long period.

revered father Auguste and his friend and teacher Cournot. Like them he was committed to methodological individualism: 'rareté is personal or subjective' (Walras, 1874, 146). In Walras, the meaning of the word *rareté*, namely subjective scarcity, is close to the concept of marginal utility. He consistently kept this approach at the foundations of all his arguments. The superior rigour of his arguments allowed him to extend the reach of marginalist theory to new results. First, Walras was the first marginalist who succeeded to derive demand curves from utility functions by using household budgets.[25] Moreover, he understood better than his predecessors (including Jevons and Menger) that contemporary markets are becoming increasingly complex and interdependent institutions that coordinate the exchange of a vast plurality of goods among a host of heterogeneous agents. He was thus led to recognise that the choice set of individual agents is constrained by the interaction between markets. Moving from binary exchange to progressively broader sets of exchanges among a growing number of traders, the impact of individuals on prices progressively diminishes, becoming nil in the extreme case of perfect competition when agents are mere price-takers. William Jaffé (1976, 513), one of the deepest connoisseurs of Walras's contributions, maintained that 'instead of climbing up from marginal utility to the level of his General Equilibrium system, Walras actually climbed down from that level to marginal utility'. This insightful observation confirms that Walras combined the methodological individualism of the utilitarian tradition with the French tradition of formal structuralism rooted in Descartes's rationalism and Laplace's mathematical formalism, and represented in political economy, among others, by Cantillon, and Quesnay. The tension between the two souls of Walras's GE model contributed to its intellectual appeal but raised controversial methodological issues many of which are still hotly debated. The structural constraints coupled with rationality assumptions put individuals in a condition of *situational determinism* (to use the expression introduced by Popper) that is hardly consistent with methodological individualism unless we deprive individuals of their freedom. Marshall's approach never spoiled the individuals of their freedom, although at the cost of accepting

[25] Walras (1874, Ch. 8, 11).

a certain degree of indeterminacy in pure theory to be restricted through a historically determined analysis of the social, institutional, and psychological features characterising the issue under investigation.

6.6 Rise and Decline of Marginal Utility Theory

The Marginalist Revolution of the 1870s was not as successful as it may seem today. The first stage of this process of paradigmatic change led by Jevons was a sort of 'insurrection' rather than a full-fledged 'revolution'. Nevertheless, it was an insurrection that started a long and bumpy path of transition towards a new mainstream economic theory. The initial insurgence obtained some success but met a widespread resistance. The publication of the Jevons's masterpiece (1871) solicited a certain number of reviews but most of them were critical.[26] Menger's masterpiece (1871) immediately attracted a number of highly talented pupils such as von Wieser and Böhm-Bawerk but the Austrian school of thought inspired by Menger soon clashed with the historicist school led by Schmoller that was then, and remained for a few decades, the mainstream school in Germany.[27] Walras (1874) was almost completely ignored by his contemporaries with the exception of some of the best mathematical economists such as Edgeworth and Wicksteed in Great Britain, Pareto and Pantaleoni in Italy, Wicksell and the Stockholm School in Sweden, and Clark and Fisher in the USA. The fact that the rare admirers of Walras's great masterpiece were influential economists, who are today recognised as the best mathematical economists at the turn of the century, may give the wrong idea of an early appreciation of the GE model much superior to the real one. As a matter of fact, until the late 1930s, the marginalist approach maintained an influence mainly in the hybrid version of Marshall (1890), a version that played down the gap between Classical and marginalist theory and suggested a shrewd but fragile synthesis of the two.

[26] Marshall himself, who later recognised the influence of Jevons, wrote a lukewarm review emphasising his analytic weaknesses. Even the originality of Jevons's book was not recognised by many economists.

[27] See Section 7.4.

The evolution of the new vision suggested by the marginalists appears today as broadly consistent with the problem-solving view of scientific research suggested by Kuhn (see Chapter 4). The concept of marginal utility aimed to resolve a few puzzles of mainstream economic theory that generations of economists had struggled to solve without success. How can we provide sound utilitarian foundations to the theory of exchange value, considered by many the core of economic theory? How can we solve the dualism between value and price? The solution had been sought since long, at least since Bentham's path-breaking contributions. However, the traditional concept of utility in its multifarious declinations had not succeeded to provide the required foundations. This led a few economists – including Auguste Walras, the father of Léon, to introduce a second conceptual ingredient, namely scarcity or rarity (*rareté)*, as a crucial determinant of exchange value. However, these scholars were keeping the traditional objective notion of rarity, defining rare a good that 'is offered to general demand in a limited quantity'. The conflict between the subjective meaning of utility and the objective meaning of scarcity prevented for many decades the construction of a coherent subjective theory of demand. The decisive step made by Jevons, Menger, and then Walras, was the conceptualisation of scarcity in mathematical terms as the derivative of a function of subjective utility, a notion that seemed fully consistent with the advocated methodological individualism and the mathematical formalisation of economic theory. Nevertheless, marginal utility which seemed at the beginning the main pillar of the new marginalist theory of value was soon perceived as an obstacle to the acceptance and diffusion of the new paradigm. In fact, most economists increasingly perceived the concept of marginal utility as a sort of mathematical artifice aiming at promoting an approach lacking a sound rationale. Since its very beginning, most economists felt disturbed by the fact that the magnitude defined then as marginal utility seemed to be unobservable, unmeasurable, and untestable against all the requirements of sound scientific methodology. The formalisation of marginal utility theory seemed then more a way of concealing the methodological weaknesses of the new approach than a genuine advance of the new view. In addition, such a theory proved less useful than expected. As Moore (1914, 84–85), an early disciple of

Walras, recognised in a lucid assessment of the widespread sense of delusion:

> In the closing quarter of the last century, great hopes were entertained by economists with regard to the capacity of economics to be made 'an exact science'. According to the view of the foremost theorists, the development of the doctrine of utility and value had laid the foundation of scientific economics in exact concepts, and it would soon be possible to erect upon the new foundation a firm structure of interrelated parts which, in definiteness and cogency, would be suggestive of the severe beauty of the mathematico-physical sciences. But this expectation has not been realized. On the contrary, faith in the possibility of an adequate 'exact' treatment of the science has progressively diminished, and interest in economic theory in general has decidedly lost ground.

As a matter of fact, at the turn of the century, many economists withdrew from marginalist theory perceiving it as a stagnating research programme and moved back towards the more empirically oriented research programme of Marshall whose hegemony remained substantially unscathed until the publication of the *General Theory* (1936). The marginalist approach survived in select places: Vienna, where the Austrian School continued to flourish; Stockholm that continued to pursue the Wicksellian marginalist research programme; and thrived mainly within the entourage of a few great economists such as Fisher in Yale, and Clark at the Columbia University. The treatises used for didactic purposes remained often influenced by the marginalist views (Marshall, Wicksell, and Pareto are cases in point). Nevertheless, as Viner observed:

> In the scientific periodicals ... in contrast with the standard treatises, sympathetic expositions of the utility theory of value have become somewhat rare. In their stead are found an unintermittent series of slashing criticisms of the utility economics (Viner, 1925).

This growing scepticism stimulated the evolution of utility theory towards versions more acceptable to the contemporaneous philosophy of science. Edgeworth contributed in his major economic work (1881) to this transformation by introducing into economics the generalised utility function, and by drawing the first version of indifference curves. In addition, he argued that the only way to solve the indeterminacy of exchange is by applying the utilitarian principle of maximising the sum of the utilities of traders over the range of final settlements. Since his first major economic work, the *Cours d'économie politique* (1896–1897), Pareto struggled to infuse more realism in Walras's GE model to show all its potential for the real world. His exposition of pure economic theory was made livelier by many excurses on methodology and applied economics accompanied by a wealth of sociological remarks. Pareto reacted to the utilitarian foundations of political economy by rejecting its hedonistic overtones. To avoid any confusion with the value-charged concept of utility he substituted it with a neologism, *ophelimity*, derived from the Greek name for utility. The new name did not catch on beyond the circle of his most faithful followers, but its orientation towards ordinal preferences paved the way for the subsequent advances in microeconomics. In addition, Pareto warned that the focus on *ophelimity* in pure economics (as that on marginal utility) captures only one limited aspect of economic agents' actual motivations and advocated the necessary attention for other factors in the more realistic branches of applied economics and economic policy.

6.7 The Conundrums of Early Marginalism

In this chapter, we have seen a progressive tendency of political economy to work out a more sophisticated mathematical approach, coupled with a tendency towards a more reductionist vision of economic theory. The Marginalist Revolution struggled to connect two traditions within a common mathematical framework. The first tradition was the theory of marginal utility that – via Bentham, Gossen, and Jevons – had transformed earlier utilitarianism in a proto theory of individual decision-making capable of explaining demand and supply and thus market prices. The second tradition was the representation of the economic process from the point of view of exchange value that Say had combined with the Smithian view of economic gravitation emphasising the structural constraints to individual economic behaviour. This approach led to the formulation of the so-called law of the markets, usually called 'Say's law', providing suggestive foundations for an optimistic view on the performance of competitive markets. Walras realised a powerful synthesis of the two traditions in the GE model by restating Say's law in the more rigorous Walras's law that takes into account the totality of money exchanges in equilibrium.

The Marginalist Revolution completed the long gestation of microeconomics. Traditional individualism for the first time could claim to be able to provide effective foundations to the whole of economic theory. Jevons, Walras, and Menger started a new research programme that aimed to extend and consolidate rigorous microeconomic foundations of economics. Jevons suggested a first operational version of decision theory based upon marginal utility that seemed in principle capable of providing rigorous foundations to economic theory. Menger provided the methodological foundations of the new paradigm arguing that is the only one consistently based on methodological individualism. This approach rejected the dominant approach in political economy based on the crucial role of social relations, history, and institutions but was in tune with the emerging philosophical wave that will generate logical positivism in Austria (Vienna Circle) and Germany (Berlin Circle). Walras, under the influence of French rationalism, worked out for the first time a model that seemed in principle capable of explaining how the strategic interaction of economic agents in a perfect competitive market implements the gravitation towards a GE. However, Walras was sorely aware that, by allowing the actual existence of exchanges out of equilibrium, one would jeopardise the coherence and plausibility of his equilibrium model. Therefore, in the fourth and fifth editions of his masterpiece he explored a way out from this dilemma by suggesting the clever but misleading theory of virtual *tâtonnement*. Walras insisted, however, that the scope of his GE model was restricted to pure economics. Therefore, in his view, the application of the model to the empirical evidence required a full-fledged development of the other two main branches of political economy, namely applied economics and social economics. In its turn, Pareto developed further the GE model and introduced his influential optimum criterion to isolate the problem of redistribution *in the small* within given constraints (Pareto optimum) from the problems of distribution *at large* under relaxed constraints. However, also Pareto – like Walras – insisted that we should not apply directly the GE model to a specific empirical issue without considering all its relevant complexities. In his opinion, this requires the previous development of a broader science of society that he called sociology. The reductionist methodological drive of mainstream economics after the Marginalist Revolution had progressively restricted the scope of economic theory to what Walras and Pareto called pure economics. This approach progressively shifted Walras's applied and social economics, and Pareto's economic sociology, in the hazy background of interdisciplinary relations.

7 Visions and Disputes at the Turn of the Nineteenth Century

> *Alfred Marshall:*[1] *… the more I studied economic science, the smaller appeared the knowledge I had of it, in proportion to the knowledge that I needed; and now, at the end of nearly half a century of almost exclusive study of it, I am conscious of more ignorance of it than I was at the beginning of the study.*
>
> *Joseph A. Schumpeter (1952):*[2] *Unlike Mill, [Marshall] would never have said that some problem or other was settled for all time to come and that there was nothing about it that called for further explanation either for himself or any other writer. On the contrary, he was fully aware that he was building an essentially temporary structure […] All of us know that today no scientific achievement can be permanent in the sense that it is not subject to amendment by the progress of research.*

The marginalist 'insurrection' started in Great Britain by Jevons did not obtain in the 1870s the desired impact on economic thought. Its influence was still stagnating in the 1880s and risked an early decline. Its defence and promotion followed different paths in different countries reflecting the persisting geographic segmentation of economics. Everywhere, at the turn of the century, a harsh confrontation raged between new and old theories taking different forms. I limit myself to consider two polar cases: that of German-speaking countries and that of Great Britain. The comparison between these two cases is particularly significant to pursue a more in-depth analysis of pluralism.

At the turn of the century, Marshall (1942–1924) developed a highly influential vision of economics in an eclectic direction that aimed to

[1] Marshall, quoted by Keynes (1933, 167) from an unpublished manuscript written about 1917.
[2] Schumpeter (1952, 92 and 89).

integrate the Classical and marginalist approaches within a broader conceptual system capable to contain them as special cases (Section 7.1). In Great Britain his masterpiece (Marshall, 1890) managed to gather a wide consensus in the economic profession. His approach to economic research became a model of academic commitment, integrity, and partial but viable pluralism. The Cambridge School of Economics that flourished in the first three decades of the nineteenth century under his seminal influence promoted a lively dialogue between different points of view on important theoretical and methodological issues. This open intellectual climate stimulated important innovations. Marshall's research programme remained open to evolution by accommodating within itself new problems, methods, and theoretical constructs implementing a sort of *internal pluralism*. This evolutionary strategy was based on a tolerant approach towards different paradigms and theoretical constructs leaving always open the possibility of a future accommodation within a broader research programme (Section 7.2). This is the case with the Classical and marginalist research programmes that the Marshallian Synthesis eventually encompassed in a more tolerant and flexible version. In the same period, in the German-speaking countries a similar marginalist insurrection occurred. It was led by Carl Menger (1840–1921) independently of that led by Jevons but with convergent arguments and purposes. Menger and his brilliant pupils Friedrich von Wieser (1851–1926) and Eugen von Böhm-Bawerk (1851–1914) reacted not so much against the Classical school, which was not particularly influential in German-speaking countries, but against the perceived general disregard for economic theory and its foundations. Menger built on the principles of methodological individualism a particularly careful and well-articulated research programme (Section 7.3). The lack of reaction by the German Historical School led by Gustav von Schmoller (1838–1917), who was then ruling the German academia in the field of economic history and economics, prompted Menger to starting a harsh dispute characterised by reciprocal intolerance and censurable acts of active repression of the alternative vision (Section 7.4). The main issue was the correct relationship between the deductive method of formal theory and historical evidence. The two camps advocated irreconcilable methodological principles succumbing to the apparent incommensurability between their competing economic paradigms. Section 7.5 summarises the rise and decline of the marginalist approach at the turn of the century. The young Schumpeter, who was a follower of Menger and pupil of Böhm-Bawerk worked out a vision of the evolution of economics that recognised the crucial importance of pluralism. In particular, he was able to combine quantitative theory and history in an original research programme. His pluralist point of view greatly contributed to make him a first-rate historian of economic analysis (Section 7.6). Section 7.6 focuses on the contemporaneous evolution of microeconomics within second-generation marginalists. Section 7.7 investigates the revival of marginalism that occurred in the 1930s in Great Britain. The concluding remarks draw from the disputes reviewed in this chapter a few implications for the concept of pluralism.

7.1 The Marshallian Synthesis

Marshall had an excellent formation in mathematics and studied to join the clergy with the intention of improving the condition of common people. After a personal crisis, he changed the means but not the goal of his deeply felt vocation. His humanitarian motivations led him to study political economy to understand the constraints that limit the wellbeing of the poor in the hope of finding the way to relax them. The main problem that motivated his research programme was, thus, that of the poverty of wage earners and the increasing inequality in income distribution. His major theoretical work, *Principles of Economics*, was published relatively late in his research career (Marshall, 1890). However, this treatise was very well received and soon became in Britain the main reference for teaching and research in economics for more than three decades. This book provided a clever synthesis of the classical and marginalist research programmes, a synthesis that tried to overcome their deep-seated divergencies. The outcome reflected his original but unpublished analytical elaborations worked out since the early 1970s that anticipated many marginalist innovations. However, this treatise could not claim priority for its analytical content because, as Schumpeter pointed out, the late publication of his innovative contributions prevents it.[3] The main reason for

[3] Schumpeter specified some of the main sources of Marshall's analytic synthesis:
'the marginal utility principle is Jevons's; the system of general equilibrium is Walras's; the principle of substitution and the marginal productivity theory are Thünen's; the demand and supply curves and the static theory of monopoly are

its success was the breadth and depth of its comprehensive synthesis that, after many decades of harsh disputes, succeeded to outline the guidelines of a broad consensus within the profession. The main goal of this tour de force was that of promoting the role of economics to face with its help the most important practical issues. In his opinion, this goal required a basic consensus in the economic profession playing down the divergencies between different scientific visions. In this spirit, Marshall insisted on the complementarity between Classical and marginalist theory.[4] In particular, Marshall's value theory combined the insights of Ricardo on the costs of production as crucial determinants of supply with those of marginal utility as the principal determinant of demand. Marshall argued that the role of demand in price determination is greater in the short run than in the long run when supply costs become crucial. In the short-run 'market period', he maintained, marginal utility determines price because the quantity supplied is inelastic to price. The short-run supply curve is assumed to be positively sloped, so both marginal utility and marginal cost have a role to play, while in the long run prices equal marginal costs.[5] As this crucial example shows, Marshall always distanced himself from the unilateral propositions of marginalist and labour value theories but tried to capture and retain the invaluable insights one can get from a sympathetic appraisal of both visions. In particular, he rejected the asymmetrical successivism of Classical economics emphasising instead the interdependence between the endogenous variables of the economic system; however, he never endorsed the mainly formal interdependence of GE theory that abstracted too much from the specific features of the empirical evidence. In his opinion, the economic system is too complex for a single model to comprehend all the relevant factors simultaneously. Therefore, to study concrete issues in all their relevant complexity, Marshall advocated the necessity of focusing on one single issue, often manifesting itself within a single market, to understand all its specific

Cournot's (as is the concept, though not the word, price elasticity); the consumers' rent is Dupuit's; the 'diagrammatic method' of presentation is also Dupuit's or else Jenkin's' (Schumpeter, 1954).

4 He is reported to say that there is all in Smith; analogously his pupils used to repeat that there is all in Marshall.

5 The role played by marginal utility depends also on the behaviour of returns to scale. If they are constant, marginal utility does not affect price determination, while it plays a role if returns are increasing or diminishing.

complexities, calling this approach the partial equilibrium method. He argued that the simplifying assumptions required by his advocated method are usually safe because the behaviour of a particular market has often only feeble consequences on the rest of the economy, so that we can ignore – at least as a first approximation – the feedback effects between markets.

According to a common cliché, the Marginalist Revolution – started in the 1970s by Jevons, Menger, and Walras – ousted the Classical school and rapidly became the dominant paradigm before the Keynesian Revolution. According to this narrative, Marshall was the most eminent British marginalist of the second generation and played a crucial role in establishing the hegemony of Marginalism in the period that goes from the publication of his major work, the *Principles* (1890), to the publication by Keynes of the *General Theory* (1936). This standard narrative is misleading. Marshall inserted the marginalist principles in his analysis only as partial explanatory factors to be supplemented by the necessary analysis of further factors that he considered not less important, at least from the policy point of view. A case in point is the theory of marginal productivity that he contributed to introduce in economic theory. As for economic policy, Marshall followed Smith in regarding economic competition as beneficial to society claiming that it induces individuals to act in a more alert and rational manner. However, he never advocated rigid forms of laissez-faire. On the contrary, he advocated the wise intervention of the State to correct and improve the results obtained by unfettered markets. We can conclude that the received view understates the crucial role played by Marshall, at least in Great Britain,[6] in the establishment of a large consensus of economists on an overarching paradigm. Referring mainly to Marshall, Thorstein Veblen (1857–1929) was the first to call the emerging mainstream consensus neoclassical economics (Veblen, 1900). Accepting this terminology, Marshall should be considered as the actual founder of neoclassical economics rather than a mere influential follower of Marginalism. As is well known, he insisted on the continuity between the old (classical) school and the new (marginalist) school implying that his

[6] Though the capitalist system was then more segmented than it is today, we should not forget that Great Britain was still at the forefront of the capitalist evolution, both in the real economy and in economics.

suggested paradigm could be seen as an updated version of classical economics; however, he did not adopt the label neoclassical economics.[7]

7.2 Marshall and 'Internal Pluralism'

Marshall's research programme has interesting implications for scientific pluralism. His attitude on competing hypotheses, theories, and models is deeply rooted in his evolutionary approach because in his opinion scientific constructs and methods have to adapt to the endless structural changes of capitalism.[8] The continuous evolution of the real economy and the ceaseless flow of new evidence shift the emphasis of research towards new problems. This evolutionary process changes the potential contribution of existing theories to the interpretation of facts and to the choice of policy measures. However, in his view, the innovators should resist the temptation of considering definitely falsified previous theories.[9] A case in point is the uncompromising attack of Jevons against the Classical school that Marshall considered unilateral. As we have seen in the previous section, Marshall's comprehensive attitude towards the existing schools of thought guided his research path since his first steps in the late 60s inducing him to mediate between the two main schools that in the 1970s and 1980s were contending for the hegemony in political economy: the declining Classical school and the emerging

[7] This terminology became quite popular in the following decades, but its definition remained controversial. Veblen included in this category the Marshallian vision and the Austrian School initiated by Menger contrasting it with the vision of institutional economics to which he belonged, and the historicist schools such as German historicism and Marxism. The Austrian School preferred to maintain an autonomous identity. The GE approach started to be included in the category only since the 1930s as a consequence of the revival promoted by Hicks and Samuelson (see Chapter 8).

[8] Marshall's evolutionism is a pre-analytic belief that he never tried to translate in an analytic framework based on an in-depth study of biological evolutionism. His vision of evolutionism is qualified by two idiosyncratic postulates that he often reasserted. First, the process of evolution is slow and gradual ('*natura non facit saltus*'); second, this process tends to select continuous improvements, at least from the point of view of the adaptation to current environment. Both principles have been questioned by subsequent biological evolutionism.

[9] The recurrence of similar conditions may revive a theory made obsolete in the past by a change of conditions.

marginalist school.[10] The Classical school had succeeded in the titanic task of providing an insightful interpretation of the contemporaneous *Great Transformation* brought about by the industrial revolution in the economy and in society. In particular, the Classical economists emphasised the growing role of competitive markets in consequence of the internationalisation of the economy and the progressive extension of commercial, industrial, and financial capitalism. As the Classical economists maintained, the growing centrality of markets in the economy provided a full-fledged autonomy and coherence to the core of political economy identified and kept together by the process of market gravitation. Marshall asserted that the gravitation towards the equilibrium of demand and supply was 'the great fact of pure science'.[11] However, the Classical economists also believed that the symmetric interdependence of competitive markets did not seem to be able to explain the growing accumulation of power on the part of capitalists over the previous ruling class, the aristocracy, and the growing inequality between capitalists and wage earners. Their pre-analytic vision induced them to identify the asymmetric causal relations that could account for the new social hierarchy. In their opinion the main production factors – labour, capital, and natural resources – that before the capitalist era were largely independent of the market, in contemporaneous capitalism, were growingly influenced by the market but were still preserving a certain degree of independence of market pressures. Labour was still largely independent of the market, being instead determined by demography, custom and law. As for the vexed issue of income distribution, Marshall approached it differently from the Classical economists and the marginalists. Differently from the Classical economists, he preferred to focus on the distributive implications of industrial relations rather than on the functional distribution of income, an approach that he judged too abstract. However, Marshall was also

[10] This did not exclude personal behaviours hardly consistent with his pluralist paradigm. Schumpeter stigmatises his occasional 'academic pontificality ... assertiveness of fundamental creed ... unreasonable sensitiveness to criticism' (Schumpeter, 1952, 103, n.6). Many eminent scientists and philosophers have been victim of this sort of contradiction. Schumpeter points out the analogy with Newton's personal contradictions. I could add the case of Mill that we have already emphasized. These inconsistencies do not impair the soundness of their arguments in favour of scientific pluralism.

[11] Marshall quoted in Dardi (1982, 88).

reluctant to accept the marginalist thesis that the interplay of supply and demand is sufficient to explain exhaustively both prices and income distribution. In his opinion, the market could explain *how* equilibrium is reached but not *why* the equilibrium value is what it is, because the latter depends on a complex interplay of factors including custom and policy constraints.[12] In other words, the interplay of demand and supply may explain the process of gravitation towards short-term market equilibrium but the position and shape of the supply and demand curves and their long-term equilibrium depend mainly on factors strictly related to the process of capital accumulation and distribution of income. More in general, Marshall believed that pure theory is just a preliminary stage of analysis of a concrete problem. He agreed with the marginalists that mathematics could be precious in this stage of research but mainly as a heuristic instrument.

The hope of Marshall was that economics could orientate the lively but contentious debate over wages determination by appealing to rational arguments rooted in economic theory. Since his earlier writings, Marshall maintained an instrumental view of economics defined as a 'highly organized machinery [...] in the successive improvements of which are stored up the results of the work of many generations'.[13] The implementation of this objective required the construction of an authoritative professional community whose advice on practical matters could be relied by policy makers and public opinion. In his opinion this required a basic consensus in theory and an established role within the university. Marshall succeeded in implementing both these goals.

The conceptual system that summarises in any moment the knowledge accumulated in economics by previous efforts is conceived by Marshall as a sort of complex and articulated living organism characterised by a high degree of flexibility to promptly adapt to an

[12] The young Marshall was influenced by the Classical vision, as worked out by Ricardo and updated by Mill, which emphasised the role of some of the crucial causal factors: capital accumulation, marginal rent, and the Malthusian law of population (Malthus, 1798). However, he was convinced that in contemporary capitalism the law of population left a significant space for rational agreements on income distribution, agreements that economic theory had to rationalise and orientate.

[13] Quoted in Dardi (1982, 69).

ever-changing environment. He built such a conceptual system endowing it of a robust backbone spine that keeps together and articulates its constituent parts (specific models or theories). This is the principle of substitution (at the margin) that is fully consistent with the alleged continuity and gradualism of the evolution process. This principle provides a robust bridge with the crucial role attributed to marginal utility by marginalists. However, the ubiquitous Marshallian principle of substitution acts differently in different specific theories. For example, in the market of factors the principle acts on their demand considering the variation of their marginal productivity in the light of the constraints of custom and policy rules. So doing, he managed to avoid, or play down, most of the criticisms levelled against the first versions of marginalism. First, he always directed his methodological approach towards realism and practical influence. Second, he built a syncretic paradigm meant to provide a constructive synthesis between Classical economics and marginalism. Realism and syncretism are strictly linked in his vision. As is well known, Marshall recognised the general interdependence between the endogenous variables of the economic system; however, he rejected the GE approach in favour of a less ambitious but more focused partial equilibrium approach. This choice was not motivated by an underestimation of the appeal exerted by the GE model but by its conviction that the latter was unable to support the necessary research to solve the urgent social problems brought about by the recent evolution of capitalism. In particular, he rejected the strategy, first explored by the late Walras, to get rid of time. He introduced instead a different approach to time that became, and still is, extremely influential, namely the distinction between short-term and long-term equilibrium.

To use the language of Lakatos, Marshall's research programme is endowed with a robust safety belt that defends it efficiently from any attempt of falsification.[14] The conflict between Marshall's and Popper's views of scientific progress could not be more evident. However, this powerful system of defence does not transform his paradigm into a dogmatic doctrine. The safety belt acts as an efficient immunity system that presides on the smooth physiological process of its evolution to cope with the inevitable and continuous changes in the

[14] Marshall's view of progress in economics is closer to the late version of Kuhn that plays down the scope and significance of his earlier concept of scientific revolutions stressing the degree of continuity in the evolution of scientific disciplines.

social, technological, and institutional environment. The defended paradigm is open to accommodate within it new or different ideas granting a sort of internal pluralism. Schumpeter endorses this view through a perceptive metaphor[15]:

> He always pointed beyond himself and toward lands into which it was not given to him to enter. New problems, ideas, and methods [...] came to his work as allies. Within the vast fortified camp that he built, there was room – in fact there was accommodation prepared in advance – for them all.

Marshall's wide and persistent hegemony was established and maintained based on a high degree of tolerance for different theories and schools of thought. He practiced this attitude of tolerance in his research and advocated its adoption in economics. Marshall's pluralism is greatly strengthened by the evolutionary philosophy entertained by Marshall. His paradigm is conceived as an open system to be continuously revised and updated to cope with substantive, possibly irreversible, historical changes. Pure economics itself is dethroned from the pre-eminent role, differently motivated and implemented, attributed to it by the Classical and marginalist schools. The machinery of pure economics can be fruitfully applied to the interpretation of economic life only if one acquires a profound and detailed knowledge of the actual facts of industry and trade.[16] This engine should always combine all the useful insights one can find in the literature.

Marshall's vision of scientific evolution suggests a distinction between *external* and *internal* pluralism referring to a different attitude of tolerance towards theories that can, or cannot, be accommodated within a certain flexible and open research programme. Marshall himself advocated especially internal pluralism. His research programme is open to the contributions of different schools of thought whose insights may be assimilated within a more general paradigm. This attitude contributed to the power of attraction exerted by the Marshallian research programme also on scholars originally motivated by a different inspiration. A case in point is Edgeworth whose original marginalist approach in his book published in 1881 was later tempered by his adhesion to the Marshallian consensus. This made him an excellent editor of the *Economic Journal* that wisely reflected the Marshallian 'internal' pluralism.

[15] Schumpeter (1952, 93). [16] See Keynes (1933, 207).

7.3 Menger and the Austrian School

In his masterpiece *Principles of Economics* published in 1871, Carl Menger introduced in German-speaking countries an approach based on marginal utility and market interdependence starting an influential school of thought that is still alive and evolving as Austrian economics. His achievements are no doubt sufficient to justify the title of cofounder with Jevons and Walras of the Marginalist Revolution. He sought to decouple from history the pure theory of a monetary economy in a way that many economists found convincing. So doing, he advocated a methodological approach that became a hallmark of mainstream economics. As Schumpeter maintained, 'Menger belongs to those who have demolished the existing structure of a science and put it on entirely new foundations' (Schumpeter, 1952, 83). He was not the first to pursue this goal. In particular, the cofounders of Marginalism, Jevons and Walras, moved along similar lines. However, they were not recognised by the contemporaries as founders of a new, full-fledged paradigm. It was much easier to dismiss Jevons's book as a pamphlet or preliminary brochure, and Walras's GE mathematical model as an esoteric contribution that required further elaboration. Menger instead built a systematic reconstruction of economic theory starting from the obvious observation, fully compliant with the requirements of methodological individualism, that people value goods because they need them.[17] The strength of Menger's argumentation is that this apparently trivial foundational assertion is argued to be sufficient to explain the system of relative prices, production, distribution, and the role of money in any form of money economy, including those recently implemented by rapidly evolving capitalism. In his opinion, contrary to the opinion of the Classical economists, pure economic theory may be applied to all historical circumstances. In other words, what gives Menger a prominent role in the history of economics is the alleged discovery that

> the laws of human needs are wholly sufficient to explain the basic facts about all the complex phenomena of the modern exchange economy. And that, in spite of striking appearances to the contrary, human needs are the driving force of the economic mechanism (Schumpeter, 1952, 84).

[17] See Schumpeter (1952, 83).

A corollary of this assertion is 'the recognition that price formation is the specific economic characteristic of the economy – as distinct from all the other social, historical, and technical characteristics – and that all specifically economic events may be comprehended within the framework of price formation' (ibidem). The critics of Menger's theory argued that the nexus between subjective valuation and human needs is a triviality of which all economists, including the Classical economists, have always been fully aware. Schumpeter objected that 'almost every one of the classical economists tried to start with this recognition [... but] could not make progress with it...' (Schumpeter, 1952, 83). However, what Menger considers as specifically economic is rather narrow, much narrower than the ground covered by the Classical economists. This is acknowledged also by committed admirers such as Schumpeter who recognised that the scope of his achievements is much narrower than that of Adam Smith (Schumpeter, 1952, 85). Menger greatly contributed to the adoption of a radical reductionism by mainstream economics but did not endorse its progressive shift towards the adoption of a mathematical method.

7.4 The Method Dispute

The evolution of economics may proceed through a process of continuous accumulation of evidence, refining of theoretical constructs, and integration of complementary points of view, as Marshall advocated and practiced with some success. Otherwise, it may proceed through an open conflict between divergent points of view, as in the case of the first-generation marginalists. In the same period of the Marshallian consensus in Great Britain, we find in the German-speaking countries a significant example of scientific confrontation between scientific visions judged irreconcilable by their adepts. The 'Method Dispute' began in the 1880s and raged for more than a decade extending its impact much further in time and space. Menger, the early leader of the Austrian School, and Gustav von Schmoller, the leader of the German Historical School, intervened in this increasingly harsh dispute to defend and support their scientific and methodological visions. The debate focused mainly on the role of general theory in social sciences and the use of history in explaining the behaviour of economic agents, issues that are still central and not less controversial in the methodological disputes in economics. Carl Menger triggered the dispute by attacking in his

1883 book on the *Method of the Social Sciences* Schmoller and the German Historical School that was then the mainstream school in Germany. Reflecting on their neglect of his recently published book *Principles of Economics* (1871), he realised that the divergence between his method and that of the German Historical School was a serious obstacle to the understanding of his contribution. Therefore, he amended the first edition of the book with methodological clarifications and eventually wrote an entire book to solicit a frank discussion on the methodological issues dividing the two approaches. Menger argued that the study of human motives and social interaction in specific situations is too abstract for the inductive and historical methods advocated by the German Historical School. In addition, he maintained that the explanations of the behaviour of aggregative (or collective) magnitudes could not have adequate foundations unless we derive them from simple components referring to individuals. Therefore, Menger claimed that the best approach to economics should work out general theories that deduce universally valid precepts from rational principles of individual choices. Menger reaffirmed thus what he had called 'methodological individualism' focusing upon self-interest, evaluation on the margin, and incomplete knowledge of the economic agents. Schmoller immediately responded to Menger's challenge with a harshly critical review of his book. He reaffirmed the conviction of the German historical School that economics could work out significant generalisations only by investigating descriptive statistics and historical evidence, rather than relying on groundless laws derived from abstract theories insufficiently rooted in historical experience. In particular, he emphasised the crucial importance of economic and political institutions in explaining the most significant events and policy implications of political economy. This cross-purpose dialogue between different representatives of the conflicting schools continued in an increasingly hostile atmosphere. The misunderstandings arose from arguments rotating around dichotomies differently understood by the two competing schools. Particularly divisive was the different understanding of the dichotomy between the abstract-deductive method and the empiric-inductive method, and of the dichotomy between methodological individualism and methodological collectivism. As is usual with different visions, the different language was concealing substantial differences that jeopardised the comprehension of the interlocutors. Schmoller advocated an easy synthesis between the polarities of the dichotomies: no one could deny that any empirical science must integrate deduction and induction, as well as knowledge of parts and wholes. Menger, however, aimed to emphasise the autonomy of economics from other social and human sciences. Once the disciplinary boundaries had been established, he would not object to use within them inductive methods like those advocated by the German Historical School within the framework dictated by economic theory. Moreover, the autonomy of economics would not exclude interdisciplinary research on a common subject. The divergence between uncommunicating visions was influenced also by discrepancies between the German and Austrian cultural traditions. German philosophy had been characterised by a deep historicist and holist inspiration that spread since the turn of the nineteenth century along a genetic line going from Kant to German idealists (Schelling, Fichte, and Hegel) to the Young Hegelians (including Feuerbach, the young Marx and Engels). This tradition continued then in the second half of the nineteenth century, including German 'Historism' represented by philosophers and historians such as von Ranke, Droysen, and Meinecke, and the jurists of the German Historical School of law (led by von Savigny). Also the neo-Kantians that dominated the academic philosophy in Germany from 1870 to 1918 showed a keen interest in history.[18] In Austria, instead, the philosophical orientation was increasingly influenced by the seminal neo-positivism of Mach paving the way to the emergence of the Vienna Circle.

The Method Dispute emphasised how difficult is a mutual understanding between exponents of different scientific visions. As we have seen in Chapter 4, this difficulty was interpreted in terms of incommensurability by Feyerabend (1962) and Kuhn (1962). Since then, the dispute over this concept has been at the centre of particularly hot debates in the philosophy of science, a debate that is far from exhausted. The Method Dispute confirms the difficulty of translation of a scientific statement from one vision to another one (as emphasised by Kuhn), and thus of mutual understanding, a difficulty that is analogous to that arising from the translation of a poem from one language to another. This difficulty is greater if the two languages belong to different linguistic traditions (e.g. from a romance language into Chinese). In the case of different scientific visions, the difficulty of mutual comprehension persists even when the

[18] See, in particular, Dilthey (1996).

interlocutors use the same language because they attribute subtly different meanings to similar, or even identical, words.

A serious consequence of this intolerant scientific debate was that Schmoller went so far as to declare publicly that members of the 'abstract' school were unfit to fill a teaching position in a German university. Schmoller's influence in the German academia was so firmly established that his anathema was sufficient to determine the exclusion of all adherents to Menger's doctrines from academic positions in that country for a long period, while Menger and his pupils behaved in a similar way in Austria. The Method Dispute between Menger and Schmoller is the visible tip of an iceberg whose huge, submersed part started in the late nineteenth century to extend its reach much beyond German-speaking countries. The difficult translation of the ideas of the opponent into a different language reflects the ongoing divergence of two broad cultural visions. We can see now with more clarity which are the deep reasons of the reciprocal misunderstandings. Menger's approach was deeply rooted in the Austrian analytic tradition that found expression in the early works of Wittgenstein and the Vienna Circle, while Schmoller was deeply rooted in the so-called continental historicist and hermeneutic tradition that was particularly influential in Germany. This interpretation is confirmed by the fact that in his review Schmoller contrasts his negative opinion on the book by Menger with a positive review of a recent book by Dilthey, a leading representative of the continental *weltanschauung* that influenced subsequent streams of thought, in particular the hermeneutic school (Gadamer). The different vision explains why Schmoller was scandalised by the narrowness and reductionism of Menger analysis, while the latter played down the crucial importance of history. As often happens in this sort of dispute, the interlocutors did not understand the deep motivations of their opponents. The following generations of scholars criticised the sterility of methodological disputes for their own sake but ended up by being deeply influenced by this dispute. This is the case, among others, of Böhm-Bawerk and Schumpeter in Austria. In the next section I discuss the case of Schumpeter, whose intellectual trajectory is of particular interest for the rest of this book.

7.5 The Pragmatic Syncretism of Schumpeter

Since his early works (including the classic *Theory of Economic Development* originally published in 1911), Schumpeter (1883–1950) claimed to regard methodological controversies, including the *Methodenstreit*, altogether sterile and a sheer obstacle to the progress of economics.[19] It could seem thus surprising that Schumpeter published his first book in 1908, when he was 25, on methodological issues largely overlapping with those discussed during the method dispute whose echoes were still alive. In this early book, Schumpeter had a main goal, like that of Menger, of providing adequate foundations to pure economics able to guarantee its rigour and disciplinary autonomy. Therefore, in his words, he aimed to 'examine as correctly as possible the foundations, methods, and main results of pure economics with reference to its nature, its significance, and its development possibility' (Schumpeter, 2010 [1908], 20). This implied the adoption of a method capable of providing sound answers to the research questions posed by economics. So far, the approach looks like that of Menger (1883) when he started the dispute on method. However, the differences are deep and lead to a diverging research programme. First, differently from other contributions to economic methodology, including the book by Menger, Schumpeter aims at a synthesis between methodology and theory in economics:

> In our view, one should not construct a methodological viewpoint a priori but adopt what leads us farthest in each case without being affected by any preconception [. . .] One cannot separate the study of methods from the study of concrete problems. Only in relation to the latter has the former a meaning' (p. xiii–xiv).

This view leads him to advocate an insightful form of pluralism based on a principle of methodological tolerance:

> I am convinced that the contentions of almost all 'schools' and of all individual authors are correct; most contentions are true in ways for which they are meant and for the purposes intended' (p. vi) . . . Each method has its concrete areas of application, and it is useless to struggle for its universal validity' (ibidem, p. 7).

This point of view that he calls 'pragmatic' inspires the adoption of a form of methodological pluralism that is more consistent and far-reaching than that of Menger and Schmoller. Both of them favoured pluralism within their own scientific vision but they were also too

[19] Shionoya (1990, 187).

ready to trace a sharp demarcation between good and bad science. Schmoller lamented the narrowness of the exact theory advocated by Menger emphasising its lack of realism and its consequent alleged sterility. Menger lamented instead the lack of rigour and autonomy of Schmoller's view of economics. In both cases, the rigid demarcation line between good and bad science seemed to justify the exclusion from academia and policy jobs of the followers of the rival School and translated the battle of methods in a battle of power. The battle between the Austrian School and German Historical School did eventually degenerate beyond the boundaries of methodological divergences mainly because of their different scientific visions that were only partially made explicit and never constructively discussed. We can clearly spot the chasm between these great scholars and their respective followers by emphasising the differences between their paradigmatic exemplars of sound economic theory. Schumpeter argues that the static theory of the circular flow as expressed by Walras's GE model provides the paradigmatic expression of sound economic theory because it:

(i) describes facts not individually but schematically.
(ii) is a 'pure' or 'exact' theory in the sense that it is independent of metaphysical, psychological, political, social, and historical conditions. This independence assures the 'clarity and autonomy' of economics (p. 23).
(iii) represents in a unified scheme the core of the economic system, namely the generalised logic of exchanges (also called 'catallactics') including production and consumption.
(iv) is based on methodological individualism.
(v) describes the interaction between all the endogenous variables avoiding causal simplifications 'in exact reasoning we avoid the concepts of 'cause' and 'effect' whenever practicable and replace them by the more satisfactory concept of function (p. xvi).

Schumpeter maintains that this sort of theory, though static, has very wide applicability to facts. In his opinion, what he calls the *circular flow* described by static theory captures what is ordinary in real life while economic development and structural change are exceptional events (Schumpeter, p. 568). This sentence sounds odd in the light of Schumpeter's subsequent work mainly focused on development and change. However, what he calls 'static theory' is the GE approach that can be made dynamic and can be extended to study steady states and other routine tendencies, although not development and structural change.[20] Nevertheless, we could say that, if Schumpeter puts his reason in Walrasian equilibrium, he puts his heart in structural dynamics and evolution. It is this tension that makes his arguments so lively. I am inclined to say that his economic vision is eclectic. Even if one does not like eclecticism in economics, the kind of eclecticism practiced by Schumpeter is full of new insights that make his contributions sometimes attractive and sometimes unpalatable, but always inspiring.

In an excellent essay on Schumpeter's methodology, Shionoya (1997) links the methodology to the instrumentalism of Mach and the conventionalism of Poincaré. The influence of Mach's ideas is quite natural considering the persisting prestige of his ideas in Austria witnessed by the emergence of the Vienna Circle. The link with Mach's instrumentalism should avoid any confusion with the meaning of instrumentalism that Popper popularised later. Here, I limit myself to observe that Schumpeter takes clear distances from the simplistic criterion of falsification advocated by the early Popper (1959 [1934], 64):

> In general we shall. . .not abandon a system only because it fails in one point. If, for several reasons, we are induced to stay in the system in question, we do so with the aid of auxiliary hypotheses'.

This and other similar statements connect the instrumentalism of Schumpeter not so much with the critical realism of Popper but with the conventionalism of Duhem (1904–1905), who emphasised the defensive role of auxiliary hypotheses, and Lakatos who clarified the role of the auxiliary hypotheses as a protective belt of theories. In addition, in his opinion, a theory is an instrument but not so much for prediction, as later Friedman maintained, but to understand facts by organising, classifying, and reconstructing them. However, Schumpeter did not like to attribute simplistic labels to the points of view of serious scholars, particularly the labels ending in -ism that are often emotionally led and used as substitute of serious arguments blocking their critical development. I think that the adjective pragmatic used by Schumpeter himself is appropriate to qualify his own

[20] His contention that the equilibrating mechanism of an economy described by the so-called static theory plays a crucial role in the adaptation of an economy to new circumstances confirms this interpretation (ibidem, 562).

methodological approach and understand its implications for the issues covered by this book.

I conclude this section by observing that although Schumpeter criticised the methodological disputes for their own sake, he also insisted on the importance for scientists, even social scientists, of being concerned with methodology. This justifies his early book on the methodology of economics, the clever use of his own methodological eclecticism in the study of specific economic problems such as development and business cycles, and his explicit attention for the role of the pre-analytic vision in the history of economic analysis. Methodological awareness is a necessary support of economic analysis to inform and inspire the sound interpretation of models, theories, empirical evidence, and their links.

7.6 Second-Generation Marginalists

The marginalists of the second generation tried hard to mitigate the narrow reductionism of the first generation by extending their approach to problems so far neglected. The most important early breakthrough was the elaboration in the early 1990s of the marginal productivity theory of distribution by a few distinguished economists such as Clark, Wicksell, Wicksteed, and Barone. According to this theory, in a competitive market the repartition of the social product depends on the productivity of the last physical input of each productive factor. This assertion was taken to be a simple extension of the marginalist approach to the determination of the price of productive factors. In this view, the equilibrium price is fixed by the equality reached in the production sector between the marginal product and its marginal cost. However, this long-run equilibrium is meaningful under a long list of unrealistic assumptions that go much beyond the standard assumptions of the GE model as they include, for example, the homogeneity of production factors, an assumption hardly reconcilable with methodological individualism. That is why Marshall considered the GE results as mere general references to be integrated by the analysis of other important factors. This and other similar reserves did not prevent the immediate success of the marginal productivity model that seemed to confirm the descriptive and predictive potential of the marginalist approach to solve the real problems of a capitalist economy. In addition, the normative implications of marginal productivity theory seemed to justify the fairness of capitalism notwithstanding the unequal distributive consequences. In this view, everyone obtained the earnings deserved by their (marginal) contribution. Clark did not hesitate to assert that the political message of the marginal productivity theorem is: '[W]hat a social class gets is, under natural law, what it contributes to the general output of industry'.[21]

This alleged success of the marginalist approach conquered many new adepts to the marginalist research programme in the last decade of the century. However, this theory was soon criticised also by some of the most influential representatives of the new research programme, such as Pareto (1964 [1896–1898]). The limits of this application of the marginalist theory went much beyond its general limits (unrealism of hypotheses such as full employment of all factors, and unbounded rationality of agents). The marginal productivity theory of distribution touched upon some of the basic tenets of the marginalist vision. In particular, the homogeneous treatment of production factors, including work, was hardly consistent with the methodological individualism underlying marginalist theory, and the exclusive focus on the demand side was not consistent with the general interdependence between demand and supply conditions.[22] This critique was already clearly visible in his first major economic work (1964 [1896]). The subsequent evolution of Pareto's research programme may be interpreted as a progressive attempt of escaping from the reductionism of the original version of the GE model (see Section 8.6).

7.7 The Revival of Continental Marginalism

As we have seen, the most promising advances of Marginalism after the initial 'insurrection' were worked out by continental schools such as the Franco-Italian School of Lausanne, the Swedish School of Wicksell, and the Austrian School initiated by Menger and developed by von Wieser and Böhm-Bawerk. In the Anglo-Saxon world we find significant contributions in the USA, mainly by Fisher and Clark, that however remained for many years relatively isolated. In the UK, the evolution of marginalism was inhibited until the early 1920s by the

[21] Clark (1886, 56).

[22] As Samuelson asserted a few years later, the marginal productivity theory cannot pretend to be more than a partial theory of one aspect of the demand for productive services by the firm.

prestige of the Marshallian synthesis. Even the most brilliant exponents of the second marginalist generation (such as Edgeworth and Wicksteed) were progressively captured within the broad boundaries of the Marshallian School and its internal pluralism, eventually losing their initial innovative edge. A new impulse towards the advancement of the marginalist revolution came from the decline of the Marshallian synthesis that occurred in the 1920s and early 1930s and was accelerated by the Great Depression. The most devastating criticism to the Marshallian synthesis came from Cambridge economists who had a deeper critical knowledge of the Marshallian vision and method. However, the Cambridge criticisms (e.g. by Robinson, Chamberlin, Sraffa, and then Keynes) went all in a direction opposite to the vision of the original marginalism. The first impulse towards a revival of the early vision of marginalism came from outside Cambridge. Since the early 1930s, under the impulse of Lionel Robbins, the London School of Economics promoted a revival of the marginalist approach challenging first the Marshallian hegemony, and then organising an active resistance against the Keynesian Revolution. The Paretian approach to preferences was the main source of inspiration for the diffusion in the Anglo-Saxon countries of versions of marginal utility theory more attuned to the emerging logical positivism. Hicks and Allen (1934) resumed and developed the ordinalist approach to preferences advocated by Pareto. A few years later, Samuelson worked out a new approach to the inference of preferences from empirical observation dubbed 'revealed preference approach'.[23] This approach contributed to the rescue of utility theory confirming its consistency with the ruling principles of positivist methodology. These advances provided the first impulse to revive the marginalist research theory in a new, more constructive, way. Building on this basis, Hicks worked out a very influential contribution publishing *Value and Capital* in 1939. His excellent conceptual and linguistic skills allowed him to work out a creative synthesis of different streams of the marginalist literature that took account of the non-English literature (in particular Italian, French, German, and Swedish), keeping in mind the recent debate on the *General Theory* in which he had participated from the eclectic point of view of a rudimentary GE approach. This tour de force was

[23] As is well known, this approach was first suggested by Samuelson (1938) and gave birth to a vast literature.

influential on the subsequent evolution of both main contending schools in macroeconomics. He provided sound arguments and convincing innovative examples questioning the usual view of the sterility of the GE approach. The unity of the book, he claimed, lied 'not in unity of subject but in unity of method'.[24] Hicks's approach favoured the emergence of the so-called neoclassical synthesis that became hegemonic in the following quarter of century. A case in point is Hicks's seminal analysis of the dynamics of the economic system. This aspect of his method was particularly innovative and influential on the subsequent evolution of macroeconomic theory, notwithstanding its shortcomings. The dynamics of the system is analysed from a specific point of view: the stability of the equilibrium position.[25] This was an important step forward showing a way to liberate GE theory from the shortcomings of Walrasian atemporal *tâtonnement*. That preliminary step soon stimulated further advances in economic dynamics. However, Hicks did not consider the global dynamics of the system, and so the results he obtained remained questionable. A more rigorous approach to the dynamics of the GE system and its stability will soon be introduced by Samuelson who had received an excellent training in mathematics by Gibbs, the famous physicist.

7.8 Varieties of Pluralism

This chapter offered the occasion to go a bit deeper into the phenomenology of scientific pluralism in the field of economics. The lively debate at the turn of the nineteenth century discussed in this chapter makes clear that there are different aspects of scientific pluralism. In addition, we must consider a possible trade-off between different dimensions of pluralism. A workable version of scientific pluralism requires a full awareness of the complexity of its features and consequences. In this final section, I discuss some aspects of this complexity in the light of the disputes raged in economics at the turn of the nineteenth century. First, any form of pluralism requires some form of fallibilism, namely the awareness that our scientific beliefs can be affected by limits and mistakes that interlocutors with different

[24] Hicks (1946 [1939]).

[25] The words 'stability', 'stabiliser', and 'disequilibrium' appear in the Index more than twenty times.

scientific beliefs may discover and correct. This aspect already emphasised by Mill was underlined in a more articulated way by Marshall. Limits and mistakes are usually correlated in a specific way to the issue under investigation, considering its logical, historical, and geographic features. A different point of view may disclose a hidden logical contradiction or a concealed conflict with the empirical evidence. This may depend on the incongruence between the theoretical assumptions and the main features of the reality investigated. This does not imply that the assumptions must be 'realistic' in one of the meanings of this ambiguous word; however, the assumptions must be appropriate for the research question in the sense that they should not exclude the possible occurrence of the essential features of the empirical evidence under investigation. Therefore, a pluralist attitude must recognise that dissimilar assumptions may fit better different historical, geographical, or institutional situations. This leads to what I call 'internal pluralism', internal to the extent that different theories, models, and approaches are tolerated within the same broad research programme. This does not imply any contradiction or ambiguity because the competing epistemic variants are considered valid on different issues or circumstances, or from different, but compatible, points of view. As we have seen in Section 7.2, internal pluralism plays a crucial role within Marshall's research programme. The analogy of the scissors whose blades play a different role under different assumptions is just a brilliant example of internal pluralism that combines the classical and marginalist approaches. Schumpeter's pragmatic pluralism may be interpreted as a variant of internal pluralism based on an eclectic approach. Menger, on the contrary, did not show a propensity to tolerate different approaches. In the case of the German Historical School the chasm between the two approaches was particularly deep. However, Menger was not that tolerant towards the theory of capital worked out by his illustrious pupil and follower Böhm-Bawerk, notwithstanding the similar scientific vision. The self-assertive approach of Menger contributed to the foundation of the Austrian School and its persistence through time. The Austrians did not show the kind of tolerance consistent with internal pluralism. However, this did not prevent the members of this school to adopt a significant variety of approaches. In addition, a thoughtful and detailed criticism of different paradigms is an important requisite of what I call external pluralism, namely a serious dialogue between different Schools of thought. The

Austrians played often this important role. Böhm-Bawerk engaged in a memorable confutation of the Marxian theory that started a lively controversy with the Marxists. Von Mises followed suit from a different point of view. Hayek played a similar role against Keynesianism. Not by chance Popper, who was deeply influenced by the Austrian School of economics, argued in favour of the constructive role of falsification in the evolution of science. Genuine pluralism requires a sharp, critical attitude towards alternative theories and visions. Ignoring them is the worst sign of intolerance and lack of respect. The Austrians took seriously the alternatives to their theories and built sound arguments to falsify them. From this important point of view, they contributed better than other schools of thought to the survival of a critical dialogue between schools of thought, which is a crucial ingredient of lively pluralism. The criticism of Marxism is a case in point. Both Mill and Marshall declared on many occasions a deep sympathy with the socialist ideas but asserted at the same time that Marxian economic ideas were deeply faulted. Nevertheless, they did not try to articulate a full-fledged rejection of the Marxian economic theories based on detailed arguments, but adopted instead an attitude much less explicit, and thus much less potentially constructive, than that of the Austrians.

8 The General Equilibrium Approach from Walras to Hicks

Simonde de Sismondi:[1] *Let us beware of this dangerous theory of equilibrium which is supposed to be automatically established. A certain kind of equilibrium, it is true, is reestablished in the long run, but it is after a frightful amount of suffering.*

Lee Smolin:[2] *It is in the interest of the scientific community as a whole to encourage the widest diversity of approaches consistent with the evidence in hand … it is competition among diverse viewpoints and research programs that drives the progress of science.*

Since its first appearance in the path-breaking book of Walras (1874–1877), the GE model played a growing role in the evolution of economic theory. The early evolution of the model largely overlaps with that of mathematical economics. This model was ignored by most economists but soon attracted the attention of the best mathematical economists at the turn of the century, including Edgeworth, Pareto, Marshall, Wicksell, Wicksteed, and Fisher. Many of them saw in the model the rigorous translation of Smith's scientific vision in updated mathematical language. In this view, a competitive market is ruled by a pervasive force of gravitation generated by the general interplay of demand and supply within and between markets. This complex interaction tends to implement a general economic equilibrium that clears simultaneously all the markets and maximises the satisfaction of all traders. Since its first appearance, most economists drew from the results of the GE model arguments in favour of laissez-faire, although neither Smith nor Walras had advocated such a crude policy strategy without significant qualifications and exceptions. At the same time, the opposition to this model and its policy implications was not less radical. In particular, the critics emphasised the lack of realism, the

[1] Simonde de Sismondi (1819, vol. 1, 20–21). [2] Smolin (2019, 172).

static imprinting, the structural invariance, and the neglect of social, institutional, and historical factors. Several critics saw this approach as an escape from the social problems of production and distribution haunting the real economy and thus interpreted it as an apology of competitive capitalism. This was by no means the case of Walras who was a reformist with utopian inclinations. However, a widespread instrumental use of the GE model was liable to this sort of criticisms. The dialectic between different points of view on the limits and implications of the model exerted a strong influence on the following evolution of different schools of thought in economics.

In this chapter, I sketch some aspects of the early evolution of GE theory to clarify the emergence of a spectrum of alternatives in aggregate economics, especially as far as its relationship with microeconomics is concerned. The GE model has been seen by most mainstream economists as the only rigorous bridge between microeconomics that studies the behaviour of single decision-makers and aggregate analysis that studies the behaviour of the economic system as a whole. This bridge can be constructed in different ways and track different paths. In Section 8.1, I discuss the genesis of the model distinguishing the different approaches of Jevons and Walras. In Section 8.2, I consider the evolution of Walras's GE model focusing on the emergence of his late approach based on virtual groping and its far-reaching implications. Section 8.3 focuses on the specific form of reductionism adopted by Walras under the influence of the French rationalist tradition. The following sections focus on two early followers of the GE research programme: Pareto (Section 8.4) and Fisher (Section 8.5). In the concluding section, I mention some aspects of the early debate on the optimality of the GE model.

8.1 The Genesis of the General Equilibrium Model

The Marginalist Revolution initiated by Jevons (1866 and 1871) aimed to establish the internal consistency of economic theory by showing that marginal utility may explain demand, supply, and prices in all the articulations of a competitive market. To this end, this theory aimed to determine the equilibrium prices, and the corresponding quantity exchanged of all goods. Jevons was not able, however, to implement the analytical model beyond bilateral exchange. Proceeding in the same direction, Léon Walras (1834–1910) accomplished a further step that played a crucial role in the subsequent evolution of economic theory. He was the first who succeeded to express in analytic terms the intuition of Smith that in a competitive market a unique force, similar to that of gravitation, presides over the dynamic behaviour of all economic variables relevant in the exchange of goods determining a strict interdependence between them. Walras was aware of the limits of his results. He emphasised, however, that his model was the pivot of pure economics that focuses on the sphere of circulation of exchange value under ideal conditions. In his contribution, Walras focused on a systematic treatment of the mathematical theory of exchange allowing him to draw a few original implications that outline the first, trailblazing version of the GE model (ibidem, viii). Walras asserted that the theory of social wealth so developed contained the germs of all pure and applied political economy. He argued that his approach clarifies that the origin of value is the scarcity of goods as perceived by individuals. The curves of utility and the quantities possessed are ultimately the necessary and sufficient conditions of equilibrium prices. Demand curves are derived from these conditions under the assumption that all traders maximise the satisfaction of their needs so that a perfect competitive market fixes a unique price assuring the equilibrium between demand and supply. He also emphasised that the application of this model to a real economy should be integrated by the insights coming from the other two branches of political economy: applied economics that studies the specific factors of a real economy, and social economics that examines alternative policy strategies in the light of social implications and moral principles. We will see that successive mainstream economists often ignored the wise methodological cautions advocated by Walras. He himself moved the first steps in this direction by seeking a way to dispose of all the complications derived by the actual behaviour of the economic system outside equilibrium. Before discussing this crucial point, we must consider briefly the role of mathematics in the construction and use of the GE model. Walras uses mathematics not so much as an instrument of manipulation of symbols and quantities but as a conceptual device. The basic idea is that of representing the economic system as an interdependent system of equations showing that it is possible to find a simultaneous solution (interpreted as equilibrium) for the prices and quantities of all the goods exchanged in a competitive market. I focus first on the version of the model published in

Éléments d'économie politique pure (Walras, 1874–1877]) as developed in its third edition because this version of the model became afterwards particularly influential (Walras, 2014 [1896]). In reference to this model, Wicksell perceptively observed that

> Walras is undoubtedly the greatest synthesiser of his time, perhaps of all time. Prior to him, no one had conceived and carried out the magnificent plan of presenting all the factors in the national economy in a single logical whole (Wicksell, 1936 [1889], vol. II, 179).

What distinguishes Walras from Jevons has to do with their links with two different traditions of thought. In the aftermath of Newton's death, most British scientists continued to adopt in physics the traditional inductive methodology of British Empiricism and developed its formalisation mainly in the direction of applied science and technological innovation. In France instead, the persisting influence of Cartesian rationalism promoted the systematic use in physics of an axiomatic-deductive method relying on a formalist style of mathematics less influenced by geometry and much more by logic and algebra.[3] In particular, Lagrange reformulated Newton's mechanics as a rigorous formal system of pure mathematics (Lagrange, 1788). Following Lagrange, Laplace tied up the loose ends of Newton's mechanics through rigorous formalist mathematics, maintaining the Cartesian philosophical view 'that all phenomena, both celestial and terrestrial, could be explained by a uniform set of laws'.[4] Walras was strictly linked to this tradition through Cournot who was a close friend of his father and his instructor and advisor on the use of mathematics in economics. He tried to transfer this approach to the field of pure economics starting an ambitious research programme that has been highly appreciated by the following economists. Schumpeter asserted that Walras is the 'greatest of all economists' because

> His system of economic equilibrium, uniting, as it does, the quality of 'revolutionary' creativeness with the quality of classic synthesis, is the only work by an economist that will stand comparison with the achievements of theoretical physics (Schumpeter, 1994[1954], 795).

[3] Malebranche and his followers, especially Maupertuis and Clairaut, played a crucial role in the diffusion of Newton's mechanics in France and Prussia in a version that sought to reconcile Newton with Descartes.

[4] Laplace (1799–1805).

As Walras himself proudly emphasised,[5]

> it took from a hundred to a hundred and fifty or two hundred years for the astronomy of Kepler to become the astronomy of Newton and Laplace, and for the mechanics of Galileo to become the mechanics of d'Alembert and Lagrange. On the other hand, less than a century has elapsed between the publication of Adam Smith's work and the contributions of Cournot, Gossen, Jevons, and myself.

All the scholars quoted in this passage (with the obvious exception of Newton in physics and Jevons in economics) have been deeply influenced by the French rationalist tradition.[6] Walras applied this formal approach to the synthesis, already hinted at by Say, between the physiocratic approach focused on the circulation of exchange value and the Newtonian approach of Smith based on the gravitation towards a GE. Walras praised Say for his understanding of the importance of pure economics conceived as a natural science. With his model, Walras provided the required new foundations to pure economics maintaining via Walras's law a strong conceptual link to the circular flow as depicted by Quesnay. The link between Walras and Say is clearly evidenced by the acceptation of Say's law that he generalised into Walras's law. While Say's law assumes that goods ultimately exchange with goods (as in a barter economy), in the more realistic monetary economy depicted by Walras, an excess supply of goods may occur when it is matched by an equal value of excess demand for money. Walras claimed that his own version of the pure theory had the potential of furnishing the solution to the most important problems of applied and social economics.[7] To this end, however, he recognised that any application of the model has to clarify the nature of the equilibrium so determined; we have to clarify in particular whether the equilibrium exists, is unique, and is stable. Walras felt that he had succeeded to prove the existence of a GE in a perfectly competitive market model that in principle could represent the equilibrium of an entire national economy. However, he was also keenly aware that a

[5] Quoted In Wood (1993, 32–33.)

[6] This is true also of Gossen (1983 [1854], who lived in Prussia where this approach was hegemonic under the influence of Maupertuis who became the first president of the Prussian Academy of Science, at the invitation of Frederick the Great.

[7] Walras (1874–1877, 32–33).

fruitful application of his theory to the empirical evidence had to solve the problem of stability of the configuration of GE. In the second (1989) and third (1896) editions of his masterpiece he improved substantially his equilibrium model, but he struggled unsuccessfully with the dynamic behaviour of the system out of equilibrium in the hope of proving its stability. He eventually realised that the assumption of the effective and irrevocable disequilibrium decisions in exchange and production determined path dependence that was likely to prevent the convergence towards a stable GE. In the fourth edition published in 1900, he started to explore a way out from this shortcoming that he continued to elaborate until his death in 1910. The solution he explored in the fourth and fifth editions was that of considering merely virtual all adjustment decisions outside equilibrium by introducing the treacherous assumption of 'written pledges'. This apparently eliminated the contradiction between disequilibrium behaviour and equilibrium solutions in pure theory but jeopardised the applicability of the model to the real world where path dependence occurs and cannot be neglected without misleading consequences. In addition, as Walker and van Daal (2014) observe in their thoughtful introduction to their recent translation of the third edition of Walras's masterpiece, the adoption of the 'written pledges' construal made the argument confusing if not contradictory. In the end, Walras failed to work out a consistent dynamic model of a general virtual market. Since there are no equations of demand in the modified model, there are more unknowns than independent equations. In addition, in most of the pages that deal with the question of the stability of equilibrium, Walras retained most of the descriptions of disequilibrium transactions and production that he had developed in the third edition (ibidem). The tension between actual and virtual disequilibrium dynamics (as analysed respectively in the third and fifth editions), is the root of the bifurcation between a genuine dynamic approach – that started to be practiced by Wicksell, Samuelson, and Patinkin – and an axiomatic approach first hinted at by the late Walras and the young Pareto and then accomplished by Arrow and Debreu. The two approaches use two different streams of mathematics reflecting divergent epistemic visions of the model and its methodological and policy implications. As we will see in Chapter 11, a similar bifurcation will underlie the opposition between two alternative schools in macroeconomics: neoclassical synthesis and New classical Economics.

8.2 Walras and the Scourge of 'False Trading'

Walras recognised two main intellectual influences in the genesis and early development of his work: that of his father Auguste on his economic vision, and that of his father's schoolmate Augustin Cournot (1801–1877) on his methodology. His father's influence was mainly on the adoption of a theory of value based on scarcity (*rareté*) whose rigorous mathematical foundations inspired his entire scientific trajectory. As for the methodological influence of Cournot, we can detect a strong influence in the way Walras used mathematics in his construction of pure theory. While theoretical physics relied on specific functional forms suggested by observation and corroborated by experiments and successful predictions, Cournot maintained that a sound application of mathematics to the discipline of economics should not rush to fix a highly specific functional form, for which we usually have insufficient evidence before having understood the relevant interactions between the endogenous variables (Friedman, 2000).[8] At the end of his book Cournot recognised, however, that the solutions obtained via his 'partial equilibrium' method could not take into account all the relevant interactions between markets. Nevertheless, he maintained that trying to determine the GE of the system 'would surpass the powers of mathematical analysis'.[9] This assertion by a mathematician holding two doctorates in physics confirms the excellence of the analytical achievements of a self-taught mathematician such as Léon Walras.

Léon Walras, the most influential early prophet of mathematical economics, was not a trained mathematician. He entertained an early project of becoming an engineer. However, he failed the examinations to be admitted in the *École Polytechnique* and failed to obtain the grades necessary to continue the engineering curriculum at the *École Impériale des Mines*. After a few false starts in many directions,[10] he

[8] In the introduction to his masterpiece (1838), Cournot clarified that his purpose in using mathematics in economic theory was merely to guide his reasoning and clarify his argument rather than to perform numerical calculations as in natural sciences.

[9] Cournot (1838, 127).

[10] He published in that period a novel and a short story, but he decided soon (1858) to give up his literary ambitions to devote himself to the continuation of his father's economic studies, providing sounder mathematical foundations to his theory of scarcity. However, his literary skills contributed to the terse elegance of his prose.

resumed the study of mathematics to provide better foundations to the theory of value based on the concept of *rareté* advocated by his father. However, he remained mainly self-thought in mathematics and geometry although he occasionally profited from Cournot's advice. He also sought the advice of a few mathematicians who were his colleagues in Lausanne, but their contribution did not go much beyond the checking of his book's proofs. He was able, however, to profit from his knowledge of what we would consider today intermediate mathematics by exploiting his exceptional capacity of analytic conceptualisation. He was guided in his use of mathematics by a deep intuitive understanding of the meaning and implications of the mathematical representations of the relevant quantitative relations between economic variables. His main strength was his capability of providing insightful interpretations of the mathematical results. Walras's pride for the achievements obtained with his model was more than legitimate. He claimed to have demonstrated for the first time the existence of a GE in a perfectly competitive economic system by showing that the system of equations that represents it has a solution that clears simultaneously all the markets. The argument he used in support of this conviction was simply that the number of equations corresponded to the number of independent variables. We know that this argument does not show more than the *possibility* of a general solution for the endogenous variables of the system, while its *effective existence* requires further conditions. In addition, the mathematical demonstration that, according to Smith's intuition, a competitive market gravitates towards a significant equilibrium would have required much more sophisticated arguments able to prove that the equilibrium under investigation is unique and stable in a rigorous sense.

Walras was keenly aware of the shortcomings of his model and tried hard to overcome them. He focused on the dynamic process of groping (*tâtonnement*) towards such equilibrium, but he felt unable to represent it in a convincing way. He was deeply disturbed by the path dependence of the process of convergence toward equilibrium that emerges as soon as we assume that irrevocable exchanges may occur in disequilibrium (the problem that is also called *false trading*). This problem emerges because of the interaction between endowments of capital goods and equilibrium. In principle, in the Walrasian model, each possible endowment leads to a different equilibrium. This implies that the equilibrium solution eventually reached by *tâtonnement* does not correspond to the solution of the original timeless equation system.[11] In the second edition published in 1889, Walras explicitly recognised the problem and suggested that the model should assume that exchange out of equilibrium is suspended to avoid path dependency. The results of his heroic efforts were worked out in the fourth edition published in 1900 and maintained until his death in 1910. Later alterations were included in the posthumous fifth edition published in 1926, edited by his daughter Aline based on unpublished revision notes. The basic idea of the virtual process of *tâtonnement* is the introduction of the device of written pledges (*engagements écrits* or *bons*). Walras assumed that would-be sellers of products and services sign commitments to supply given quantities at a certain price without actually supplying them until a set of prices is found at which supply and demand is equal simultaneously in every market.[12] This assumption excludes any change of non-virtual activity (such as transactions, production, consumption, savings) until virtual disequilibrium persists. Therefore, the amount of capital goods, asset holdings, and durable goods remains unchanged so that their endowment does not affect the supply and demand functions until the virtual gravitation process reaches GE. This process of virtual groping (*tâtonnement*) seems to confirm the existence of equilibrium, though only by avoiding the complications of path dependency. However, the outcome of the process does not go beyond the possible existence of a general solution for the model. As for the dynamics of the system, the equilibrium reached at the end of the process of learning represented by the process of virtual *tâtonnement* is just an epistemic equilibrium and not an effective economic equilibrium because the coordinating institutions underlying the virtual groping do not exist, and cannot exist, in real markets. In addition, the convergence of such a model of learning to the equilibrium prices is just assumed but not analysed. Of course, the process of coordinated learning of economic agents in a competitive market may contribute to its stability, but the conditions for a general convergence to a common true value are not thoroughly explored by Walras and his early followers. We have realised from the vast subsequent literature that the process of learning in a real market including

[11] This problem was soon pointed out also by the mathematician Joseph Bertrand (see Walker and Van Dal (2014, 9).

[12] Walker and Van Dal (2014, 9).

expectations dynamics may also be destabilising.[13] The device introduced by Walras was ingenious but self-defeating. Many economists pointed out the shortcomings of the virtual *tâtonnement* process. However, the underlying ideas managed to exert a huge influence on the evolution of economics and macroeconomics. The rational expectations approach that was going to dominate macroeconomics since the early 1980s is a direct descendant of Walras's virtual equilibrium as it creates the same confusion between the solution of a mathematical system and the equilibrium of a dynamical system. We may speculate that Walras would have defended it by remarking that his virtual process of *tâtonnement* does not pretend to be realistic but only logically consistent, as is required by any conceptual construct of pure economics. According to Walras, the application of pure economics to the empirical evidence requires a specific adaptation to the issue to be investigated, which is the task of the branch of theory he calls *applied economics*. We may speculate that Walras would not have endorsed a direct application of his ideal-type model to the empirical evidence.[14] Unfortunately, he could not clarify this crucial issue in his volume on applied economics because its original project did not go beyond the collection of some of his published papers on monetary issues.

The influence of this late version of the GE model has been greatly enhanced by the fact that the only translation available in English for many decades was the translation by Jaffé of the fifth edition of 1926. Only recently the translation of the third edition of 1895 that contains the most sophisticated and consistent version of the model became available. This is the version that seeks to provide dynamic foundations to the model by showing that its stability is granted by the effective working of market gravitation. It is this version that inspired, among others, Pareto, Marshall, Wicksell, Hicks, and Samuelson to work out more pragmatic versions of the GE model in the half a century that followed the publication of the third edition.

8.3 The General Equilibrium Model: Reductionism versus Complexity

The persisting appeal of Walras's GE model depends in part on its ability to combine in an intriguing synthesis two methodological ingredients that

[13] See for example Friedman (1968) discussed in section .
[14] Walras (1874, 32–33).

may seem at first sight irreconcilable: the reductionism of marginal utility theory explaining agents' decisions as free choices and the structural constraints to individual choices imposed by a competitive market system. This conflict plays a crucial role in the evolution of GE theory and in the interpretation of its significance for the real world. In Jevons and Menger prevails the reductionism of marginal value theory that is strictly linked to their committed adhesion to methodological individualism. Walras's model does not reject methodological individualism but combines it with a sort of 'methodological structuralism' that constrains the option set of individual agents. The link between these two sides of his approach is made clearly visible by so-called Walras's law. This 'law' formally closes in a coherent whole the interdependence of markets and the underlying interdependence of decision-makers. So doing, Walras combines the insights of British Empiricism, as applied to value theory by Jevons, and the structuralism of the French tradition as pursued by French economists such as Cantillon, Quesnay, Say, and Cournot. The approach introduced by Walras raises crucial methodological issues that are still at the centre of the methodological debate: individualism vs collectivism, reductionism vs structuralism, and realism vs instrumentalism. In this section I discuss only the issue of realism that from the very beginning has greatly affected the evolution of GE theory.

The realism of the GE model depends on a fragile trade-off between different dimensions. The increased realism deriving from the interdependence of markets has been obtained by expelling from the model a host of significant causal factors that had previously played an essential role in political economy. I mention in particular four controversial issues: the functional distribution of income (Ricardo), the demographic factor (Malthus), economic development (Smith), and the ubiquitous deviations from self-interest (Mill). All the variables 'expelled' from the model risk to be neglected by the core of mainstream theory, or to be considered in the diminutive causal role of exogenous variables on which it is impossible to act within the economic system. This trade-off is still today a crucial issue of theories based on the GE model jeopardising their realism and the fecundity of their empirical application. Is what we gain by relying on a GE model more than what we lose? Do the severe restrictions on the set of endogenous variables distort the scientific vision? Can we extend the sound application of this vision to the problems neglected by the model?

Since the first publication of Walras's GE model, many economists questioned its realism and thus also its relevance for the real world. The standard defence of Walras and his early followers was that this is a model of pure economics that necessarily resorts to the idealisations of assumptions, concepts, and theoretical constructs, as it happens in the pure theory of all scientific disciplines, including physics. Walras argued that the pure theory of political economy must be conceived as a physical-mathematical science, exactly as mechanics and hydraulics. These sciences borrow their types (concepts) from experience (*types reel*) but then abstract from them their ideal types (*types idéaux*) upon which they build a priori all the scaffolding of theorems and demonstrations of theoretical arguments.[15] They come back to experience, in this view, not to confirm or falsify their conclusions but to apply them.[16] According to Walras, the GE model itself is an ideal type, or rather a mathematical system built on ideal types. The model does not pretend to be realistic but to be applicable with profit to significant economic issues. The first goal of the model was that of explaining the tendency towards a GE in a perfectly competitive market. To this end, Walras focused on the long-term equilibrium of the system ignoring short-term perturbations. Therefore, he assumed that profits had levelled out to zero in all markets. Analogously, he did not consider uncertainty, bounded rationality, innovations, and all the other complicating factors that cannot be ignored in applied economics. Even economists sympathetic with the GE approach objected to this sort of simplification. Irving Fisher, for example, after the crash of 1929, asserted:

> It is as absurd to assume that, for any long period of time, the variables in the economic organization, or any part of them, will 'stay put,' in perfect equilibrium, as to assume that the Atlantic Ocean can ever be without a wave (Fisher, 1933, 339).

Walras (1954 [1926], 380) had anticipated this sort of objection claiming that

> The market is like a lake agitated by the wind, where the water is incessantly seeking its level without ever reaching it. But whereas there are days when the surface of a lake is almost smooth, there never is a day when the effective

[15] In this passage Walras shows that the concept of ideal type made famous by Max Weber was not introduced but only wisely elaborated by him.

[16] Walras (1874, 38).

demand for products and services equals their effective supply and when the selling price of products equals the cost of the productive services used in making them. The diversion of productive services from enterprises that are losing money to profitable enterprises takes place in various ways, the most important being through credit operations, but at best these ways are slow.

In other words, the model aims to focus on the general gravitation towards a long-period equilibrium (calm sea) without whose reference we could not describe the waves themselves or their short-run dynamics. Here as elsewhere, the issue of realism touches upon the interpretation of the model and the limits of its use. What is sure is that, according to Walras, Pareto, Fisher, and the other pioneers of GE theory, we cannot use the model to deny, or play down, the ubiquitous existence of waves, or even the possibility of a catastrophic tsunami. The mere existence proof of a GE position does not exclude the eventuality of disequilibrium processes that can be awkward or even cataclysmic. And what is worse, even the mere existence of a GE position is not granted in a real market. The existence proof of Walras that relied on the mere equality of variables and equations of the model is obviously a very weak argument, much more than Walras himself had believed and cannot prove more than a mere possibility of equilibrium under ideal conditions.

The realism of a model is appraised in different ways by different authors. Marshall disputed the Walrasian research programme because the limited influence of far-fetched markets is likely to distract the researcher from the issue under scrutiny often located within a single market. Walras tried to exorcise the problem of realism by distinguishing between pure and applied economics and shifting the search for realism to applied economics but then he left the second largely unexplored, with rare exceptions including his excellent analysis of the role of money and entrepreneurship in a competitive market. A possible explanation for this apparent lack of scientific motivations, notwithstanding his scientific courage and ethical motivations, may be possibly found in his greater interest for a utopic model of society rather than for the detailed comprehension of the existing one.

8.4 Pareto and the Limits to Equilibrium Economics

All the best economists who could read French, Italian (through Pareto), or German (after the translation in 1881), and thus most continental economists, could immediately appreciate the formal beauty and analytical potential of the model elaborated by Walras. However, it was soon clear that this model risked remaining sterile for the deep chasm between its assumptions and the real world. The second generation of neoclassical economists tried hard to give more empiric and pragmatic substance to the model. Vilfredo Pareto (1848–1923), successor of Walras at Lausanne University, gave important early contributions in this direction. In 1869, he earned a doctor's degree in engineering from what is now the Polytechnic University of Turin.[17] For some years after graduation, he worked as a civil engineer, first for the State-owned Italian Railway Company and later in private industry. The interest of the young Pareto for economics was enticed by his active commitment to the diffusion of liberal doctrines supporting free exchange and expressing hostility against the State intervention in the economy. Around 1890, under the suggestion of Pantaleoni, he discovered the works of Walras and started to publish significant contributions within the GE research programme. After six years Pareto published his first book, *Cours d'économie politique* (1896–1897), in which he provided his own version of the model. Though he expressed his deeply felt admiration for Walras's pure theory, he tried to correct and extend it beyond its limits. At the same time, he did not conceal his disregard for his applied and social economics:

> Professor Walras' great contribution to economic discussion was his discovery of a general system of equations to express the economic equilibrium. I cannot, for my part, sufficiently admire this portion of his work, but I must add that I entirely disagree with him on what he has to say in his work entitled Études d'économie sociale (Pareto, 1897, 491).

Pareto adopted and extended the dichotomy of Walras between pure and applied economics increasingly focusing on the second branch. He continued to believe that pure economics was a necessary starting point to study the real problems of society, but he increasingly emphasised that it was too abstract to fully understand and solve them. Applied economics must deal with more concrete phenomena. Pareto himself clarifies this distinction with an example: 'Pure economics determines the function of money in the economic sphere of life.

[17] It was then called Technical School for Engineers.

Applied economics describes monetary systems now in existence, monetary systems of the past, and their transformation. . ..'[18] Pareto agreed with Walras that we must study pure economics by adopting an approach like that of physics. His solid background in engineering assimilated at the University of Turin, where the teaching of mathematics was still under the prestigious influence of Lagrange, allowed him to correct a few mathematical imprecisions of Walras's model and to improve the rigour of the mathematical language. In addition, Pareto disposed of the controversial notion of cardinal utility in the theory of value, by showing that we can explain the decisions of the economic agents in terms of ordinal utility, or mere preference ordering. Moreover, he replaced the usual utilitarian criterion for policy choices by introducing the notion of Pareto-optimality, the idea that a system is enjoying maximum economic satisfaction (*ophelimity* in his language) when no one can be made better off without making someone else worse off. As is well known, Pareto optimality is currently widely used in welfare economics and game theory. By adopting this criterion, he found the way to exclude the issue of distribution of income from pure economics, conceived as value-free 'scientific analysis'. This issue, together with a host of other social issues, remained a crucial theme of applied economics that, in his view, had to integrate pure economics with sociology, conceived as a value-loaded historical interpretation of social and economic facts. His extensive empirical studies on the subject led to a celebrated empirical generalisation summarised by his famous 'law' showing that a large portion of wealth is held by a small fraction of the population according to the '80–20 rule' (Pareto, 1897).

Pareto soon convinced himself that his broad vision of applied economics was insufficient to introduce the necessary degree of realism and required a more general level of analysis that he called sociology. For example, in his view of sociology, money is not studied only from the point of view of its general economic functions but also as a specific instrument for levying taxes impinging on social relations (Pareto, 1935 [1915–1916]).[19] Pareto's distinction between economics and

[18] Pareto (1915–1916, §2014).

[19] In other words, according to Pareto, pure economics aimed to explain the general effects of taxes on wealth; applied economics utilised these causal links in the light of the empirical evidence in given circumstances, while sociology had to investigate why different countries have different tariffs, or even why some

sociology has been often interpreted as defining a sharp dividing line between them and this seemed to justify a separate appraisal of Pareto economists and sociologists.[20] The usual interpretation of Pareto's dividing line is that economics studies what he called 'logical' actions, often confused with rational actions, while sociology studies 'non-logical' actions. This interpretation is not supported by a careful reading of Pareto's writings. First, according to Pareto, rational actions are just actions guided by reasoning. To be logical, rational actions must be guided by scientific knowledge supported by experimental observation and logical arguments.[21] The action is non-logical when it reflects the subjective belief of the actor without adequate support of up-to-date scientific arguments. This case is ubiquitous because, according to a well-known assertion of Pareto, 'Human beings have a very conspicuous tendency to paint a varnish of logic over their conduct'.[22] In his opinion '... non-logical actions originate chiefly in definite psychic states, sentiments, and subconscious feelings'.[23] Most human actions are non-logical.[24] Logical actions are common only in specific fields such as pure economics, as well as military and legal matters. This is why economics studies mainly logical actions while sociology focuses mainly on non-logical actions.[25] This does not imply that economics may ignore non-logical actions. In most economic issues, especially those studied by applied economics, logical actions interact with non-logical actions that make it hard to understand economic phenomena, or predict them, unless we consider these interactions. According to Pareto, sociology is thus not a social discipline separate from economics but a more general approach that is required to understand real social phenomena, including economic phenomena. Therefore, the scope of sociology encompasses that of applied economics that in turn encompasses the scope of pure economics.[26] To explain social behaviour, Pareto resumes the crucial role of sentiments previously emphasised by Smith (1959) but develops it in a different

countries thrive under free trade and other countries under protectionist policies (Aspers, 2001, 524).

20 See Aspers (2001) for critical references to the literature.

21 Pareto's philosophy of science was strongly influenced by the ideas of Mach (see Aspers, 2001).

22 Pareto (1915–1916, §151). 23 Pareto (1915–1916, §161).

24 Pareto (1915–1916), §153). 25 Pareto (1915–16), §152).

26 Pareto (1915–1916), §2015).

direction. According to Pareto, sentiments are relatively stable in history and drive both its undulations (i.e. cyclical fluctuations) and its evolution. However, sentiments interact with economic factors because '… sentiments depend on economic conditions just as economic conditions depend on sentiments …' (ibidem, §2097). A case in point is the evolution of his interest for the distribution of income. Since his *Cours*, Pareto rejected the marginalist solution that remained internal to pure economics. To assess the ensuing loss of empirical insight of marginalist pure economics, Pareto engaged himself in a daring analysis of the few available data sets on the functional distribution of income, eventually claiming to have discovered a robust empirical regularity, later called Pareto law, that justified to some extent on empirical ground the neglect of distribution of income in pure economics. However, this path-breaking econometric excursus into applied economics gave more weight to his suggested normative criterion, subsequently called Pareto optimum. He showed that the substantial exogeneity of the distribution of resources assumed by the GE model does not prevent a redistribution of income that may improve the wealth of some individuals without reducing the wealth of anyone. However, the so-called Pareto law, a path-breaking excursus into applied economics and sociology could give more weight to his suggested normative criterion applied to pure economics. Although he did not like any form of redistribution implemented by policymakers, his insightful conceptualisation of the boundaries of acceptable redistribution gave birth to an entire literature subsequently called welfare economics, which played a crucial role in mainstream economic theory. He recognised that the conflict between social groups to improve their own share of income played an important role in a capitalist society, not only in politics but also in economics, but he believed that the study of the causes and consequences of this conflict was the task of sociology. For example, within his main contribution to sociology he delved in some depth on the distributive conflict between rentiers and speculators. These two types of economic actors have 'quite opposite traits': the rentiers want to preserve the stability of the system that guaranties the stability of their income, while the speculators are 'adventurous souls, hungry for novelty in the economic as in the social field ….'[27]

[27] Pareto (1915–1916), §2232).

Pareto was by no means a narrow or reductionist thinker, but the mainstream reading of his work contributed, against his intentions, to narrowing the specific scope of economic theory and to constraining its approach within a more reductionist methodology. According to Pareto, the determination of economic equilibrium is only an aspect of the broader social equilibrium. From the substantive point of view, we cannot thus separate economics from the broader framework of Sociology. This point of view is radically different from that of subsequent mainstream economics that progressively restricted the scope of economics to rational actions. In addition, Pareto tried hard to encompass pure economics within a theory of society. In his opinion, society is made up of different interdependent elements (the soil, climate, fauna, flora, the actions of other societies on it, history, race, residues, derivations, interests) 'making up a system which we shall call a social system [. . .]. This system changes form and character in the course of time and when we name the social system, we understand this system as considered both at a particular time and in the successive transformations which it undergoes in a particular space of time" (Pareto, §2066).

To analyse the dynamics of a social system, exactly as in the case of the economic system, we must take as reference the state of equilibrium considering the relationships of interdependence between its parts. Of course, there may be disruptions in the equilibrium – such as wars, epidemics, floods, earthquakes, deep economic crises, and other disasters – but the imbalances arising from the exogenous shocks tend to return automatically to equilibrium. The interaction between exogenous shocks and reversion to stability gives social phenomena a wavy form. Pareto's qualitative theory of social equilibrium was suggestive but failed to explain in analytic terms the causes of social dynamics and the transition from one system to another. However, Pareto's research programme remains an inspiring reference for economists and social scientists who reject the reductionism of mainstream economics. This is fully recognised by Schumpeter who rightly asserted that 'Pareto message, however one-sided, is a healthy antidote' to mainstream thinking (Schumpeter, 1951, 142). This is particularly true today, in the era of rational expectations, after decades of progressive reductionism in mainstream economics. The recent developments of behavioural economics resumed some of the themes addressed by Pareto such as the ubiquity of irrational, or not fully rational, economic decisions.

8.5 Fisher and the Quantity Theory of Money

Irving Fisher (1867–1947) has been considered the most influential early neoclassical economist in the USA. He was the first Ph.D. in economics at the University of Yale under the supervision of the great mathematical physicist Gibbs and of the distinguished sociologist Sumner. His thesis was an original version of the GE model that he drafted before knowing the earlier version of Walras (Fisher, 1892). The number, originality, and scope of his main achievements defy comparison with economists of any generation. He was the main promoter of the Econometric Society (1930) and became its first president (1931–1934); he was also advisor to many US presidents; he was a journalist, inventor, economic reformer, and social and health campaigner (see Allen, 1993). His contemporaries considered Irving Fisher as the most eminent American economist at least until 1929, when his protracted undervaluation of the Wall Street crisis jeopardised his prestige in many quarters. The admiration for Fisher soon revived.[28] It is particularly remarkable for the purposes of this book because he has been, and continues to be, praised not only by the neoclassical economists, who consider him as a founding father of their vision, but also by Keynes and many of his followers (as diverse as Tobin and Minsky) who considered him as a predecessor. In particular Keynes, who often quoted him approvingly, had to say that 'I find, looking back, that it was Professor Irving Fisher who was the great-grandparent who first influenced me strongly towards regarding money as a "real factor"' (Keynes, 1937, 241–255). In addition, as Minsky rightly maintained 'when Irving Fisher [. . .] identified the characteristics of a debt deflation process [. . . he] identified essential forces which make for the observed instability of capitalist economies' (Minsky, 1982, 393). In addition, eminent exponents of behavioural economics (e.g. Thaler, 2016) and behavioural finance (Shiller, 2013) praised Fisher as a forerunner of the behavioural approach.

In this section, I will limit my analysis to a few contributions by Fisher to aggregate analysis. I must start from his epoch-making research on the QTM (Fisher, 1911). He was the first to provide solid

[28] I can mention, among others, Schumpeter, Samuelson, Tobin, and Friedman.

foundations to modern monetarism by distinguishing between the equation of exchanges (henceforth EQE) and QTM. He clarified that the EQE is an identity equating the aggregate quantity of money in circulation M multiplied by its velocity of circulation V, to the total of goods and services transacted T multiplied by the general index P of their prices: $MV = PT$. He clarified that the equation of exchanges is an identity that does not specify by itself any causal relation between the variables. The quantitative theory of money is thus a specific causal interpretation of this identity based on a few particular assumptions. Usually, the exponents of the QTM assume that the quantity of money is exogenous and the velocity of circulation is constant, or changes slowly, at least in the short period.

Fisher's theory of debt deflation suggested to explain the Great Depression, 1933), has been recently revived to explain the recent crisis of 2007–2009 and discuss its policy implications.[29] The main novelty of Fisher's theory is the 'discovery' of a vicious circle (cumulative feedback) between debt and deflation: 'so far as I know, no one hitherto has pointed out how debt liquidation defeats itself via deflation' (Fisher, 1933, 350, n.4). Within Fisher's argument, however, we may detect two other cumulative processes that are part of the main feedback. It is better to analyse the two parts of the main feedback separately before recombining them within a unitary framework. The first and crucial feedback between debt and deflation is triggered by firms' widespread over-indebtedness, bringing about a process of forced liquidation of assets. The ensuing generalised deleveraging reduces the amount of deposit currency and the velocity of money circulation deflating consumer prices and further increasing the real value of debt (Fisher, 1933, 342). This chain of events is framed in terms of Fisher's equation of exchanges (Fisher, 1911). In consequence of this causal chain,

> deflation caused by the debt reacts on the debt. Each dollar of debt still unpaid becomes a bigger dollar, and if the over-indebtedness with which we started was great enough, the liquidation of debts cannot keep up with the fall of prices which it causes. In that case, the liquidation defeats itself (Fisher, 1933, 344).

This is explained in terms of what is today called 'herd behaviour':

[29] See, e.g., Krugman (2012), Tropeano and Vercelli (2017), and Vercelli (2017).

> ... the very effect of individuals to lessen their burden of debts increases it, because of the mass effect of the stampede to liquidate ... Then we have the great paradox which I submit, is the chief secret of most, if not all, great depressions: 'The more the debtors pay, the more they owe' (ibidem).

Fisher's detailed analysis of this crucial feedback includes seven main factors, but he emphasises that 'in the great booms and depressions, each of them has played a subordinate role as compared with two dominant factors, namely over-indebtedness to start with and deflation following soon after' (Fisher, 1933, 341).

Fisher's conviction of the prominence of the debt-deflation feedback over the other feedbacks has induced us to examine it in its pure form before recombining it with the others. A second feedback, however, also plays an important role in Fisher's analysis as it establishes a direct link to the real economy. He emphasises that, during a process of debt-deflation the profit rate and the net worth of businesses keep sinking and bring about a growing number of bankruptcies; this leads to a progressive reduction of output, trade, and employment that further deteriorates the net worth of businesses and increases further over-indebtedness. This strengthens the debt-deflation vicious circle.

The third feedback implicit in Fisher's analysis is based on his influential theory of interest rate: the cumulative processes summarised above produce 'complicated disturbances in the rate of interest, in particular, a fall in the nominal, or money, rates and a rise in the real, or commodity, rates of interest' (ibidem). This increases the real value of debt (Fisher, 1933, 343). The ensuing flight to safety has a differential impact on the interest rate of loans according to their perceived risk. Therefore, money interest on safe loans falls while money interest on unsafe loans rises (ibidem). According to the feedback implicit in this analysis, the rise in the real rate of interest brought about by price deflation worsens the net worth of economic units enhancing their distress sale of assets and thus also the process of deflation which further revaluates the real rate of interest. The reduction in the nominal rate of interest determined from the flight to quality is believed to be insufficient to compensate this positive feedback because there is an obvious downward floor limiting the fall of the nominal rate of interest. According to Fisher, the second and third cumulative feedback are triggered by the first one and reinforce its effects. This is not generally true. In the Great Recession (2007–2009) the second mechanism has been active independently of the first mechanism. This implies a crucial shift of emphasis from the deflation of prices to the deflation of the real economy. This change in perspective approaches Fisher's theory of debt-deflation to the Keynesian theory of effective demand. Fisher draws clear policy implications from his theory of debt-deflation. In his opinion the vicious spiral between debts and deflation may 'continue, going deeper … for many years' (Fisher, 1933, 346). In this paper, he anticipates Keynes in emphasising that the market does not succeed to self-regulate if not at the end of a dire economic catastrophe: 'There is then no tendency of the boat to stop tilling until it has capsized. Ultimately, of course, but only after almost universal bankruptcy, the indebtedness must cease to grow greater and begin to grow less' (ibidem). Fisher emphasises that there is a simple and viable alternative to the traditional, classic, policy strategy based on laisser-faire and austerity measures, 'the so-called "natural" way out of a depression that brings about needless and cruel bankruptcy, unemployment and starvation' (ibidem). In principle, '…it is always economically possible to stop or prevent such a depression simply by reflating the price level' (ibidem). In his opinion, Roosevelt's reflation in 1933 is a case in point:

> Those who imagine that Roosevelt's avowed reflation is not the cause of our recovery but that we had 'reached the bottom anyway' are very much mistaken. At any rate, they have given no evidence, so far as I have seen, that we had reached the bottom … Had no 'artificial respiration' been applied, we would soon have seen general bankruptcies of the mortgage guarantee companies, saving banks, life insurance companies, railways, municipalities, and states (ibidem).

In Fisher's opinion, the Great Depression could have been avoided by preventing deflation. Hoover's policy based on orthodox liberalism and austerity policies was thus complicit of the degeneration of the stock-exchange breakdown in 1929 in a Great Depression. His late attempt to promote recovery was pursued too late in a too timid manner:

> recovery was apparently well started by the Federal Reserve open-market purchases, which revived prices and business from May to September 1932. The efforts were not kept up and recovery was stopped by various circumstances, including the political 'campaign of fear' (ibidem).

Summing up, the policy prescriptions that Fisher draws from his theory of debt deflation are crystal clear. We can escape from a deep depression such as that of the 1930s only by a timely and consistent reflation policy. Owing to his theoretical background, he focuses mainly on monetary measures that would avoid a negative rate of change in consumer prices and would establish a moderate rate of inflation capable to devalue the burden of debt. This would thwart by itself the first and third mechanisms in their aggregate version. However, we may observe that any policy measure able to improve the net worth of economic units and to restore their confidence would improve the situation in the light of the second feedback and the disaggregated part of the third mechanism. This includes in principle all the policies meant to increase aggregate demand, in particular real investment. In the second case, the words deflation and reflation would refer to the real part of the economy rather than to its monetary part and fiscal policy would come to the front. From Fisher's strictly monetary point of view, one could praise these measures to increase the velocity of circulation of money.

8.6 On the Optimality of Free-Market General Equilibrium

The alleged optimality properties of the free-market equilibrium position nurtured the persistent appeal exerted by the GE model as well as the pertinacious criticisms against the claims of its advocates. The subsequent evolution of the GE research programme has been largely driven by the evolving dialectic between advocates and critics of its optimality implications. Let us start from the intuitive background of the optimality claims. The protagonists of the Marginalist Revolution were motivated by the conviction that free economic agents choose the preferred available option and that a GE implies that not all agents have a better option available, otherwise they would modify their choices to reach their individual optimum. At first sight, this conclusion seems plausible but, after closer inspection, it appears as potentially misleading. The interaction of maximising individuals within a perfectly competitive free market may produce constraints for individual choices that prevent some agents to reach the position that would be their maximum. This issue was not clear in Jevons (1971) because of his down-top approach proceeding from the individuals to the market, or in Menger (1971) for his literary style that could not easily analyse the quantitative interactions between individual decisions and their complex market feedback. This crucial issue became evident within the model put forward by Walras, as his approach made crystal clear that self-interested agents maximise within the constraints set by interacting markets. The virtual *tâtonnement* introduced in the fourth (1899) edition of his masterpiece manages to sterilise some of these potential constraints. Unfortunately, as we have seen before, this approach jeopardises the applicability of the model to the real world.

PART III

Keynesian Revolution and New Classical Counter-Revolution

9 Keynes on Probability and Complexity

> *Reichenbach:*[1] *The ideal of an absolute truth is . . . a phantom, unrealizable; certainty is a privilege pertaining only to tautologies, namely those propositions which do not convey any knowledge.*
>
> *Suppes:*[2] *Certainty of knowledge – either in the sense of psychological immediacy, in the sense of logical truth, or in the sense of complete precision of measurement – is unachievable.*

John Maynard Keynes is one of the few economists of the twentieth century whose teachings are still perceived as topical, in the substance of his arguments if not in the analytic language utilised. This explains why an immense literature grew, and continues to expand, on his pivot ideas and why many working economists still draw inspiration from his insights. No wonder that the influence of Keynes on current economic ideas goes much beyond that of source of epigraphs as maintained by some critics.[3] The main reasons for his persistent influence may be found in two factors mutually correlated. The first reason is his pregnant analysis of the Great Depression that prompted the writing of his masterpiece. Whenever a new major crisis emerges, Keynes's teachings are revived. The crisis of 2008–2009 is a case in point. However, this is not to say that Keynes's authority may be restricted to the explanation and control of major crises as many mainstream economists would be prepared to recognise. Keynes's ambition was that of working out a general theory able to analyse the complex dynamics of a capitalist economy, including not only major crises but also business cycles and growth. The claim that Keynes's theory is more general than

[1] Reichenbach (1937, 90). [2] Suppes (1984, 10).
[3] Lucas (1981, 278) expected that 'economists who find Keynes's style congenial will continue to use his writings as Dennis Robertson did Lewis Carroll's, but surely there is more to the cumulative nature of economics than this!'

classical theory reposes on the belief that it applies not only to periods of tranquillity but also to periods of turmoil. This thesis has been rejected by mainstream economists since long, even by some of those who define themselves Keynesian. To be Keynesian today, according to 'medianomics' (the common wisdom of mass media) is not much more than to recognise that real markets are liable to failures that require policy interventions to prevent them or mitigate their effects. However, there is a second reason that explains the topicality of Keynes: his attempt of building a theory that recognises in a constructive way the methodological implications of the growing complexity of economic phenomena. Several followers of Keynes have in common the effort of introducing one or more complex features neglected or played down by classical macroeconomists. However, in the recent macroeconomic consensus, the residual resistance of mainstream Keynesian economists to the vision of contemporary classical economists does not go much beyond the focus on specific market failures and their implications. It is my conviction that the contributions of Keynes to the epistemology of complexity underlying his economics (and his theory of probability) go much beyond what is recognised by mainstream Keynesians. This is a part of Keynesian thought that has been so far only partially explored but is likely to be a robust reason of his persisting topicality. To understand the causes and consequences of the Keynesian Revolution we have to distinguish the evolution of his epistemic revolution from his economic revolution. In Keynes, the two revolutions are organically linked so that we can understand their ultimate motivations, their controversial success, and unavoidable limits only by analysing the second in the light of the first. Both followers and critics too often decoupled, though in different ways, the epistemic and economic sides of Keynes's scientific vision. In this chapter, I focus on the epistemic revolution of Keynes that he elaborated during the preparation and writing of the *Treatise on Probability* (1921; henceforth TP). In the next chapter, I will focus on the economic revolution implemented in the *General Theory* (1936) in the light of the epistemic revolution that he had started before. Readers and reviewers have usually considered the TP mainly from the point of view of the history of probability. Looking at it from this narrow point of view, most reviewers praised or criticised Keynes as an original initiator of the logical (or logistic) approach to the foundations of probability theory. Though pursuing this approach would not be devoid of interest, it would shift the focus of this book beyond its planned scope. I adopt a different – more limited – point of view. I appraise the TP as an early significant contribution to the foundations of complexity science, which foreshadowed the more recent interdisciplinary advances introduced since the early 1970s. Looking at the TP from this point of view, we can better appreciate its sweeping epistemological originality while playing down the technical shortcomings underlined by the specialists. On the other hand, the way in which Keynes pursued the logicist approach has a few misleading implications for the vision of science he advocated. In particular, the alleged normative implications of this approach induced him to transfer a sort of logical necessity into his own epistemological context as a hallmark of 'objective' rationality fully independent of psychology. After the publication of the TP, in his economic contributions culminating in the GT, Keynes progressively broadened his concept of rationality and attenuated his anti-psychologism. In addition, he elaborated his epistemology of complexity in a more constructive direction. To clarify this narrative, I sketch a preliminary account of the epistemic revolution that Keynes felt motivated to initiate while working on probability theory (Section 9.1). This revolution pointed toward a direction radically divergent from that of the logical positivism of Russell, later cultivated within the Vienna Circle (Section 9.2). In Section 9.3, I discuss the normative implications of the logicist approach pursued by Keynes. This approach leads Keynes to sketch new concepts that are relevant for applied science such as probabilistic causality (Section 9.5) and weight of argument (Section 9.6). In the concluding section, I introduce a preliminary assessment of the nexus between Keynes's theory of probability and his early economic contributions.

9.1 Keynes's Antireductionism

It is arguable that Keynes was the first scholar to suggest a full-fledged theory of logical probability in his TP, which he conceived and drafted mainly in the period 1907–1911 but published only in 1921.[4] In his late autobiographical essay 'My early beliefs' (Keynes, 1938 in CW10,

[4] In the introduction to TP, Keynes mentions Leibniz as the predecessor of a logistic theory of probability. We could also mention De Morgan and Boole as more recent predecessors but none of their contributions is comparable to the depth and breadth of the TP (see Galavotti, 2005, 136–144).

435), he explains how influential on his personal formation was the book by the philosopher of Cambridge Moore *Principia Ethica* published in 1903. However, he could not accept his moral conclusions because Moore 'had one foot on the threshold of the new heaven [the attitude towards oneself], but the other foot in Sidgwick and the Benthamite calculus and the general rules of correct behaviour' (ibid., 436). Keynes rejected utilitarianism confined to the narrow principle that the best course of action is the one with the highest expected (or most probable) utility, because we do not have the knowledge needed in order to calculate it and thus we cannot know all the future effects of an action (see Marchionatti, 2010, 2). Keynes explained that the conviction that this wrong moral theory reposed on a defective theory of probability was 'an important contributory cause to [his] spending all the leisure of many years on the study of that subject' (Keynes ibid., 445). Keynes wanted to show that the standard calculus of probability works only under strict conditions and cannot thus provide sound foundations to general rules of conduct. This motivated the research programme underlying the TP that he extended to induction, statistical inference, and the positivist method of empirical sciences. Keynes never retracted from his rejection of utilitarianism, Positivism, and their underlying reductionism.

Keynes pursued a more sophisticated research programme considering probability a logical relation between propositions expressing the premises of an argument (specifying the relevant reasons, grounds, and evidence) and the proposition expressing its reasonable conclusions. Differently from classical logic, which provides the principles for rational demonstrative arguments, probability theory deals with the principles of non-demonstrative arguments. The novel focus of Keynes on propositions rather than on events was influenced by the 'linguistic turn' advocated in the same years by Russell and his Cambridge coauthors and pupils as foundation of 'analytic philosophy'.[5] This

[5] The expression 'linguistic turn' started to be used in the 1950s and was popularised by Rorty (1967). He used the term in a stricter sense than that adopted in this book following Dummet (1993). According to the narrow definition, the 'linguist turn' starts with the publication of Wittgenstein's Tractatus (1921) and characterises the first phase of logical positivism. In my opinion, it is correct to distinguish the first phase of the linguistic turn, initiated by Frege (1959 [1884]) and extending until Wittgenstein's Tractatus (1921), from a second more articulated phase starting in the 1920s and extending until the early 1960s. However, we cannot ignore that the first phase prepared the second

reorientation of epistemology initiated by Frege maintained that 'it is only in the context of a proposition that words have a meaning' (Frege, 1959 [1884] §62, 73e). As Dummett (1993, 5) emphasised, from its very beginning this linguistic turn was characterised by a marked anti-psychologism:

> The accessibility of thoughts will ... reside in their capacity for linguistic expression, and their objectivity and independence from inner mental processes in the common practice of speaking the language, governed by agreement among the linguistic community on standards of correct use and on criteria for the truth of statements

In other words, we can grasp the meaning of words only by studying the logical structure between and within propositions. According to Russell, we may have access to the realm of thoughts only through the language by submitting it to a rigorous logic analysis that is altogether independent of the subjective features of thoughts and language. Russell and his coauthors built on the logical implications of the linguistic turn so conceived to provide rigorous logical foundations to mathematics. Keynes was influenced to some extent by Russell's linguistic approach, its anti-psychologism, and the emphasis on axiomatisation.[6] However, notwithstanding these significant analogies, Keynes's research programme proceeded in a direction radically divergent from that of Russell and his coauthors and pupils. Moore, Whitehead, Russell, and Wittgenstein prepared the terrain for the emergence of the first phase of logical positivism, while Keynes started from their initial base camp an anti-positivist research path that foreshadowed the emergence of a full-fledged anti-reductionist vision of science. For Keynes, probability theory was not so much a specific field of scholarship – as it was for Laplace, Venn, Reichenbach, and the other earlier interpreters of probability – but the field that had to

one (Losonsky, 2006). Historians of philosophy identified a previous linguistic turn implemented by Locke. More recently, other scholars mentioned the linguistic turn of Kuhn inspiring the post-positivist stream of history of science. We can interpret linguistic turns as periodic returns to the original meaning of rationality (*logos*) elaborated by Greek philosophy that was strictly connected to the analysis of language and its logical structure (see Chapter 1).

6 The axiomatisation of probability theory suggested by Keynes was praised by contemporary scholars including Russell but was soon obscured by that of Kolmogorov (2018 [1933]) that provided the standard to which most scholars adhered.

provide the general foundations of rational knowledge and action. In Keynes's view, probability is the hypothesis upon which it is reasonable to act in conditions of limited knowledge (TP, CW VIII, 339; Carabelli, 14). Since, according to Keynes, limited knowledge characterises the usual condition of human beings, in most circumstances we must rely on probability theory to guide our understanding and our conduct. However, probability theory should not be reduced to probability calculus. On the contrary, one of its crucial goals should be exactly that of instructing us when and how we can use probability calculus. He concluded that the scope of the safe application of probability calculus is very limited, much narrower than argued by previous probability theorists. Moreover, he argued that the attempt of applying it outside its safe boundaries is dangerous and misleading. Most readers and interpreters failed to see the general implications of the TP and kept their comments within the boundaries of two different, though related, points of view. The first reviewers and readers discussed the TP mainly from the point of view of the epistemological interpretation of probability and its consequences for the foundations of probability calculus.[7] Only since the 1970 the economists started to discuss the TP as a crucial key to understand Keynes's economic theory[8]. I will here discuss, instead, the TP from the point of view of the vision of science there outlined, a vision that Keynes applied and further refined in his economic works. I will argue that the vision of science outlined in the TP and developed in the GT started an anti-reductionist research programme in probability theory and in economics that will later merge with other important contributions, following different but related paths, in the interdisciplinary science of complexity.[9]

To an economist of the twenty-first century it may seem odd that Keynes dedicated the initial stage of his research to the epistemology of probability while he was already contributing to the analysis and solution of contemporary economic problems. However, he followed

[7] In his detailed biography of Keynes, Harrod (1951) focuses on this aspect of the TP without discussing in any depth the links with Keynes's economic contributions.

[8] See, for example, Carabelli (1988) and Vercelli (1991 [1987]).

[9] Among these paths, I signal the qualitative theory of dynamical systems and that of 'deterministic chaos' initiated in the early 1980s (Poincaré, 1882) but developed in a systematic way only more than half a century later.

the established tradition of studying the history of science and its epistemology as a propaedeutic step to personal research in science. This tradition was especially influential within eighteenth- and nineteenth-century British Empiricism: Smith, Whewell, John Stuart Mill, Jevons, and Edgeworth are eminent examples. We might add Keynes's father Neville, a strict collaborator of Marshall on economic issues, who wrote a successful essay on the epistemology of economics. This tradition of thought understood the importance of epistemology and history of science as fertilisers of high-level critical research, also because the division of labour within economic research was still consistent with a sound global view of the discipline and its epistemological and practical scope. Keynes continued this tradition with great profit. To understand the genesis of the TP, its goals and its significance, we must focus first on the period 1906–1911 when Keynes dedicated himself full time to this task (Harrod, 1951). His admiration for Moore, and his frequentation of Johnson, Whitehead, Russell, and Wittgenstein within the effervescent cultural life of Cambridge at the beginning of the century, exposed him to the emerging research programme of analytic philosophy shared in different variants by the most brilliant young philosophers. One strong initial motivation of Russell and his coauthors was the desire of debunking the British stream of idealist philosophy, which at the turn of the century was still particularly influential in England, working out a radical form of atomistic realism based on logical foundations.[10] To this end, Russell published *Principles of Mathematics* in 1903, an early manifesto of his influential analytic philosophy that aimed to provide logical foundations to the whole of mathematics.[11] To improve and generalise his results, he then worked with his former teacher Whitehead to publish the ambitious *Principia Mathematica* in three volumes (2010, 2012, and 2013). The introduction of this influential masterpiece emphasised three main aims: (1) to provide logical foundations to mathematics minimising

[10] As Klement (2020, 5) points out, 'In 1959, Russell himself dated his first acceptance of logical atomism to the years 1899–1900, when he and G.E. Moore rejected the main tenets of the dominant School of philosophy in Britain at the time (to which both had previously been adherents), the tradition of neo-Hegelian Idealism exemplified in works of Bradley and McTaggart, and adopted instead a fairly strong form of realism.'

[11] One of the most famous items of its contents is the formulation and early discussion of the Russell paradox.

the number of primitive notions, axioms, and inference rules; (2) to express mathematical propositions in rigorous symbolic logic; (3) to solve the paradoxes that plagued logic and set theory at the turn of the twentieth century, like the so-called Russell paradox. The impact of this book on logic, mathematics and analytic philosophy was profound and went much beyond Cambridge. This fervour of original and passionate thinking prompted Keynes to start a kindred research programme that in his intentions was complementary to that of Russell and his coauthors but represented in his treatment a radical critical deviation from their main theses. As for the object, while Russell and Whitehead focused on the logical foundations of the demonstrative arguments of mathematics, Keynes focused on the logical foundations of the non-demonstrative arguments of probability: 'If logic investigates the general principles of valid thought, the study of arguments, to which it is rational to attach some weight, is as much a part of it' (TP, 3). The rules of the game of the two research programmes looked similar as in both cases the logical foundations focused on propositions and sought to find the minimum set of axioms that allowed the derivation of the propositions covering the entire field under investigation. Some reviewers and later commentators were misled by these analogies to assert that also the philosophical approach was similar. However, the philosophical assumptions, the contents of the arguments, their results, and the consequences on scientific practice were radically divergent. We will see in the next section how the outcome of the two research paths branched in deeply different epistemological directions.

9.2 Reductionism and Complexity in Probability Theory

Keynes was not the first anti-reductionist economist. Limiting myself to the British tradition in the century before Keynes's birth, I can mention the masterpieces of Smith, Malthus, Marx, and Marshall as particularly significant examples of a complex vision of economic theory rejecting simplistic reductionism. However, we find in Keynes the first systematic criticism of reductionism leading to a bold attempt to find a way to investigate the methodological and policy implications of the growing complexity of economic reality. An in-depth awareness of complexity and its implications is the hallmark of Keynes's view in epistemology, probability theory, and economics. The awareness of the complexity of the object under investigation does not require a complicated theory but only well-targeted simplifications. In the constructive part of both the TP and the GT, Keynes resorted to simplifications not less drastic than those of the classical scholars in probability theory and economics, but he was always keen to evaluate whether the adopted simplifications were fit for the issue under investigation. This epistemological orientation, adopted already in the first decade of the century, motivated the young Keynes to undertake a research programme diverging from that of the Cambridge philosophers with whom he was actively interacting. In this period, the research path pursued by Russell, his coauthors, and pupils – in particular Wittgenstein who was writing under his supervision the famous *Tractatus* (Wittgenstein, 1921) – was a radically reductionist research programme often called logical atomism.[12] According to the usual understanding, reductionism is a research strategy that aims at systematically reducing complex objects to the elementary constituent parts to make them more easily amenable to mathematical and statistical analysis. Atomism is one of the classical reductionist research strategies that assumed varied forms in different research areas. The original appeal of this reductionist approach may be related to Russell's drastic rejection of the idealist philosophy and its pivot concept of an all-encompassing organic whole. Russell perceived the idealist holism as an obstacle to a rigorous analysis of philosophical and scientific issues. The logical atomism of Russell greatly influenced Wittgenstein's *Tractatus* that inspired the first stage of logical positivism, as pursued by important exponents of the Vienna Circle – such as Carnap, Hempel, and Ayer – extending the tradition of the early twentieth-century analytic philosophy much beyond Cambridge.[13] Keynes, on the contrary, rejected Russell's logical atomism and started to explore an untrodden epistemic territory that could find scanty contemporary interlocutors. Keynes maintained that, apart from specific exceptions that are very rare in probability arguments and economics, the world is not simple and cannot be reduced to mock simplicity without incurring fundamental fallacies and mistakes. Of course, Russell – as all wise reductionists – did not deny the ubiquitous existence of significant

[12] See in particular Russell (1956 [1924]).

[13] The name 'analytic philosophy', and the broad definition of its contents, drew inspiration from what Russell called 'analytic method'.

complexity in epistemic and practical issues. Nevertheless he was convinced that it is always possible and desirable to transform a complex system into a simpler equivalent system starting from its constituent parts: 'I confess it seems obvious to me (as it did Leibniz) that what is complex must be composed of simples, though the number of constituents may be infinite' (Russell, 1956 [1924]). Keynes believed, on the contrary, that in many relevant cases the reduction of a system to its constituent parts is in principle impossible. Keynes was one of the first scholars who reflected in depth on the peculiarities of complex systems and their epistemic and practical implications. This is not to deny that Keynes often adopted bold procedures of simplification in theory of probability and economics to streamline the object of analysis or the method to analyse it. The point of his critical anti-reductionism is that the adoption of a procedure or reduction must be properly justified to assure that the crucial issue investigated is not implicitly eliminated or distorted. Keynes discussed at length the most significant cases of misleading reductionism. First, whenever a system is organic, it is characterised by non-linear, not homogeneous, interactions between the parts, and so we cannot reconstruct the behaviour of the whole system just by summing up the behaviour of its parts. The organic nature of a system, as investigated by Keynes, is an empirical issue that should not be confused with the metaphysical organicism of idealist philosophers against which Moore and Russell reacted.[14] In many cases studied by both natural and social sciences, the empirical evidence shows that the 'whole is more than the sum of the parts' because the complex organic interdependence among the parts produces emergent properties that one could not detect in the parts. Whenever the problem under investigation refers to the emergent qualities of an organic system, an atomist strategy would be unable to provide a sound investigation of the problem. According to Keynes,

[14] The organicism of the young Keynes was influenced by Moore. In both cases, we should not confuse the idealistic organicism that was heavily dependent on metaphysical assumptions from the evidence-based organicism of Keynes and Moore influenced by biology. According to Moore, who had previously adhered to British idealism, idealist philosophers asserted that organic wholes have three properties: (1) the parts are related to one another and to the whole as means to ends, (2) the parts have no significance apart from the whole, (3) the whole has a value which is greater than the value of the sum of the parts. In *Principia Ethica* Moore rejected the first two metaphysical properties and endorsed the third (see Marchionatti, 2010, 5 n.7). Differently from the first two properties, the third one is common in natural sciences such as biology.

this is the usual case encountered in applied probability theory: 'A degree of probability is not composed of some homogeneous material and is not apparently divisible into parts of like character with one another' (TP, 32). Another typical reductionist strategy is the homogenisation of heterogeneous magnitudes by measuring them in a common unity of measure. This is an issue that Keynes discussed at the beginning of both TP (Chapters 3–5) and GT (Chapter 4) in the conviction that the philosophy of measure had a great foundational importance for what followed. The crucial point is that often we cannot compare complex magnitudes, even in a mere ordinal sense, as many of them are intrinsically incommensurable because they are not reducible to a common quantitative unit or qualitative order. Keynes argued that this is the case of logical probabilities: 'Some probabilities are not comparable in respect of more and less, because there exists more than one path, so to speak, between proof and disproof, between certainty and impossibility' (TP, 35).

The success of probability theory was strictly related to the apparent magic of the calculus of probability that seems to transform our ignorance into reliable knowledge. Keynes does not concede much to such a presumption. In his opinion, only in a very special type of case, probabilities are susceptible to numerical cardinal measures that are unambiguously comparable. In most cases, 'no comparison of magnitude is possible; . . . we can say, nevertheless, of some pairs of relations of probability that one is greater and the other less, although it is not possible to measure the difference between them' (TP, 36). The limited comparability of probabilities and the extension of their incommensurability depend on the heterogeneity of their underlying nomological and existential conditions. The fact that, according to Keynes, the calculus of probability is safely applicable under particular conditions dear to reductionists – such as atomism and limited variability – has misled a few scholars to interpret Keynes's probability theory as based on reductionist assumptions similar to those of Russell. However, the focus of Keynes, differently from that of logical atomism, was on the use of probability and its limits in all the cases in which the reductionist assumptions are not applicable.

9.3 Normativity in Formal Logic and Probability Theory

While Keynes's vision of complexity sketched in the TP is quite compelling, his interpretation of probability theory remains somewhat open ended. His definition of probability is a good starting point for a critical investigation of the complex conceptual problems of probability theory. Given two sets of propositions, the set h of premises and the set x of conclusions, a probabilistic argument x/h is, according to Keynes, a logical relation that permits one to infer x from h with a certain degree of rational belief p that defines the probability of x given h. This definition raises a host of problems. The most important point is the boundary between subjective and objective nature of probability, and the related issue of the normative weight of Keynes's logical probabilities. This point has been particularly controversial in the past and has crucial implications for the issue of pluralism. Keynes (TP, 3) points out that the judgment of probability is relative to the corpus of knowledge of the judge (reasons, grounds, and evidence):

> The Theory of Probability is logical, therefore, because it is concerned with the degree of belief which it is rational to entertain in given conditions, and not merely with the actual beliefs of particular individuals, which may or may not be rational . . . What particular propositions we select as the premises of our argument naturally depends on subjective factors peculiar to ourselves; but the relations, in which other propositions stand to these, and which entitle us to probable beliefs, are objective and logical.

This excerpt, and similar others that qualify Keynes's logical approach, may seem to suggest that the probability relation has, or should have, a normative force comparable to that of classical logic, where, in the standard circumstances, only one conclusion would be consistent with rationality. In classical logic, the rational conclusion is the only one that avoids logical contradictions. In this case, the normative weight of the argument is overwhelming. In the case of probability, instead, the judgement of probability is relative to a series of premises, and we cannot rely on a simple and unquestionable criterion of rationality to discriminate the rational from the irrational (or less rational) probabilistic arguments. In this case, the judgement of probability must take account of all the relevant dimensions of rationality (not only logical consistency but also theoretical and evidential conditions). In addition, as Ramsey (1922) emphasised in his critical review of the TP, under a given set of axioms, a psychological approach may be based on the logical coherence of beliefs, the same criterion of rationality that characterises formal logic. In the obituary written just after the premature death of Ramsey, Keynes (1933, 339) recognised that he had succeeded

in showing that the calculus of probability simply amounts to a set of rules for ensuring that the system of degrees of belief which we hold shall be a *consistent* system. Thus, the calculus of probability belongs to formal logic.

As is clear from this passage, Ramsey's argument attenuated Keynes's hostility against subjective probabilities previously perceived as not amenable to the rules of logic and rationality. This acknowledgment by Keynes, however, should not be interpreted as a change of perspective on probability theory from his earlier logicist view to a subjectivist view similar to that of Ramsey. Nevertheless, this admission may have contributed to Keynes's greater attention for individual and social psychology that emerges in his economic works, in particular in a few well-known passages of the GT inspired by his first-hand knowledge of individual behaviour in financial markets. The evolution of his vision of probability was mainly motivated by his systematic application of probabilistic arguments to a particular subject matter, economics and finance, but the shift of focus is justified by a more balanced view of the nexus between psychology and rationality. Therefore, this admission does not imply that Keynes embraced a subjective interpretation of probability similar to that suggested by Ramsey and then developed, along similar lines, by de Finetti and Savage. After the passage quoted above, Keynes reiterated his dissatisfaction for a merely subjectivist theory of probability, even in the sophisticated version of Ramsey:

in attempting to distinguish 'rational' degrees of belief from beliefs in general he was not yet … quite successful. It is not getting to the bottom of the principle of induction merely to say that it is a useful mental habit (ibidem).

In other words, according to Keynes, the link between subjective beliefs and rationality cannot be reduced to a mere issue of logical consistency, and its practical justification cannot be reduced to its utility. We must take account of the other crucial dimensions of epistemic and practical rationality. Some of these dimensions, particularly the evidence possessed by a certain subject, are not independent of subjective interpretations but the role of the subject is not merely amenable to psychology or deductive consistency from basic axioms. Therefore, we should not assimilate that Keynes's scientific vision is not exclusively based on one of the dimensions of rationality (e.g. Rationalism based on epistemic reason, or Empiricism based on evidence). Keynes has always struggled to take account of all the relevant dimensions of rationality.[15] In particular, Keynes observes, 'the fact that we ultimately depend upon an intuition need not lead us to suppose that our conclusions have, therefore, no basis in reason, or that they are as subjective in validity as they are in origin' (TP 70).

Unfortunately, pressed by the urgency of a sequence of grave collective problems in which he was directly involved, Keynes did not find the time to revise his theory of probability taking full account, as he wished, of the complex nexus between beliefs and rationality. Therefore, the only thing I can do in this chapter is to focus on some fragments of TP that hint to a more articulated approach that he further explored in economics, in particular his passages on probabilistic causality and on the weight of argument. In both cases, I do not pretend to know what Keynes wanted to say but I will provide some hints for a rational reconstruction of these concepts that seems to me consistent with his vision of probability theory and economics as complex scientific disciplines.

9.4 Keynes Causality and Macroeconomic Methodology

Keynes dedicated to the weight of argument one of its first foundational chapters and inserted his 'Note on probabilistic causality' in the final part of the TP[16]. My investigation of these two intriguing Keynesian concepts inverts the original order because the Note on causality is particularly illuminating on Keynes's vision of science, while the chapter on the weight of argument, if taken as self-contained, may be confusing and sometimes misleading.

In the early 1970s, the attention turned towards probabilistic causality in both natural sciences and philosophy. Economics and econometrics were not exceptions. A few scholars pointed out that Keynes had discussed this issue in some detail in the TP (1921, *CW*

15 'There is little likelihood of our discovering a method of recognising particular probabilities, without any assistance whatever from intuition or direct judgment' (ibid).

16 The Note on causality is the Note (ii) to part III of the TP (pp. 316–319) and has the title 'On the Use of the Term Cause'.

VIII), where he worked out the foundations of his epistemological point of view. We find there an interesting outline of a theory of probabilistic causality that in many respects anticipates the most influential recent theories.[17] The interpreters of Keynesian thought have often underplayed the originality of Keynes's causality conception in his economic works, interpreting it as a version of deterministic causality close to that of Simon and Wold. (Early exceptions were Carabelli (1988) and Vercelli (1991 [1987].) However, Keynes explicitly judged deterministic causality not very useful for social sciences (including macroeconomics) in which

> One is led, almost inevitably, to use 'cause' more widely than 'sufficient cause' or than 'necessary cause', because, the necessary causation of particulars by particulars being rarely apparent to us, the strict sense of the term has little utility (Keynes, 1921, *CW* VIII, 306).

Therefore, Keynes felt the need of a much more comprehensive concept of causality:

> What is required is a concept of 'probable cause', where there is no implication of necessity and where the antecedents will sometimes lead to particular consequents and sometimes will not (ibidem, 306).

Keynes was fully aware of the novelty and difficulties of this task, because 'a partial or possible cause involves ideas which are still obscure' (ibidem, 182). The main obstacles arise from the conviction, then still rarely disputed, that the laws of nature are deterministic. Keynes manages to get round the obstacle by introducing a crucial distinction between '*causa essendi*', namely the ontological cause traditionally conceived as deterministic, and '*causa cognoscendi*', namely the epistemic cause that he conceives as probabilistic. He puts the main emphasis on the second concept, focusing on whether knowledge of one event may throw light of any kind upon the likelihood of another (Keynes, 1921, CW VIII, 308).

According to Keynes, a deterministic cause would make sense only if one had a complete knowledge of a certain set of phenomena to be able to define a necessary or sufficient cause. It is doubtful that this is possible in the real world. It would require the knowledge of the nomological conditions K (expressed by proposition k), both formal

[17] See, for example, Suppes (1970) and Granger (1969).

and theoretical, and the existential conditions, both general L (expressed by proposition l) and hypothetical H (expressed by proposition h), which make the causal influence of an event on another event sufficient and/or necessary condition for its occurrence. Keynes clarified the nexus between ontological and epistemic causality through a sequence of formal definitions of causality, definitions that progressively relax the hypothesis of complete relevant knowledge. The starting point is the definition of sufficient cause:

Event B is a sufficient cause of event A in conditions kl, iff:

(i) proposition b describes an event B prior to event A, described by proposition a
(ii) $a/bkl = 1$ and $a/kl \neq 1$.

This definition is progressively restricted in relation to hypothetical existential knowledge, expressed by proposition h, leading to the definition of a possible cause under conditions l. The final, and weakest, definition is that of *causa cognoscendi*, which Keynes conceives as an epistemic relation defined as follows:

> Event B, described by proposition b, is a causa cognoscendi of event A, described by proposition a, relative to the background knowledge hkl, iff $a/bhkl \neq a/hkl$.

Keynes does not develop further his seminal investigation of probabilistic causality because the final version of his theory of epistemic causality overlaps with his theory of probability.[18] Keynes causality anticipates the recent theories of probabilistic causality such as those of Suppes (1970) in philosophy and Granger (1969) in econometrics (see Vercelli, 2001). However, behind the formal analogies, we may detect profound epistemological divergences between these theories. In particular, while Keynes insists that it is necessary to relate any causal statement to a well-defined theoretical background, the supporters of Granger causality claim that their conception of causality is superior to the alternative theories precisely because of its alleged independence of specific theoretical hypotheses. This different view on causality impinges on the lively debate between New classical economists and different streams of Keynesian economists (see Chapters 10 and 11).

[18] See the appendix to Vercelli (1991 [1987]).

9.5 The Weight of Argument

We may understand better the nexus between Keynes's probabilistic causality and macroeconomics by referring to another original contribution of Keynes to probability theory: the concept of weight of argument defined as 'the degree of completeness of the information upon which a probability is based' (Keynes, 1921, *CW* VIII, 345). Given two sets of propositions, the set h of assumptions and the set x of conclusions, a probabilistic argument x/h is, according to Keynes, a logical relation the knowledge of which permits to infer x from h with a certain degree of rational belief p that defines the probability of x given h. In his view, the epistemic and pragmatic relevance of an argument depends not only on the probability of its conclusions but also on its 'weight' (TP, 72–85 and 345–349; GT, 148 and 240). The concept of 'weight of argument' has been interpreted in different ways. We find in the TP different definitions that, at least at first sight, do not seem altogether congruent:

(i) According to a first definition often repeated in Chapter 6 of the TP headed 'The weight of argument', 'one argument has more weight than another if it is based upon a greater amount of relevant evidence' (TP, 84). Keynes dubs this specific definition 'weight of evidence'.
(ii) According to an alternative definition that may be found in the same chapter, the weight of argument 'turns upon a balance ... between the absolute amounts of relevant knowledge and of relevant ignorance respectively' (TP, 77).
(iii) Finally, in chapter 26 the weight of argument is defined as 'the degree of completeness of the information upon which a probability is based' (TP, 345).

Each of these definitions aims to measure the degree of knowledge relevant for probability; however, the first measure is presented as absolute, the second measure is a balance between relevant knowledge and relevant ignorance, the third measure is the degree of completeness of relevant information. In my opinion, contrary to the first-sight appearance, the three definitions can be understood as fairly consistent (see Vercelli, 2010). Most interpreters picked up the 'absolute' definition identifying the weight of argument simply with the amount of relevant available knowledge K:

$$V(x/h) = K. \tag{9.1}$$

The choice of this definition may depend on the fact that it appears at the very beginning of Chapter 6 on the weight of argument and on the frequency of its explicit and implicit references to it in the TP. This measure, however, is inconsistent with Keynes's crucial assertion that additional evidence may increase the relevant knowledge without increasing the weight of argument: 'the new datum strengthens or weakens the argument, although there is no basis for an estimate how much stronger or weaker the new argument is than the old' (TP, 34). This observation clarifies the rationale for the second definition. Unfortunately, this important clarification may be found not in Chapter 6 on the weight of argument, but in Chapter 3 on the fundamental ideas of the TP, before having explicitly introduced the concept of weight of argument, which may explain why Keynes's assertion has been often neglected. We notice that, according to Keynes, the new evidence may reduce the weight of argument as it may alert the awareness of the agent that the gap between relevant knowledge and complete relevant knowledge is bigger than believed before. Consistently with the preceding considerations and the second definition of weight of argument, Runde (1990) suggests the following measure:

$$V(x/h) = K/I. \tag{9.2}$$

This simple ratio between relevant knowledge and relevant ignorance takes account of the exigency, emphasised by Keynes in his second definition, of taking in due account relevant ignorance. Differently from the first one, this measure implies that the weight of argument increases only if the relevant knowledge increases more than the relevant ignorance. Also, this measure, however, is not fully satisfactory because it would be absurd and hardly operational for values of the relevant ignorance tending to zero. We may overcome these shortcomings by introducing the following measure that descends directly from the third definition:

$$V(x/h) = K/(K + I) \tag{9.3}$$

In this case, the weight of argument increases only if the relevant ignorance I diminishes. This measure also has the advantage of being clearly defined in the extreme case of complete relevant knowledge

(V (x/h) = 1). In this case, accepting the usual convention K + I = 1, we could say that the more the relevant ignorance I increases approaching 1 and K diminishes approaching 0, the more the awareness of ignorance of the decision-maker increases. This is important because I believe, following Socrates, that the degree of awareness of ignorance of the decision-makers is a variable that is likely to exert a great influence on their behaviour (see Chapter 13). The range of values from zero to one of the weight of argument corresponds to that of the usual measures of uncertainty, such as probability, and conforms to the range of values that Keynes too seems to have in mind (see TP, 348). In what follows, therefore, I will define and measure the weight of argument as in relation (9.3). It is interesting to observe that this last definition may be interpreted as a second-order measure of uncertainty, since knowledge and ignorance refer to first-order measures of uncertainty. It is thus possible to interpret Keynes' measure of weight of argument as a measure of the degree of non-additivity of the probabilities involved.[19]

In Chapter 6, Keynes explored under which conditions we can compare the weights of two arguments, concluding that this is possible 'only in a restricted class of cases' (Keynes, 1921, 78). An in-depth analysis of these few exceptions would easily raise further problems not considered by Keynes. All the examples discussed in Chapter 6 refer only to one specific kind of premises of the arguments: the propositions referring to the evidence available. However, as the case of probabilistic causality confirms, we have to distinguish – within the

[19] A simple measure of this kind has been suggested by Dow and Werlang (1992a, b):

$$c(P, A) = 1 - P(A) - P(Ac), \tag{9.4}$$

where A is an event and Ac is its complement. According to Dow and Werlang the (9.4) defines a possible measure of (second-order) uncertainty aversion but it may also be interpreted as awareness of (second-order) uncertainty on the part of the decision-maker. It is evident the strict analogy between (9.4) and (9.3). The unity stands for a complete second-order knowledge while c(P,A) is an index of second-order ignorance. By applying to (9.4) the notation utilised in (9.3) and the normalisation of note 3 we obtain that the weight of argument is the complement to one of c(P,A), that we have interpreted as an index of ignorance awareness:

$$c(P, A) = 1 - P(A) - P(Ac) = 1 - K = I/(K + I) = 1 - V(x/h). \tag{9.5}$$

Therefore, the higher the awareness of ignorance, the lower is the weight of argument.

premises of an argument – the nomologic conditions N (expressed by propositions n), both formal and theoretical, and the existential conditions, both general L (expressed by propositions l) and hypothetical conditions H (expressed by propositions h). The weight of argument depends thus not only on the evidence (that is part of the existential conditions) but also by the theory (underlying the nomological conditions both formal and theoretical) and the specific hypothetical conditions. The weight of argument may thus change also because the theory or hypothetical conditions change. Notwithstanding the title of Chapter 6 ('The Weight of Arguments') Keynes deals there almost exclusively with what he calls more correctly in the text of the chapter *weight of evidence*. In what follows, I will use the concept of weight of argument in the more general case here outlined. Keynes was right when he asserted that 'in deciding on a course of action, it seems plausible to suppose that we ought to take account of the weight as well as the probability of different expectations.' (1921). However, these normative implications are relative to the robustness of our measure of weight of argument. Unfortunately, this research programme is still in its infancy. This does not prevent, in the meantime, a use of the concept of weight of argument as a second-order subjective measure of uncertainty. We may interpret it as a subjective measure that expresses to what extent the assumptions of probability theory on which first-order probabilities rely are adequate for the complexity of the problem under investigation. When the relevant complexity is high, the weight of the probabilistic argument is low. High values of the weight of argument mark the cases under which probability theory is to some extent reliable. When the weight of argument is equal to one, we are in a sort of Olympian world characterised by determinism and full 'rationality' where the agents have a complete knowledge of all the systematic causes, and the residual uncertainty is nil. This extreme point of view has been abandoned long ago in macroeconomics. However, in the 1970s New Classical Economics made fashionable a similar point of view characterised by rational expectations implying that the residual uncertainty is restricted to stochastic factors. In this case, the world to which the theory is applied is assumed to be closed and thus not subject to unexpected structural changes. In this world, the agents are fully 'rational', as they cannot learn more than they already know from empirical evidence, apart from the necessary updating of the values assumed by the systematic factors. In the opposite case, when the weight of argument is zero, the uncertainty is radical and produces negative externalities that can be reduced only through appropriate policy instruments, such as those advocated by Keynes himself. When the weight of argument is intermediate between one and zero, the uncertainty is strong and can be dealt with only by adopting different decision rules considering the hypothesis that the world is open (see Chapter 13).

9.6 Keynes's Probabilistic Vision of Complexity: Early Applications to Economics

In the first decade of the century, Keynes 'complained' because the job in the Indian Office left him too much free time that, however, he wisely used to write his academic dissertation on the theory of probability. By the end of this intense and passionate endeavour, Keynes had reached a clear vision of the approach required to study and solve complex problems of human conduct, including a few awkward problems of economic policy that he had the occasion of studying in some detail. In the second decade of the century, as representative of the British Treasury, Keynes was absorbed by a host of policy problems of great consequence and complexity. Therefore, he did not find the time to finalise and publish his *Treatise* but could test the methodological approach explored there to solve complex problems: first, the problems originated by the Indian currency and finance (1913), then the management of the war and the treatise of peace eventually signed in Versailles (1919). Only in 1921 he managed to publish the TP after minor revisions before being absorbed as freelance by new problems of economic policy not less complex than those dealt with before: the breakdown of the golden system and the economic consequences of Mr Churchill's policy. The crisis of 1929 and the following Great Depression extended the focus of his research to complex issues of economic theory in the conviction that the causes of the economic breakdown could not be removed without a radical regeneration of economic theory. To this end, Keynes developed a radical critique of mainstream economics that had proved unable to predict and control the Great Depression and outlined a new theory capable to overcome its epistemic and political shortcomings. In the destructive part of his titanic effort we find the same foundational arguments that he had already developed against reductionist science in the TP.[20] First, he rejected the atomism of the methodological individualism underlying marginalist microeconomics. Second, against the mainstream uncritical mathematisation of economic theory, which presupposes the commensurability of all the key variables involved, he extended to economics the thesis of incommensurability of complex variables already developed in the TP. Keynes argued that this is the case of many magnitudes playing a crucial role in aggregate analysis. In particular, he investigated the case of crucial index numbers such as the general price level (Keynes, 1919, 1923, 1931), aggregate income, and real aggregate capital (Keynes, 1936). The heterogeneity of probabilities affects also the dynamic behaviour of probabilistic functions. Moreover, in the absence of additivity, the functions describing the dynamic behaviour of the economic system are non-linear and exhibit a marked sensitivity to initial conditions. In particular, the economic system may have multiple equilibria some of which may be unstable so that small changes may produce large effects introducing significant discontinuities that are typically ignored by the reductionist method. This restricts the applicability of the reductionist methods to a narrow subset of actual economic problems. In his 1924 biographical essay on Edgeworth, Keynes summarised the epistemological reasons that were inducing him to reject the surging wave of marginalist microeconomics: 'Mathematical psychics has not fulfilled its early promise. The atomic hypothesis which had worked so splendidly in physics breaks down in psychics' (Keynes, 1924, 262.). This is because 'We are faced at every turn with the problems of organic unity, of discreteness, of discontinuity – the whole is not equal to the sum of the parts, comparisons of quantity fail us, small changes produce large effects, the assumptions of a uniform and homogeneous continuum are not satisfied' (ibidem).

The kind of reductionism pursued by Jevons, Walras, Menger, Edgeworth and the other followers of the Marginalist Revolution is subject to the criticism of being inadequate to find the right explanation and the policy solutions of the economic problems evidenced by the Great Depression. Keynes rejects this form of misplaced and misleading reductionism by calling this crucial source of fallacies with the

[20] See Carabelli (2021).

Latin expression *ignoratio elenchi* (Keynes, CW VII, 259). This language sounds enigmatic to the ears of contemporary economists, as it did to Keynes's contemporaries, contributing to the dismissal of its crucial importance. *Ignoratio elenchi* is one of the 13 fallacious arguments listed by Aristotle in his criticism of Sophists philosophy:[21]

> In logic, ignoratio elenchi is considered an informal fallacy of relevance [that is] an error in reasoning depending not on the form of the argument but on its content. In particular, an informal fallacy of relevance occurs when the premises of an argument are irrelevant to and incapable of establishing the truth of the conclusion of an argument (Carabelli, 2021, 85)

This fallacy often introduces in the argument *semantic incongruence*s.[22] A crucial example is the classical assumption of persistent full employment to study structural or involuntary unemployment. Of course, a judgement of semantic incongruence does not have the same normative cogency of logical inconsistency, but it is a fundamental source of misleading argumentations that may easily degenerate in, possibly hidden, logical inconsistency. In a complex world, the different interpretations of the existence and implications of semantic incongruence play a crucial role in comparing a plurality of research programmes and must be considered in their appraisal (see Chapter 14).

[21] See Carabelli (2021, 84), and the literature there cited.

[22] *Ignoratio elenchi* is an argumentative fallacy that consists in the alleged refutation of an opponent's assertion while what is actually refuted is something that the opponent did not assert. The Latin expression *ignoratio elenchi* is a Latin translation of Aristotle's expression 'ignorance of refutation'. The ignorance involved is either ignorance or deliberate neglect of the conclusion to be refuted or ignorance of what constitutes a valid refutation, so that the alleged refutation misses the mark. The same concept is often dubbed in English as *red herring* from the practice of drawing a red herring across a trail to confuse hunting dogs. In other words, a red herring is something that deliberately distracts attention from the real issue.

10 *The Keynesian Revolution*

> *Alfred Marshall:*[1] *I do not assign any universality to economic dogmas. [Economics] is not a body of concrete truths, but an engine of discovery of concrete truth.*
>
> *John Maynard Keynes:*[2] *The theory of economics does not furnish a body of settled conclusions immediately applicable to policy. It is a method rather than a doctrine, which helps its possessor to draw correct conclusions.*

The Marginalist Revolution started in the 1870s greatly enhanced the conflict between microeconomic analysis and aggregate analysis. The two branches of economics diverged systematically since the late eighteenth century when Adam Smith conceived the free market as a self-contained system capable of coordinating the individual choices towards a GE (general equilibrium). This apparent separation of individual decisions from aggregate magnitudes generated the issue of consistency between micro- and macro-analysis. In the nineteenth century several economists sought to assure the internal coherence of economics by subordinating aggregate analysis to microeconomic analysis. Pure economics, as conceived by marginalist scholars, was meant to explain individuals' behaviour in terms of their perception of marginal utility, while the collective behaviour studied by applied economics was recognised to depend also on social, demographic, technological, and distributive factors (Jevons, 1883). In Classical economics, the tension between individual and social behaviour was not absent but remained mainly internal to value theory in the form of a dichotomy between *use value* that depends on individual tastes and *exchange value* that depends primarily on production, distribution,

[1] Inaugural Prolusion (1985). Quoted by Keynes (1933, 208).
[2] Keynes (CW XII, 856).

and institutions. Jevons believed that he had succeeded in solving this dualism by reducing the exchange value of goods to the ratio of their marginal utility. Few contemporary economists accepted this simplistic reductionist solution. Marshall argued that we should continue to attribute to production costs a crucial role in pricing, especially in the long period. However, the GE model worked out by Walras gave new force to the advocates of methodological individualism by suggesting that, at least in principle, we can explain the properties of the entire market system by starting from the equations that describe microeconomic behaviour. This optimistic view seemed to confirm the belief in the self-regulating properties of a competitive market. The approach based on methodological individualism appealed to the advocates of personal liberty, as it seemed to suggest that, by allowing all individuals to pursue their own preferences without policy constraints, the society could spontaneously reach the collective optimum. Pareto clarified that this argument crucially depends on the initial distribution of wealth coupled with the initial allocation of resources. However, he supplemented the logical argument with an empirical argument – the *Pareto law* – aiming to question any policy intervention to modify significantly the distribution of income.[3] In applied economics, however, Pareto argued that the conflicts over the distribution of income and wealth have a crucial role in explaining the empirical evidence. The econometric turn, which incubated in the first two decades of the twentieth century and culminated in the establishment of the Econometric Society in 1931, encouraged the direct application of economic models to the empirical evidence, ignoring (or playing down) the contributions from sociology, history, technology, and institutional variables. The Great Depression deeply questioned this over-optimistic reductionist paradigm. Keynes argued that to solve the problems evidenced by the Great Depression we had to reject the subordination of aggregate analysis to mainstream microeconomics. To pursue this research programme, Keynes had to implement the consequences of his personal scientific revolution (Section 10.1). The new scientific vision was founded on his epistemology of complexity already

[3] The Pareto law states that 80% of the effects come from 20% of the causes. In particular Pareto applied this law to the distribution of wealth claiming that a small proportion of the population (around 20%) holds the majority (around 80%) of a society's wealth. He also claimed that the empirical evidence shows that in most countries the (80/20) rule is approximately true.

introduced in the TP (Section 10.2). This motivated the building of a new model radically different from that of the classical economists that led to completely different policy implications (Section 10.3). The Keynesian Revolution was soon watered down by the neoclassical synthesis (NCS) that, on the basis of the classical principles, justified only some of the Keynesian policy conclusions. The first phase of this synthesis was based on the IS-LM model suggested by Hicks (1937), and then on the dynamic foundations of GE as suggested by Samuelson and Patinkin (Section 10.4). In the second half of the 1960s a few economists started to question the interpretation of Keynes concocted by the NCS and started to distinguish sharply between Keynesian economics and economics of Keynes. This started a few research programmes proceeding closer to the original intentions of Keynes. One stream led by Clower and Leijonhufvud tried to build a non-Walrasian dynamic theory of GE restoring the crucial importance of disequilibrium dynamics (Section 10.5). An alternative research programme, soon called post-Keynesian economics, aimed to update and develop Keynes's vital insights with any useful instrument, analytical or not, but without succumbing to the myth of mathematical economics and econometrics (Section 10.6). The classical economists who continued to reject Keynesian policies revived the monetarist vision based on the QTM in a more sophisticated version. This monetarist vision, led by Milton Friedman, became increasingly influential as an alternative to the NCS but failed to oust the Keynesian policies pursued by most governments until the early 1970s (Section 10.7). A decisive battle was fought on the explanation of the evidential anomalies shown by the Phillips curve in the 1970s. The monetarist explanation given by Friedman soon attracted the consensus of a growing number of economists (Section 10.8), preparing the path towards a more radical counter revolution (see next chapter). The final remarks in Section 10.9 summarise the evolution of economic pluralism after WWII until the early 1980s.[4]

10.1 Keynes's Personal Revolution

Since the late nineteenth century, the evolution of mainstream economics took a direction of increasing reductionism not only in method but

[4] The contents of this and next chapter partially overlap with the contents of a previous book of mine (Vercelli, 1991 [1987]) where similar arguments are analysed in more depth.

also in contents. Many problems that were still a central concern of political economy until the mid nineteenth century – such as demography, functional distribution of income, and development – were progressively displaced from the core of economic theory. The narrowing scope of economics was induced by the adoption of an increasingly reductionist epistemology. While methodological individualism pretended to play a foundational role for the whole of economic theory, Keynes reacted to this research programme by focusing first against its underlying epistemology and then against its proliferating applications to economics. His main thesis was that 'classical economics' – that is contemporaneous mainstream economics – was based on assumptions that were in principle unable to shed full light on the issues to be investigated (*ignoratio elenchi*). The kernel of the problem was not the patent lack of realism of the hypotheses, because Keynes was fully aware that scientific assumptions must often deviate from realism. Keynes criticised mainstream axioms whenever their nature was inappropriate to study the problem under investigation. To use a metaphor, to enlighten the stage of a theatre, we need reflectors pointed on the stage where the main action evolves, leaving all the rest in the dark, and then we must direct their beam in such a way to follow accurately the moving action. According to Keynes, the reflectors of classical economics did not enlighten the core of the stage or, at least, did not follow the movements of the main action.[5] This is because, in his opinion, classical economics did not succeed in coping with the relevant complexity of the real world and its evolution. The latter requires theories and models that take into due account the complexity of the subject. This does not imply that theories and models must be more complicated; on the contrary, they should be as simple as possible if they focus boldly on the issue to be investigated. We have seen in the preceding chapters that the evolution of economics in the nineteenth century was characterised by the birth and systematic development of what we would call today microeconomic analysis as ultimate foundations to the whole of economics. The two main pillars of the newborn microanalysis were the mathematical theory of marginal utility and the GE model. The first pillar provided a theory of relative prices which acted as the core of economic content. The second pillar

[5] This is the epistemological shortcoming that Keynes defined *ignoratio elenchi* (see Chapter 9).

provided the foundations and defined the scope of economics as an autonomous discipline referring to the market as a whole. Keynes worked out a radically diverging scientific vision based on the idea that economics cannot be based on methodological individualism because the interactions between individuals are organic and thus too complex to be captured by an atomist approach. This view implies that we must preserve the autonomy of aggregate analysis and rebuild its foundations by taking full account of the relevant complexities that characterise this field. In the *General Theory* (1936) Keynes popularised the neologism *macroeconomics* to emphasise that we cannot derive the behaviour of the main aggregate variables from the individual decisions as studied by classical microeconomics. Therefore, in this view, we must build an autonomous discipline based on different axioms. The issues discussed in Keynes's macroeconomics were not new and had been discussed since long in aggregate terms (in particular, monetary theory, business cycle theory, growth theory, and development economics). However, Keynes argued that the aggregate analysis of these themes required new foundations in the light of the evolution of capitalism. Keynes's macroeconomics soon became influential as a promising response to the Great Depression of the 1930s and the war economy of WWII. Many economists contemporary to these events and some historians of economic thought did not hesitate to speak of a Keynesian Revolution. Some of them pointed out in retrospect the deep analogy with Kuhn's concept of scientific revolution (Kuhn, 1970 [1962]).[6] Other scholars rejected this language emphasising the elements of continuity with previous theory. I will use the expression 'Keynesian revolution' in a sense that does not exclude important elements of continuity, some of which have been sometimes unduly neglected or played down. As it happens in other sciences, the evolution of economic theory never stops but in certain periods slows down. These periods are ruled by what has been called by Kuhn 'normal science' dominated by a strong mainstream school that manages to resist any sort of significant change. The conceptual revolution advocated by Keynes was a reaction against the previous dominant scientific vision that he himself had entertained until the beginning of the Great Depression when he was still 'a faithful pupil of the classical School' (Keynes, 1936, 334). The *Treatise on Money*

[6] See the discussion of the Kuhn approach in Chapter 4.

(1930) was a bold attempt to develop further the Marshallian theory of money in the light of the recent evolution of money and finance. However, as Keynes himself recognised, while writing this work, he was still inside the epistemic vision of classical economics: 'my lack of emancipation from preconceived ideas showed itself in what now seems to me to be the outstanding fault of the theoretical parts of my work' (Keynes, 1936, xxii). The transition towards a new scientific vision started soon after the publication of the *Treatise on Money* (1930) under the pressure of the Great Depression and its unexpected gravity and persistence that mainstream economics was unable to explain and control. The rejection of the Marshallian consensus, to use a Freudian analogy, was a sort of symbolic patricide to conquer the desired higher level of autonomy in thought and action. A process of emancipation of this sort is always painful: 'the composition of this book has been for the author a long struggle of escape … from habitual modes of thought and expression' (Keynes, 1936, xxiii). He was aware that the merging of the Classical school with the Marginalist School was defective:

> Alfred Marshall, on whose Principles of Economics all contemporary English economists have been brought up, was at particular pains to emphasise the continuity of his thought with Ricardo's … It was in this atmosphere that I was brought up (Keynes, 1936, xxv).

The identification of his intellectual father in Marshall is consistent with his intellectual roots. The Marshallian merging of the Classical school, with the Marginalist School derives from the common features he perceived in them. What is common to them is the idea that a competitive market self-regulates as revealed by the common acceptance of Say's law. To emphasise the radical change of paradigm underlying the *General Theory*, Keynes also used the analogy of a Catholic priest converting to a Protestant faith, or a snake changing skin. Both analogies emphasise the discontinuity between the two successive visions but implicitly recognise a high degree of continuity. In particular Keynes preserves a deep epistemological continuity with Marshall: I limit myself to mention his anti-reductionism, his focus on the complexity of economic phenomena, his mistrust in the incautious use of formal models, and his evolutionism. Nevertheless, Keynes's new version of these features is updated within the frame of a new vision of economics that denies the consistency of marginalist microeconomic analysis with his new view of macroeconomic analysis. In particular, while Marshall liked to repeat that also in economics *natura non facit saltus*, Keynes argued that we have to introduce bold discontinuities in economic theory to tackle the rapid structural changes of its object shockingly revealed by the Great Depression.

10.2 Complexity and the Critical Inception of the GT

In the GT, Keynes developed and refined the epistemological approach to complexity worked out in the TP, an approach that he had already started to apply in his first economic works. His early conviction that the economic events are deeply complex had been further corroborated by the Great Depression. Keynes's mistrust in the reductionism of marginalist microeconomics was greatly enhanced by the failure of 'classical' economics to explain its causes, to predict its evolution, and to implement successful policy measures. He thus resumed and generalised previous arguments against methodological individualism in reference to the shortcomings of classical theory. He further enriched them with new critical arguments focusing on the crucial role of historical time, strong and radical uncertainty, the importance of psychological assumptions (such as propensity to consume and liquidity preference), and significant deviations from rational beliefs. On the other hand, in the GT, Keynes resorted to a host of daring simplifications, some of which are more radical than those already used in his previous works, such as the adoption of a simplistic method of comparative statics, questionably simplifying assumptions such as the alleged identity of investment and saving, and the insertion in the model of a timeless investment multiplier. These and other bold simplifications eluded a rigorous and explicit specification of the dynamic behaviour of the system. This is especially disturbing because verbal dynamic arguments recur throughout the GT in an essential way. They qualify the positions of involuntary unemployment as genuine positions of rest because of the compensation of opposed dynamic forces. The weakly justified mix of epistemic antireductionism and radical simplifications was found confusing by many readers and, from the very beginning, encouraged a wide spectrum of interpretations motivating diverging research programmes. Therefore, I must sketch a rational reconstruction of the Keynesian epistemological approach that may assess strength and shortcomings of different interpretations of the GT, whether sympathetic or hostile. Following Keynes, my assessment is based on the appropriateness of adopted simplifications to answer a given research question.[7] This requires a preliminary appraisal of the complexity of the object under investigation. After having summarised in Chapter 18 (Section 18.2) the factors that explain effective demand and aggregate employment, Keynes recognised that 'there is not one of the above factors which is not liable to change without much warning, and sometimes substantially. Hence the extreme complexity of the actual course of events' (GT, 249). The main problem investigated in the GT is the stubborn persistence of involuntary unemployment triggered by the downfall of Wall Street in 1929. The possibility of a persistent level of involuntary unemployment was excluded a priori by classical microeconomic theory that hinges on Say's law. Keynes claimed that Say's law may be justified in a barter (or real exchange) economy but not in the contemporaneous monetary economy. As he had written in 1933 in *The Monetary Theory of Production*, the assumption of real exchange economics 'is a singularly blunt weapon for dealing with the problem of booms and depressions. For it has assumed away the very matter under investigation' (CW XIII, 410–411). This destructive argument is reasserted at the very outset of the GT to motivate his titanic attempt of outlining a different approach in the following chapters of the book. The urgency of the policy problems to be solved encouraged his bold attempt of finding a solution without delay. He believed that the already crumbling building of classical economics had been destroyed beyond repair by the financial earthquake of the Great Depression and he felt the pressing priority of reconstructing a more robust building to cope with its catastrophic consequences. In his opinion, this had to be done as soon as possible with the material already at his disposal, as in a work of bricolage. He was fully aware that the outcome of his effort could not compete with the analytic precision of *classical* models after more than one century of refinements. However, he did not feel discouraged by the comparative weakness of his new building from the analytic point of view because he believed that it is better to be vaguely right than exactly wrong. The structure of his 'model' was thus the outcome

[7] As we have seen in the former chapter, Keynes related his criterion of appropriateness to the fallacy of *ignoratio elenchi* in Aristotle's meaning (CW VII, 259).

of this sort of 'bricolage' that connected analytic and qualitative bricks with evidential mortar. In the first book of the GT (including the first three chapters), Keynes immediately reiterated his deeply-felt conviction that the solution to the problem cannot be found within the paradigm of methodological individualism that explains aggregate employment by relying upon Say's law. The latter was the main pillar of *classical* economics, asserting that there are no obstacles to persistent full employment because aggregate supply creates its own demand. Keynes rejected Say's law and introduced instead the principle of effective demand. Keynes argued that Say's law does not hold in a monetary economy where the exchanges are necessarily mediated by money and money may become the ultimate object of desire. As is well-known, in the preparatory notes for the GT, Keynes had emphasised the different properties of an exchange (or barter) economy where money D plays only the role of mean of exchange between two goods M (M-D-M) and a monetary economy where the goal of exchange is an increase of money (D-M-D' and D'>D). He argued that the classical principle of neutrality of money presupposes an exchange economy and does not hold in a monetary economy. The tacit assumption that a monetary economy behaves as an exchange economy is a form of extreme reductionism that prevents the use of classical theory to explain systemic economic crises:

> ... the conditions required for the 'neutrality' of money, ... are ... precisely the same as those which insure that crises do not occur. If this is true, the real exchange economics ... is a singularly blunt weapon for dealing with problems of booms and depressions. For it has assumed away the very matter of the investigation. (CW XIII, 410–411)

The failure to distinguish between the functioning rules of a monetary and a barter economy is a particularly subtle and misleading form of reductionism because it presents full employment as a logical necessity rather than as a possible dynamic equilibrium that may or may not occur. By assuming Say's law, we render meaningless the research on the conditions that make GE possible. This implies that all the issues related to the aggregate disequilibrium of the system cannot exist or at least cannot be discussed as such. According to this reductionist view, what in ordinary language is described as an endogenous shift to a disequilibrium position, in formal theory is interpreted instead as an exogenous shift of equilibrium. The word equilibrium itself changes meaning as it indicates the solution of the system of equations and loses any relation to the compensation of dynamic tendencies underlying the etymology of the word. The difference of vision epitomised by the acceptation or rejection of Say's law plays a crucial role in divaricating two different types of aggregate analysis and different policy strategies. Summing up, from the first book of the GT, the argument of Keynes radically diverges from the usual path pursued by classical economics. Before continuing this path, in the second book Keynes discusses the problems of definition and measurement of the aggregate magnitudes that will be the main players in his arguments. To this end, he adapts to economics and further develops the arguments already used in the TP.

10.3 The Basic Model and Its Use

In book I, Keynes specifies what he calls the *quaesitum* (we would say today 'research question') – namely the determination of aggregate employment – and claims that a satisfactory answer requires a new approach. He then criticises the mainstream solution (the self-regulation of the system as a whole guaranteed by Say's law) and sketches his own solution: the determination of actual unemployment in a monetary economy by the level of effective demand. But what determines the effective demand? This is what the rest of the book aims to determine.

After a preliminary methodological discussion in Book II of the choice of units, the role of expectations in determining output and employment, and the definition of the main aggregate variables (income, saving, and investment), from the third to the fifth book (namely from Chapters 8 to 18) Keynes works out his basic model for the determination of effective demand. Notwithstanding a few specific analytic insights, this model is not a full-fledged analytical model. We could call it a pre-analytic model in the sense of Schumpeter, a model that inspired a wealth of analytical models each of which tried to capture some of its insights. However, we cannot doubt that it is a model in the Keynesian sense. In his opinion, economics is a science based on models, but these models must keep the necessary flexibility to take account of the relevant complexities of the object. Keynes was not against the use of mathematics and statistics. But his main concern was not the analytic solution of the mathematical model or its econometric fit but its logical structure. Often the latter can be grasped better by a critical use of symbolic logic and algebra but in other cases nothing can substitute the semantic richness and flexibility of ordinary language. In the GT, the structure of the model is given by epistemic causality as defined in the TP. This model is thus used according to a hierarchical order to take into account levels of complexity ignored by the basic model. This approach is applied in sequence to the market for good in book III (chapters 8–10), and then to the market for real capital (book IV, chapters 11–14), and the market for monetary capital (book IV, chapters 15–17). The last chapter of book IV (chapter 18) summarises the 'argument of the previous chapters, taking the factors in the reverse order to that in which we have introduced them' (p. 247). The order between these markets is given by what Keynes called epistemic causality in the TP.[8] In the market for labour, the level of involuntary unemployment is determined by the exogenous factor of effective demand. In the market for goods the effective demand is determined by the endogenous real forces summarised by the investment multiplier that depends on a crucial monetary variable: the rate of interest. The latter is determined in the market for monetary capital, given the supply of money as a policy variable controlled by the central bank. Keynes verifies if it is useful to assume that the causal chain starts from the supply of money to compare his macro analysis with that prevailing in mainstream macroeconomic analysis that was still relying on the QTM. He had already rejected the assumption of neutrality of money usually assumed within the GE approach. However, a version of the QTM elaborated by Hume recognised that money could be non-neutral in the short period by increasing aggregate income and demand with the temporary effect of increasing employment. The persistence of unemployment in the 1930s had the effect of reviving this vision especially among policymakers. Keynes argues that this is not the right approach to study the non-neutrality of money. In the introduction to the French edition, Keynes clarifies the rationale of his rejection of the QTM: 'The following analysis registers my final escape from the confusions of Quantity Theory, which once entangled me' (p. xxxiv). Keynes argues that money is not neutral, particularly in the short period, but its short-period positive impact on aggregate demand is volatile and depends on many unpredictable factors. He maintains that

[8] Namely, cause for knowledge, or *causa cognoscendi*.

to investigate the effects of the quantity of money we need a different approach that considers all the relevant factors. In particular, the basic model shows that the prevailing expectations may shift the curve of liquidity preference in an adverse direction so that the resulting rate of interest may be too high for the multiplier to implement full employment income. However, here and elsewhere, the basic model articulates in different levels of analysis that corroborate his rejection of the classical analysis. In this sort of higher-order analysis, the model is partially modified. Keynes introduces a crucial feed-back, missing in the basic model, between the real sector and the monetary sector: 'An increment (or decrement) of employment is liable . . . to raise (or lower) the schedule of liquidity-preference' (GT, 248). This is because the increase in employment tends to increase the output, the wage unit, and the prices of goods owing to increasing costs (TG, 248–249). I do not need to list other examples of higher-order analysis. What is important to emphasise is that, according to Keynes (GT, 249), the position of equilibrium will be influenced by these and other repercussions:

> there is not one of the above factors [the variables of the model] which is not liable to change without much warning, and sometimes substantially. Hence the extreme complexity of the actual course of events. Nevertheless, . . . if we examine any actual problem along the lines of the above schematism [the basic model], we shall find it more manageable; and our practical intuition (which can take account of a more detailed complex of facts than can be treated on general principles) will be offered a less intractable material upon which to work.

In the light of the nature of the model worked out in the GT we may understand the ultimate foundations of Keynesian macroeconomics policy. Considering that the market may be unable to self-regulate and that the spontaneous repercussions of any change in conditions are extremely complex, we need a government capable of controlling an evolving situation with the decision, wisdom, and flexibility required to tame, so to say, such a savage horse. Is this possible? It depends on the nature of the problem, the quality of public institutions, and the technical skill of honest civil servants. The followers and critics of Keynesianism will soon split on the required answers to address constructively this question. The justification of the public interventions in economic policy appealed to many in the late 1930s to mitigate the depression and then to manage the war economy. The confrontation on Keynesian economics became particularly intense after the war: which economic policy can best promote reconstruction and growth after the war's destruction?

10.4 IS-LM and the Neoclassical Synthesis

After the publication of the GT, most young economists were attracted by the approach of Keynes that looked particularly topical in a period of persistent depression followed by a long period of war economy and then post-war reconstruction. These environments required rules of public management that traditional mainstream economics seemed unable to justify and implement. Most reviewers of the GT defended the classical approach from Keynes's critiques. A few reviewers defended the constructive novelties introduced by the author. One of the reviewers, John Hicks, who was then working on a manageable version of the GE theory, took a different interpretive line that was soon expounded in a highly influential full-size journal paper: 'Mr Keynes and the Classics' (Hicks, 1937). Hicks's view was that these two apparently opposite theories may be reframed within a common theoretical framework. He argued that the crucial issue at stake was the interaction between the real and the monetary sides of the economic system. He thus represented the possible equilibria of the real side with the IS curve and the possible equilibria of the monetary side with the curve LM in a diagram measuring the rate of interest on the vertical axis and employment on the horizontal axis. The GE of the system is then determined by the crossing of the two curves. The divergence between the two theories is thus reduced to different assumptions on the shape of the curves that reflected different factual and theoretical assumptions. In this representation, the bridge between the two subsystems is the rate of interest. According to classical economists, in a competitive market the rate of interest is always flexible enough to keep the economy in a state of full employment. On the contrary, according to Keynes, the system may be stuck in a different position characterised by involuntary unemployment so that full employment equilibrium requires the intervention of public policy. Hicks's view updated a position of internal pluralism in the spirit of Marshall by sketching a scientific vision capable of encompassing both Keynes and the classics. Although Hicks's eclectic vision became quite influential, his simplistic representation of the conflict between Keynes and the classics concealed many of Keynes's deep-seated motivations. The pupils and followers closest to Keynes rejected what they saw as an attempt of counter-revolution. However, after WWII the most successful followers of Keynes progressively converged towards a vision analogous to that of Hicks, a vision that accepted only in part the vision of Keynes and recovered several classical features. They agreed with Keynes that it is impossible to reduce macroeconomics to microeconomics and tried to avoid what Keynes had called fallacy of composition. However, they accepted methodological individualism for explaining the decisions of the economic agents and their effects. They also accepted the Keynesian critique to the QTM, including Hume's version, maintaining that the causal nexus between money supply and the level of the prices index depends on a host of factors neglected by QTM, including the expectations of the economic agents and the level of unemployment. This hybrid scientific vision was soon dubbed neoclassical synthesis.[9] We must distinguish four main aspects of this synthesis. The first is that in any given period the relevance and prominence of the two components depends on the specific historical conditions. This is reflected in the special shape attributed to the IS-LM curve under investigation. If, during the Great Depression the Keynesian vision found overwhelming support by the special shape of the LM curve; during the steady growth in the 1950s and 1960s the classical vision re-emerged and de-emphasised the significance of fallacy of composition, especially in finance. This issue deeply motivated a second stream of eclectic research that tried to reconcile the GE model with Keynesian macroeconomics. A first attempt was worked out by Hicks in his book *Value and Capital* (Hicks, 1939) that elaborated the eclectic scientific vision sketched in the IS-LM model in terms of a reinterpreted GE model. The most ambitious early contribution to this research programme came by Samuelson in his Ph.D. thesis (1947).

[9] As Blanchard (1991, 504) argued, 'The term "Neoclassical Synthesis" appears to have been coined by Paul Samuelson to denote the consensus view of macroeconomics which emerged in the mid-1950s in the US.' To quote from the third edition of Samuelson's Economics (1955, 212),

> In recent years, 90 per cent of American economists have stopped being 'Keynesian economists' or 'anti-Keynesian economists'. Instead, they have worked toward a synthesis of whatever is valuable in older economics and in modern theories of income determination. The result [. . .] is accepted in its broad outlines by all but about 5 per cent of extreme left-wing and right-wing writers.

He aimed to provide dynamic foundations to the Walrasian GE model consistent with the observed weak self-regulation of markets. A similar path was followed by other distinguished Keynesian economists such as Modigliani, Patinkin, and Tobin. This research programme ignored or played down the basic conflict between the Walrasian *tâtonnement* approach and the actual dynamics of markets. Foundational weaknesses did not prevent a wealth of innovative contributions in different fields of macroeconomics such as growth, business cycle, and taxation. In addition, they gave a great impulse to the development of analytic finance based on the principles of microeconomics.[10] The third stream of mainstream Keynesianism bridged and developed many motivations of the other two by building large-scale econometric models of the national economy to understand its empirical structure and find the best way to forecast and control its behaviour. This stream was particularly appreciated by governments that were glad to receive such detailed support for choosing, justifying, and implementing their policies. They used mathematical and econometric models without the cautiousness of Keynes contributing to develop statistical economics and econometrics.[11] Finally, we have to mention a fourth stream that applied mathematical dynamics to specific economic problems such as growth (Harrod), and business cycle (Samuelson, Kaldor, and Goodwin). This stream revived the epistemology of complexity emphasised by Keynes translating it in analytical terms but failed to provide a general research programme alternative to the mainstream one. Under the tolerant indulgence adopted by the NCS, this innovative work could be pursued and appreciated. Internal pluralism could thrive within broad boundaries provided that the basic principles of the NCS were not seriously challenged.

10.5 Keynesian Economics and the Economics of Keynes

In the late 1960s the apparent successes of Keynesian countercyclical policies started to be questioned. First, in consequence of growing exogenous impulses, the stop-and-go policies to keep the economy close to full employment, struggling to maintain at the same time monetary stability, started to amplify business cycles rather than

[10] See Vercelli (2019).
[11] See in particular Klein (1947), Klein and Goldberger (1955).

dampening them. This encouraged a few economists to reconsider the foundations of the NCS pointing out its uncritical acceptance of the classical school in microeconomics while agreeing with Keynes that macroeconomics cannot be founded on it. The awareness of this disturbing inconsistency had been soothed by the assertion that, in a Walrasian GE, full employment is allegedly the unique stable equilibrium, while Keynesian unemployment states are to be interpreted as temporary disequilibria states (Patinkin, 1956). This point of view aimed to reconcile the belief in the self-regulation of a competitive market and the potential contribution of Keynesian policies to speed up the process of convergence towards equilibrium. This eclectic position was debunked in the late 1960s by Robert Clower with deep theoretical insights that became very influential in the subsequent evolution of macroeconomics. Clower (1967) argued that the ultimate theoretical root of the conflict between Keynes and the classics had to be sought in their different dynamic foundations. The attempt by the leading NCS economists – in particular Hicks (1939), Samuelson (1947), and Patinkin (1956) – of reconciling classical microeconomics with Keynesian macroeconomics had failed. All of them sought a synthesis in the dynamic foundations of Walrasian GE theory that is deeply inconsistent with the macroeconomics of Keynes. Clower emphasised that classical microeconomics is based on the Walrasian notion of *tâtonnement* that guarantees the validity of the Walras law, while Keynes emphatically rejected Say's law (implicitly including also Walras's version of the law). Many NCS economists did not take seriously Keynes's rejection of Say's law, and so doing they missed his crucial, although somewhat hazy, sketch of alternative foundations. The latter must be pursued by abandoning the subtle but unrealistic device of *tâtonnement* that assures ex ante the coordination of agents' behaviour. In the real world, the exchanges depend on effective prices that may be different from the equilibrium prices. We must introduce a distinction between notional demand (when the desired transactions are not constrained in any market as in the case of Walrasian GE) and effective demand (when transactions are constrained in one or more markets as in the Keynesian case of involuntary unemployment). If we admit the possibility of 'false trading' (exchanges at non-equilibrium prices), the trajectory of the system can shift to a disequilibrium position and may then converge to an equilibrium different from the full employment equilibrium.[12,13] Clower endorses Keynes's rejection of classical household behaviour and the implicit adoption of a different one that he calls the 'dual-decision hypothesis' in which realised transaction quantities affect adjustments in output. In such a world, also money plays a different, more important, role. The agents may implement their desired transactions only to the extent they possess in advance the necessary quantity of transaction money and this may alter the timing, sequence, and consistency of exchanges and their consequences. Clower dubs this monetary constraint to exchanges *money-in-advance* principle. This confirms the fundamental difference between barter economy and money economy as emphasised by Keynes.

The Keynesian component in the NCS is not much more than a sort of ad hoc shortcut to reach more easily the macroeconomic policy implications of a certain state of the economic system. The NCS economists recognised that they were unable to provide classical microeconomic foundations to these shortcuts. However, they did not take seriously the radical criticisms of Keynes to classical microeconomics that motivated and provided sketchy foundations to the new macroeconomics. For this reason, the exponents of NCS endorsed their version of Keynesian macroeconomics but were reluctant to speak of Keynesian economics. By using updated analytical methods Clower debunked this point of view by endorsing Keynes's claim that Walrasian GE is inconsistent with Keynesian macroeconomics. In addition, he claimed that the latter is in principle more general and applies to all the possible dynamic states of the system, while the classical approach applies only to the limit case of full employment equilibrium. This convinced many economists of the necessity of distinguishing sharply between Keynesian economics (as understood by mainstream NCS economists) and economics of Keynes (according to the original intentions and scientific vision of Keynes). Leijonhufvud, a pupil and coauthor of Clower, spelled out this thesis in a book that became immediately very influential (1967). His criticism of the mainstream interpretation of Keynes focused on the IS-LM

12 See Vercelli (2019).

13 This equilibrium may be a temporary equilibrium unlikely to persist. However, the possibility of false trading introduces significant non-linearities that complicate the stability analysis of the economic system making possible a plurality of alternative equilibria with different characteristics.

model that had continued to be the main introduction to Keynesian macroeconomics in standard textbooks. This approach, in the usual versions, focuses exclusively on equilibrium, while in this view Keynes's analysis of involuntary unemployment focused on disequilibrium. In addition, the standard equilibrium analysis lacked the necessary dynamic foundations. Leijonhufvud's brilliant and eloquent arguments revived a direct study of Keynes that soon fragmented in a plurality of research programmes. I will mention in this book only two of them: the disequilibrium macroeconomics of Clower and Leijonhufvud and post-Keynesian economics (discussed in the next section). Leijonhufvud advocated a 'cybernetic' approach to Macroeconomics to study the adjustment of prices and quantities without the strictures of Walrasian *tâtonnement*. In particular, he emphasised that in a more realistic model-economy without the Walrasian auctioneer, we must model how information affects the decision of the agents. Leijonhufvud insights stimulated the development of a few specialised branches of economics such as information economics, computational economics, and general disequilibrium models. This multiplication of interacting research programmes contributed to enhance the level of internal pluralism since the late 1960s until the late 1970s.

10.6 Post-Keynesian Economics

The origin of post-Keynesian (henceforth PK) economics is rooted in the writings of Keynes's 'apostles' (close collaborators and pupils working in the Cambridge University, such as Joan Robinson, Kahn, Kaldor, and Kalecki). After Keynes's death, they defended what they believed to be the genuine interpretation of their master's theory from hostile interpretations by neoclassical economists and 'revisionist' interpretations by exponents of the neoclassical synthesis. This Cambridge tradition[14] catalysed streams of research in different countries such as the UK (Chick and Thirlwall), the USA (Weintraub, Davidson, and Minsky), Italy (Pasinetti, Garegnani, and Graziani), Austria (Steindl and Rothschild), their numerous pupils, and many

[14] The genesis and evolution of this school interacted with the neo-Ricardian school pioneered by another eminent collaborator of Keynes (Sraffa). Unfortunately, the analysis of this interaction would go beyond the limits of this book.

more. The common radical criticisms against the neoclassical approach produced a growing convergence that gave birth in the 1970s to an autonomous school of thought. This PK school managed to exert a significant influence among academic economists and practitioners but failed to exert a systematic impact on policymakers and regulators. The PK school remained articulated in many streams that agreed on a few common theses. First, it argued that the macroeconomic equilibrium implemented by unfettered markets may be characterised by what Keynes called involuntary unemployment. This suboptimal state is caused by a deficient amount of effective demand that depends mainly on the product market and the financial system. In addition, they focus on the Keynesian idea that, contrary to the mainstream opinion, the causation goes from investment to saving and not *vice versa*. This implies that the crucial physiological role of the financial system is not the intermediation between saving and investment but the financing of real investment. Post-Keynesians agree with Keynes that a monetary economy is quite different from a barter economy. In particular, the classical dichotomy between real and monetary sides of the economy does not hold, money is not neutral, and finance plays a crucial substantive role that goes much beyond mere intermediation. In this view, we have to reject the QTM for three basic reasons: (i) the creation of money is mainly endogenous, so that causation goes from income to money; (ii) the velocity of money circulation is highly variable, as it depends on money demand and liquidity preference; (iii) inflation may be affected also by a cost-push induced by increases of wages or of the price of primary products. Cost-push inflation requires a different monetary policy that depends on its specific cause. While the supporters of the NCS reverted to the Marshallian position of the young Keynes (1924) accepting in principle the long-run neutrality of money, the post-Keynesians made a more radical rejection of the QTM by clarifying that in modern capitalism money is endogenous since most money is credit money created by banks in response to demand for it from the private sector. In particular, post-Keynesians showed '... that the existence of a credit multiplier, as a result of some exogenous control by the monetary authorities, does not necessarily imply a causality running from high-powered money (monetary base or central bank money) to the money stock. On the contrary, causality runs from higher credit needs to higher bank deposits, to higher required reserves' (Lavoie, 1984, 776–777).

Post-Keynesians share these basic principles but combine and articulate them in different ways. A case in point is uncertainty, with its far-reaching implications for pluralism of methods. Minsky argued that the analysis of capitalism without (strong or radical) uncertainty is like Hamlet without the Prince of Denmark (Minsky, 1975, 57). In particular, a sophisticated financial system is characterised by strong or radical uncertainty that is the cause and effect of its instability, while the equilibrium approach of mainstream macroeconomics crucially depends on the assumption of weak uncertainty, or mere risk (in the language of Knight), underlying known additive probability distributions. As Minsky brilliantly argued, in a capitalist economy, even if we assume that the economy is in a state of equilibrium, financial tranquillity cannot persist for a long time because the growing confidence in the stability of the system validated by a persisting equilibrium would induce the economic units to increase their indebtedness.[15] This would displace from equilibrium the economic system starting a sequence of financial fluctuations that could eventually degenerate into a great crisis. In addition, most post-Keynesians reject the mainstream concept of uncertainty as simple and measurable risk, namely mere stochastic variance that does not affect the equilibrium value of systematic variables. This common trait of PK scholars confirms their deep affinity with Keynes's epistemology and its pluralistic implications in an open world. In an uncertain world, the weight of macroeconomic arguments is bound to be limited and controversial.[16] As Keynes had already argued in the TP, in empirical sciences such as macroeconomics, 'arguments are rational and claim some weight without pretending to be certain … most of the arguments, upon which we habitually base our rational beliefs, are admitted to be inconclusive in a greater or less degree …' (Keynes, 1921, 3). We can thus correct systematic mistakes by learning from a frank dialogue with dissenting interlocutors in the light of the evolving empirical evidence.

10.7 Friedman and the Monetarists

Orthodox Keynesians, namely NCS economists, became very influential in the three decades after the end of WWII because they provided

[15] On this point, see also Sordi and Vercelli (2012).
[16] See Vercelli (1991 [1987], 220–224).

the workable economic foundations for mixed economies and the necessary instruments to manage them. The exponents of the NCS, as Keynes before them, did not reject the basic principles of liberalism but only tried to update them. Nevertheless, the new approach to politics and economics progressively altered the relationship between market and government. In particular, the percentage of public expenditure on the GDP increased from the level of 10–15% to the substantially different level that could reach 40–50% (Lindert, 2004). This gradual but continuous change occurring in the 1950s, 1960, and still in the 1970s notwithstanding a growing resistance, progressively altered the balance of power between State and market. This explains the orientation of the most influential opposition to the Neoclassical synthesis in this period led by Friedman. Friedman attacked the Keynesian mainstream from different points of view: political philosophy, methodology, explanation of inflation, causes of business cycles, and economic policy. Friedman argued that the growing interventions of the State in the economy is bound to limit the freedom of the individuals in an unacceptable manner that is paving the way towards a new kind of serfdom. Systematic public interventions are also preventing the market from self-regulating efficiently and preserving monetary and real equilibrium. In addition, the Keynesian policies meant to keep full employment introduced a growing inflationary bias in the economy while the policies of stabilisation of the business cycle ended up by worsening its negative effects. He argued that the multi-equation econometric models developed to support the decisions of policy authorities were unable to capture the overwhelming influence of the monetary policy on inflation and business cycle. He maintained that much simpler models based on the QTM performed better than the multi-equations Keynesian models confirming the superiority of classical economics. In particular, the temporal lag occurring between changes in money supply and the correlated changes in the real economy confirmed the causal influence from money to income against the opposite convictions of Keynesian economists. Therefore, considering the interaction between policy rules and expectations, the only way to stabilise the economy must rely on fixed monetary rules avoiding discretionary interventions in the real and monetary economy that disrupt spontaneous market coordination. The monetarists progressively increased their influence in the 1950s and 1960s but the persisting good performance of many mixed economies managed by

Keynesian policies contributed to maintain a substantial hegemony of NCS economists. Within this context, the exponents of NCS succeeded also to produce robust counterarguments against the radical criticisms of Friedman and his followers. Most citizens experiencing growing welfare and improving social services did not perceive a reduction in their freedom. Notwithstanding the growing intervention of the State in the economy, a substantial economic stability was preserved in most mixed economies until the late 1960. From the methodological point of view, the instrumentalism of Friedman did not find much support from the contemporaneous post-positivist philosophy of science,[17] while the argument that a temporal lag between two correlated variables indicates the causal direction was not considered a conclusive proof of causality direction. Finally, the reliance on fixed policy rules required a constant environment whose plausibility found different counterexamples in an era characterised by growing turmoil.

10.8 The Battle over the Phillips Curve

The confrontation between the NCS economists and monetarists has always been very hot from the early 1950s to the late 1970s. However, notwithstanding a few episodes of excessive animosity, in most cases the debate complied fairly well with the basic rules of pluralism. Both schools of thought managed to keep an influential presence in most departments of economics. At the same time, both of them found supporters among policymakers, the Keynesians mainly in the mixed-economies governments and the monetarists mainly in central banks. Overall, the two opposing schools of thought did not ignore each other, but took issue with each other's findings by using genuine scientific arguments based on different interpretations of the empirical evidence. Top scientific journals did not object to the publications of good-quality contributions of both camps. Consistently with the basic rules of pluralism, a host of papers were published that compared the performance of their different assumptions, methodologies, and policy implications. At the beginning, the debate focused mainly on the plausibility of the assumptions of the QTM such as the exogeneity of the supply of money, the stability of the velocity of circulation, the neutrality of money. In the early 1960s the debate extended to the

[17] See Chapter 4.

interpretation of the Phillips curve and its implications for countercyclical policies. In the late 1960s and 1970s the Phillips curve became the crucial battle terrain between the two schools. The original Keynesian model did not have a clear relation between effective demand and (wage or price) inflation. Keynes maintained that, whenever the economy is characterised by involuntary unemployment, an increase in aggregate demand would be reflected in a reduction of unemployment accompanied by a moderate increase in money wages and prices accelerating in proximity of the full employment position. He also emphasised that, the closer the economy gets to full employment, the higher the monetary effect until, at full employment, the whole direct effect would become monetary as maintained by the QTM. These and other similar hints could be sufficient to argue that Keynes's approach was in principle more general than that of the usual simplistic version of the QTM, but such a merely qualitative – and utterly vague – link between unemployment and inflation made Keynes's approach on this point hardly operational and vulnerable to easy criticisms. The Phillips curve (1958) came to the rescue of NCS on this crucial point. Phillips was able to fit the data series of money wages and employment in the UK from 1861 to 1957 with a stable curve. In England, the most pragmatic exponents of the NCS made immediately an incautious instrumental use of this curve to forecast the inflationary effects of Keynesian full employment policies under the assumption that the shape and position of the curve were substantially invariant to policy changes. In many countries Keynesian economists implemented the same approach with local data. Many of them went so far to interpret the curve as a stable menu of policy choices to fix the money wages–employment combination that could maximise the function of social welfare. This approach seemed to work fairly well until the early 1960s corroborating the policy hegemony of mainstream Keynesians. However, starting from the mid-1960s, a phase of structural change in the European and North American economies increasingly questioned the adequacy of mainstream Keynesianism. A complete description and explanation of these structural changes would go beyond the narrow scope of this book. For my purposes it is enough to recall two crucial factors that contributed to the crisis of the welfare state and mainstream Keynesianism. First, as Kalecki had predicted in the early 1940s, the persistence of full-employment policies progressively empowered the trade unions that obtained substantial increases in the real wages at each contract renewal. The firms reacted by increasing the prices of their product enough to preserve their profits, while the central banks reacted to inflation by triggering restrictive monetary policies. These policies of 'stop and go' gathered momentum in the 1960s and 1970s but did not interrupt the trend of growth. However, the growing economic and social tensions were reflected by progressive changes in the Phillips curve that pointed to an increasingly unsustainable trend. In many countries the short-term Phillips curve shifted upwards and assumed a more vertical slope suggesting that any attempt to reduce unemployment beyond the natural value had to be paid with a rapidly growing inflationary bias. Keynesian exponents explained this disturbing trend by focusing on temporary exogenous factors. Though some of these shift factors were not implausible, it was easy for the monetarists to argue that their introduction in the econometric specification of the curve was an ad hoc device to defend the Phillips curve and with it mainstream Keynesianism. Friedman (1968) intervened with a very influential paper that provided a different kind of explanation of the shifting Phillips curve fully consistent with classical economics. In Friedman's opinion, any attempt of reducing unemployment beyond its natural rate was bound to generate inflationary expectations that would progressively accelerate until adequate recessive policies did not bring back unemployment to its natural level. This 'accelerationist' explanation convinced many economists and policymakers, including a few of Keynesian ascendency. This defeat started a process of rapid decline of the neoclassical synthesis. In the 1970s the confrontation broadened to new variants of the classical and Keynesian paradigms that tried to rescue the original message of Keynes. Within the Keynesian camp the lively debate between new variants of the Keynesian paradigm did not lead to the convergence towards a new mainstream version. On the contrary, within the classical camp started a process of mutation that rapidly led to a new hegemony, not only within the classical tradition but often also within macroeconomic analysis.

10.9 Remarks on Post-War Pluralism

The Keynesian Era (from 1936 until the late 1970s) was a period of lively debate between different schools of thought. The Keynesian Revolution broke the Marshallian consensus and its tolerant but muffled pluralism. The conflict between Keynesian and classical economists revived external pluralism. The new consensus of NCS economists shifted external pluralism to a conflict with monetarists. The resurgence of diverging research programmes since the late 1960s revived both internal and external pluralism throughout the 1970s, until the early 1980s, when one of these research programmes, New Classical Economics, eventually attracted the consensus of a large part of the profession. The evolutionary pattern observed in this period in economics is substantially like the typical evolutionary pattern of natural sciences as reconstructed by Kuhn. Periods of scientific revolution (such as the Keynesian one of the 1930s or the New classical one in the 1970s) alternated with periods of normal science in which mainstream economics obtained a wide, though variegated, consensus (as in the case of the Marshallian synthesis from the early 1890s to 1929, the NCS from the end of WWII to late 1960s, or the New classical synthesis at the turn of the millennium). The late Kuhn stigmatised the unrestrained plurality of competing research programmes that characterises the revolutionary periods. I contend that, at least in the case of economics, the plurality of interacting research programmes is a sign of healthy pluralism, while the restricted pluralism of the periods of normal science is conducive to dogmatism in economic theory and technocratic intolerance about economic policy and politics itself.

11 Macroeconomics after the Great Stagflation

> *Paul Anthony Samuelson:*[1] *what makes macro efficiency impossible is the hard fact that economic history is at best quasi-stationary time series. [This is the] crucial already mentioned truth that 'economic history obeys no stationary probabilities.' No means none at all. At best, the keenest trader is faced only with quasi-stationary approximations.*
>
> *Niels Bohr:*[2] *you should never express yourself more clearly than you are able to think.*

After the post-war reconstruction, the classical approach tried hard to challenge the academic and political hegemony of the Keynesian approach by resorting to an updating of the time-honoured monetarism as refurbished and updated by Friedman (1969). This alternative approach sees the State not as a potential solution of economic problems but as their ultimate source. In this view, any intervention in the economy is bound to impair the spontaneous autoregulation implemented by free markets. Under these conditions, the government typically succumbs to the temptation of manipulating the money supply in a way inconsistent with market stability. The persistent stagflation of the 1970s seemed to confirm the monetarist thesis. The policy interventions inspired by the Keynesian orthodoxy managed to reduce the unemployment rate only by accelerating the inflation rate. This conundrum gradually shifted the academic and political consensus towards monetarism until at the end of the 1970s a full-fledged anti-Keynesian counter-revolution broke out and shifted the hegemonic view towards a new version of the classical paradigm. In the 1970s, a group of economists of the younger generation led by Lucas (1972, 1976, 1980, 1981) accepted the policy implications of the criticisms

[1] Samuelson (2009, 26, 29.) [2] Quoted in Rovelli (2022, 48).

advanced by Phelps (1967) and Friedman (1968) to Keynesian economics but provided different foundations to the classical revival. First, they rooted both microeconomic and macroeconomic analysis in stochastic GE theory as worked out by Arrow and Debreu.[3] This new kind of foundation, apparently based exclusively on axioms, gave the illusion of being able to dispose of all the quibbles of the dynamic foundations that had haunted Walras and his followers. However, in the absence of an encompassing dynamic setting, one is unable to explain under what empirical conditions the system tends to converge towards the Walrasian GE. If the process of collective learning described by the virtual *tâtonnement* occurs in real time, we cannot avoid false trading and the complex impact of volatile expectations. The most visible and shocking consequence of these new foundations was the systematic adoption of the so-called Rational Expectations Hypothesis (henceforth REH) that assumes that the relevant collective learning has been already completed before the empirical observations. Under these assumptions, the so-called GE is just a solution of the system without dynamic implications as misleadingly suggested by the word equilibrium. The new conceptualisation of the classical paradigm made the contrast with the Keynesian paradigm much more radical than before. In particular, the autonomy of Keynesian macroeconomic analysis is altogether rejected. The New Classical economists claimed that the suggested microfoundations of aggregate GE analysis fully recovered the unity, and internal coherence, of economic theory (Section 11.1). In this view, the economy is assumed to be always in a state of full-employment equilibrium so that the Keynesian notion of involuntary unemployment is made altogether meaningless. This view does not exclude fluctuations of the 'natural' full-employment equilibrium triggered by exogenous factors, in particular the disturbances induced by Keynesian interventionist policies (Section 11.2). Notwithstanding these perturbations, the New Classical approach asserts that money is neutral also in the short run sweeping away the rationale for countercyclical policies. The new equilibrium method advocated by Lucas and his followers raises many epistemological issues that have been hotly discussed, mainly in the 1970s (Section 11.3). Notwithstanding a host of early severe criticisms, by the late 1970s, 'New Classical Economics' with unprecedented rapidity

[3] See, in particular, Debreu (1959).

became the new mainstream school of pure economics, at least as far as the analytic method is concerned (Vercelli, 1991). The New classical research programme underwent updating and refinements but did not alter its basic scientific vision. However, the monetarist explanation of business cycles accepted by Lucas, based on the so-called monetary business cycle model, was soon questioned by the 'real business cycle' model (Kydland and Prescott, 1982; Long and Plosser, 1983) that accepted much of Lucas's New classical equilibrium methodology but reversed the main causal link between the real and the monetary economy explaining business cycles as a consequence of random technological shocks (Section 11.5). The new approach succeeded to narrow the gap between the results of the model and the empirical evidence by adopting a more pragmatic methodological approach dubbed calibration. In Section 11.6, I discuss some of the shortcomings of calibration from the point of view of pluralism. Even most mainstream Keynesian economists eventually adopted the New classical methodology, including in the prototype model at least one kind of market failures, which inevitably imply diverging policy rules that maintained a Keynesian flavour (Section 11.7). Therefore, many Keynesian economists accepted the REH and intertemporal maximisation but introduced in the stochastic GE model a variety of market imperfections such as monopolistic competition, coordination failures, price rigidities, and asymmetric information. The existence of at least one market imperfection turned out to be sufficient to justify Keynesian policy implications.[4] The second generation of this school strived to build on these microfoundations full-fledged dynamic stochastic GE (DSGE) econometric models capable of assisting policymakers and supervising authorities. The gradual migration in the 1980s of several Keynesian economists towards the methodology of New classical Economics significantly contributed to reduce the gap between classical and Keynesian macroeconomics models focusing mainly on the policy differences. This led a few influential economists to assert that the new mainstream economics ruling after the early 1990s represented a 'New consensus', that is a combination of elements drawn from the classical and Keynesian traditions (see in particular Woodford, 2003). This alleged New consensus was based on the agreement that a flawless

[4] Comprehensive surveys may be found in Mankiw and Romer (1991) and Goodfriend and King (1997).

competitive market is in principle self-regulating, but the emergence of specific market failures may require specific public interventions. In the final section, I discuss some implications for pluralism of the evolution of macroeconomics at the turn of the twentieth century.

11.1 The Counter-Revolution of Lucas

The 1970s are years of turmoil and rapid structural change in mixed market economies. This period may be interpreted as the final stage of a trajectory started in the 1940s, evolving in the 1950s and 1960 towards thriving mixed market economies, but then hitting a sort of ceiling in the late 1960s. Macroeconomics proceeded along a similar trajectory that accompanied, with limited leads and lags, the evolution of facts. Sometimes, the evolution of macroeconomics anticipated and inspired the process of evolution of the real economy (as in the case of Keynes during the Great Depression). This was reflected in the 1970s by the growing difficulties of mainstream Keynesianism to justify its policy strategy, while also the monetarism of Friedman started to be questioned from the classical point of view, mainly for its methodology and its interpretation of the empirical evidence. As we have seen, in the 1960s and 1970s, different Keynesian alternatives to the neoclassical synthesis emerged to respond better to the new challenges but none of them gathered a sufficient consensus to become a new mainstream. Within the classical camp, instead, in the early 1970s started a process of radical transformation of the methodology of macroeconomics that soon became highly influential. The most visible early innovation was the adoption of the REH as standard foundational assumption in macroeconomics (Lucas, 1972). Within a few years from its first introduction in macroeconomics, it became clear that the REH was just one aspect of the new scientific vision. The leader of this transformation was Robert Lucas who was soon followed by a new generation of scholars – such as Sargent, Wallace, and Barro – who contributed many details and worked out many implications of the new scientific vision. In his first contributions, Lucas played down the novelty of his approach presenting it simply as a more rigorous way of corroborating the monetarism of Friedman. Lucas fully accepted Friedman's criticism of the Phillips curve and his policy conclusions but aimed to provide more robust foundations to his classical analysis and monetarist policy conclusions. For that reason, in the 1970s the new approach advanced by Lucas was often dubbed 'monetarism mark 2'. However, it soon became clear the sweeping implications of the new method went much beyond the monetarist implications. Though Friedman's dynamic analysis of the feedback between subjective expectations and effective variables outside the natural equilibrium had been found compelling by most classical-minded economists, Lucas believed that this sort of analysis was insufficiently rooted in the rational fundamentals of economic behaviour and was vulnerable to be disproved under mutated circumstances. Friedman's analysis combined exogenous dynamics (triggered by the attempt of shifting employment equilibrium towards a state lower than the natural rate) with the endogenous dynamics generated by the interaction between the observed state and the adaptive expectations of economic agents. According to Lucas, macroeconomic analysis must be rigorously microfounded in the individual behaviour of rational agents according to the principles of methodological individualism. To this end, Lucas rooted the monetarist arguments into the axiomatic version of the stochastic GE model of Arrow and Debreu.[5] This had the advantage of disposing of endogenous dynamics as the latter cannot be easily reconciled with the assumption of unbounded rationality, especially in the ubiquitous case of non-linear dynamics. A similar frustration had inspired Walras to introduce the process of *tâtonnement* that made endogenous dynamics merely virtual. Under these assumptions the only hypothesis of expectations formation consistent with this sort of axiomatic foundations is the REH, the only one believed to avoid any inconsistency within the model and between the model and the modeler. The REH had been formalised a few years before by Muth[1] (1961) in a *microeconomic* context. Lucas was the first to suggest its generalised adoption as an essential assumption of sound *macroeconomic* analysis.[6] The new methodological approach marked a very radical discontinuity with previous macroeconomic analysis. Both classical and Keynesian approaches had been built upon endogenous dynamic foundations. According to Keynes, the trouble with macroeconomics was that there are circumstances under which the market equilibrium established by the endogenous factors is not the full-employment equilibrium. According to Friedman, the natural equilibrium established by endogenous market forces is stable, but

[5] See, in particular, Debreu (1959).

[6] The temporal priority should be assigned to Walters (1971), an influential advisor to Mrs Thatcher, but Lucas was the first to draw the systematic implications of this hypothesis.

exogenous policy interventions can make it unstable and deteriorate its average value in the longer period. In both cases, the disequilibrium trajectory of the economy crucially depends on the interaction of endogenous expectations and policy rules adopted or simply announced. According to Lucas, the equilibrium of a market economy is optimal while the expectations always reflect the economic fundamentals and manage to avoid systematic errors.[7] The radicality of Lucas's methodological stance appears clearly as soon as we look at it from the point of view of his peculiar conception of rationality of the economic agents that is identified with the logical consistency of their thought and behaviour. The market equilibrium is seen as an optimal state that maximises the welfare of all rational agents. Therefore, states different from equilibrium are seen as intrinsically irrational representing 'unintelligible "disequilibria"' (Lucas, 1981, 225). What Lucas calls equilibrium is in fact the solution of the system of endogenous variables. To call equilibrium the general solution of a mathematical system is misleading because, in the absence of endogenous dynamics, there is nothing that equilibrates or disequilibrates a certain state. For the same reason, Lucas's rationality is reflected by the true knowledge possessed by the agents and seems independent of their learning efforts. We usually learn from our mistakes, but only stochastic mistakes are admitted from which, by definition, we cannot learn. Therefore, it is not clear where knowledge comes from. What is learning if not correction of systematic mistakes? What is knowledge if not the fruit of learning? And what is rationality? Complete knowledge of systematic factors? But knowledge is never conclusive and complete and always requires further learning. Thus, it is difficult to deny the primacy of learning in assuring the maximum possible epistemic and practical rationality. What is interpreted as knowledge in a certain moment will be interpreted in the future just as an intermediate stage of learning.

11.2 Epistemic Implications of the Equilibrium Method

In what follows, I will call 'Equilibrium Method' the approach introduced by Lucas and his early collaborators (in particular Sargent, Prescott, and Wallace). The use of the word equilibrium is questionable from the semantic and analytic point of view because Lucas considers

[7] Stochastic mistakes by definition cannot be avoided.

disequilibrium states as unintelligible and the endogenous dynamics of the system remains in principle neglected in the model. Lucas, as Walras with his *tâtonnement* process, seems to have in mind some sort of endogenous dynamic process that is considered analytically irrelevant if not misleading. Nevertheless, Lucas (1981, 181) feels compelled to introduce in his prototype equilibrium business cycle model two endogenous factors to mimic better the wave-like dynamics observed in the empirical evidence:

> no forces are present to account for the persistence or cumulation of the effects of the initial disturbance. In the present study, two such forces are introduced: information lags, such as to prevent even relevant past variables from becoming perfectly known, and physical capital, introducing a form of the familiar accelerator effect.

Lucas never considered these or other endogenous mechanisms as crucial explanatory factors of business cycles, but rather as mere transmission mechanisms that may improve the empirical fit of the model. In what follows, I ignore the auxiliary assumptions,[8] focusing on the (pure) equilibrium method that provides the paradigmatic reference for the basic arguments and the model-building strategy. This method has sweeping epistemic implications that have been so far insufficiently discussed, notwithstanding their idiosyncratic foundations and implications. As is well known, properly speaking, an equilibrium is a resting state of a dynamic system; to study whether an equilibrium is stable or unstable, or when we want to determine the effective dynamic trajectory of the system, we must study the behaviour of the dynamic system out of equilibrium. This analysis, far from being unintelligible, is necessary to determine whether the system is characterised by one or more equilibria and whether they are stable or unstable.[9] Therefore, to know whether a given economic system converges or diverges towards one of them we need a thorough study of the system in disequilibrium. In the absence of essential endogenous dynamics, the so-called equilibrium states describe nothing but the solutions of the system. The use of the term equilibrium can make more plausible the approach in the eyes of its scientific and policy

[8] I use here the expression auxiliary assumptions in the sense of Duhem (1954 [1904–1905]) and Lakatos (1978).

[9] It is important to keep in mind that a non-linear dynamic system typically has a plurality of possible equilibria with different stability properties.

utilisers but is misleading for rigorous analysis. Notwithstanding these terminological qualms, I use the word equilibrium to keep in touch with the language used by the exponents of the New classical School. The focus of economic analysis on rational agents is rooted in a long tradition in economics. But what do New classical economists mean by rationality? Essentially, current and intertemporal coherence in the behaviour of agents. This is a very idiosyncratic view of rationality that diverges radically from alternative views that identify other crucial dimensions of rationality. In this specific view, the hallmark, and measure, of rationality is merely the amount of true knowledge possessed by the agent. But what can guarantee that a certain knowledge is true? How can we compare the knowledge of different agents? Where does this knowledge come from?

11.3 The Monetary Equilibrium Business Cycle

The New classical economists led by Lucas carried on a far-reaching counter-revolution that took macroeconomics by storm rapidly becoming mainstream in many quarters (Lucas, 1981). The crucial innovation was a new view of equilibrium that started to be seen not as a possible state that can or cannot be reached according to the dynamic properties of the system, but as the only possible object of scientific analysis on the part of economics, at least if we take the latter as a genuine scientific discipline. Lucas argued that the equilibrium state is the only state consistent with the substantive rationality of the agents that, in this view, have full information on the systematic factors underlying the empirical evidence in economics. Their expectations are thus bound to be rational, implying that their ex post errors are the inevitable consequence of the stochastic factors acting in the market. Disequilibrium is considered as unintelligible and, consequently, unemployment is denied being involuntary because of structural factors such as the insufficient effective demand on which Keynes focused his analysis. In this view, business cycles are not endogenous oscillations around an equilibrium trend but exogenous displacements of the equilibrium itself. The core of the theory is the so-called equilibrium business cycle approach, which excludes by definition the Keynesian proposition that counter-cyclical policies can contribute to stabilise economic fluctuations. Counter-cyclical policies would only increase the variance of the stochastic determinants of economic behaviour, reducing the efficiency of the market. In the influential monetary business cycle model of Lucas, the exogenous shocks that trigger and sustain the fluctuations derive from an active, and thus not fully predictable, monetary policy. This approach revives the policy prescriptions of Friedman, endowing his anti-Keynesian stance of new microfoundations alleged to be more robust. The adoption of the New classical assumptions implies that the Keynesian policies cannot improve the results of unfettered markets, because any sort of policy intervention would only increase the confusion between change of absolute and relative prices, reducing the efficiency of markets. The New classical economists rejected the opposite conclusions drawn from the Keynesian models arguing that they are derived from an approach that does not provide adequate microeconomic foundations in terms of deep parameters that are invariant to the policy rules. According to this rejection, often called the 'Lucas critique', the agents would react to a new policy environment by changing their behaviour in a way to reach the goals previously established. We can speculate that the advocates of the equilibrium method believe that endogenous dynamics does not affect significantly the behaviour of economic agents. This belief seems to me completely devoid of any justification also from the classical point of view. For example, Friedman's confutation of the mainstream Keynesian interpretation of the Phillips curve is a compelling counterexample. According to Friedman, the obstinacy of policymakers who insist on keeping unemployment at a value lower than its *natural* equilibrium value involves significant welfare losses caused by stop-and-go policies. Another compelling example to be found in the classical camp is the process of debt deflation put forward by Fisher (1933) to explain the Great Depression. In addition, we can mention Wicksell's cumulative process that explains the typical growth cycles of a capitalist economy. Going back further in time, we could mention Hume's analysis of the short-term effects of an increase in money supply. This dynamic approach is found not only in monetary theory but also in other fields of macroeconomic analysis. In particular, the analysis of the balance of trade is based on a dynamic analysis of trade equilibrium. This is true in Ricardo, Mill, Marshall and their followers. As for the Keynesian camp, Keynes focuses on alternative equilibrium states considering their stability properties. The neoclassical synthesis linked the ultimate foundations of Keynesian macroeconomics policy on the weak stability of GE. The crucial role of dynamic analysis is even more clear and explicit in specific fields of Keynesian macroeconomics. In business cycle analysis, the model of Samuelson focusing on the interaction between multiplier and accelerator is an early dynamic analysis that explores the role of disequilibrium trajectories. The same is true of the other early business cycle models such as those of Goodwin, Hicks, and Kaldor. The innovative analysis of steady-state growth started by Harrod focuses on the instability of such optimal trajectory. And so on. This short list of examples should be enough to emphasise how extreme is the reductionism of the equilibrium method suggested by Lucas.

11.4 Early Critiques against the Equilibrium Method

In the 1970s and 1980s the Keynesian economists tried to fight back the ongoing New classical counter-revolution that was jeopardising their influence in the Academia and policymaking. The first opposition targeted the REH, the most shocking conceptual innovation of the emerging school.[10] In the late 1970s, the main exponents of mainstream Keynesianism continued an outspoken resistance against the emerging visions discussing other aspects of the new paradigm. I limit myself to three outstanding criticisms whose scope goes beyond the specific argument by challenging the hard core of the equilibrium method. Samuelson rejected the soundness and viability of New classical microfoundations maintaining that optimisation is sound at the micro level but not at the aggregate level. In addition, he always maintained that the use of the GE models in applied economics cannot prescind from the study of its stability properties. Modigliani (1977, 6) argued that by using the equilibrium method one is led to explain episodes of severe employment declines as 'severe attack[s] of contagious laziness'. This criticism challenges the basic neoclassical idea that business cycles in a perfect competition economy reflect the optimal response of rational agents to external shocks rather than the adaptation to a market failure. However, in a situation of deep crisis characterised by a severe deficit of effective demand, the options of employment among which many workers may effectively choose may be so restricted to constrain the decision-maker to the option that minimises the expected disutility. For example, if a robber in a dark street forces one

[10] In the 1970s, many opponents of the new school of thought called it 'rational expectations School'. This label was rejected by Lucas asserting that the 'hypothesis of rational expectations is a technical model-building principle, not a distinct, comprehensive macroeconomic theory' (Lucas, 1981, 1). Therefore, this terminology is not 'a useful terminology in discussing research on business cycles.' (ibidem).

to give the wallet pointing a revolver, the optimal choice between the only two viable options would be improving survival expectations rather than the economic utility defined in a narrow sense (see Vercelli, 1991). In a case like this we could define the choice as involuntary because the drastic reduction of the option set would be independent of the victim's will. Similarly, unemployment may be defined as involuntary when it derives from a severe limitation of job options that jeopardises the chance of finding a utility-improving job, taking into account all personal and family costs associated with the acceptance of the new job (moving to another place, finding another home, accepting a job conflicting with health conditions, and so on.)

The third example goes directly to the core of the equilibrium method. Grossman and Stiglitz (1980, 393) argued that 'the assumptions that all markets, including that for information, are always in equilibrium and always perfectly arbitraged are inconsistent when arbitrage is costly'. This paradox focuses on the main shortcomings of the New classical equilibrium method. First, it reiterates from a different angle that the concept of rationality underlying this method is highly idiosyncratic as it identifies rationality with knowledge rather than with learning (that aims toward the improvement of knowledge). This peculiar notion of rationality justifies the exclusive focus on equilibrium that makes the equilibrium method unable in principle to analyse the dynamics of the economic system, especially in situations characterised by crisis and structural change. Surprisingly, this is lucidly recognised by Lucas himself: in order for Rational Expectations to 'have an operational meaning, the analysis will be restricted to the situation in which the relevant distributions have settled down to stationary values and can thus be 'known' by traders' (Lucas, 1981, 187). In other words, the REH should be used only when the agents have already completed the relevant learning. This is strictly connected with the assumption that business cycles are recurrent events: 'Insofar as business cycles can be viewed as repeated instances of essentially similar events, it will be reasonable to treat agents to react to cyclical changes as 'risk' [in Knight's terminology], or to assume their expectations are rational' (ibidem, 224). Lucas's awareness of these severe limits of the equilibrium method did not confine, as would have been necessary, the application scope of New classical models to recurrent events or stationary processes and did not inspire the necessary caution in the interpretation of their results. This became evident when the equilibrium method proved unable to forecast the economic disruptions of the third millennium.

During much of the 1970s, there was a lot of focus on monetary theories of the business cycles – a huge industry had developed that stressed the importance of unanticipated money shocks as the key source of business cycle fluctuations. I didn't find that work terribly compelling. And so, I was beginning to question whether such theories were the right way of approaching macroeconomic fluctuations (Plosser in Prescott et al., 2013, 9).

Only in the 1980s was the simplistic monetarism mark 1 of Friedman and mark 2 of Lucas superseded by more pragmatic schools of thought such as the Real Business Cycle School and the New Keynesian School (see Section 11.7).

11.5 The Real Business Cycle Approach

The New classical Revolution implemented by Lucas in the 1970s remained highly controversial until the early 1980s for many reasons. First, differently from the Keynesian Revolution, the blueprint of Lucas's Revolution appeared 'in instalments', that is in a sequence of papers each of which treated specific aspects of it. Only in 1981 Lucas collected the most significant contributions that provided the new view at a glance. Second, this blueprint foreshadowed a radical change in the scientific vision of economics that immediately attracted an avant-garde of young quantitative economists of classical orientation, but its first implementation in Lucas's model of monetary business cycle was found unconvincing also by many followers of the new vision. The main problem was the poor empirical fit of monetary business cycle models. The impasse was overcome by a new generation of models that redirected Lucas's research programme towards a pragmatic direction that was found more convincing by mainstream economists and was eventually endorsed by Lucas himself (1987). The 'manifesto' of the new approach appeared in two different but complementary articles by Kydland and Prescott (1982) and Long and Plosser (1983).[11] These

[11] As for priority, the protagonists agree that 'the short time gap in publication is inconsequential. This is also because both were widely circulated as working papers and presented at seminars prior to publication and had the time of cross-fertilising their contents (Prescott et al., 2013). In addition, they are complementary as the Kydland-Prescott (K-P) model is an aggregate model

models and their offspring were usually called real business cycle (henceforth RBC) models because, in contrast to the monetary business cycle models, they focused mainly on the real causes of economic fluctuations. These models were based on the New classical scientific vision worked out by Lucas, although the latter was modified in many ways.[12] First, the definition of macroeconomics underwent a radical change:

> What is macroeconomics? I think it is largely defined by [the] national income accounts of Kuznets. I use them the way he laid them out, though some people improved on the income side. ... You basically measure output and inputs and report them and use prices to aggregate. That's what the national accountants do. These accounts are consistent with capital theory where you have a special recursive technology, and you can talk about income (Prescott, in Prescott et al., 2013, 3).

The crucial foundational role of the Arrow–Debreu GE model is rejected at least for applied economics, because 'It is hard to talk about income in Arrow–Debreu, as it is not part of that language' (Prescott, ibidem, 3). This does not imply that the RBC research programme gives up the requirement of microfoundations in GE theory but that it seeks a more pragmatic anchorage in Stochastic Dynamic GE (henceforth SDGE) models. Also, the object of the model changes significantly by integrating the analysis of economic fluctuations with the empirical regularities of long-run growth (Rebelo, 2005, 1). As Prescott asserted: 'The key to making macroeconomics a hard science is the Neoclassical growth model. Before the 1980s, growth theory was not part of [New classical]macroeconomics [...] we integrated fluctuations with growth' (Prescott in Prescott et al., 2013, 3). The neoclassical prototype of growth model mentioned by Prescott (ibidem, 4) is that of Solow:

while the Long-Plosser (L-P) model is a multisector model. In this section, I focus mainly on the first of the two models because most RBC models are aggregate and, as a matter of fact, the K-P model has been the main paradigmatic reference for the issues discussed in this section.

12 This has always been recognised by the architects of the RBC models. For example, Prescott put it in this way, 'Lucas said, "Well, we study abstract worlds where the problems are sufficiently simple that we can solve them and build our economic intuition based on what happens in these economies." That was a well-defined research programme. It's working, pretty well, and it doesn't seem to me that there is any other alternative' (Prescott in Prescott et al., 2013, 18).

Solow is a key person there. His aggregate production function is a theory of the income side of the national income accounts. Factors are paid their marginal products and firms can freely enter and exit – these are the microfoundations of his aggregate production function.

In addition, the early emphasis on technological shocks did not exclude that to explain business cycles other real factors could turn out to be particularly relevant. As Prescott (ibidem, 4) summarised, in these models,

> of particular importance are persistent changes in productivity. These changes are in part the result of variations in the growth of the stock of knowledge, but changes in the regulatory and legal environment are of greater importance. Other real factors that have been found to be [important] are changes in the tax system, terms of trade, and demographics.

The new approach of RBC models exhibited a significant degree of flexibility that contributed to its success. The initial emphasis on the reversal of the monetarist causality nexus did not prevent the integration of monetary shocks in a later phase of the model's evolution. In addition, the RBC approach was more open towards the study of the endogenous dynamics of the system that had been regarded with deep suspicion by Lucas for its focus on disequilibrium states.[13] Prescott recognised instead that 'with dynamic economic theory the law of motion is an endogenous element and not a data' (Prescott et al., 2013, 4).

All these injections of methodological flexibility contributed to reconcile, to some degree, the equilibrium approach of New classical Economics with the empirical evidence. However, a decisive boost towards the alleged empirical soundness of these models came from the systematic reliance on a set of inductive procedures dubbed as calibration 'that restricts the mapping between competitive equilibria and the data so that the equilibria display certain desirable properties' (Thomas Cooley in Prescott et al., 2013, 16). This greatly enhanced the capacity of RBC models to mimic the empirical evidence.[14]

Lucas and RBC economists emphasised the crucial importance of the quantitative nexus between the empirical implications of the model and the empirical evidence. They insisted that these implications must be quantitative to support adequately policy choices and their detailed

[13] See the preceding section. [14] See the next section.

implementation. Notwithstanding the early efforts of adaptation of traditional methods to equilibrium methods of estimation,[15] the fit obtained was poor and could not sustain the repeated superiority claims of equilibrium models over the alternative ones. The RBC economists adopted a different strategy of empirical validation based on a wide variety of existing information such as national accounts, panels, and any other relevant data banks. The validation of the model is then performed by comparing the model's simulation of second moments of volatilities, correlations, and auto-correlations with those summarising the empirical evidence under investigation. They consider the model validated to the extent that the model simulation succeeds to mimic the empirical observations.[16]

The first reaction of Keynesian economists to the RBC models was not less critical than that against Lucas's monetary equilibrium business cycle. For example, Larry Summers (1986) argued that the RBC approach did not provide a very sound structure for analysing business cycles, as its foundations were not better than a loosely anchored flapping tent.

11.6 Calibration and Pluralism

Many New classical economists considered *calibration* as a fundamental innovation and adopted it in most RBC models.[17] The systematic use of calibration triggered a hot debate on its advantages and disadvantages as compared with different strategies of econometric inference. This debate is extremely interesting because it touches upon a host of unsettled issues of empirical research methodology. In this section, I consider only some implications of this debate for pluralism.[18] Lucas rejected the NCS models for their abuse of free parameters that makes it too easy to concoct a good empirical fit of the model. Lucas observed that 'since the synthesis was formed by the

[15] See the standard collection of the most significant early contributions in Lucas and Sargent (1981.)

[16] For example, Kydland and Prescott (1982) compare the second moments of their model with that of the US economy.

[17] Kydland and Prescott introduced the terminology in economics and developed its implementation, but the basic idea may be found already in Lucas (1980).

[18] An excellent introduction to all the issues touched upon by the early phase of this debate may be found in Hoover (1995).

addition of free parameters to a static GE system, the general class of models it suggested admitted a wide variety of possibilities for business cycle behaviour. Thus, it seemed a framework open enough to contain virtually any point of view toward policy as a special case' (Lucas, 1980, 1981.) This form of pluralism is close to Feyerabend's methodological anarchism ('anything goes'), a point of view that Keynesian economists did not endorse. Popper would have agreed with this criticism because the mere existence of free parameters prevents a crisp falsification of a model. According to Lucas, to avoid vacuity, the model builder should exploit all the relevant knowledge that can be gathered independently of the model:

> The central idea is that *individual* responses [to a policy] can be documented relatively cheaply, occasionally by direct experimentation, but more commonly by means of the vast number of well documented instances of individual relations to well-specified environmental changes made available 'naturally' via censuses, panels, other surveys (Lucas, 1980, 1981, 288–289).

So conceived, calibration has the advantage of exploiting all the available relevant information while reducing the number of free parameters. However, this procedure has been often criticised for its ad hoc selection of existing information aiming to improve as much as possible the fit of the model. To clarify the implications of calibration for pluralism I have to recall the idiosyncratic New classical definition of theory, model, and their link. In this view, a 'theory' is just 'an explicit set of instructions for building' quantitative models able to mimic the behaviour of the real economy:[19]

> Any model that is well enough articulated to give clear answers to the questions we put to it will necessarily be artificial, abstract, patently 'unreal'... we need to test them as useful imitations of reality by subjecting them to shocks for which we are fairly certain how actual economies ... would react. The more dimensions on which the model mimics the answers actual economies give to simple questions, the more we trust its answers to harder questions (ibid., 271–272).

We are now in the position of understanding the implications of the New classical approach for pluralism. As for the equilibrium business cycle models, the limits in their capacity of mimicking real fluctuations are not considered a reason for falsifying them but rather a prompt to

[19] Lucas (ibid., 272).

improve their calibration and the details of their specification. The dialogue on RBC models specialised to provide answers on different policy issues has always been hot and lively. On the other hand, the dialogue on the underlying theory remained muffled if not repressed. Lucas repeated often that there is no alternative to his suggested theory (that is his model-building strategy). For example, he argued:

> There is a real sense in which this picture [of the advocated theory] seems to me not the best account of employment fluctuations, but rather the *only* account: its main attraction to me from the first has been the absence of serious alternative (Lucas, 4).

This explains why New classical economics has been characterised by a lively internal pluralism, while external pluralism remained underdeveloped. The internal dialogue was involving not only New classical economists but also the Keynesian economists who had adopted the New classical model-building approach (often called New Keynesians) but excluded the Keynesian economists who rejected this model-building strategy (for example post-Keynesian economists). This monist point of view was accepted by most RBC economists. For example, Prescott asserted that 'RBC methodology is a powerful scientific tool. And I don't see any competing discipline' (Prescott et al., 2013, 6). At the end of his arguments, Lucas repeated often the rhetorical question 'which is the alternative?' implying that he did not see any credible alternative to his suggested methodology (see, e.g., Lucas, 1981, 16).[20]

The New classical theory is a clear example of a dichotomy that is ubiquitous in empirical science, not only in economics.[21] Following Lakatos, we can often distinguish in a research programme the *hard core* that constitutes its essence that deeply motivates its advocates, from the *safety belt*, that is the set of assumptions required by empirical applications, assumptions that researchers are ready to modify in case of emerging shortcomings. Lakatos's dichotomy revives the famous observations of the physicist Duhem (1954 [1904–1905]) on the crucial role of auxiliary assumptions that support a theory and the

[20] This rhetoric question has been often repeated by many New classical economists. For example, in Prescott et al. (2013) where the main protagonists of the 'RBC revolution' assess their experience, this anti-pluralist question is repeated many times.

[21] See Lakatos (1978) and the discussion of his point of view in Chapter 4.

readiness of scientists to assure the survival of the core of the theory by changing them. One should not see the safety belt as a merely instrumental device because there are often good reasons for avoiding a too easy falsification of a theory and because the evolution of the auxiliary assumptions may contribute to its progressive updating. It is arguable that this is the case of RBC models. However, this kind of theoretical flexibility could make it more difficult to identify when a certain research programme becomes regressive and could prevent the potential progressive evolution of the hard core. The deficit of dialogue between alternative theories heavily distorts the free spirit of science. In the recent decades, several mainstream economists made an instrumental use of this deficit of external scientific pluralism, concealed by an apparent thriving of internal pluralism, to repress external pluralism.[22]

11.7 New Keynesian Economics and New Consensus

In the 1980s, several economists advocating Keynesian policies adapted to the new environment started to use modified versions of the NC (New classical) models to support and quantify their proposals. The Keynesian criticisms did not succeed to hold back the NC counter-revolution that in a decade succeeded to dethrone the neoclassical synthesis from its prominence in academic and policy mainstream. The success of NC economics, however, regarded more the New classical foundations of aggregate analysis, than their policy implications. The most extreme policy consequence of the new foundations, the thesis of inefficacy of policy interventions, was soon abandoned. Analogously, the monetarism of Lucas and some of his early followers became increasingly controversial since the late 1970s. On the other hand, some of the Keynesian policies continued to attract the interest of policymakers and public opinion. In such a situation, many mainstream Keynesian economists started to argue that, even if one accepts the hard core of NC economics it is enough to admit the existence of a single significant market failure to justify the adoption of Keynesian policies meant to correct such a failure. Therefore, the Keynesian economists started to build models based on the hard core of the equilibrium method changing only the auxiliary assumptions that

[22] See next chapter.

would have denied the utility of the advocated policy interventions. In particular, they accepted the methodological requirement of microfoundations in terms of the model of SDGE. Consequently, they also adopted the REH, abandoning the alternative expectations hypotheses utilised by the Keynesian exponents of the neoclassical synthesis and by Friedmanite monetarists. In addition, they forsook the dynamic foundations of equilibrium that had provided until then the main justification of Keynesian policies as the only way to conquer full-employment equilibrium. However, the NK economists argued that, even within the NC methodological context, it is sufficient to allow for the existence of one systemic market imperfection to justify the adoption of Keynesian short-run policies. In this view, the spontaneous equilibrium reached within unfettered but imperfect markets is not optimal. The list of market imperfections considered by NK economists is very long. The early contributions focused on price rigidities (Calvo), mainly because of staggered contracts (Fisher) or wages stickiness (Taylor). In the 1980s, the NK economists modelled further kinds of market imperfections, focusing on the existence of efficiency wages (Shapiro and Stiglitz), menu costs (Mankiw), bounded rationality (Akerlof and Yellen), monopolistic competition (Blanchard and Kyiotaki), coordination failures (Cooper and John), and so on. The New Keynesian models analysed the consequences of one or more of these imperfections that may have different impacts in different countries and historical periods. Models that considered more than one imperfection showed that their coexistence and possible interactions make a significant difference in analysis and policy that become more complex and context dependent. Though the methodological approach of NK economics is similar to that of NC economics, the policy implications are quite different. The basic idea is that it is possible to improve the welfare of citizens by eliminating, or at least mitigating, the existing market imperfections, and/or counteracting their negative consequences. While NC economists assume that flexible prices and wages succeed to maintain the full-employment equilibrium within a short-term time horizon, NK economists assume that the market's optimal equilibrium may be reached only in the longer run through policies succeeding to counteract market imperfections. For example, in the case of nominal wages stickiness, fiscal and monetary policies may intervene to affect price inflation to implement variations in real wages consistent with full employment.

The NK approach has been often criticised for its lack of generality and its ad hoc justifications of Keynesian policies. However, as we have seen in Chapter 9, a higher awareness of complexity leads to more methodological fragmentation. The important point is that the element of complexity introduced in the model must be appropriate for the study of the case under investigation. This inevitably brings about a fragmentation of models that have to add specific auxiliary assumptions on the relevant market imperfections. On the other hand, the adoption of the equilibrium method seems particularly inadequate to study market failures that cannot be conceived as uniform through time. Notwithstanding these unsolved problems this convergence of paradigms produced in the 1990s a new broad consensus in mainstream economics.[23] The main Keynesian contribution to the synthesis was imperfect competition and sluggishness, as well as a focus on the complex role of the central bank. The resulting fusion was dubbed New classical synthesis and provided the theoretical foundations for much of contemporary macroeconomic analysis and policy (Woodford, 2009). These models adopted the Keynesian distinction between the short and long run because market imperfections have different consequences according to the time horizon. This implies that the pillars of classical monetary economy, namely the classical dichotomy between monetary and real economy as well as money neutrality hold only in the long run. Therefore, this approach recovers a role for monetary policy and counter-cyclical policies, though limited to the short run. In this view, business cycles do not depend only on money shocks, as in the monetarist approach of Friedman and Lucas, but also on other kinds of shocks, including the technological shocks emphasised by the exponents of the RBC theory, as well as on output gaps as in the traditional Keynesian macroeconomics models. For our purposes we do not need to enter into further details on the evolution of the New classical synthesis. I limit myself to mention that, as it had already happened in the past with other forms of eclecticism, this alleged consensus was fragile and was destabilised by the financial crisis of 2007–2009 and the ensuing Great Recession. This led to a renewed polarisation between the classical and the Keynesian sides. After a short-lived swing in 2007–2009 towards the Keynesian

[23] See in particular, Goodfriend and King (1997).

polarity, most policy makers reverted towards the rigid NC orthodoxy based on laissez-faire and financial austerity.[24]

11.8 The New Classical Vision and Pluralism

The new paradigm introduced in the 1970s by the New classical economists under the charismatic leadership of Lucas presents many peculiarities that had, and still have, a great impact on pluralism. The high degree of attraction exerted by the equilibrium method on active economists is stunning as soon as we realise how idiosyncratic it is in the light of the contemporaneous evolution of mathematics, empirical science, and philosophy. In mathematics, nonlinear dynamics clarified the idiosyncratic nature of linear reductionism, as argued by all the branches of complexity science. The scientific vision underling the equilibrium method in macroeconomic analysis is difficult to justify from the point of view of the object of methodology and epistemology. As for the object, Lucas focuses on business cycles, ignoring – or subordinating to this object – other traditional objects of macroeconomic analysis such as development and distribution of income. From the epistemological point of view, this school of thought adopted idiosyncratic notions of realism, truth, and rationality that are difficult to accept in the light of the contemporaneous evolution of philosophy of science (post-positivism), and science (in particular, in relativity theory, quantum mechanics, and complexity theory). In any case, as a matter of fact, this paradigm had far-reaching implications for the validity scope of economic models and the role of pluralism. First, the assumption that rational agents forecast correctly (apart from unavoidable stochastic errors) establishes a univocal link between rationality and truth that is hardly consistent with pluralism. Let us suppose that two agents A and B have to forecast in the real world the value of the same variable for the same future period on the basis of the same information set. Notwithstanding their common commitment to be as rational as possible, it is extremely unlikely that their forecasts, and thus their expectations, will coincide. To formulate the best possible forecasts, they have to interpret the empirical evidence in the light of the relevant theory in the frame of their vision of the world. It is doubtful that they can take account of all the relevant systematic

[24] See next chapter.

factors. In most cases, comparing ex post their forecasts with the actual realisations, they will detect systematic errors. This will incentivise the correction of observed mistakes. However, it is extremely unlikely that this process of learning will eventually produce Rational Expectations for at least two reasons. First, as the history of science clearly shows, our knowledge of the systematic factors is always provisional and is destined to be falsified by future scientific advances. Second, the world is not stationary which makes the path of convergence towards the elimination of systematic mistakes often frustrated by structural changes of the systematic causal relations before the target is reached. This defective link between rationality and truth suggests that both basic notions of the New classical epistemology are questionable. The New classical paradigm conceives of rationality in its essence as atemporal and intertemporal consistency. From the methodological point of view, this extreme reductionism is unacceptable. First, the process of learning implies a revision of our knowledge and acting that is bound to violate intertemporal coherence. Second, rationality cannot be reduced to mere coherent knowledge and acting, as it has other dimensions that should not be neglected to avoid dogmatism. In particular, the assumption of the primacy of knowledge over learning is conducive to a dogmatic view of knowledge that represses the necessary degree of pluralism. In the last analysis, pluralism is justified by the awareness that any knowledge is limited, provisional, and subject to interpretation so that we may always learn from new observations, new deductions, and an active dialogue with critical interlocutors.

PART IV

Pluralism and Complexity in Economics

12 Complexity and Economics

Albert Einstein:[1] *It can scarcely be denied that the supreme goal of all theory is to make the irreducible basic elements as simple and as few as possible without having to surrender the adequate representation of a single datum of experience.*

Stanislaw Ulam:[2] *Using a term like nonlinear science is like referring to the bulk of zoology as the study of non-elephant animals.*

As I have argued in the previous chapters, a crucial criterion to appraise alternative economic visions is the attitude towards complex phenomena. At this stage of the argument, I need to go beyond the intuitive meaning of complexity. To this end, in this chapter I intend to consider in more depth the main dimensions of complexity and their implications.[3] There are two main alternative strategies to cope with complexity in science: the traditional reductionist approach and different varieties of antireductionist approach, this basic conflict plays a crucial role in economics, as well as in other empirical sciences (including physics). I use the simplistic dichotomy reductionist–antireductionist because this is the usual terminology whenever the epistemic issues discussed in this chapter are investigated. However, I have to emphasise that this terminology may be misleading because it seems to suggest that, while the reductionist approach is based on the

1 From Einstein (1933). This quotation has been often simplified in the apparently paradoxical but catchy form: 'Everything should be made as simple as possible, but not simpler'. However, there is no written evidence that Einstein adopted this sweeping version himself. The original quotation reported above clarifies without any ambiguity that simplicity should be pursued until it does not violate the criterion of adequacy of simplifications that I have endorsed in this book.

2 Quoted in Campbell (2004, 455–456).

3 This chapter resumes in some more depth a few crucial epistemological issues already introduced in previous chapters; I revive the discussion on these topics as a preparation of what I am going to discuss in the next chapters.

drastic reduction of a complex system to simple relations between its elementary constituents, the opposite approach rejects any significant strategy of simplification of the object under investigation. On the contrary, I argue in this chapter that the simplification of the object analysed plays a crucial role in both approaches although the simplification strategies pursued are different and have divergent implications.

We have seen in Chapter 1 that the genesis of the concept of rationality has been characterised by a conflict between the concept of reason focused on timeless rules and the ubiquitous existence of change. The concept of equilibrium seemed to provide a solution to the dilemma, interpreting equilibrium as a relatively persistent state that may characterise a process of change.[4] This compromise provided the germs of a vision of the world that was developed and articulated by the mathematical discipline of dynamics. The degree of persistence of equilibrium (stability), and its features (unicity or plurality of equilibria and topological properties of the dynamic behaviour) can be assessed only within the underlying dynamical model. However, the dynamic behaviour of real systems is in general quite complex. To understand it, we have to consider all the principal dimensions of complexity and their interaction that make extremely difficult the understanding and prediction of the system's behaviour (see Section 12.1). The main dimension of complexity is the non-linear nature of dynamics. In non-linear dynamics, prediction is partially possible only under very strict conditions such as short period, low degree of non-linearity, and additive probabilistic approach. This is because of the queer but realistic properties of non-linear dynamic systems: sensitivity to initial conditions, multiple equilibria that may be stable or unstable, bifurcations, limit cycles, and so on. The mainstream approach simplified the analysis of complex systems dynamics by reducing their dynamic behaviour to the linear case. Unfortunately, in many cases, the assumption of linear dynamics induces an oversimplified view of the world that leads to misleading results. I illustrate this point by examining two famous cases of reductionism in physics (Newton and Boltzmann) whose shortcomings stimulated the first steps of the science of complexity. The inability of Newton to demonstrate the stability of the solar system (Section 12.2) stimulated the birth of non-linear dynamics (Section 12.3). The development of complex dynamics gave birth to a new

[4] A stable equilibrium is persistent as far as the endogenous causes are concerned.

vision of the physical world that englobed linear dynamics and additive probability theory as particular cases (Section 12.4). The imaginative non-determinist vision of the universe concocted by Boltzmann's reductionist approach to thermodynamics greatly contributed to the process of removal of irreversible time from large parts of modern physics (Section 12.5). The expulsion of time from contemporary physics is discussed in Section 12.6. This seemed to support the contemporaneous process of expulsion of history and irreversible time from social sciences (Section 12.7). Section 12.8 discusses the implications of the preceding analysis for economics. In Section 12.9, I hint to a theme that has been so far unjustly neglected and under-researched: the crucial role of Richard Goodwin and Hyman Minsky in keeping alive and developing the legacy of Keynes on complexity economics. In the concluding section, I discuss the consequences of complexity for the relation between mathematical language and ordinary language in economics and other empirical sciences.

12.1 The Principal Dimensions of Complexity

In common understanding, complexity is seen as a special case of a system's behaviour that in most cases can be reduced to simplicity by dedicated reductionist procedures. This point of view is highly misleading. The crucial feature of a complex system is the non-linear nature of the links between its parts and thus of its behaviour. Only in special cases the behaviour of a generic system is linear or may be reduced to be linear without any loss of crucial information. And only in these special cases we can apply the usual reductionist methods, 'without having to surrender the adequate representation of a single datum of experience' (see Einstein's epigraph to this chapter). The former chapters mentioned a few examples of complexity that resulted intractable to standard reductionist methods. As I anticipated in the Introduction to this book, the main sources of complexity of a system, apart from non-linear dynamics are, its structure (focusing on the number of its parts and the number of levels or the degree of order of their internal organisation), the heterogeneity of the constituent parts, and the nature of their internal interactions. This sort of structural complexity is not by itself unsurmountable. If the interactions among the parts can be described by linear equations without conflicting with the available evidence, the dynamic behaviour of the whole is in principle derivable from the dynamic behaviour of the parts. In this case, the properties of the system may well be established after bothersome calculations, which, however, can be today rapidly performed by computers. Also, the heterogeneity of the parts can be irrelevant whenever their interaction can be adequately described by linear dynamic equations. What really matters is the homogeneity and additivity of the relevant interactions among the parts of the system. No doubt, the likelihood of non-linear dynamic interrelations among the parts usually grows with their number and heterogeneity but the complex behaviour of the system ultimately depends on the relevance of non-linear interrelations among its parts. In the case of an evolutionary system, we can still cope with complexity but only by introducing two very restrictive assumptions: linear dynamical connexions and exogenous structural change. Finally, random complexity implies that the prima facie behaviour of the system results intractable with the standard methods of probability calculus based on additive probabilities.[5] Summing up, the behaviour of a complex system is impossible to predict, even by approximation, after a time scale that depends on the parameters of the system and the degree of approximation required. In the case of the three-body system, Newton was able to calculate that the anomalies observed by astronomers could jeopardise the stability of the solar system only in the very long period when compared with the metric of human life (see Section 12.2). In meteorology, instead, the initial conditions may produce radically diverging results already in the period of a few weeks, and this restricts the (moderate) reliability of weather forecasts to a few days. This was proved for the first time by the meteorologist Edward Lorenz. In his path-breaking paper published in 1963, he exploited the emerging techniques of computer simulations to prove that, for critical parameter values, his simple model (composed of three ordinary non-linear differential equations) exhibited unpredictable exotic behaviours characterised by dynamic and structural instability, bifurcations, strange attractors, and so on.

Complexity science developed vigorously mainly after 1970s branching in a growing plurality of trans-disciplinary sub-disciplines with different name, approach, technical language, and preferred area

[5] It is not clear, though, to what extent randomness is a factor of complexity independent of complex dynamics. A determinist non-linear system can exhibit an irreducible complex behaviour that prevents correct forecasts and produces chaotic results that may be interpreted as random (theory of determinist chaos).

of application. I list some of them with the name of the main initiator: cybernetics (Wiener), (complex) system theory (von Bertalanffy), catastrophe theory (Thom), chaos theory (Lorenz), non-equilibrium thermodynamics (Prigogine), theory of fractals (Mandelbrot), and (non-linear) network theory (Barabasis). The research on complexity science grew exponentially since the 1970s and was favoured by the establishment of specialised research institutes (more than fifty starting from the well-known Santa Fe institute). Most of these sub-disciplines have been applied to economics but notwithstanding the extreme fragmentation of complexity science being intrinsically pluralistic, they did not have, so far, a significant impact in education and policy.

12.2 Newton and the Stability of the Solar System

I start a brief excursus on the genesis of complex dynamics by discussing a famous episode of frustrated reductionism. Notwithstanding repeated attempts, Newton did not succeed in demonstrating the stability conditions of the solar system jeopardised by anomalous observations. With the analytic instruments at his disposal, he could prove only the stability conditions of a two-body system (such as earth and moon) but the further dynamic complexity introduced by a three-body system (as in the case of earth, sun, and moon), remained beyond his analytic skills. Nevertheless, the dynamic method utilised in the *Principia* (1687) which, notwithstanding his previous discovery of calculus, was still mainly based on a more traditional geometric approach, allowed him to identify deviations from the expected stable trajectories, deviations that potentially conflicted with his scientific and religious convictions. Though these deviations were too small to jeopardise the stability of the solar system at the scale of human life, Newton understood that their cumulation could eventually produce catastrophic instability. After much reflexion, despairing of his own capability to find a mathematical solution to the problem, Newton felt eventually compelled to cling, literally, to deus ex machina hypothesising that God intervened when necessary to adjust the trajectories of the system and preserve its stability. The young Laplace (1749–1827), who was later called the 'French Newton', rejected the idea of God acting as a watchmaker periodically fixing an imperfect craft, and used up-to-date mathematical dynamics to suggest an alleged solution in a few works published in the 1770s. These works made Laplace famous.

However, even his sophisticated methods proved eventually unable to demonstrate the stability of the solar system. The crucial step forward had to wait for the emergence of non-linear dynamics that started its laborious genesis about one century later (see Section 12.3). In the meantime, the scientific vision of Laplace based on timeless linear determinism started to be increasingly questioned.

12.3 Linear and Complex Dynamics

As is well known, a linear system is characterised by two convenient properties, homogeneity and additivity, that greatly limit the range of its possible behaviour allowing the aggregation of the dynamic behaviour of the parts into the dynamic behaviour of the whole. Also, the analytic treatment of time irreversibility and evolution call for non-linear dynamics. Notice that the usual terminology is highly misleading because it clouds the fundamental fact that the systems characterised by linear dynamics are a rare limiting case of non-linear dynamic systems. The distinction between linear and non-linear dynamics is like classifying all the animals as cats and non-cats. We can, to some limited extent, expand the applicability of linear dynamics by linearising the dynamic system in the proximity of equilibrium, but the results so obtained should be handled with great care. An acritical extension of our knowledge of cats to other felines could be misleading if not dangerous.

Until the Scientific Revolution, the vision of dynamics remained dominated by what we call linear dynamics. Moreover, as we know, after the crisis of irrational numbers, the mathematical reasoning about change became mainly geometric. A mathematical theory of dynamics originated only when the new needs of navigation solicited pressing interests towards a more operational version of astronomy at the end of the seventeenth century. Two fundamental innovations made possible a rapid progress towards the mathematical discipline of dynamics. First, analytic geometry, introduced by Descartes and Fermat in the early seventeenth century, built a two-way bridge between geometry and algebra. The established correspondence between geometric curves and algebraic equations made it possible to reformulate problems of geometry as equivalent problems of algebra, and vice versa. This was an important step forward in scientific analysis. Each of the two languages has its own advantages that could then be aptly integrated.

The geometric approach is closer to our intuition favouring conceptualisation, while the algebraic approach is more efficient for calculations. Analytic geometry encouraged another epoch-making innovation in mathematics, namely the introduction of calculus by Newton and Leibniz. These spectacular advances made possible the great achievements of physics in the seventeenth and eighteenth centuries in many fields. The solar system started to be conceived as a dynamical system in which a function describes the time trajectory of a representative point in a state space. The success of Newton's approach determined the application of the same method to a wide variety of problems not only in natural sciences but also in social sciences, including economics. In this chapter, I limit myself to discuss the influence of dynamics on the pluralism of scientific visions. To this end, we have to distinguish linear and non-linear dynamic systems. Until the eighteenth century, the paradigmatic exemplar of dynamic system was what we call today deterministic linear system, namely a system that satisfies the additivity and homogeneity properties.[6] This bias encouraged a view of nature as a simple and regular object. This approach remained dominant for much of the nineteenth century and beyond, notwithstanding the progressive accumulation of observations and theoretical insights inconsistent with such a vision. In physics, it was only the scientific revolution of relativity theory and quantum mechanics that forced the elaboration of a new scientific vision more conversant with complexity. One of the first examples of mathematical analysis of nonlinear systems was the study of the dynamic behaviour of pendulum clocks that was thoroughly studied by Huygens. The attention soon extended to difference and differential equations describing the dynamic behaviour of non-linear systems. Early examples of nonlinear differential equations are the Navier–Stokes equations in fluid dynamics and the Lotka–Volterra equations in populations biology. Problems involving non-linear differential equations are extremely diverse, and methods of solution or analysis are problem dependent. This slowed down their adoption in empirical sciences, including economics.

[6] As is well known, a linear function is additive if $f(x + y) = f(x) + f(y)$ and homogeneous if $f(\alpha x) = f\alpha(x)$. A function is non-linear when at least one of these properties are not satisfied. The conditions of additivity and homogeneity are often combined in the superposition principle: $f(\alpha x + \beta y) = f\alpha(x) + f\beta(y)$.

12.4 The Emergence of Non-Linear Dynamics

As I recalled in Section 12.1, Laplace himself did not succeed in solving the three-body problem. A fundamental breakthrough came only about one century later when the young Poincaré (1854–1912), one of the greatest mathematicians and polymath of his era, in a few works published in the 1880s (Poincaré, 1882, 2017 [1890]), found the way to elicit fundamental qualitative information on the dynamic behaviour of systems defined by non-linear differential equations. In this way, he succeeded in deriving from the value of parameters and the initial conditions the possible dynamic trajectories of the system, the number of equilibria or attractors, their dynamic and structural stability, the possible bifurcations, the existence and nature of limit cycles, and so on. This information was extracted from the virtual dynamic behaviour of non-linear equations without having to solve them, an endeavour that was, and still is, rarely possible. Poincaré successfully designed his suggested geometric approach to solve, or at least to clarify, a few puzzling problems of celestial mechanics and mathematical physics. In 1889 he won the mathematical competition launched by Oscar II, King of Sweden, for the resolution of the three-body problem concerning the free motion of multiple orbiting bodies.[7] Though Poincaré did not fully succeed in solving the problem, his memoir was rightly recognised as a path-breaking contribution towards the solution of this, and similar, problems. His suggested approach can be considered as the first building block of a rigorous analytic approach to complex dynamics.[8] Poincaré's contribution illustrates well that complexity may be tamed, at least to some extent, by adopting sweeping simplifications such as his suggested geometric representation of non-linear trajectories. This simplifying approach provided the guidelines for the successive work on non-linear dynamics inspiring much of the recent complexity science.[9] In particular, it

[7] Oscar II, King of Sweden, to celebrate his 60th birthday established a prize for anyone who could find the solution to the problem.

[8] More specifically, Poincaré paved the way to what is called today 'deterministic chaos theory'.

[9] Poincaré focused on an autonomous ordinary differential equation on a differentiable manifold M, or dynamical system on M, and examined it from the point of view of the geometry of the set of its trajectories: If X is a vector field on M, the partition of M into its set of trajectories of X is the phase portrait of X. The

started the geometric (or qualitative) theory of dynamical differential equations that greatly contributed to make intuitive the investigation of the properties of non-linear dynamic systems. Notwithstanding the substantial step forward accomplished by Poincaré, the development of non-linear dynamics and its application in empirical sciences started to gather momentum only in the latter half of twentieth century. In the intermediate period we find a very limited number of highly original contributions that no one was able to coordinate within a unified research programme. The first contribution that has to be signalled, slightly later than Poincaré's contributions and in many ways complementary to them, was the theory of stability of differential equations suggested by Lyapunov (1857–1918), a young Russian mathematician who defended the thesis *The General Problem of Stability of Motion* at Moscow University in 1892. He worked out a general theory of stability applicable to linear and non-linear, continuous or discontinuous, dynamic systems. In particular, he rigorously defined three concepts of stability that continue to find broad applications in science and technology. We have what is today called Lyapunov stability: if the initial conditions of a solution trajectory are near an equilibrium point, the trajectory remains near it forever. Whenever all the solutions eventually converge towards equilibrium, the latter is called asymptotically stable. Finally, exponential stability allows a measure of the rapidity of convergence towards equilibrium. Notwithstanding a prompt translation in French where the recent work of Poincaré had alerted a small readership of motivated mathematicians, this path-breaking contribution fell into oblivion for many decades.[10] Only in 1936 the Russian mathematician Chetaev, who was then working at the Kazan Aviation Institute, exhumed the contribution of Lyapunov and was the first to appreciate its potential and extended its application

qualitative, or geometric, theory of Poincaré deals with the geometry of the phase portrait of differential equations (Pugh and Peixoto, 2008).

[10] At the turn of the nineteenth century, the interest in non-linear dynamics sharply declined as Poincaré's qualitative approach was not in tune with the contemporaneous turn of mathematics towards the formalist approach initiated by Cantor and developed by Hilbert and Bourbaki. An important but isolated exception was the US mathematician Birkhoff (1884–1944) who in 1913 proved Poincaré's 'Last Geometric Theorem' a special case of the three-body problem. In 1927, he published a book on *Dynamical Systems* that developed Poincaré's approach. However, he was more influential on his contemporaries in other mathematical fields connected to his notable ergodic theorem.

to technological problems. However, the interest in Lyapunov stability took off only when after WWII the 'Second Method of Lyapunov' started to be successfully applied to aerospace guidance systems that typically contained strong non-linearities not treatable by other methods. In that time, Lyapunov methods entered as a fundamental pillar in the expanding literature on the forecast and control of non-linear systems. In particular, Lyapunov exponents and their spectrum found extensive applications in chaotic systems as indicators and measure of their limited predictability.

Summing up, the geometric theory of dynamic system is a compelling example of constructive simplified analysis of complex dynamic systems. These simplifications are quite different from those typically introduced by the usual reductionist approach. Both analytic strategies may be consistent with the rigour required by the argument. The choice depends on their adequacy for the object investigated. In the initial version of this approach, Poincaré did not build formal topological structures from the set of differential equations and did not clarify what they meant by saying that two differential equations are qualitatively equivalent. Andronov (1901–1952) and Pontrjagin (1908–1988) mended this shortcoming by introducing in 1937 the concept of structural stability in a note written in French hoping to find in this language a more motivated audience. Andronov and collaborators (often dubbed as the Gorki School) applied extensively the qualitative theory of non-linear dynamic systems to cyclical phenomena characterising physical and technological systems.[11] What we call today structurally stable systems were initially called *systèmes grossiers* by Andronov and Pontrjagin in their joint work written in French (1937).[12] Lefschetz, an eminent Russian-born American mathematician,[13] chose to translate the word 'rough' (or coarse) as 'structurally stable'. As Pugh and Peixoto (2008) maintain, this insightful translation contributed to the appeal of this approach 'conveying the interplay between the concepts of stability and a certain structure, the phase portrait, subject to topological equivalence'.

[11] In particular, I have to mention the important books by Andronov (1929), Andronov and Khaikin (1937) and its second extended edition by Andronov et al. (1949).

[12] These systems were initially translated in English as rough, or coarse, systems.

[13] Lefschetz edited in 1949 the translation in English of the first edition of the book of Andronov and Khaikin (1937).

12.5 Boltzmann and the Limits of Reductionism

After the collapse of the Enlightenment and the tragic parabola of the French Revolution, the great novelty of the nineteenth century emerging in all the branches of Western thought was the irruption in the pure theory of time, the irreversible time of human experience. In philosophy it is enough to mention the dialectical idealism of Fichte, Schelling, and Hegel, or the dialectical materialism of Marx and Engels, as well as different varieties of historicism flourishing in Germany and other continental countries. Irreversible time progressively percolated also in most evidence-based natural sciences such as natural history (Buffon), palaeontology and comparative anatomy (Cuvier), geology (Hutton and Lyell), biology (Lamarck, Wallace, and Darwin), and physics (Carnot and Clausius), as well as the growing attention for the history of natural sciences (Whewell and Mill). Something similar happened in social sciences including political economy (Marx, Marshall, Spencer, and Veblen) and sociology (Comte). In natural sciences it is particularly interesting to focus on the arrows of time progressively introduced in physics since the early nineteenth century. I mention here only the first, and most important, time arrow introduced in modern physics with the discovery of the second law of thermodynamics. Its origin is connected to the systematic observation of the behaviour of the first steam and heat engines. In particular, Lazare Carnot and his son Sadi observed that the work of heat engines invariably dissipates useful energy. These observations led the Prussian physicist Clausius (1867) to formulate a general law, the second law of thermodynamics, asserting that in a closed system the loss of usable energy, dubbed entropy, can only increase. This law was soon accepted as one of the fundamental laws of physics, but its foundations were found puzzling by most physicists. While all the known laws of physics were characterised by reversible time, the time of the second law of thermodynamics was irreversible and introduced an embarrassing 'arrow of [irreversible] time' within the core of fundamental physics. The first field to which the law was applied was the kinetic theory of gases where macroscopic magnitudes are expressed by variables – such as pressure, temperature, and volume – aggregating the movements of molecules. The best physicists of the time immediately sought a solution to the strident contradiction between the microphysics governing the behaviour of the single molecules of a gas based on time reversible classical physics and the macrophysics of a cloud of gas obeying the irreversible time of the second law of thermodynamics.[14] To solve this contradiction, Maxwell (1831–1879), Gibbs (1839–1903), and Boltzmann (1844–1906) provided a statistical interpretation that in their opinion could explain the second law of thermodynamics as emerging from the motion of molecules complying with the laws of classical physics. It is worthwhile to hint to Boltzmann's solution that represents an emblematic example of reductionism showing its strength but also its shortcomings. Boltzmann distinguished two levels of description. At the microscopic level we may provide for any particular system a precise (determinist) description of the dynamic behaviour of all the component molecules. This description is called the *microstate* of the system and is based on the laws of classical physics characterised by reversible time. The macroscopic level to which the second law of thermodynamics refers, called *macrostate*, is an approximate description in terms of a few aggregate variables such as the temperature and pressure of a cloud of gas. Usually, there is a huge number of microstates that may lead to the same macrostate. Its number is called *entropy*, that is a measure of the degree of order exhibited by the macrostate under investigation. Entropy is a measure inverse to information because we need more information to describe a more ordered system that is characterised by lower entropy. Boltzmann, as is typical of reductionism, considered the micro level fundamental because it is relatively easy to proceed from the knowledge of the position and dynamic behaviour of the components of the system to the characteristics described by aggregate magnitudes. For example, if we know the position and dynamic behaviour of the molecules of a gas, we can derive its density and temperature which correspond to the average energy of motion. On the contrary, we cannot proceed from the description of the macrostate to the actual generating microstate because there are too many equivalent options, the more so the higher is the entropy of the system. Entropy is thus interpreted as an emergent property of the macroscopic description that we cannot identify in microstates. The measure of the entropy of a system relies on probability theory that requires the assumption that all the microstates are equally probable, the usual reductionist device to

[14] The analogies with the conflict started in the same period between microeconomics and macroeconomics are suggestive.

tame the complexity of randomness. In the case of a gas, this assumption is defended by the observation that the chaotic motion of molecules tends to randomise their dynamic behaviour. The most probable macrostate, characterised by the maximum value of entropy, is called equilibrium as it is the state towards which a macrostate tends. The reductionist explanation of the second law of thermodynamics suggested by Boltzmann was at the beginning very controversial and engaged its author in persistent harsh controversies. Owing to his suicide in 1906, he could not enjoy the triumph of his ideas that started with the publication in 1905 of the famous paper on Brownian motion by Einstein. This paper corroborated Boltzmann's assumptions based on the actual existence of atoms and molecules. Boltzmann's explanation of the second law of thermodynamics is a masterpiece of reductionism in modern physics. It solved in a stroke the contradiction between microphysics based on reversible time and macrophysics based on irreversible time. So doing, he provided more credibility to the research in microphysics by corroborating the beliefs in the existence and fundamental role of atoms and molecules that was then at a low of credibility. In particular, with Maxwell and Gibbs he established from scratch the new discipline of statistical mechanics which was going to play a fundamental role in contemporary physics. But the main reason for its eventual success was his imaginative updating of the traditional scientific vision of the cosmos, the so-called block universe,[15] characterised by fundamental equilibrium and reversible or illusory time.

Also, in the case of Boltzmann, however, the apparent success of reductionism carried with it a host of serious problems concealed by its assumptions. First, the second law of thermodynamics applies only to closed systems. This assumption is often introduced as if it were the general case. However, all the macroscopic systems that make possible the existence and evolution of life are open systems. The biosphere depends on solar energy and all living beings learned through evolution to reduce the internal entropy (or accumulate negentropy). If these are considered only local exceptions let us focus on the entire universe, conceived by Boltzmann as a block universe, that by definition is assumed to be a closed system. In this case, how can we explain the

[15] The reason for that peculiar name is that it suggests that what is real is the whole history at once; the allusion is to a block of stone (Smolin, 2014 [2013], 59).

tendency of entropy to increase until the thermic death is reached? Boltzmann's reply is very imaginative. We have to assume that the initial conditions of the universe were far from equilibrium and that the second law reflects a process of convergence towards equilibrium. Yes, but what explains these peculiar initial conditions? The answer by Boltzmann is not at all convincing: in his opinion, the initial displacement from equilibrium is the consequence of a massive fluctuation around equilibrium. In the absence of a sound theory of cosmic fluctuations able to explain the required huge size of the initial macroscopic deviation from equilibrium, this is nothing more than an ad hoc explanation. Surprisingly, this deus ex machina solution is still accepted by most mainstream physicists. In this view, time irreversibility is nothing more than a reshuffling of cards that tends to randomise whatever order could be detected in the initial conditions. But God, we could say by paraphrasing Einstein's critique of indeterminism, does not play cards.

12.6 Time in Physics: Reality or Illusion?

The irreversibility of time is a fundamental property of complexity deriving from non-linear dynamics. Not surprisingly, the reductionist research programmes tried hard to deny the relevance of irreversibility if not that of time itself. The belief that the irreversible time of our human experience is a mere illusion has always attracted philosophers and scientists. We find this point of view already in Parmenides and his followers who prefigured a vision of the cosmos as a block universe. This insight was soon defended by the Eleatic School, in particular through the influential paradoxes of Zeno. Plato elaborated a more sophisticated version of the same view based on the five regular polygons. A similar scientific vision also inspired physics that conceived scientific laws as time reversible, without significant exception until the mid nineteenth century. The assumption of an absolute time by Newton did not question the time reversibility of the universal gravitation laws. The first apparent exception, the second law of thermodynamics, was soon tamed by Boltzmann who maintained that 'For the universe, the two directions of time are indistinguishable, just as in space there is no up and down'.[16] Einstein went a step further by

[16] Quoted in Smolin (2014 [2013], 53).

questioning also the reality of reversible time. In the theory of special relativity the founding principle of 'relativity of simultaneity' implies that the present has no special claim to reality,[17] and all that's real is the whole spacetime, a mathematical object that includes what we could interpret as the entire history of the universe. General relativity introduced radical changes in Einstein's theory that, however, did not substantially modify his vision of the cosmos as a timeless block universe. The geometry of spacetime changed shape in consequence of its curvature and gravitational waves resembling more a 'mollusc' rather than a stone block.[18] In addition, the spacetime became fully internalised within the physical processes as the motion of matter influences the geometry of spacetime, while the latter influences the motion of matter. But there is no way within this theory to distinguish the specific role of time that remains just a dimension of spacetime. The block universe described by Einstein in his theory of general relativity carries on the process of demotion of time within the laws of physics.[19] However, we could contend that in general relativity, time still plays a causal role, although only as a dimension of spacetime.[20]

The successive development of quantum physics gives controversial indication on the reality of time. According to the mainstream point of view, 'to describe the world, the time variable is not required'.[21] However, in quantum theory there are different opinions on this issue. Since its first inception, the evolutionary tree of quantum theory grew at an accelerating rate multiplying its branches and their bifurcations. It is impossible to reconstruct a simplified map of the whole evolutionary tree in short space. I will limit myself to a focus on a recent example that is of particular interest for this book. As soon as quantum theory found a sufficiently broad and coherent conceptual framework,

[17] As Smolin makes clear, in special relativity two events are equally real if some observers see them as simultaneous. This point of view is also called *eternalism*. As the great mathematician Hermann Weyl asserted, in this view 'the objective world simply is, it does not happen'. (On these citations and related issues, see Smolin (2014 [2013], 61).

[18] Rovelli (2018 [2017]).

[19] See Smolin (2014 [2013], chapter 6).

[20] Einstein did not believe that possible counterarguments could restitute a significant reality to time; it is well known that he wrote in a famous private letter, 'People like us who believe in physics, know that the distinction between past, present and future is only a stubbornly persistent illusion' (quoted in Rovelli, 2018 [2017], 96).

[21] See Rovelli (2018 [2017], 102).

scholars at the frontier of research in physics tried hard to find a synthesis with the other major fundamental theory, the theory of general relativity, which is based on a radically different approach. So far, no one has found a satisfactory solution, obtaining the necessary robust experimental support and a sufficiently large consensus among physicists. This led to a growing plurality of specific research programmes (such as string theory, loop quantum theory, multiverse theory, causal set theory, dynamical triangulations, and so on). One of the most developed approach to quantum gravity is the loop quantum theory initiated by Smolin and Rovelli in the 1980s. This theory assumes that space is not continuous but is made of discrete units connected by a network of relations. A typical quantum state may be depicted as a graph constituted by many edges that join nodes or vertices (such as in a lattice). The dynamics of spacetime as described by Einstein's equations can be coded in simple rules that lead to the equivalent evolution of the graphs of loop theory. This coding works well both ways providing a sound 'quantisation' of general relativity. The main challenge that is still unsolved is the application of this synthetic approach to the entire universe. The pioneers of quantum gravity research, the American physicists Wheeler and DeWitt, worked out in 1967 what is today called the Wheeler–DeWitt equation based on the integration of the assumptions of both relativity theory and quantum mechanics. They noticed that one striking implication of applying this equation to the entire universe is the complete disappearance of time. In other words, this equation does not describe how events evolve in time but how they happen in relation to each other.[22] This unexpected and puzzling result created a great impulse to research in quantum gravity, multiplying further the research programmes. A striking example comes from the initiators of one of these research programmes, the so-called loop theory, Smolin (a Ph.D. student of DeWitt) and Rovelli (under the encouragement of Wheeler). They continued to share a radical relationalism and pluralist openness but reached opposing conclusions about the reality of time and space. Rovelli argued that, at the fundamental level of quantum gravitation, space is real and time is an emerging magnitude, while Smolin reached the opposing conclusion. Obviously enough, both worked out a theory of the emergence of the 'illusory magnitude'. In particular, Rovelli

[22] Rovelli (2018 [2017], 104).

explained how time emerges from the fundamental level of quantum gravity to the scale of human experience. And both expressed their views in brilliant and successful books of high-level scientific popularisation.[23] Although they became close friends since the beginning of their scientific career,[24] and continued to discuss passionately about their radical scientific divergencies, no one succeeded to convince the other. However, both of them repeatedly recognised the fundamental stimulus they received from the dissenting friend. Rovelli, the 'poet of physics',[25] commented with a moving ode to Socratic dialogue and pluralism inspired by his friendship with Smolin: 'Science is like affection: those who are dearest to us are those with whom we have the liveliest disagreements' (Rovelli, 2018 [2017], 191).[26] This episode illustrates well how important is dialogue between top physicists at the frontier of physics and how committed to constructive pluralism many of them are.

12.7 Time in Economics: Reversible or Irreversible?

According to many mainstream physicists, 'The growth of our knowledge has led to a slow disintegration of our notion of time.'[27] However, what is our notion of time? What should it be? And, in particular, what should be the notion of time in social sciences? And specifically in economics? To answer these questions, we should distinguish different scales of reality and their links to human observation. To simplify the argument, I will distinguish only three fundamental scales of reality from the continuous dimensional spectrum including them: the micro scale of quantum mechanics, the macro scale of our daily experience and social sciences, and the maxi scale of cosmology. The mainstream conceptualisation of time has progressively become different at the three scales and this poses an ineludible problem of consistency between them. According to the prevailing reductionist approach of physics, the fundamental scale of reality is the micro scale

[23] I signal, in particular, Smolin (2014 [2013]) and Rovelli (2018 [2017]).
[24] Rovelli defines Smolin as a great scientist 'for whom I have a particular friendship, affection and admiration' (Rovelli, 2018 [2017], 190).
[25] One reviewer wrote, 'Physics has found its poet', and this assertion was reported on the cover of his book (Rovelli, 2018 [2017], 190).
[26] In particular, Smolin (2014 [2013]) and Rovelli (2018 [2017]).
[27] Rovelli (2018 [2017], 3).

of mainstream quantum theory where time does not play any role. As for the cosmological scale, most physicists believe that Boltzmann and Einstein successfully updated the age-old Parmenidean vision of a timeless block universe. However, at the scale of our individual and social experience, time continues to play a fundamental role impinging on our vision of the world and on our behaviour. What does it mean that time at the human scale is a mere illusion? Nothing more than that our experience of time at the human scale is apparently inconsistent with our experience of time at the micro and cosmological scales as we interpret it through the models of physics. What we are comparing at the three scales is always our observations on the role of time. At the human scale the observations and the experiments are dated in the past or present and take time, while by definition the predictions refer to the future and their assessment has to wait the occurrence, or non-occurrence, of the expected events. I emphasise thus the paradox that to build a rigorous scientific argument that asserts the inexistence or irrelevance of time requires time, the irreversible time of our observations, as well as their time-dependent interpretation in the light of relevant theories. Moreover, if our time is believed to be an illusion because it does not correspond to the time of physics, this does not imply that it is not real at our scale because this alleged illusion has a crucial role in the explanation of human behaviour.

Time regulates the activity of all individuals and implements the coordination of individual activities every day, month, and year, as well as the coordination of overlapping generations of human beings. It is true that what we call time (at our scale) is derived from the regular movements of the earth, sun, moon, the other planets, and the stars. And it is true that these movements are relative to the shifting position of any individual in space. Einstein's principle of relativity of time simultaneity is certainly inescapable also to our scale. But the humankind elaborated a unified concept of time exactly to coordinate the individual times of all interacting individuals. What is definitely without empirical support is the notion of absolute time introduced by Newton. Even casual observation, or mere good sense, shows that human time is relative to individuals, their position in space, and their movements. But this does not imply that time is unreal at the scale of the biosphere encompassing the human scale. In all its forms, life is regulated by irreversible time that determines and coordinates the intraspecific and interspecific interactions. Irreversible time determines the evolution of all living beings and living species. Therefore, this notion of irreversible time should be the time playing a crucial role in biological and social sciences, otherwise we could not understand the evolution of individuals and societies. Sometimes, too often, social scientists – including the economists – defend the adoption in their models of a reversible time justifying their approach by recalling the reversibility of time in physics. This point of view has to be rejected because, at the scale of the biosphere, irreversible time matters and plays a crucial causal role.[28] The apparent inconsistency between the time at our human scale and that of quantum mechanics and cosmology does not need to perturb us as social scientists and it may be solved in different ways. Rovelli and Smolin explored two ways that may be both suggestive from the point of view of social sciences. Rovelli, who believes in the irrelevance of time at the scale of quantum gravity, provided a sketch of the emergence of time at the human scale (Rovelli, 2018 [2017]). This is the typical reductionist strategy that relies on the microfoundations of macro phenomena. The strategy of Smolin is much more unusual in physics but is robustly justified and suggests new exciting links between the method of social sciences and natural sciences. Smolin has a list of arguments in favour of an evolutionary vision of the universe. Many of these arguments seem to me quite compelling (see Smolin, (2014 [2013]). I limit myself to add a further argument that derives directly from combining assumptions and implications of current mainstream physics, biology, and nonlinear dynamics. According to quantum physics, reality at the micro scale is nothing more than a structure of dynamic relations among undated events. This 'relationalism',[29] not to be confused with relativism, is shared – among many other physicists at the frontier of research – by both Smolin and Rovelli. At the macro scale, instead, the mainstream view of biologists and ecologists is that the ruling laws are evolutionist and specify a fundamental direction of time. Now,

[28] Robinson (1978) rightly pointed out that the almost exclusive focus of mainstream economists on equilibrium has produced a fracture with the irreversible time of history. The subsequent debate on this important issue is summarised by Harris (2004).

[29] Smolin (2014 [2013], xvi) defines relationalism as 'a philosophy that asserts that the truest description of something consists of specifying its relationships to the other parts of the system it is part of'.

even if we suppose that this is the only arrow of time in the universe,[30] non-linear dynamics tells us that an infinitesimal evolutionary change at an insignificant corner of the universe may be sufficient to produce a significant evolutionary change – a sort of macroscopic 'butterfly effect' – at a much larger scale. Since planet earth is not isolated, any significant change happens in a directional time and may affect further changes at different scales.

12.8 Reductionism and Complexity

The more complex the object of analysis, the higher the likelihood that a plurality of scientific visions will emerge and conflict. This is the case of economics. Most economists emphasised that the economic issues are, at least prima facie, particularly complex. The economists worked out two basic strategies to cope with economic complexity that we may call, with words routinely used in epistemology and natural science, reductionist and antireductionist. As we have seen in the preceding sections a similar dichotomy is ubiquitous and may be found also in physics and other empirical sciences. Notwithstanding the popularity of the word 'reductionism', its meaning is by no means clear and univocal. The etymology suggests an epistemic process aimed to simplify drastically the object of analysis by reducing it to its basic components with the aim of obtaining results that apply successfully, at least with good approximation, to the original object of analysis. The reduction of a complex problem to a simpler one is a fundamental strategy of science that has greatly contributed to its successes. This assertion has been emphasised by most scientists and philosophers of science at least until the first half of the twentieth century.[31] Sound criticisms of reductionism have nothing to do with the particular propension of reductionists to simplify drastically the object of their analysis but with the strategy of simplification pursued. The trouble is that the usual reductionist strategies may conceal or distort relevant aspects of empirical evidence and lead to misleading results. Therefore, a wise use of a specific simplification strategy must be explicitly justified in each practical application. The problem is not that the

[30] Smolin lists seven major arrows of time: cosmological, thermodynamic, biological, experiential, electromagnetic, gravitational wave, black hole (see for details Smolin (2014 [2013]), 204–205).

[31] 'Occam's razor' is just an example of the prevailing scientific attitude.

procedure of reduction may lead only to approximations of the true results because this is unavoidable with any scientific strategy of empirical investigation. The trouble is that an acritical use of the standard procedures of reduction may easily lead to sterile or misleading conclusions. However, I have to emphasise that the sound criticisms against reductionism stigmatise simplifications not in themselves but only when they are inappropriate. A sound antireductionist strategy to deal with complexity does not shy away from simplifications but seeks to adopt appropriate procedures of simplification that take account of the research question and the specific kind of complexity involved by the object investigated. The antireductionist simplifications may sometimes be even bolder than those implemented by reductionist strategies. This is the case, for example, of the geometric approach worked out by Poincaré to study the non-linear dynamics of a system. Where, then, does the distinction lie? The main criterium is the following: a simplification is inappropriate when it prevents a sound answer to the research question under investigation. So, for example, as Keynes emphasised, the organic nature of most real economic systems prevents an atomistic approach such as that usually prescribed by methodological individualism.[32] In particular, according to Keynes, the classical assumption that a competitive market is always in full-employment equilibrium prevents a thorough understanding of persistent involuntary unemployment and its policy implications. Reductionist economists reject this argument because in their opinion the requisite of assumptions adequacy to answer the research question would destroy the generality of theory and would encourage their instrumental (ad hoc) use. They usually accept instead the positivist criterion of appraisal of a theory or model that relies exclusively on the correctness of their predictions. Friedman adopted this doctrine, called instrumentalist by philosophers of science, to fight against the emphasis of Keynesian economists on the realism of theories and models. The instrumentalist point of view is usually rejected by contemporary philosophy of science.[33] However, the dialectic between reductionism and complexity may be itself 'complex' and does not

[32] See Chapter 9.

[33] The requisite of theoretical realism is also questioned today as specific metaphysical position. However, the pragmatic criterion of adequacy (or appropriateness for the research question) endorsed by Keynes, Minsky, and other economists may be interpreted like a non-metaphysical form of realism as

authorise any form of *Manicheism*. For example, Walras was the first economist who succeeded to provide a rigorous analysis of a conspicuous source of complexity in economics: the general interaction of markets. However, the potential scope of this model was greatly reduced by two reductionist simplifications. The dynamic interaction between markets was restricted to the simultaneous existence of market-clearing solutions in all specific markets. In addition, since the third edition of his model, the process of *tâtonnement* supporting the interpretation of the system's solutions as equilibria is interpreted as merely virtual. The final result is that, notwithstanding the complex dynamic interaction between all the markets, we cannot exclude that an aggregate market may be characterised by a GE as all the specific markets may be simultaneously in equilibrium. This result is by no means trivial, but the model of Walras is unable to answer the crucial research questions. In particular, we cannot say that full-employment equilibrium is stable, considering the general interaction in disequilibrium between the single markets. And, more in general, we cannot answer the research question of whether the GE is unique and stable. We have to conclude that Walras succeeded in extending our knowledge on a specific source of complexity, namely general market interaction, but introduced a reductionist strategy to tame it that greatly restricted the research questions to which we can actually answer with its model.

It is a pity that Keynes, who cited Poincaré in the TP for his contributions to probability theory ignored the analytical potential of his approach to a theory of complexity. The insightful observations of Keynes on the implications of complexity played mainly a negative role of restriction of the validity scope of orthodox theories of probability and economics, but his attempts of building up a new antireductionist approach in probability theory and economics did not go very far, at least from the analytic point of view. Therefore, what could seem to many scholars a purely negative use of complexity arguments contributed to clip the wings to the Keynesian Revolution. This goes a long way to explain why the Bayesian approach to probability theory advocated by his young colleague and friend Ramsay, and then by de Finetti and Savage, prevailed over the thoughtful, but scarcely

the appropriateness of the assumptions depends on the evidential features of the issue under investigation.

operational, logicist approach of Keynes. As for the GT, Keynes struggled to excogitate an innovative operational model to tackle economic complexity, but its analytic and policy potential turned out to be wanting. Notwithstanding all his Herculean efforts and the wealth of far-reaching specific insights, he did not succeed in building up a compelling general model of the entire economy. His original model looked like the fruit of an ingenious bricolage more than of a sound analytic approach to complexity. His insights on uncertainty and microfoundations (composition fallacy) resumed and developed in a constructive way the epistemological beliefs expressed in the TP but the path trodden stopped short of a satisfactory analytical stage. As for dynamics, the principal source of economic complexity, the Keynesian approach in the GT is ambiguous and confusing. The sense of urgency of his policy message induced Keynes to forsake the more thorough dynamic approach sketched in the *Treatise* towards a sort of rudimentary comparative statics aiming at comparing the likely consequences of different policy interventions. This shortcut of the link between theory and policy greatly simplified the foundations of his message contributing to his immediate efficacy but left many loose analytic ends. In particular, in the absence of rigorous dynamic foundations, the plurality of possible equilibria and their stability property are merely postulated. The introduction of the Phillips curve in the late 1950s by his followers to clarify this issue eventually became the Achilles heel of mainstream Keynesian economics.

12.9 The Legacy of Keynes and Complexity Economics

It is a common belief that the mainstream followers of Keynes abandoned completely his approach towards complexity to seek a synthesis with the reductionism of classical economics. This is only partly true. Even the exponents of the neoclassical synthesis continued to share the idea of Keynes that the complexity of the interactions between economic agents prevents grounding macroeconomics in classical microeconomics. In addition, they recognised that further complexities may lead to market failures that require specific state intervention. However, it is true that a more general link between macroeconomics and complexity was kept alive in a creative way outside mainstream Keynesian macroeconomics. I have already briefly analysed the cases of disequilibrium economics (Clower and Leijonhufvud and followers) and post-Keynesian economics (Chick and followers). However, there are also other eminent scholars that gave important creative contributions to the survival and development of complexity economics in the spirit of Keynes. I will briefly mention only two of them: Goodwin and Minsky who contributed greatly to keep alive, develop, and disseminate different aspects of Keynes's views on complexity economics. Goodwin applied systematically non-linear dynamics to economics since the early 1940s and was instrumental to his dissemination in Europe, as reader in Cambridge, and then full professor in Siena. Goodwin was the first economist to apply systematically and consistently non-linear dynamics to business cycles, fluctuating growth, and distribution of income, drawing inspiration from Keynes integrated by insights from Marx and Schumpeter. He had to flee Harvard under the pressure of McCarthyism. He went first to the University of Cambridge where his Ph.D. pupils included Cozzi of the University of Turin and Velupillai (Vela) who taught in different countries, keeping alive his complexity approach.[34] He was then called full professor by the University of Siena where he influenced among other researchers the current writer, Sordi, Basili, Di Matteo, Punzo, Delli Gatti, Gallegati, Giansante, Dávila-Fernández, and many others.[35] Siena became a hub of numerous followers, not only from Italian universities but also many other European and non-Europeans universities.

Minsky taught in the USA and ended his academic career as full professor at the University of Bergamo where he was a frequent coauthor with Ferri, who was then the Rector of the University. There he found many followers such as Bellofiore and Variato. He used first mathematics and then ordinary language formalisable only with complex dynamics to analyse the Financial Instability Hypothesis, Fisher's debt-deflation model.[36] This theory was not taken seriously by most mainstream economists until the deep crisis of 2007–2009 forced all economists and financial operators including Central Banks to take very seriously his heterodox theories. The expression *Minsky moment* became and still is used to dub the initial phase of a deep depression.[37] The University of Bergamo became an important hub for his followers in Italy and elsewhere. The network of followers of Goodwin and Minsky almost

[34] In Turin, the influence of Goodwin started a tradition involving, among others, Lombardini, myself, Cugno, Montrucchio, Egidi, Marchionatti, and pupils.
[35] See, for example, Goodwin et al. (1984), Sordi and Vercelli (2006).
[36] See, e.g., Minsky (1975, 1982).
[37] See, for example, Vercelli (2009).

overlapped, not by chance, because these eminent scholars cultivated two different aspects of complexity economics emphasised by Keynes.

A reconstruction of the map of the influences springing from these two eminent scholars would show a surprisingly extensive network of economists working on complexity economics. This network has been, and still is, hardly visible because its observability succumbed to the inevitable fragmentation of complexity economics. Keynes dubbed his new aggregate theory 'general' in the specific sense that it is applicable not only under full employment and weak uncertainty as classical economics, but also to situations characterised by involuntary unemployment and strong uncertainty. However, no one can consider it general in the sense that it covers by itself the entire universe of economic problems. Analogously, the theory of general relativity of Einstein includes the theory of special relativity but has been unable so far to merge with the theory of quanta. The illusion of discovering the 'theory of everything' in a certain field of research has always been frustrated by unexpected scientific revolutions shifting the focus of research and rekindling the awareness of ignorance. This is true also of natural sciences, including physics (see Smolin, 2008 [2007]. The reasons are becoming progressively clearer. The more researchers become aware of the crucial importance of complexity, the more they are induced to fragment what used to be a common field of research into a plurality of fields to be studied with different methods and approaches. The growing fragmentation of research cannot thus be considered a shortcoming in a certain broad field of research, but on the contrary a constructive reaction to our increasing awareness of ignorance. The effort of building more general theories than the existing ones will continue to be a fundamental research goal, but its successes will at the same time introduce new unexpected untrodden fields of phenomena and problems.

12.10 Mathematical and Ordinary Language

The issue of complexity discussed in this chapter impinges on an important and controversial methodological problem. Which is the correct relationship between mathematical language and ordinary language in an empirical science such as economics? The first economists who advocated and practiced the transformation of economics in an exact science based on mathematical foundations were the leaders of the Marginalist Revolution, especially Jevons and Walras. However, both of them continued to give an important role to ordinary language to explain the introduction of specific equations and to interpret their results. Marshall, who was a good mathematician, demoted mathematics to a simple instrument to reach the conclusion of the theory whose meaning and use had to be expressed and implemented in ordinary language. Keynes, who was a good logician, argued against the widespread acritical use of mathematics but never excluded a more appropriate use of mathematics in economics. In the 1950s and 1960s, some followers of Keynes progressively extended the use of mathematical models without renouncing to an extended use of ordinary language to explain the specification of the models and their results. (Many contributions by Samuelson, Harrod, Patinkin, Goodwin, Kaldor, and Tobin are examples of this balanced attitude.) The relationship between the two languages started to change with the progressive penetration of logical positivism into economics (Friedman, 1953 is one of the first examples). The New classical School in all its variants (Lucas, Sargent. Barro, Prescott, and so on) shifted further the core of mainstream economics mainly towards mathematics and econometrics relegating ordinary language to a growingly subordinate role. The logical positivism adopted a view of the scientific language that focused on its syntactic dimension while the semantic and pragmatic dimensions remained underdeveloped. The semantic dimension of language was usually restricted to mere denotation (relation of a word or syntactic symbol with a specific empirical object), while the pragmatic dimension was restricted to prediction. Ordinary language was little involved: denotation could be implemented with stipulative definitions, while predictions required just the specification of the time and space to which the prediction referred. Ordinary language is much richer from the semantic and pragmatic point of view as it establishes a wealth of effective or potential relations with a much broader network of meanings, emotions, and pragmatic implications. The complementarity between mathematical language and ordinary language is particularly compelling in the investigation of complex system. In this case, the semantic and pragmatic dimensions often cannot be grasped by the ordinary language without the support of formal languages (such as Poincaré's geometric representations of non-linear dynamics) while the meanings and implications of mathematical models cannot be grasped without a careful interpretation requiring the necessary help of ordinary language.

13 *Ignorance Awareness and Economic Decisions*

Marcus Tullius Cicero:[1] *Our interest should be centred not on the weight of the authority but on the weight of the argument.*

Carlo Rovelli:[2] *Science is like affection: those who are dearest to us are those with whom we have the liveliest disagreements*

In this chapter, I wish to focus on one crucial aspect of complexity in economics: the relationship between *individual decisions* and *aggregate variables*. On this issue, we have found in previous chapters two polar views. According to the point of view of methodological individualism – as advocated by marginalists, neoclassical, and New classical economists – the behaviour of system-wide variables depends on the individual decisions whose effects are aggregated according to linear laws of composition. According to the point of view of complexity economics, as advocated by Keynes and many followers, in most cases we cannot find reliable laws of composition to derive macroeconomics from microeconomics.[3] Macroeconomics is thus to be recognised as a subdiscipline of economics substantially autonomous of microeconomics.[4]

If we wish to provide sound microeconomic foundations to macroeconomics, we need first a decision theory that may explain and predict the behaviour of individuals. We must then aggregate the consequences of their decisions in a sound way to explain and predict the behaviour of macroeconomic variables. One obvious condition for the existence of reliable laws of composition is the linearity of the relations between the relevant variables. In a utilitarian perspective applied to a

[1] Cicero (1972 [44BCE], section V). [2] Rovelli (2018 [2017], 191).

[3] Keynes (1936) dubbed the contrary opinion as 'composition fallacy'.

[4] On the contrary, Lucas maintained that there is no reason to distinguish an autonomous 'macroeconomics' from the general corpus of economic theory based on methodological individualism.

deterministic context, the first step of the problem has an obvious solution. If individuals know all the possible acts and the utility consequences of each of them, they will choose the act that maximises their utility. If the decision-makers have to face a problem characterised by uncertainty, even the first step becomes problematic. Nevertheless, many scholars ascertained that utilities of act consequences, their probabilities, and rational preferences are all intimately linked, and this stimulated the search of a solution. De Finetti (1937) derived probabilities from utilities and rational preferences. Von Neumann and Morgenstern (1944) derived instead utilities from probabilities and rational preferences. Finally, Ramsey (1931 [1926]) and Savage (1972 [1954]) derived probabilities and utilities from rational preferences alone.[5] These links reveal a deep connection between utility, probability, and decision theories.[6] We have thus to choose a probability theory and/or a utility theory that may provide adequate foundations to decision theory under uncertainty. This choice has always been a controversial issue particularly in a context of complexity. We have seen, for example, how different, on this crucial matter, were the polar viewpoints of Keynes and Lucas who inspired the debate between the two most influential schools of economic thought in the last century.

In this chapter, I wish to go in some more depth on this and related issues to explore the implications of complexity for pluralism. First, I will introduce a variant of the concept of weight of argument, that I dub *awareness of ignorance* (Section 13.1). In the light of this criterion, I appraise the limited scope of some of the most influential decision theories (Section 13.2). In Section 13.3, I provide a synthetic sketch of the implications for pluralism of alternative decision theories. In particular, I argue in Section 13.4 that the decision theories under 'risk' are unable to give an appropriate role to rationality since in this approach learning results in being a mere by-product of utility maximisation. In Section 13.5, I summarise and comment on the ongoing lively debate on the pros and cons of 'subjective' vs 'objective' Bayesian analysis that depend on divergent scientific visions of rationality. In Section 13.6, I discuss the pivot hypothesis of New classical monism, the Rational Expectations Hypothesis (REH), showing some of its

[5] This result was already obtained in a less rigorous version by Port Royal Logic (Arnauld and Nicole (1996 [1662]) that derived utilities and probabilities from rational preferences.
[6] On this issue, see, in particular, Hájek (2023, section 3.3.3).

shortcomings. In Section 13.7, I question the conviction that Granger causality, which plays a crucial role in New classical methodology, is able to identify the relevant causal relations independently of specific theoretical assumptions. In Section 13.8, summing up the preceding critiques, I have to conclude that the requisite of microfoundations of macroeconomics in terms of the New classical methodology cannot be considered as compelling. I conclude by observing that the reasons for economic pluralism rightly withstood a series of formidable attacks started after the 1970s.

13.1 Individual Decisions and Ignorance Awareness

In Section 9.5 I defended the Keynesian concept of weight of argument from some of the most common criticisms. In particular, I emphasised that Keynes did not interpret the weight of argument as a second-order *probability* so that the usual objection that this concept triggers a regress ad infinitum is not applicable. This does not imply that a second-order measure of *uncertainty* such as Keynes's weight of argument is necessarily faulty or useless. In this chapter, I suggest a similar approach to draw a few significant implications for economics. To this end, I will use a terminology, slightly different from the standard one, that aims to be more operational. I start from the definition of *uncertainty* that is ubiquitous in all the issues under investigation in this chapter. Since in ordinary language we usually distinguish between different modalities and degrees of uncertainty, it is better to avoid a too narrow technical definition that could perhaps minimise ambiguity but would cloud the semantic and pragmatic richness of the arguments. I use the word uncertainty whenever an agent facing a problem is aware of a lack of relevant knowledge to solve it in the best possible way. Since the seventeenth century, an operational measure of uncertainty, probability, started to be used to solve epistemic and practical decision problems characterised by a lack of relevant knowledge. The trouble is that classical probability theory is applicable only when the relevant systematic ignorance is zero and the weight of argument cannot be improved. In this view, the relevant ignorance excludes stochastic uncertainty, that is the kind of ignorance that – by definition – cannot be reduced by learning. For example, the player of a lottery is uncertain about the number that will be extracted but knows which are all the possible events (number of tickets) and the probability of each of them. In this case, the relevant systematic knowledge is complete although the stochastic uncertainty about which number will be extracted may be highly significant. Unfortunately, we find this kind of manageable uncertainty almost exclusively in games of chance, but this is not the usual case of uncertainty that we have to face in our decisions. Probability theories struggled to extend the paradigmatic case of games of chance to more complex forms of uncertainty but the application scope of each of them turned out to be strictly limited. Their limits should thus always be carefully assessed to avoid misleading applications. If we define the language of probability calculus as an object language, because it refers directly to the object of probability (such as events or propositions), we can assess its application scope by using a meta-language appraising the object language of probabilities. A case in point is Keynes's elaboration of the concept of weight of argument, a second-order measure of uncertainty that is not expressed in the object language of probabilities. My suggested second-order measure of uncertainty is akin to Keynes's weight of argument (according to my preferred interpretation) as the defining ratio has the same denominator (I + K),[7] but focuses on a different numerator, namely *relevant ignorance* rather than relevant knowledge. I propose thus the following measure of second-order uncertainty:

$$a = I/(K + I).$$

I suggest calling this ratio *awareness of ignorance*, a name that has a prestigious Socratic pedigree. This name is also useful to underline the differences of this suggested approach from Keynes's measure of weight of argument. First, I do not restrict its application to arguments, as Keynes did, but extend it also to all the other probability objects, including events, to be allowed to compare the application extension of different probability theories.[8] Second, while the word *weight* gives the

[7] In words, relevant ignorance I plus relevant knowledge K, represent complete relevant knowledge.

[8] The requirement of relevance for both knowledge and ignorance is very important. Many philosophers and scientists repeated that our ignorance is infinite. (See, e.g., the epigraphs in this book.) However, what qualifies ignorance or knowledge as relevant? This question is by no means liable to a straightforward appraisal. The answer depends, first of all, on the object of our investigation. If we study an economic problem. our ignorance of chemistry is in principle irrelevant. However, within a given science – say economics – it is much more difficult to define as irrelevant the ignorance of aspects that seem, at first

illusion that this measure may be expressed in objective quantitative terms, the word *awareness* underlines the ineliminable subjective dimension of this alternative measure. This emphasis on its subjectivity does not imply that this measure is arbitrary and thus useless. On the contrary, from the descriptive and predictive point of view, the awareness of ignorance plays a crucial role in explaining and predicting economic decisions. First, as I argue in the next section, the modality and degree of ignorance awareness may crucially affect the decision strategy adopted by the agents. In particular, it affects the willingness to spend time and money to learn. We can interpret this measure as a Socratic version of Keynes's weight of argument as it assumes implicitly that the hallmark of rationality is not the extent of the relevant knowledge possessed by agents, of which they can never be sure, but the awareness of relevant systematic ignorance that can be evaluated much more easily, especially in familiar worlds. As Socrates maintained, and his avatar practiced in Platonic dialogues, the awareness of ignorance is the mainspring of learning. It is necessary for motivating the efforts, in the light of a frank dialogue with the interlocutors, (i) to ascertain whether the knowledge possessed is relevant and (ii) to learn new knowledge that is relevant to answer correctly the research question under investigation. The focus on the awareness of ignorance shifts our concern for rationality from the primacy of knowledge to the primacy of learning.[9]

13.2 Ignorance Awareness and Decision Theories

The index of ignorance awareness has a descriptive and normative use. From the descriptive point of view, it depends on the subjective

sight, unrelated to the problem under investigation. For example, if we study the market of labour we could have the temptation of considering irrelevant our ignorance about the behaviour of monetary variables. But we know that the latter may influence in a significant way the real variables of the market of labour. This example suggests that the judgment of irrelevance depends on the structure of probabilistic causality and the theory that underlies it. Therefore, it depends also on the time horizon of our investigation that affects our probabilistic judgements. For example, as is well known, the influence of monetary variables on the real ones depends on the time horizon of our analysis. The requirement of relevance links deeply the issue of economic decisions with that of causality (see Section 13.6).

[9] The conflict between these two views underlines many crucial debates in statistics, probability, and decision theories. In Section 13.4, I will discuss an important case study.

features of the decision-maker, in particular: the epistemic background (knowledge of the relevant field) and psychological attitude (degree of self-confidence). From the normative point of view, it may help the agent to choose the approach more adequate to answer the research question. In this book I use this index exclusively to provide a basic taxonomy of different first-order measures of uncertainty to assess and compare their validity scope.[10]

The measure of the awareness of relevant ignorance $a = I / (K + I)$ varies from 1 when the relevant knowledge is zero ($K = 0$), to 0 when the relevant knowledge is complete ($I = 0$ and $K = 1$). This suggests that we may distinguish between three basic modalities of uncertainty (see Table 13.1, top line). We may call the two opposite extremes as *radical uncertainty* when the relevant knowledge is 0, and 'risk' when the relevant knowledge is complete but for an ineliminable 'residual' of stochastic uncertainty.[11] Between these extreme cases, the relevant knowledge is partial and the relevant ignorance not merely stochastic and thus subject to be reduced by learning. It is usual to distinguish between weak (or soft) uncertainty when our measure is closer to 0 and strong (or hard) uncertainty when it is closer to 1. This dichotomy may be useful as a first qualitative reference to the relevant modality of uncertainty for the problem under investigation, but it is deeply misleading when it is extended to include the two extremes. To use a metaphor, in our measure of awareness of ignorance, between the black of complete ignorance ($a = 1$) and the white of complete relevant knowledge ($a = 0$) there is an extensive zone of progressively whitening grey that covers most real situations. We should avoid using a simple dichotomy of uncertainty modalities that is condemned to be highly misleading. This is the case of the distinction between risk and uncertainty first suggested by Knight – and often adopted afterwords. This dichotomy defines as *risk* the case of systematic $I = 0$,[12] and uncertainty when systematic $I > 0$.

[10] I consider this application as the first step of a research programme aiming at assessing the reliability of first-order uncertainty measures according to the nature of the problem to be investigated and the specific circumstances.

[11] Also, the distinction between systematic and stochastic uncertainty is inevitably subjective. The boundary depends on the current knowledge and the assessment of potential future learning within the relevant time horizon.

[12] We find a similar dichotomy also in a few passages of Keynes that seem to consider uncertainty proper only the case $a = 1$. However, the concept of weight of argument and weight of evidence clearly focus on the grey zone.

Table 13.1 *Awareness of ignorance and decision theories*

Ignorance awareness $a = I / K + I$	$a = 0$	$0 < a < 1$	$a = 1$
Uncertainty modality	Risk	Uncertainty	Radical uncertainty
Probabilities	Additive	Non-additive	Undefinable
Subjective decision theories	Ramsey (1931 [1926]) De Finetti (1937) Savage (1972 [1954])	Schmeidler (1982) Ponsard (1986) Gilboa (1987)	Consequentialist theories
Objective decision theories	Von Neumann and Morgenstern (1944) Reichenbach (1949)	Jeffreys (1961 [1939]) Walley (1991)	

13.3 Decision Theories and Pluralism

The first axiomatised decision theory that was applied in empirical science was suggested by Von Neumann and Morgenstern (1944) who based it on 'objective' probabilities interpreted as stable frequencies. The Bayesian theory axiomatised by De Finetti (1937) and Savage (1972 [1954]) took instead a subjectivist (or 'personalist') point of view, but relied on formal axioms that are substantially equivalent to those of von Neumann and Morgenstern.[13] Though their epistemological foundations are radically different, the axioms of both theories imply unique, additive, and reliable probability distributions for the relevant variables. A crucial but controversial role is played by the axiom that was called 'axiom of independence' by Von Neumann and Morgenstern, and 'sure thing principle' by Savage. This axiom ensures the absence of systematic errors through time and thus assures the intertemporal coherence of decisions.[14] The axioms of classical theories are very restrictive and confine the field of their sound application to a very limited sub-set of economic phenomena characterised by mere risk. In this case, in the problem under investigation, the agent does not know which specific events *will* actually occur but knows which event *may* occur and is able to assign a probability to each of them. This is the case of chance games such as roulette, cards, and dice. This approach may be extended with vigilant caution to phenomena that may be assimilated to them.[15] According to the frequentist theory, only phenomena characterised by sufficiently stable frequencies may be assimilated to the ideal type of chance games.[16] These are fairly numerous in natural science but definitely scarce in social sciences, including economics. Some of the supporters of the subjectivist theory, such as De Finetti (1937), often claimed that their suggested approach may be applied to any kind of uncertain phenomena without a priori

[13] Savage built his theory on the insights of Ramsey ((1931[1926]) and De Finetti (1937). A more detailed critical survey of these issues may be found in Vercelli (2024).

[14] This theory implies rational expectations, since all the alternative hypotheses of expectations formation imply the existence of systematic errors. See Section 13.4.

[15] Standard textbooks often prescribe the use of the objectivist theory for 'known' probabilities, and of the subjectivist theory for 'unknown' probabilities. Both cases describe situations of risk that exclude relevant systematic uncertainty.

[16] See, in particular, Von Neumann and Morgenstern (1944).

limitations. However, the axioms of the subjectivist theory are not less demanding than those of the frequentist theory and restrict quite severely the empirical scope of its applications. Savage (1972 [1954]) himself restricts its full validity to 'small worlds', the behaviour of which is familiar to the agent. In what follows, adopting the traditional language, I group both frequentist and subjectivist theories in the category of *classical* decision theories under risk. I call them *classical* because they have been, and still are, mainstream in economic applications. In addition, notwithstanding the different language and philosophical interpretations, they have similar axioms that lead to similar conclusions. In all these cases the option that maximises the expected utility is chosen. These theories are straightforward extensions of the pristine determinist decision theory that aimed to single out the option that maximises utility. Unfortunately, classical theories are applicable only when the awareness of systematic ignorance is zero. This does not imply that there is no uncertainty but that the relevant uncertainty is only stochastic ('risk'). As we have seen before, this is the case of games of chance that offer the paradigmatic exemplar on which these theories are built. The polar case is that of situations characterised by complete relevant ignorance. In this case, probability theory does not apply, and decision theories must rely on the comparison of the expected consequences of the available options. If this is possible (limited number of options and sufficiently homogeneous consequences that permit a sufficiently reliable comparison) we can choose the preferred option according to a significant decision criterium such as the Maximin (but also the Minimax and Maximax criteria are occasionally used). As for the vast grey zone of partial systematic ignorance, a number of decision theories have been suggested since the 1980s. In all these theories, probabilities are not additive and are often called hard, imprecise, or ambiguous. An early stream adopted as first-order measures of uncertainty the *capacities* suggested by the French mathematician Choquet (1954).[17] Another interesting stream is based on probability intervals. A further approach adopts the theory of fuzzy sets (Ponsard, 1986). The synoptic Table 13.1 aims to provide an intuitive understanding of the application scope of decision theories in terms of ignorance awareness.

[17] The first example was worked out by Schmeidler (1982).

Table 13.1 shows that we have to choose a decision theory that is adequate to respond to the research question under investigation. Rationality requires both epistemic and pragmatic adequacy. This severely restricts the application scope of decision theories. The classical theory of Laplace, the frequentist theory of Von Neumann and Morgenstern (1944), and the subjectivist Bayesian theory developed by Savage (1972 [1954]) based upon Ramsey (1931 [1926]) and De Finetti (1937) are applicable only in the extreme case of additive probabilities and zero awareness of ignorance (risk). At the other extreme of complete awareness of ignorance, we cannot use a theory of decision that uses probabilities because the latter require a minimum of knowledge about possible events. Finally, in the intermediate case, we can use a decision theory based on non-additive probabilities such as those mentioned in Table 13.1. This simple table suggests that, according to the criterion of adequacy adopted here, the hope of finding a specific theory of decision that dominates all the alternatives in all circumstances is, in principle, illusory. On the other hand, several decision theories have their own niche of validity. Also, in the case of randomness the hallmark of complexity is fragmentation. This observation provides further robust justification of pluralism in economics.

13.4 Decision Theories and Learning

The existing decision theories have radically different implications for learning that our suggested taxonomy based on the awareness of ignorance may contribute to clarify. The decision theories used in microeconomics do not focus on learning because they assume complete knowledge of the relevant systematic variables. This is particularly clear in the subjectivist Bayesian theory elaborated by Savage (1972 [1954]). The hallmark of the Bayesian theory of probability is learning through conditionalisation by applying Bayes' theorem. However, Savage's models are first of all optimising models that have as their principal motivation expected utility maximisation that follows from the axioms. In these models, learning 'is not a goal or objective in its own right. Learning only occurs as a byproduct, reflecting the information constraints faced by the agents' (Kiefer and Nyarko, 1995, 41). Of course, these theories cannot ignore the necessary updating of the information set. Bayes' probability conditioning is the natural approach to updating but this approach is usually restricted to the inclusion in the information set of the new realisations of the stochastic variables. This is a very limited kind of learning. In the case of frequentism a long succession of updates of the empirical evidence is necessary to significantly change the relevant probabilities. That is why Von Neumann and Morgenstern restricted the validity of their theory to stable frequencies. However, what has been a stable frequency in the past may become unstable in the future. In addition, what had been interpreted as a stochastic variable may appear as a systematic variable in the light of new knowledge. This is the case of *deterministic chaos* where the behaviour of the relevant variables that had been interpreted as stochastic may be recognised as systematic in the light of new advances of non-linear dynamics or more precise measurements. Finally, in the case of the theory of Savage, the requirement of intertemporal coherence as imposed by the controversial axiom of independence constrains the process of revision based on the Bayes conditioning. But the process of learning in science is often characterised by a change of theory or empirical approach or even scientific vision that is bound to violate the simplistic formal requisite of intertemporal coherence. This is particularly true in the case of scientific revolutions. On the contrary, what is called today *objective* Bayesian analysis (to distinguish it sharply from the so-called *subjective* Bayesian analysis) focuses on learning.[18] This approach acquired growing importance in the recent decades because it inspired machine learning hardware and software, inspiring the current spectacular advances in Artificial Intelligence. However, the applications of this approach to learning in economics are still limited. According to the mainstream marginalist paradigm of economics, the focus is still the maximisation of expected utility, and learning is not considered a genuinely autonomous goal but only an accessory instrument to increase expected utility. A case in point is liquidity preference. Liquidity has a value because it gives time to learn. But this value becomes relevant only if the time horizon of decision is long enough for significant learning and some sort of relevant irreversible change is expected. In addition, the value of liquidity is really significant only if uncertainty is strong and irreversibility compelling. Learning, however, requires a minimum of relevant knowledge to formulate credible hypotheses justifying the effort of pursuing significant research to reduce relevant ignorance.

[18] See Williamson (2010).

Of course, we can always pursue a research investigation according to random criteria, but this is unlikely to bring any significant results. Summing up, the vision that motivates learning is that of partial ignorance associated with ignorance awareness and preference for increasing knowledge.

13.5 Subjective and Objective Bayesian Analysis

A particularly interesting ongoing debate on the complex issues of probability and decision-making opposes subjective and objective Bayesian analysis. The adjective 'Bayesian' started to be adopted in statistics, probability, and decision theory only since the late 1950s in the loose sense of analysis making a systematic use of the Bayes' theorem.[19] The Bayes' theorem had been published posthumous two centuries before.[20] Its importance was soon understood by the outstanding probability theorists of the time. In particular Laplace perfected and extended the implications of the theorem in his famous treatise on probability (Laplace, 1814). The specificity of this approach was phrased in terms of systematic use of *inverse probabilities* to estimate the relevant parameters from experimental data. This approach used Bayes' theorem to derive the posterior distribution of the parameter investigated from a prior distribution coupled with a conditional distribution of the data given the parameter. The revival of 'Subjective Bayesian' analysis emerged with the subjectivist (or personalist) theory of decision-making elaborated by Savage, who built on the insights of Ramsey (1931 [1926]) and De Finetti (1937). This approach soon became particularly popular in economics as it promised to provide rigorous subjective foundations to microeconomics focusing on individual rationality.[21] However, its limits and distortions were soon pointed out by the representatives of the re-emerging objective Bayesian approach adopted by most AI researchers. This research programme, in continuity with the traditional 'inverse probability

[19] See, for example, Fienberg (2006, 1). [20] Bayes (1763).

[21] Lucas pointed out that 'Milton Friedman [was] very influenced by Savage and this Bayesian way of thinking about probabilities.' (Lucas in Klamer, 1984, 40) Lucas also pointed out that the language he adopts in his own analytical work is different from that of Savage. However, at a deeper level we find in Lucas a similar emphasis on knowledge conceived as information) and coherence while learning is defined as 'red herring' (ibidem, 39).

approach', focused on learning from data sets. The advocates of the subjective approach defended with vigour their preferred approach and emphasised the shortcomings of the objective theories (see, e.g., Kiefer and Nyarko, 1995). The advocates of objective Bayesian analysis responded to these criticisms with equal determination. However, notwithstanding this ongoing hot debate, there is no growing consensus on the advantages and disadvantages of the two approaches and their several variants. I briefly comment here a few limited aspects of this debate because they are strictly connected to the main themes of this book. I start from the terminology that may easily be misleading. Several Bayesians reject the label 'objective' Bayesian analysis asserting that statistical analysis can never be fully objective. In particular, the process of data analysis inevitably involves crucial subjective choices, such as the choice of the model and of the prior distributions for model parameters (see, e.g., Berger, 2006, 386).[22] However, also the label 'subjective' Bayesian analysis may be misleading. The subjective assessment of probabilities is always affected by logical and informative constraints that cannot be reduced to the mere subjectivity of the agent.[23] Both categories of objections sound reasonable but we need a terminology to distinguish two scientific visions that diverge on many issues. Since the standard decision theory in economics likes to qualify itself as subjective Bayesian theory, the term objective seems adequate to point out in which direction the second school diverges from the first. The main difference between them is that the Subjective School emphasises the role of the axiomatic system worked out by Savage (or variants of it) to choose the option that maximises the expected utility of the agent guaranteeing at the same time the formal coherence of the arguments through time. However, this approach has a cost as it displaces learning to a secondary role as byproduct of subjective utility maximisation. The objective Bayesian theory, on the contrary, focuses on learning from the empirical evidence and adopts a more pragmatic

[22] Berger reminds that 'Other names for this approach have been suggested – such as noninformative, reference, default, conventional, and non-subjective – but none carries the simplicity or will carry the same weight outside of statistics as "Objective".'

[23] A different opinion would require either a strong ontological commitment such as the extreme subjectivism professed by De Finetti who used to repeat that 'probability does not exist', or an obsolete psychologist interpretation of the crucial logical constraints that characterize the subjectivist Bayesian analysis (Ramsey, 1931 [1926]; De Finetti, 1937; Savage, 1972 [1954]).

point of view even at the cost of sacrificing, according to critics, a few aspects of formal coherence.[24] So far, the Objective Bayesian School was unable to reach a robust formal coherence comparable to that of the Subjective School. However, the objective theory was superior from the point of view of learning from data in conditions of complexity contributing to build efficient AI models and devices.

13.6 Rational Expectations[25]

As is well known, mainstream macroeconomics adopted since the late 1970s the Rational Expectations Hypothesis (henceforth REH) as a crucial assumption of sound macroeconomic models. In the light of the preceding discussion, it is legitimate to investigate the effective scope of sound applications of this hypothesis. As is well known, the REH assumes that agents' expectations under risk are correct, as far as the systematic errors are concerned, so that the ex post errors are interpreted as stochastic and thus by definition unpredictable. This implies that the ignorance awareness attributed to the economic agents is nil so that learning is in principle without value unless it refers to the extremely narrow meaning of the necessary updating of the information set. Lucas maintained that Savage's theory influenced Friedman but did not endorse it. He endorsed instead Muth's REH 'as a corollary of the general principles of economic equilibrium' (Lucas and Sargent, 1981, xvii). He also sketched with Sargent a new 'decision theory' (p. xxii) aiming to provide sound foundations to New classical Economics clarifying 'the intimate connection between the idea of rational expectations and the modern "Arrow-Debreu" definition of competitive equilibrium for situations in which all agents possess common up-to-date information' (ibidem, xix).

As the well-known paper by Grossman and Stiglitz (1980), focusing on asset prices, pointed out long ago, the REH conceptualisation of expectations formation is somewhat paradoxical because, without any sort of tangible incentives to learning, it is not clear where the complete knowledge of the systematic factors comes from. In a rarely cited

[24] The modern evolution of the Objective School may be related to the important contributions of Jeffreys (1961 [1939]) to build on 'a completely coherent objective Bayesian methodology for learning from data' (Berger, 2006, 386).

[25] This section resumes arguments anticipated in previous chapters, but it seemed useful to me to resume them in the light of the contents of the current chapter.

paper, Lucas seemed to show awareness of the problem and the consequent limited application scope of this approach. He recognised that the REH is soundly applicable only when the issue under investigation is familiar to the decision-maker who had the opportunity in the past of learning the best solution. The limitation of the scope of the REH is conceptually very similar to the restricted sound application of Savage's Bayesian theory to small worlds that may be interpreted as familiar worlds:

> Technically, I think of economics as studying decision rules that are steady states of some adaptive process, decision rules that are found to work over a range of situations and hence are no longer revised appreciably as more experience accumulates (Lucas, 1986, 218).

This awareness of the limits of the equilibrium approach clearly excludes a profitable application of the REH to situations characterised by unexpected structural changes and economic turmoil. Unfortunately, the cautionary remarks by Lucas were soon played down, if not forgotten, by most mainstream economists. In their empirical work, Lucas and his followers did not restrict the application of the equilibrium method and the REH with the only possible exception of the Great Depression. No wonder that the Great Recession of 2007–2009 came as a surprise for mainstream economics.

13.7 Probabilistic Causality

Ignorance awareness focuses on the agents' ignorance of systematic factors relevant for the research question under investigation. This measure presupposes: (i) a criterion for distinction between relevant and irrelevant knowledge and (ii) a discriminant between systematic and stochastic factors. Both distinctions require a vision of the probabilistic causal links between the variables under investigation. The knowledge of a variable is relevant if a change in its value is likely to affect the probability of occurrence of at least one of the endogenous variables of the model. A variable is systematic if it is relevant in the above sense and is in principle predictable, while it is stochastic if it is relevant but in principle unpredictable. The occurrence of a systematic variable can be predicted with a certain degree of probability if we ascertain a reliable nexus of probabilistic causality with at least one variable of the model (Keynes, 1921;

Suppes, 1970; Vercelli, 2001, 2024). Random variables cannot be predicted because we do not know their active and passive causal links. We cannot just say 'everything holds together' as the advocates of the GE approach liked to assert, or, more specifically, postulate that all the variables of the adopted model are interdependent. This assumption may well be true but plays a misleading role in research. We are usually interested to know which are the stronger and more immediate causal links, and which is the transmission path and its timing. To this end, it is better to select the most significant causal links ascertaining the direction and timing of transmission of the causal impulse. This may be seen as a strategy of simplification of a model that is particularly valuable in case of complexity. It is not by chance that probabilistic causality was suggested by Keynes (1921) who was particularly concerned with the complexity of the real world, and later developed by Simon (1982) under the assumption of bounded rationality of the agents. The causal approach pursued by the Cowles commission was not oblivious of Keynesian complexity but operationally consistent with it. New classical econometrics adopted instead a different concept of probabilistic causality: Granger causality (1969, 1980). The basic idea of Granger causality is very simple. Correlation between two stochastic variables is neither a sufficient nor a necessary condition for causality but gives us a legitimate reason for believing that some sort of causal connection might exist between them, unless we can show that the correlation is spurious. Moreover, if we assume that the cause must precede the effect, we can ascertain empirically the direction of the causal relation. The point of view that correlation plus a time lag pinpoints a causal relation is at first sight appealing because it seems that we can demonstrate the existence and direction of a causal relation through statistical methods only, without any explicit intervention of specific subject-matter theoretical hypotheses. The causal relation so ascertained would be useful, at least for prediction purposes, under the assumption that the regularities underlying the correlation and the direction of the temporal lag will not change in the relevant period. The main issue at stake is the possible spuriousness of a given correlation and how to identify it. The supporters of this approach maintained that the likelihood of spuriousness may be settled empirically through appropriate tests, without the intervention of specific subject-matter hypotheses.

Granger causality has been at the centre of a lively debate over the extent of its validity and its implications for macroeconomic theory. It rapidly became very popular with New classical economists (such as Lucas, Sargent, and Barro) because it fitted well the equilibrium approach. This conception of causality also became an important source of inspiration for the so-called 'new econometrics', a new approach founded on time-series analysis 'without pretending to have too much *a priori* economic theory' (Sargent and Sims, 1977).[26] We could object that any procedure of selection and manipulation of data already presupposes a theoretical point of view. The crucial problem is how to discriminate between genuine and spurious causes. We cannot do it without an explicit intervention of theoretical hypotheses. The supporters of Granger causality argued that they can get round this obstacle. They discussed a list of circumstances under which an apparent cause is likely to be spurious and argued that these circumstances are extremely unlikely in the case of Granger causality. Unfortunately, this strategy failed.[27] It seems unsafe to claim too much for these testing procedures in view of the long chain of restrictive assumptions marking each step of the procedure for the implementation of the tests and in view of the fact, fully recognised by Granger, that the list of sources of spuriousness cannot be exhaustive and is relative to a given background information. However, in Keynes, the background information encompasses a theoretical framework, while in Granger causality it includes only the past and present values of the relevant stochastic variables.[28]

Summing up, the alleged unconditional nature of Granger causality is groundless for two main reasons. First, a Granger cause cannot be more than a prima facie cause unless we can exclude an exhaustive list of circumstances that might induce spuriousness. Second, the counterfactual analysis underlying normative macroeconomics requires a structural approach to causality that implies the assumption of a

[26] The existing Granger causality tests have in common a two-stage procedure of implementation. In the first stage, researchers apply a sequence of statistical tests to data without making explicit their theoretical hypotheses, while in the second stage they interpret their results as if they were unconditional on theory.

[27] See, for more details, Vercelli (2024) and literature cited therein.

[28] The inductivist approach of Granger causality leads to further limitations such as the exclusive reference to events that have actually occurred, and hence not to types of events and to dispositional variables that play a crucial role in economic theory.

specific theoretical framework. Therefore, we cannot rely on Granger causality tests to choose between alternative theoretical approaches. However, within a specific theoretical framework, Granger causality tests might legitimately influence the choice of the model and thus the policy rule to be adopted. The evolution of New classical Economics is a case in point. In the early 1980s, the main causal factor of business cycles shifted from money shocks (Lucas, 1981) to technology shocks (Kydland and Prescott, 1982) following the results of Granger causality tests showing that the monetarist point of view had become inconsistent with the empirical evidence. This U-turn on the causal direction of circulating money also modified the policy implications of mainstream theory from the strict monetarism of Volcker to the more permissive and discretionary policy inaugurated by Greenspan (the so-called 'Greenspan put' policy). In the following period, the growing awareness of the shortcomings of the VAR approach to causality introduced by Granger forced the introduction of additional structure in the model to permit a minimal counterfactual analysis. Structural VAR (SVAR) models have become the dominant approach of New classical macroeconometrics. However, this approach is hardly consistent with the New classical analysis. The structural coefficients that characterise the impulse-response functions of this approach are likely to change after a significant revision of the macroeconomic policy rules incurring in the 'Lucas critique'. The usual mainstream response, which maintains that the Lucas critique is correct but genuine changes in policy rules are rare, is not convincing and sounds as an ad hoc defence (Hoover, 2012).

13.8 Microfoundations and Pluralism

The point of view maintained in this chapter is radically divergent from the mainstream one advocating sound microfoundations of macroeconomics in terms of classical probability decision theory. A strict compliance with this methodological approach has been unwisely adopted as a demarcation criterion between updated and obsolete economics. This opinion has been adopted since the early 1980s by most editorial boards of high-ranking learned journals in economics, impairing accessibility to academic careers and top-level jobs to researchers pursuing different approaches. In the light of the previous discussion, the requirement of New classical microfoundations cannot sustain any monist claim against alternative scientific visions. The rhetorical question 'which are the alternatives?', often repeated by Lucas and his followers, does not need to remain without answer. The idiosyncratic nature of New classical microfoundations results evident as soon as we compare it with a long list of alternative conceptions advocated in the literature by epistemologists, methodologists, and social scientists.[29] In the end, we may observe with Solow (2008) that the requisite of New classical microfoundations is not a robust and compelling scientific principle but rather, to use his words, a 'rhetoric swindle' aiming to 'kill' macroeconomics as an autonomous discipline and committed to inhibit the development of alternative macroeconomic approaches. As was wittily remarked by a famous epistemologist, the only way to reduce biology to chemistry is murder (see Piaget, 1967, 1249). Analogously, the only way to reduce macroeconomics to Homo-economicus microeconomics is to ignore complexity. We could then extinguish macroeconomics as an autonomous discipline, denying its inner life rooted in its emergent properties. I believe, on the contrary, that we need a vital and lively macroeconomics with sound methodological and institutional foundations. To this end, we need a non-dogmatic investigation on the assumptions about individuals' interactions leading to emergent macro properties. This requires a critical reference to a decision theory different from the classical additive-probability decision theories assuming zero awareness of ignorance. We need at the same time also macroeconomic foundations of the individual behaviour since the macroeconomic and institutional environment introduce crucial constraints and relevant objectives in the decision process of individuals. In particular, the macroeconomic conditions affect significantly the set of options that the individuals can effectively choose and implement. In a situation of structural depression such as that investigated by Keynes in the *General Theory*, the set of implementable work options may be restricted so severely to condemn many workers to involuntary unemployment. Non-dogmatic micro- and macrofoundations do not exclude each other and are to be conceived as an important part of institutional and methodological foundations of economics. This is work in progress that has to adapt to the continuous evolution of the economy and its environment.

[29] See, for example, King (2012), Duarte and Lima (2012), and Vercelli (2016).

14 *Epistemic Matrices and Evolutionary Trajectories*

> *Adam Smith:*[1] *The learned ignore the evidence of their senses to preserve the coherence of the ideas of their imagination.*
>
> *John Stuart Mill:*[2] *... the merits of a classification depend on the purposes to which it is instrumental.*

Each researcher has their own scientific vision. This is generally true in all fields, and is certainly true in economics, our principal case study. However, to investigate the genesis, development, and implications of scientific visions, it is often useful to aggregate individual visions into a few limited paradigmatic types of influential visions. Rationality requires an indomitable independence of judgement that acts as a sort of centrifugal force from conformity. However, rationality has also a crucial social and dialogic dimension that acts as a centripetal force. In a constructive dialogue, each scientist aims to reach through persuasion a common agreement as wide as possible on the same epistemic and practical beliefs. This is a crucial requisite for efficient cooperation and division of labour. In science, each rational interlocutor seeks to persuade the fellow scholars but has to keep open the option of being persuaded by them. The balance between the centrifugal and centripetal forces of rationality leads to the aggregation of sufficiently homogeneous individual visions into schools of thought. A thorough distinction between existing scientific visions is an ambiguous and controversial issue. In this chapter, I try to provide tentative foundations for a constructive classification of visions. This suggested approach aims to be a preliminary step in a research programme dedicated to the implementation of a more rigorous and systematic

[1] Smith (1799) *History of Astronomy* IV, 35.
[2] This statement refers specifically to the classification of sciences suggested by Comte.

approach to pluralism. The paradigmatic visions discussed in what follows are ideal types to each of which some individual visions may be assimilated with the necessary caution.[3] A critical appraisal of each of these ideal types does not apply unscathed to single researchers, not even those who are usually considered its emblematic exponents. For example, Smith, Ricardo, and Stuart Mill (to whom sometimes Malthus and Marx are added) are often mentioned as the main exponents of the 'Classical' school. However, the differences between their scientific visions are by no means negligible. Analogously, the economists who are often mentioned as the main early exponents of the Neoclassical (or Marginalist) School – such as Jevons, Walras, Marshall, Wicksell, Pareto, and Fisher (debt-deflation model) – have on many crucial points significantly different visions. If we underplay these differences, we are condemned to give a deeply distorted image of individual contributions. One should thus never appraise the contributions of a specific researcher by applying simple labels denoting schools of thought. And one should never use these labels as appreciative judgements in the absence of specific sound argumentations. In particular, the derogatory use of -isms or school labels to criticise an author is an unacceptable violation of the principles of sound pluralism. The critical pluralism advocated in this book is not *relativistic* in the 'anarchical' sense of Feyerabend ('everything goes') but is *relational*. The tolerant attitude of pluralism does not exclude motivated and circumscribed criticisms, appreciations, or even rankings of authors and theories from a specific point of view; however, these appraisals should remain open to revisions and different valuations from alternative points of view. What is important is that the point of view underlying a specific valuation is made explicit in clear terms. Critical pluralism requires a critical analysis (i) of scientific visions by using an apt taxonomy, and (ii) of their genesis, development, and interaction by using an adequate evolutionary narrative. Their

[3] According to Weber's definition, 'an ideal type is formed by the one-sided accentuation of one or more points of view' according to which 'concrete individual phenomena . . . are arranged into a unified analytical construct' (*Gedankenbild*); in its purely fictional nature, it is a methodological 'utopia [that] cannot be found empirically anywhere in reality' (Weber, 1949 [1904], 90). Keenly aware of its fictional nature, the ideal type never seeks to claim its validity in terms of a reproduction of, or some correspondence with, reality. Its validity can be ascertained only in terms of adequacy, which is too conveniently ignored by the proponents of Positivism' (Weber 1949 [1917], 10).

evolution depends in part on their inner interactions (internal history) and in part on the influence of the 'environment' (external history), namely the evolution of philosophy of science, other scientific disciplines, society, institutions, politics, and emergent problems. This chapter focuses on the internal history of economics, while the next one focuses on its external history.

The structure of this chapter is as follows. Section 14.1 discusses the role of taxonomies in natural sciences, focusing on their important contribution to the shaping of a new discipline. Section 14.2 resumes the discussion (started in Chapter 4) of the Kuhnian approach to the anatomy of a natural science through disciplinary matrices (Kuhn 1970). The rest of the chapter focuses on economics. First, I suggest an approach to the analysis of the epistemic anatomy of economic visions significantly different from that of Kuhn (Section 14.3). In Section 14.4, I shift my attention to the evolution of the main economic schools, emphasising a few analogies and differences with the patterns of biological evolution. I then sketch in Section 14.5 the coevolution of the main scientific visions in economics before the publication of the *General Theory* (Keynes, 1936), and then after its publication (Section 14.6). Section 14.7 discusses the guidelines of a research programme on pluralism in economics.

14.1 The Role of Taxonomies in Natural Sciences

My suggested analysis of scientific pluralism relies on a taxonomic approach that is applied to some of the most influential schools of economics and their coevolution. Before working out the details of this approach, I have to clarify a preliminary issue. A few researchers have questioned the soundness and fecundity of taxonomic methods in empirical sciences, especially in social disciplines. In this section, I want to clarify the pros and cons of the taxonomic approach with the help of a few examples drawn from natural and analytic sciences.

Taxonomies play a crucial role in the development of science. They help to conceptualise the problems and organise the research questions, particularly in young scientific disciplines. Some historians of science argued that in mature sciences the analytic methods based on mathematics and statistics typically supersede the taxonomic approach. However, while the systematic use of analytic methods plays a crucial role to corroborate the syntactic component of the language of science, this does not imply that the role of semantics and pragmatics should be dwarfed or neglected. We have to face the problem of choosing the right model and the right procedure of its application to the empirical evidence. We have then to work out the most revealing interpretation of the results obtained. Semantics and pragmatics typically rely very much on taxonomies to draw sensible and sound conclusions. That is a crucial reason why the vision of the researcher is important. For the same reason, a taxonomic approach provides crucial insights for discussing pluralism. A taxonomy of scientific visions may play a constructive role as a sort of grammar for dialogue between people holding different visions. It makes it easier to identify the ultimate reasons for diverging opinions and to discuss the comparative merits and demerits of different assumptions. However, an improper use of value-loaded taxonomies may easily degenerate in a substitute of genuine dialogue. We should never appraise the scientific vision of a researcher by just labelling it with one of the many -isms used in taxonomies. Taxonomies may play a crucial role in the conceptualisation of theories and their application to empirical evidence. This is because apt taxonomies play the crucial function of organising our thought to understand better the issues under investigation. This point has been clarified since long. In his insightful contributions to logics and philosophy of linguistics, Leibniz, building on Descartes, focused on the crucial role of taxonomies in conceptualisation. In his opinion, deduction itself is a natural consequence of combining classified items into new classes. Leibniz aimed to build an *Alphabet of Human Thought* capable of expressing all ideas by combining a small number of primitive ideas. His pioneering reflections on conceptualisation inspired many subsequent streams of thought, including logical atomism of Russell and the young Wittgenstein, computational linguistics as developed by Chomsky, and the ongoing evolution of AI and machine learning.

Taxonomies play a crucial role also in empirical sciences, both in their theoretical part and their applications to the empirical evidence. This is evident in natural sciences where taxonomies are generally rooted in observable features of the objects. For example, the periodic table of chemical elements is based upon objective parameters such as the atomic number, the electron configuration, and the recurring chemical properties. However, the value of this taxonomy as first suggested by Mendeleev in 1869 (after one century of similar attempts progressively refined by other scholars) goes much beyond the mere description of observed elements and pointing out their analogies and differences. First, researchers used the structure of the periodic table to derive relationships among the properties of the elements so far discovered. The seven rows of the table, called periods, generally have metals on the left and non-metals on the right. Each of the 18 columns, called groups, contain elements with similar chemical behaviour. The heuristic value of the table was not only significant for the analysis of the properties of the existing elements but also played a crucial role as a guide to the discovery of new elements and the prediction of their properties. The taxonomies used in natural and formal sciences have different genesis and respond to specific exigencies. In mathematics, for example, there are different schools (intuitionists, formalists, logicists, Platonists) and each of them extensively uses the taxonomic approach. For example, the theory of categories distinguishes different varieties of categories: regular, coherent, Heyting, and Boolean categories (see Marquis, 2019). Dynamics distinguishes different types of equilibria and bifurcations. Cosmologists define different kinds of stars, galaxies, and black holes, and so on. For our purposes, we draw critical inspiration mainly from biological taxonomies. It is useful to conceptualise a scientific vision as a sort of living organism that undergoes a continuous evolution interacting with the contemporaneous evolution of other visions. Biological taxonomies after Darwin connect the hierarchical classifications of different 'taxa' (in contemporary biology: domain, kingdom, phylum, class, order, family, genus, and species) with the analysis of their coevolution. The taxonomies that we are going to use in our analysis of scientific visions and research programmes in economics have to rely much more on interpretive features. This greatly reduces the possibility of establishing a sound hierarchy of taxa but does not sever the nexus between taxa and their coevolution.

14.2 Disciplinary Matrices in Kuhn

Popper, Kuhn, and Lakatos explicitly recognised the influence of biological evolutionism on their thought.[4] In particular, we find in their contributions a deep link between taxonomies of theories and their evolution. In this view, the competition among scientific theories

[4] See Chapter 4.

contributes to their evolution that originates new scientific theories or variants of the existing ones.

In the *Structure of Scientific Revolutions* (SSR, 1962) Kuhn introduced the influential term *paradigm* to refer to the entire cluster of problems, methods, theoretical principles, metaphysical assumptions, concepts, and evaluative standards that are present in scientific achievements. In his *Postscript* to the second edition of SSR (1970), Kuhn restricted the meaning of paradigm to the 'paradigmatic examples which are established achievements serving as guides to solving new puzzles.' (Firinci Orman 2016, 49).[5] In the second edition Kuhn introduced also the new concept of *disciplinary matrix* to indicate all the other aspects of the cluster of features previously indicated by the portmanteau term *paradigm*: 'Normal science is characterized not only by a shared paradigm but also by a disciplinary matrix (Kuhn, 1970, 182). Kuhn's disciplinary matrix refers to shared elements in a social group which include common values, beliefs and procedures (Kuhn, 1970, 184). A *disciplinary matrix* is thus an entire theoretical, methodological, and evaluative framework within which scientists implement their research. This framework makes explicit the basic assumptions about how research should be conducted in a certain discipline to obtain a good scientific explanation (ibidem 49).[6] The late Kuhn played down the systemic role of the most original concepts of his masterpiece – such as paradigm, scientific revolution, normal science – and adopted a biological approach interpreting a scientific revolution as a process of speciation. This analogy is intriguing but should not blur the differences between biological and scientific evolution. First, the biological taxonomies are usually multilevel and

[5] Agamben (2002), in his analysis on how science can decide if a certain problem will be considered scientific or not, stresses the importance of paradigmatic exemplars as they can guide the investigation also in the absence of explicit rules. A paradigm, in this sense is just an emblematic example. In other words, normal science does not mean at all a science guided by a coherent system of rules; on the contrary, the rules adopted are implicitly derived from a few particularly influential paradigmatic exemplars.

[6] Kuhn justifies the terminology adopted by specifying that '"disciplinary" [...] refers to the common possession of the practitioners of a particular discipline; "matrix" because it is composed of ordered elements of various sorts, each requiring further specification. All or most of the objects of group commitment that my original texts make paradigms, parts of paradigms, or paradigmatic are constituents of the disciplinary matrix, and as such, they form a whole and function together' (Kuhn, 1970, 50).

hierarchical, and evolution may be referred to any level of a taxonomy: species, genus, and so on. In the case of economics we can interpret a few relations as hierarchical; the latter, however, are limited and do not show a systematic pattern.[7] In addition, the time scale of biological evolution is very slow while scientific evolution may be extremely rapid (as in the cases of Keynesian or Lucasian revolutions.) According to the late Kuhn, science evolves rapidly and healthily in the stage of normal science when scientists share a disciplinary matrix. This makes possible an efficient division of labour and an optimal level of dialogue and cooperation. This point of view endorses the importance of what I have called *internal pluralism* but underplays the fecundity of what I called *external pluralism*. This point of view may be found also in economics. The Marshallian Consensus, the neoclassical synthesis, and the New classical synthesis are cases of *internal* pluralism that is certainly valuable. However, in this book I claim that, even in periods of normal science, internal pluralism is insufficient to guarantee all the benefits of pluralism and must be supplemented by a vigorous external pluralism. Finally, Kuhn maintains that the evolution in science depends not on individuals but on social groups, However, there is a clear tension between the individual and social concepts of paradigm. This tension emerges clearly in the second edition of SSR (Kuhn, 1970) as a conflict between the social concept of disciplinary matrix and the emblematic role of paradigmatic exemplars that are strictly related to individual masterpieces. We find the same tension in macroeconomics where a few eminent economists produced masterpieces that became the paradigmatic exemplar of a school of thought: Keynes, Friedman, and Lucas are cases in point. To investigate this issue in some depth I reject the concept of disciplinary matrix that implicitly denies, or plays down, the role of external pluralism in the periods of normal science. I adopt instead a different approach that maintains a similar taxonomic inspiration but develops it in a different direction. I assume that each scientist founds his research activity upon an epistemic vision. Although the latter is rarely made fully explicit, we can reconstruct and represent it by a synoptic table or matrix. I introduce then ideal types of epistemic matrices that play a role similar to that of

[7] We could say, for example, that the theory of *monetary* and *real* business cycle are two varieties of New classical Economics.

Cartesian coordinates to critically locate the position of several individual researchers.

14.3 Epistemic Matrices in Economics

In this section, I compare three different ideal types of epistemic visions by using two tables, one referring to the individual features of the agents and the other to the features of the economic system. The first ideal type is represented by the first epistemic matrix. We may call this first paradigm classical, as it is inspired by methodological individualism. In it each agent is conceived as a *Homo economicus* that maximises expected utility (Table 14.1, row 1). In this view, the Homo economicus is conceived as a rational decision-maker in the strict sense that always succeeds in choosing and implementing the optimal available option given the constraints. In other words, the individuals so conceived never make systematic errors since their rationality is 'unbounded' or 'substantive' (to use the terminology suggested by Simon, 1976, 1982). This also implies that in this view the individuals do not need to extend or question their knowledge since the latter is already complete and correct by assumption. The only learning taken into consideration is required to guarantee the inter-temporal coherence of the decision-maker by updating the data set (see Vercelli, 2005).[8] The behaviour of the economic system reflects the visions of the agents but is not exhaustively explained by them as it undergoes a further series of idiosyncratic limitations (see Table 14.2, row 1). It is usually assumed that the system is characterised by one, and only one, equilibrium and that this equilibrium is stable from the dynamic and structural point of view. These by no means are only technical requirements of this reductionist approach. The attempted extensions to non-linear dynamics did not take into account the disclaimer of Lucas that the New classical assumptions (in particular the REH) are justified only under conditions of stationarity. This stochastic equilibrium path is indexed by a fully reversible 'logical' time that

[8] We have seen that these features characterize a specific class of decision theories (usually called 'classical') that implicitly assume an ignorance awareness equal, or close, to zero. These kinds of decision theories provide the foundations of microeconomics in the case of neoclassical and New classical economic theories but are inconsistent with a variety of alternative decision theories that apply when the awareness of ignorance is significant (See Chapter 13).

Table 14.1 *Epistemic matrices: The system*

Vision	Individuals	Rationality	Learning	Expectations	Interaction agents and environment	Empirical scope
Methodological individualism	Homo economicus	Substantive	Updating	Rational	Pre-established harmony	Closed and stationary processes
Behaviourism	Homo algorithmicus	Procedural	Adaptive	Adaptive	Adaptation to the environment	Open and adaptive processes
Complexity	Homo faber	Designing	Creative	Proactive	Adaptation to – and of – the environment	Open and evolutionary processes

Table 14.2 *Epistemic matrices: The agents*

Vision	Interaction	Equilibrium	Stability	Causality	Time	Empirical scope
Methodological individualism	Linear	Unique	Dynamic and structural	Exogenous	Reversible	Closed and stationary processes
Behaviourism	Nonlinear	Multiple	Dynamic stability or instability	Algorithmic	Path dependence	Open and adaptive processes
Complexity	Complex	Multiple attractors	Structural stability or instability	Probabilistic	Evolution	Open and evolutionary processes

excludes any factor of economic irreversibility such as transaction costs and sunk costs. Causality is conceived as mutual interdependence or as exogeneous impulse like in the case of Granger causality.[9] Taking account of all the features that characterise this first ideal type, we have to conclude that its empirical scope, that is the range of sound applications to the empirical evidence, is restricted to a 'closed world' deprived of genuine innovation, unexpected contingencies, endogenous structural change, and irreversible evolution. Between such idealised Olympian world and the real world of economics there is a deep chasm that the advocates of this idealised world may safely downplay only in the rare periods that are characterised by a tranquil steady state.[10]

The second paradigm is represented by the second epistemic matrix. We could define this second paradigm as 'algorithmic behaviourism' as it conceives of individuals as robots characterised by sets of algorithms that may be implemented on a computer. The *Homo algorithmicus*, as we may define the individual in this view, is characterised by procedural rationality and strives to approximate a satisfactory result by taking into account the limitations of its own knowledge and skills.[11] The *Homo algorithmicus* is aware of its ignorance and tries to eliminate, or at least minimise, its systematic errors by a process of learning. To this end, the expectations must be continuously corrected to reduce systematic mistakes. According to this vision, the economic system is characterised by less-stringent equilibrium requirements. The fixed point of the system is an attractor that may be 'strange' or a multiplicity of them as is typical with nonlinear dynamics, while their stability depends on the structural conditions of its dynamic behaviour including the strength and rapidity of the learning process. In this view, the analysis of unstable systems and their disequilibrium or exotic paths is not excluded from scientific investigation, playing on the contrary a crucial role in specific circumstances. The irreversibility of time is recognised, and path-dependency is taken explicitly into consideration. Causality is assimilated to the order of computation of variables that

9 See Vercelli and Dimitri (1992) and Vercelli (2024).

10 Lucas's contributions, as summarised in Lucas (1982), provided the paradigmatic exemplar of the New classical School represented by the first epistemic matrix.

11 A case in point is the 'satisficing' criterion introduced by Simon (1956).

involves also the endogenous variables (as in 'Simon causality').[12] Taking account of all the features of this vision, we may say that its empirical scope is much broader than that of the 'classical' vision as it extends to disequilibrium processes and irreversible time. Therefore, its empirical scope extends to an open world characterised by unexpected events, innovation, and structural change, although the emphasis remains mainly focused on adaptive systems. In the first vision, the adaptation of the *Homo economicus* to its environment is assumed to be complete since economics has 'to focus on situations in which the agent can be expected to "know" or to have learned the consequences of different actions so that his observed choices reveal stable features of his underlying preferences' (Lucas, 1986, 218). In the alternative approach suggested by the second vision the process of adaptation is analysed while it occurs without ignoring its shortcomings (systematic errors, slow convergence to equilibrium or even a possible divergence from it). Lucas is aware of the importance of learning but claims that it is the realm of psychology not economics: 'experimental psychology has traditionally focused on the adaptive process by which decision rules are replaced by others' (Lucas, 1986, 217). The logical link between the adaptive approach of psychology and the equilibrium approach of economics is thus clearly traced.[13] Lucas recognises that the assumptions of economic theory (in its own microfounded version) may work well empirically only if 'one assumes that people have long ago hit on decision rules suited to their situations – "rational" rules – and utilise theories about these rules to predict behaviour' (Lucas, 1986, 232). He admits that this is certainly not true of all problems of interest, but he maintains that the method of economics is powerful only under the strict assumptions of the first epistemic matrix.

Finally, we may sketch a third ideal-typic paradigm represented by the third epistemic matrix that we may call 'complexity approach', where the individual is conceived as *Homo faber* seeking adaptation to a complex environment also by shaping it according to desired standards. The rationality of the *Homo faber* is not the fruit of a complete adaptation to the environment as in the first paradigm, or the instrument of a better adaptation to a given environment as in the second

[12] See Vercelli (1991 [1987], 2001).

[13] Notice that this distinction is reminiscent of that between context of discovery and context of justification which has been one of the basic tenets of positivist philosophy of science and in particular of logical empiricism.

paradigm, but it is rather the source of a creative design of adaptation that involves the transformation of individuals, society, and the environment itself. This sort of 'designing' rationality is based on learning in its genuine meaning of progressive correction of systematic errors, while 'proactive' expectations aim not only to correct predictions but also to implement the rational design underlying the activity of the *Homo faber*. To this end, the *Homo faber* has to understand the complex dynamics of the system under investigation without constraints on the number, existence, and stability of equilibria. Time is here considered as irreversible in the strong sense characterising evolutionary processes, while causality is typically conceived as probabilistic and may be endogenous or exogenous.[14]

Although we can identify eminent economists that pursued a research programme close to one of these three alternative visions, we prefer to express them in their pure form as 'ideal types' to avoid exegetic quibbles on the authentic interpretation of single authors, an issue that would be beside the central point of this chapter. I just limit myself to a hint: the first epistemic matrix is close to that of Lucas,[15] while Simon's vision is close to the second one,[16] and finally the most innovative part of Keynes's vision (as we interpret it) is close to the third one.[17] Comparing the three ideal-type paradigms, we see that the empirical scope of the second matrix encompasses that of the first one, while the third matrix encompasses that of the second one. Unfortunately, the increasing realism obtained by shifting to a broader and less reductionist paradigm is associated with increasing difficulties to formalise it. This has encouraged many economists to take shelter within the reassuring assumptions of the first vision shunning in particular the third vision. I believe on the contrary that the 'rights' of real problems should always come first, even at the cost of adopting less sophisticated or more fragmentary formalisations. The crucial criterion to choose a scientific vision, a theory or model should be the criterion of *adequacy* to obtain a significant answer from the research question under investigation.

[14] I elaborated more on these concepts in Vercelli and Dimitri (1992) and Vercelli (2024).
[15] See in particular Lucas (1981, 1986).
[16] See in particular Simon (1956, 1976, 1982).
[17] I refer of course to the *General Theory* (Keynes, 1936), including the preparatory works and the subsequent interventions. (See Chapter 9 of this book and Vercelli, 1991.)

14.4 The 'Tree of Life' and the Evolutionary Tree of Economic Theories

The eighteenth century is characterised by the birth and development of new sciences including economics (established in the eighteenth century by path-breaking pioneers such as Smith and Quesnay, but still in search, after a century, of a full-fledged identity), sociology (following the initial impulses of Comte, Durkheim, and Max Weber), psychology (boosted by the experimental approach of Fechner and Mach), and biology (incubated in the eighteenth century and early nineteenth century that assumes a crucial pre-paradigmatic status with Darwin's evolutionary vision).

We have seen in the preceding chapters that economics has always been characterised by conflicting scientific visions coevolving with economy and politics. Their evolution has some analogy with, but also significant differences from, biological evolution. Limiting my tentative preliminary assessment to a comparison with Darwin's vision, I draw a sketchy 'tree of economic life' to be compared with Darwin's 'tree of life', to which he dedicated the only illustration that appeared in his masterpiece (Darwin, 1859).[18] To make possible this comparison, I assimilate the distinction between species and individuals to the distinction between a school of thought and its exponents. Even if we think, as I am inclined to do, that this alleged analogy does not go much beyond the logical distinction between a set and its elements, at this stage of the argument it does not matter too much because it prepares the subsequent stages of the evolutionary argument.

At first sight, the tree of life and the tree of economic life are not too dissimilar in appearance and contents. In both cases we see bifurcations that tend to generate new species in biology and new paradigms in economics. This analogy can be found also in natural sciences where Kuhn compares the genesis of a new theory to the biological process of speciation. As for economics, we can detect a few significant, but only partial, analogies with the tree of life:

(1) Natural selection may improve the capability of a certain species to survive and reproduce in a given environment. Analogously, the scientific debate between alternative ideas, theories, and schools of

[18] This illustration can be easily found on the internet.

thought tends to corroborate those more in tune with the prevailing worldviews and ruling social goals.

(2) As for the mechanisms of biological evolution that are independent of adaptive change (such as mutation, migration, and genetic drift) it is still possible to see some analogy. These mechanisms may cause a biological population to evolve in ways that render it less suitable for its environment. Analogously, the internal evolution of a school of thought, may sometimes jeopardise its influence in an evolving environment.

(3) Evolution does not necessarily imply progress. Biology rejected this controversial assertion long ago. In economics the impression of a continuous progress derives mainly from the science-led technological progress in the economy and in model building, but this impression is not easily corroborated by a thorough critical assessment of the empirical evidence.

In any case, the differences are not less significant than the analogies:

(1) Differently from biological species, economic schools rarely become extinct: they evolve and, sometimes after a temporary eclipse, they may reemerge in an updated form. One example is the QTM that has been revived in the version of Hume two centuries later by Friedman and other exponents of post-war monetarism. Another example is Ricardo's theory revived by Sraffa and the neo-Ricardian school more than a century later.

(2) The cross-fertilisation and hybridisation between schools of thought is easier than between biological species because it is easier to combine ideas than genes.

(3) The feedback of evolution on the environment is much larger and quicker in the case of economic theory than in biology. The evolution of economic theory influences the policy strategy that may conspicuously affect not only the economic and financial performance and their evolution, but also the sustainability of the natural environment (e.g. affecting the climate).

Notwithstanding the substantial differences between the biological and economic evolutionary trees, the economic tree may give to students a first vivid representation of pluralism in macroeconomics and its persistence. The tree's main economic paradigms should be illustrated by the teacher at the beginning of the introductory course in economics (see Chapter 16). As an example, in the two subsequent sections I adopt an elementary narrative based mainly on the relationship between the money stock, prices, and economic activity.

14.5 A Tree of Aggregate Analysis Before the *General Theory*

Figure 14.1 shows a sketch of the 'tree of economic life' from the eighteenth century to recent times. This sketch is circumscribed to the central branches that have been hegemonic or prominent challengers to the hegemonic branch. It ignores instead the heterodox schools, even those that occasionally assumed a very influential role in politics and academia, such as the Marxist school, the neo-Ricardian school, Austrian economics, and institutional economics. A tree encompassing

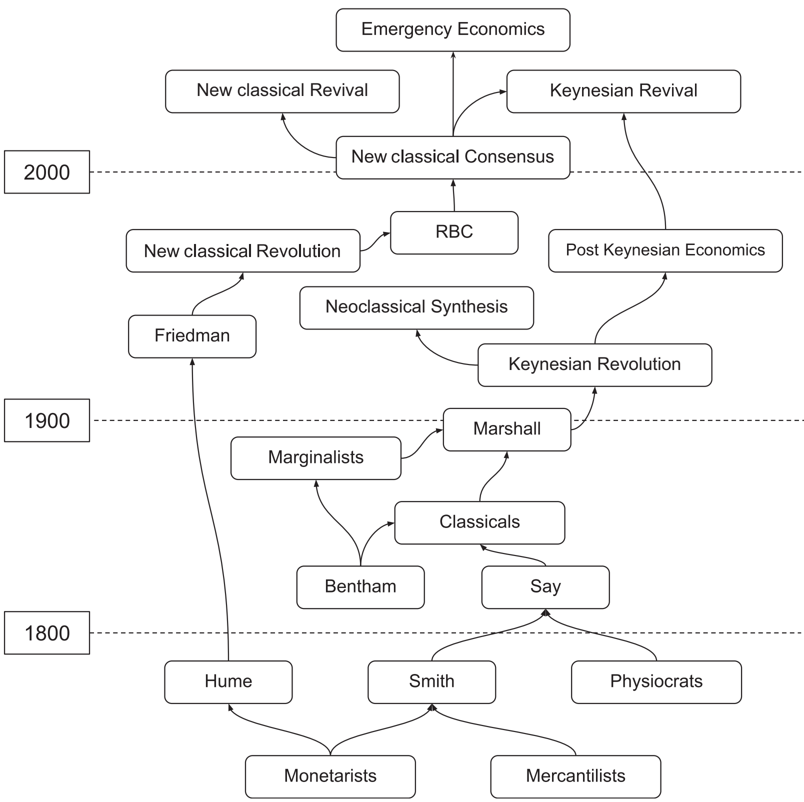

Figure 14.1 An evolutionary tree of economic paradigms

all these schools would require drawing skills that I do not possess. However, the justification for drawing a tree of economic life is mainly as a teaching instrument for students approaching economics for the first time in order to give them immediately a vivid idea of the persisting and branching pluralism characterising economics. A figure of this sort may support synthetic narratives of the epistemic and policy implications of the branching process. The drawing, of course, should be improved by the teacher and may be adapted to specialised narratives referring to specific issues of this discipline. To give an example, I suggest, in what follows, a broad narrative focused on the nexus between money and economic activity. To this end, it is convenient to start the exposition by briefly recalling the equation of exchanges in its mature form as conceptualised by Fisher (1911), fully exploiting the didactic value of its simplicity. The teacher should then explain that the equation of exchanges is liable to different causal interpretations according to the theories and circumstances.

One can then start the didactic narrative from the first empirical observations on the variations of rudimentary indexes: quantity of money, its velocity of circulation, prices, economic activity, and balance of payments. These observations became progressively more systematic, identifying persistent correlations between them. A few political economists started to advance causal explanations of these correlations drawing political implications, originating schools of thought. The most important schools of thought in the seventeenth century and early eighteenth century were the monetarists and the mercantilists. The monetarists attempted to explain the secular inflation originated by the discovery of the New World leading to a continuous inflow of precious metals in Europe. The early monetarists generalised the abundant evidence available in different European Countries on this historical episode by arguing that an increase in the stock of money, whatever its cause, does not produce a persistent increase in economic activity but only an irreversible increase in prices. This assertion was dubbed *Quantity Theory of Money* (QTM) and may be derived from the equation of exchanges by assuming exogeneity of the quantity of money and invariance of the velocity of circulation.[19] The mercantilists took a

[19] The early QTM assumes that money supply is exogenous, the velocity of circulation is substantially stable, and economic activity independent of money. Hume worked out a variant contemplating a positive influence of an increase of money supply on the economic activity but only in the short period.

different causal view: the prices increase when the economic activity increases in a country, but its resources are scarce. Building on this basic idea, the mercantilists exalted the role of accumulation of money to increase the power and wealth of a country. This school emphasised in particular the role of Colonialism and money reserves. In particular, money reserves could support the military power of the country, while a commercial surplus could increase money reserves and wealth. This vision endorsed a dirigiste attitude of the state, while the monetarists defended the liberty of the emerging markets. This conflict became the crucial focus of conflicting schools of thought in political economy. In particular, the Physiocrats in France became committed supporters of laissez-faire, emphasising that wealth is produced not by money but by agricultural labour. While this restriction confirms that France at the end of eighteenth century had not yet initiated the industrial revolution, the contemporary English liberals, who were already experiencing the great transformation brought about by the Industrial Revolution, maintained that all the forms of productive labour are a source of value. In addition, Adam Smith (1976 [1776]), under the influence of Newton's gravitation theory, argued that free markets implement the gravitation of prices and quantities towards an optimising equilibrium. Say acted as a bridge between the Physiocrats and Smith that influenced the subsequent evolution of the Classical School. In particular, under the influence of the French rationalist tradition, he added a crucial ingredient to the Classical thought, Say's law, that became a conceptual pivot of mainstream economics. The Classical School of Smith, Ricardo, and Stuart Mill became hegemonic in the first half of nineteenth century but was soon challenged by the Marginalist School. Under the influence of utilitarianism as applied by Bentham to economic and social problems, Jevons (1871) explained relative prices, market self-regulation, and development in terms of marginal utility. A branch of marginalists led by Walras (1874–1877) developed the GE model that soon became the mainspring of mathematical marginalist economics. A few years later, Marshall (1890) succeeded to create a synthesis between the conflicting Classical and Marginalist schools that dominated the emerging new profession of economists at the turn of the nineteenth century until the early 1920s. The crisis of traditional capitalism started in 1929 led to the so-called Great Depression. This produced a deep and persistent turmoil not only in the economy but also in economics. In particular Keynes, who had contributed to the development of the Marshallian tradition in the field of applied aggregate economics, argued that the Marshallian Consensus had to be broken by rejecting the marginalist component of the synthesis. The new kind of aggregate analysis that he called with the neologism of 'macroeconomics' to stress its autonomy from marginalist microeconomics reflected a different scientific vision that rejects the classical reductionism based on Say's law and methodological individualism.

This simplified narrative of the evolution of the main economic paradigms before the Keynesian Revolution is just an example of elementary narrative that might accompany the illustration of a version of the tree of economic life until the *General Theory*. Of course, one could add details and critical considerations as I did in Chapter 11, or much more. Variants of trees of economic life could focus on different aspects of this evolutionary process (e.g., theory of value and distribution) and its narrative could change focus. What is important is that, by adopting an evolutionary approach of this kind, the students would be exposed from the very beginning of their studies to the idea that in economics different paradigms coexist and coevolve.

14.6 A Tree of Macroeconomic Analysis After the *General Theory*

The main implication of the new Keynesian vision is that the market may be unable to self-regulate itself; this calls for the adoption of systematic anticyclical policies meant to maintain or recover full employment. Keynes's rejection of laissez-faire was in tune with the contemporary urgencies that made State intervention compelling: the persistence of the Great Depression (1929–1939), the subsequent 'War economy' (1939–1945), and the after-war reconstruction that remained an urgent overarching priority until the early 1950s. In the meantime, the new Keynesian vision split in different research programmes. The most influential, dubbed neoclassical synthesis, accepted classical microeconomics but endorsed Keynes's arguments against the microeconomic foundations of aggregate economics (Hicks, 1937, 1939; Samuelson, 1946). This approach inspired many extensions of the Keynesian vision to new areas (growth and business cycles, public economic, and so on). However, the steady growth of the 1950s and 1960 rekindled different kinds of inflationary tensions. The New classical synthesis tried to cope with the problems raised by the observed negative relation between inflation and employment through the Phillips curve interpreted as a stable menu of policy choices. However, in the second half of the 1960s, the short-term Phillips curve shifted upward and increased its slope in consequence of the oil shocks and severe industrial actions. These growing inflationary tensions reawakened the traditional monetarist opposition to active money management. The mainstream opposition to Keynesian economics was led by Milton Friedman who revived the monetarism of the QTM in the version of Hume that he updated to the new historical phase. In the late 1960s the conflict focused on the interpretation of the shifts of the short-run Phillips curve. Friedman (1968) maintained that these obnoxious shifts were the consequence of the persistent Keynesian use of the Phillips curve as menu of policy choices. However, in his view, the obstinate Keynesian attempts of keeping employment at a rate inferior to the 'natural' rate of equilibrium proved unsustainable for its disequilibrating influence on expectations. The perverse effects were the upward shifts of the Phillips curve, its progressive verticalisation, and the amplification of the business cycle. Therefore, in this view, the Keynesian attempt of reducing unemployment by accepting a small and stable increase in the inflation rate failed as it produced accelerating inflation and increasing unemployment. This argument convinced many economists and marked the end of the hegemony of the neoclassical synthesis clearing the way to a partial comeback to the classical principles of the dichotomy between the monetary and real system. This U-turn was soon made much more radical by the New classical vision suggested by Robert Lucas and his coauthors and followers in a series of papers published in the 1970s and collected in Lucas (1981) and Lucas and Sargent (1981). The paradigmatic exemplar of New classical Economics was the equilibrium monetary business cycle model that was microfounded on fully rational agents entertaining *rational expectations*. This peculiar epistemic vision ended up by supporting the adoption of neoliberal policy principles. In particular, this approach endorsed the adoption of a fixed rule of monetary policy analogous to that of Friedman. In the 1980s the hegemonic school adopted the epistemic and methodological vision of Lucas but gave a different explanation of the equilibrium business cycle calling it the *real business cycle*. This School rejected the Debreu (1959) version of the GE model for its inconsistency with national accounting data and reversed the causal link between money and economic activity. This School became hegemonic under the name of *real business cycle theory*. The rapid emergency of New classical Economics weakened, but did not sweep away, the influence of Keynesian economics in the academia, mass media and governments. The mainstream Keynesian school survived as main challenger of the New classical School but felt induced to change the scientific and methodological vision branching in a plurality of research programmes. The main branch accepted much of the New classical paradigm with the exception of the assumption that real markets are perfectly competitive. It was easy for the New Keynesians to show that a single market imperfection has significant implications that call for policy interventions analogous to those advocated by Keynes himself. The other main branch, often called post-Keynesian, advocated a research programme meant to develop and update the paradigm of Keynes respecting his original intentions. The convergence in the 1990s and 2000s of New classical economists and New Keynesian economists induced many commentators to speak of a New Consensus. The Great Recession of 2007–2009 broke this alleged consensus. The first reaction corroborated a revival of the original Keynesian paradigm. However, after a couple of years, the New classical paradigm managed to recover a hegemonic position in many quarters, including most universities and governments. The situation remains unsettled in the absence of a new appropriate paradigm capable of interpreting and controlling contemporaneous capitalism.

Also in the case of the evolution of economics after the Keynesian Revolution, the teacher may choose a representation of the evolutionary process of economics different from that of Figure 14.1 focusing on different issues. For example, while our narrative has focused on the issues of macroeconomics, a different narrative could focus on the evolution of microeconomics. What is important is to open the students' mind to the existence of a plurality of evolving and interacting paradigms having crucial policy and transformative implications.

14.7 A Research Programme on Pluralism

Scientific pluralism is often advocated or rejected but rarely analysed in its complexity. In this chapter I suggested a few preliminary guidelines towards a research programme on scientific pluralism focusing mainly on the case of aggregate analysis and the different ways of conceiving its links with microeconomics. To go deeper into the reality of pluralism and its implications we have to coordinate a structuralist approach with an evolutionary approach. I suggested that the structural aspect can be analysed through epistemic matrices that clarify the scientific paradigm of a researcher or school of thought in reference to an ideal type. We can use an epistemic/pragmatic matrix, as defined in this chapter, for different goals: to probe into the internal consistency of scientific visions, to implement an in-depth analytic comparison between the scientific visions of different scholars or schools of thought, and to circumscribe the empirical scope of each paradigm. The structural approach is fundamental also to investigate the reasons and details of their evolution. In particular, the internal coherence of epistemic matrices and the conflicts between them give a substantial support to understand the internal history of economics. As for the external history, we have to analyse the interactions between the evolution of economics and the economic, political, technological, and cultural features of society. The next chapter will take a preliminary step in this direction.

The reconstruction of the internal and external history of a certain discipline requires the adoption of an evolutionary approach. The one adopted in this chapter is reminiscent of the theory of biological evolution showing some significant analogy and conspicuous divergencies. In the case of economics, the evolution depends on both internal anomalies debated by peers (internal history) and the evolving adaptation to the environment (external history).

15 *Economy and Economics*

> *John Archibald Wheeler:*[1] *We live on an island surrounded by a sea of ignorance. As our knowledge grows, so does the shore of our ignorance.*
>
> *Friedrich August von Hayek:*[2] *Emergencies have always been the pretext on which the safeguards of individual liberty have been eroded.*

I summarised in Chapter 14 the evolution of mainstream economics from the point of view of its internal history. In this chapter, I extend my critical summary to its external history. The importance of external history in natural sciences is a very controversial issue.[3] In social sciences, and in particular in economics, significant feedbacks between history of theory, policy strategies, and facts are easily detectable. However, this specific interaction (henceforth Interaction tout court) is extremely complex and has always been under-researched. In this chapter, I will limit myself to some hints at some recurring features of the Interaction that impinge on the theme of pluralism.

We have seen in the preceding chapters that the evolution of economic paradigms has been greatly influenced by the evolution of the economy. In particular, in periods characterised by *great crises*, pluralism cannot be easily repressed by the mainstream school that is under attack because it has proved unable to forecast and control the crisis. On the contrary, in periods of economic tranquillity the mainstream paradigm evolves mainly in consequence of internal debates, ignoring or playing down, the relevance of external criticisms and alternative approaches. In these inertial periods, scientific progress seems to proceed within the guidelines of a mainstream research programme

[1] Wheeler (1992, 18–19).
[2] Von Hayek (1979) *Law, Legislation and Liberty*, Vol. 3, 124.
[3] See Section 4.4.

according to the typical rules of what Kuhn (1970 [1962]) calls 'normal science'. Although we can find earlier examples, the Interaction has become fairly systematic since the birth of industrial capitalism in the late eighteenth century and has grown progressively stronger since. We may observe a recurrent general pattern. A major crisis of the economy typically produces a radical redirection of mainstream aggregate theory. In its turn, the new paradigm contributes to shape a new phase of economic growth based on new policy rules. The new growth regime, after an initial success, is progressively questioned by disturbing anomalies until a new major crisis emerges. Of course, this Interaction should not be understood as mechanistic cyclical feedback. On the contrary, we have to investigate why and how its specific features change through time.

The structure of this chapter is as follows. In the first section, I start with a bird's-eye view of the Interaction: between economy and economics since Adam Smith until the 'Long Depression' (1873–1896). In the second section, I briefly examine to what extent laissez-faire mainstream policies contributed to trigger the 'Great Depression' (1929–1939) and to prolong its persistence, as Keynes maintained. Keynes reacted by initiating a radical change of his own scientific vision supporting a change of policy rules (Section 15.2). Section 15.3 examines the emergence of the neoliberal policy rules of New classical Economics as the prevailing response to the Long Stagflation of the 1970s. Section 15.4 examines the influence of New classical Economics during the subsequent period of fluctuating growth until the outbreak of the subprime crisis started in 2007. In Section 15.5, I briefly recall the salient features of the Long Recession (2007–2010) that are of particular interest for our argument, while in Section 15.6, I discuss its impact on economics. Section 15.7 summarises the long-term evolution of the Interaction between economics, policy strategies, and real economy underlying a few regularities and recent anomalies. Section 15.8 discusses some of the signs of an ongoing return to dirigisme in the form of *emergency economics*. In the final section, I introduce a few reflections on the recurring fluctuations of pluralism. I discuss then in which direction we should proceed in order to reorientate along a more constructive path the process of coevolution between economics, policy, and the real economy.[4]

[4] This chapter partially overlaps with Sections 14.5 and 14.6 that focus on the internal history of aggregate economics as represented in Figure 15.1. In economics it is difficult to separate internal and external history.

15.1 From Adam Smith to the Long Depression

The Interaction started to be particularly intense since the Industrial Revolution of the late eighteenth century and the contemporaneous foundations of modern political economy by Adam Smith (1776). The *Wealth of Nations* may be seen as a reaction to the crisis of mercantilism brought about by the ongoing Industrial Revolution, a reaction that was in tune with the views and interests of the emerging bourgeoisie. The new Smithian view of developing markets as managed by a providential (although invisible) hand had a pervasive impact not only on economic thought but also on the evolution of industrial capitalism. In particular, the liberal policy implications of this new view acquired a growing influence with governments and public opinion shaping the policy strategies of industrialising countries, particularly since the mid nineteenth century. The mild but persistent recession that characterised the last thirty years of the nineteenth century (in the USA from 1973 to 1878/1879, in Europe from 1873 to 1896), often called the *Long Depression* by economic historians, did not question the basic principles of classical liberalism but produced a more sophisticated version of the liberal ideas, that we may dub as *updated liberalism*. This new orientation explicitly rejected the extreme versions of laissez-faire and tried to clarify where to fix the boundaries between free markets and collective action by considering their comparative advantages and shortcomings in specific areas of economic activity. Around the turn of the century Marshall, Wicksell, and Pigou gave important contributions to economic policy from the point of view of updated liberalism. However, their ideas were insufficiently acknowledged by policy makers who persisted in a policy strategy mainly influenced by simplistic, and often incoherent, laissez-faire orientations. According to many observers (including Keynes), this contributed to the outbreak of the Great Depression in 1929.

15.2 From the Long Depression to the Great Depression

The Great Depression that began with the Wall Street crash of 1929 was a much deeper crisis than the previous Long Depression, a crisis that produced a much more radical change of direction in the history of facts and ideas. The unfailing faith in self-regulating markets was sorely tried, favouring the emergence of approaches meant to explain the weakness of the invisible hand and aiming to empower governments enough to restore full employment equilibrium. This set the terrain for the Keynesian Revolution. In the *General Theory* the great Cambridge economist explained why free markets are unable to self-regulate and why the mainstream economic theory that he called *classical economics* was in principle unable to cope with this basic problem (Keynes, 1936). The new general theory suggested by Keynes led to a new conception of economic policy in which the State has to play a broader role to help the market maintain or restore full-employment equilibrium. The new vision of macroeconomic theory and public policy acquired consensus in the troubled 1940s that required a public management of the war economy and post-war reconstruction. When the conditions for growth were restored in the early1950s, the Keynesian theory became in many industrialised countries the mainstream macroeconomic theory, although in an eclectic version that came to be called 'neoclassical synthesis', that is synthesis between Keynes's theory and the classical theory that he had severely criticised. In this view, the invisible hand has to be left unfettered as much as possible. It is recognised, however, that the existence of diffuse and sizeable *microeconomic* failures (so-called negative externalities first rigorously analysed by Pigou, 1920) and of the huge *macroeconomic* failure of involuntary unemployment analysed by Keynes in the *General Theory*, require a strategy of policy interventions meant to internalise the negative externalities and to avoid or mitigate involuntary unemployment. This policy strategy was synergic to the establishment of the so-called *welfare state* aiming to sustain full employment and redistribute income in favour of the disadvantaged citizens. This view underlay a period of rapid steady growth accompanied by a sizeable reduction in poverty and inequality (1950s and 1960s). The post-war success of mixed economies became increasingly vulnerable from two related points of view. First it favoured a hypertrophy of public expenditure that rapidly increased its share in the GDP of industrialised countries from about 10–20% in the 1920s to 40–50% in the 1970s. This process was often accompanied by a progressive increase in bureaucracy, cronyism, and corruption. Second, it triggered a growing inflationary bias due to the increasing strength of trade unions operating in a full employment regime. In the late 1960s and early 1970s this bias translated in periodic bouts of wage increase meant to improve, or at least defend, the share of wages in GDP. The usual reaction of monetary authorities was the introduction of a more restrictive monetary policy to curb inflation. The reaction of the market was an increase in prices to restore profits, which provoked the trade unions to start new strikes to defend real wages, bringing about a new, similar 'political' business cycle.

15.3 The Long Stagflation and the Neoliberal Response

The late 1960s marked the start of a transition period characterised by persistent inflation and growing unemployment. The crisis was greatly aggravated by the two oil shocks that occurred in 1973 and 1979 that added powerful impulses of cost inflation to the existing demand inflation. The increase in public expenditure to counteract the growing unemployment resulted in accelerating inflation and unsustainable employment. Most governments sought a remedy in a new policy strategy, later on called *neoliberal*, based on systematic privatisation and liberalisation of economic activity.[5] This radical shift in economic policy found a theoretical support from the anti-Keynesian counter-revolution of New classical economists that had occurred in the 1970s. The upheaval in macroeconomics was prepared in the late 1960 by the new monetarists led by Milton Friedman who blamed the increasing inflation on the Keynesian policies based on the systematic use of the Phillips curve as a stable menu of policy choices (Friedman, 1968). This approach was criticised for generating bouts of accelerating inflation in the illusory hope of establishing a lower but unsustainable level of unemployment. Friedman maintained that the sustainable rate, called 'natural rate' of unemployment, is the equilibrium level that would be attained by unfettered markets . A crucial analytic support to this view came from the microfoundations research programme initiated by Phelps (1967, Phelps et al., 1970) in the same years. Phelps's criticism blamed the weakness of Keynes's macroeconomic theory on its lack of rigorous microfoundations in GE theory. In the early 1970s, Lucas suggested an influential synthesis of the two streams adding a crucial new ingredient: the assumption of *rational expectations*. Lucas's model of *equilibrium business cycles* rapidly became the prototype of a new

[5] The new policy strategy was inaugurated by Mrs Thatcher in 1979 and adopted in the USA by President Reagan since 1980. Their leadership was soon followed by most other political leaders in the developed countries.

macroeconomic theory soon called New classical Economics (NCE; see Lucas, 1972, 1976, 1981). This theory aimed to recover and develop the basic insights of classical economics heavily criticised by Keynes and his followers, by adopting a new methodological approach that may be called 'equilibrium method'.[6] In this approach the economy is assumed to be always in equilibrium and agents are conceived as fully rational while observed unemployment is interpreted as always voluntary. The fluctuations of the economy are thus seen as completely independent of alleged market failures and are assumed to depend exclusively on exogenous factors such as distortional monetary interventions and oil shocks. Counter-cyclical policies are seen as impossible, or unreliable, in any case harmful interventions. The way out from the crisis was sought in a mix of privatisation and deregulation aimed to strengthen the influence of markets and curb the weight of the state interference in the economy. These prescriptions provided the foundations for what has been later called 'neoliberal' policies.

15.4 Neoliberal Economics

The early monetarist orientation of New classical Economics in the 1970s gave a theoretical justification to the strict deflationary policies implemented in the early 1980s with the full support of the central banks following the Federal Reserve under the leadership of Paul Volker (chairman from 1979 to 1987). In the meantime, New classical Economics retained and developed the equilibrium method of Lucas but abandoned its early monetarist orientation. The new prototype model of mainstream macroeconomics became the model of 'real business cycle' suggested by Kydland and Prescott (1982) where the main shocks that explain economic fluctuations are not monetary impulses but technological shocks. This point of view was soon reflected by the monetary policy pursued by Alan Greenspan, the influential chairman of the US Federal Reserve Boar who served in this role from 1987 to 2006. The new monetary policy, often dubbed *Greenspan put*, did not refrain from pumping liquidity in the real economy whenever an excess supply emerged in financial markets, such as after the 1987 stock market crash, the Gulf War, the Mexican crisis, the Asian crisis, the LTCM breakdown, Y2K, the bursting of the internet bubble, and the 9/11 attack.

[6] I spelled out this point in more details in Vercelli (1991 [1987]).

This policy strategy contributed to thwart the emerging financial crises by greatly reducing their recessive effects but introduced disruptive systemic effects in the financial system that culminated in the *subprime crisis* starting in 2007. To understand this process, we have to examine how the neoliberal reforms affected the structural characteristics of the real economy.

The governments appointed in the early 1980s in many developed countries profited from the weakness of trade unions, in consequence of the severe depression induced by the monetarist policies, to introduce structural reforms in labour markets and industrial relations meant to increase their flexibility. The neoliberal strategy pursued by governments was twofold. On the one side they started a programme of deregulation of labour markets meant to curb the power of trade unions and to strengthen the power of employers to decide whom to hire and fire, remunerations, overtimes, and so on. On the other hand, they gave the example of a very tough attitude towards workers in highly spectacular disputes such as the US air traffic controllers in 1981 and the UK coal mining dispute in 1984. The synergic policies of labour markets deregulation and demonstrative actions to break trade unions resistance were soon pursued by most governments deeply changing the behavioural rules of market economies. The unemployment rate diminished in many countries, but many permanent jobs were substituted by precarious and underpaid jobs. The Phillips curve was substantially flattened so that the inflationary bias of the real economy was substituted by an attitude of 'Great moderation'[7]. This explains why the 'Greenspan put' policy became possible. The permissive liquidity policy did not translate in significantly higher inflation in the real economy, as in the period of stop-and-go policies, but in 'financial inflation' that in the short period increased the income of financiers, benefiting, to some extent, the whole economy. However, the 'trickle down' doctrine worked only in part and the inequality of income distribution greatly increased. Also, the number of the poor increased in most countries. The widespread conviction of having found the recipe to control business cycles while sustaining growth proved to be a mere illusion. From the point of view of growth, the higher demand coming from the finance sector did not fully compensate the curtailed demand of

[7] See, for example, Iakova (2007).

workers constrained by lower and more insecure wages. This contributes to explain why, on the whole, the average rate of growth in the neoliberal era (1980–2009) has been lower than in the Keynesian period (1951–1971). The optimism spread during the roaring 1990s petered out in the first decade of the new century, notwithstanding the vigorous but ephemeral boom experienced in the period 2003–2006. Greenspan's permissive monetary policy in a growingly financialised economy had the effect of 'doping' the economy: shorter and less-painful recessions and a higher trend in growth were bought at the heavy cost of intoxicating the financial health of the economy. The 'Greenspan put' policy encouraged speculation weakening risk perception and increasing moral hazard. These dire effects were much enhanced by the policy of bailing out virtually broke bank and non-bank financial institutions considered too big to fail. The only arbitrary and devastating exception was the case of Lehman Brothers in September 2008 that was not bailed out because monetary authorities believed that, in the absence of appropriate regulation, only fear could check excessive speculation. Greenspan's (and then Bernanke's) monetary policy mitigated fear and weakened the risk perception of the agents, particularly of big operators. In consequence of this dangerous combination, the financial cycles become progressively more frequent and profound. The way in which each crisis was overcome planted the seeds for a new, likely worse, crisis to come.

It is ironic that the neoliberal policies, introduced to mend the inflationary bias in the real economy allegedly induced by Keynesianism, favoured the progressive establishment of a different – not less dangerous – inflationary bias, this time in the financial sector. The Fed policy introduced a virtual floor to fluctuations in the price of financial assets, while the refusal to prick the swelling financial bubbles (because 'the market knows better') abstained from establishing a ceiling. The rate of discount policy was too limited by heavy constraints in a highly indebted economy to provide reliable floors and ceilings. A situation characterised by 'great moderation' in the real sector and an inflationary bias in the financial sector distorted the relative prices of financial assets in terms of price of real goods, inducing financial rather than real growth and distorted the distribution of income in favour of financiers and top managers.

15.5 Some Salient Features of the Great Recession

The neoliberal policy regime and its confidence in market self-regulation started to accumulate tensions that became progressively more evident in the 1980s and 1990s. Of the eighteen bank-centred post-war financial crises,[8] only three occurred in the 1970s, seven in the 1980s, and eight in the 1990s. These financial crises were occasionally intense but circumscribed to a particular company (sometimes big and with huge systemic fallouts, such as LTCM in 1998), a particular sector (US loan and investment banks in 1984) or a country (Italy in 1990, UK in 1991, Japan in 1992, and so on). The growing financial instability of the neoliberal era, culminated in the two global crises of 2000–2002 and 2007–2010. A significant warning of the last devastating recession came with the dot.com crisis in 2000–2002 as it hit in a serious way the main centres of the global financial system but could still be rapidly countered by Greenspan's put policy. The apparent success of this stabilisation policy concealed its destabilising longer-term effects to most observers, paving the way to the successive Long Recession.

The apparent success obtained by the *put* policy in rapidly aborting financial turmoil further increased the reliance on the neoliberal vision. This widespread attitude of over-confidence in the self-regulating virtues of unfettered markets pushed the agents to take decisions that progressively increased the fragility of financial units to unprecedented levels. By the end of 2002 the speculators turned their main focus from the ICT immaterial assets to brick-and-mortar assets. The dangers of this situation became apparent only when the bubble of housing started to deflate in the middle of 2006. At the beginning, however, the rate of decrease of house prices was slow enough to seem controllable, while the rate of interest was still sufficiently low to allow a not too onerous refinancing of mortgages, including subprime and adjustable rates. Therefore, most observers expected a soft lending of house prices that would have produced not much more than manageable local effects. This hope was swept away by a sharp acceleration of the energy (and raw materials) prices in 2007–2008. In particular, the price of oil more than doubled from $63 in December 2006 to $147 in July 2008. In consequence of this shortage of natural resources

[8] See Caprio et al. (2005) and Reinhart and Rogoff (2008).

including food, in 2007 and 2008 there was a surge in price inflation. Notwithstanding the crucial impact of cost inflation and the emerging financial crisis, the central banks reacted in the canonical way by substantially increasing the discount rate. The FED perceived earlier than the BOE and the ECB the dangers arising from such a policy in a period of increasing financial fragility, by reducing in few rapid steps the discount rate from 5.75% (17 August 2008) to 1.25 (29 October) and finally to 0.50% (16 December 2008). However, this sharp reduction in the discount rate occurred too late to avoid the collapse of the housing sector and the ensuing rapid acceleration of default rates on 'subprime' and adjustable-rate mortgages (ARM). This accelerated the deflation of house prices and of the related mortgage-based securities (MBS). This process of contagion affected in sequence many other financial assets, then the companies whose net worth depended strictly on the most vulnerable assets, then their shares, triggering what many commentators called a Minsky moment.[9]

The housing bubble was the 'detonator' of the gravest financial crisis since the Great Depression of the 1930s. What was really unexpected by most commentators was the catastrophic effect of the bubble's bursting. The contagion proved to be much deeper and broader than that of preceding similar events such as the bursting of the dot.com bubble in 2001. The explanation has to be found in the increasing instability of the financial system that culminated in the second half of the first decade of the century. The intrinsic instability of a developed financial system was well known since long, as witnessed by the analyses of far-sighted economists such as Wicksell, Keynes, the late Fisher and Minsky. In addition, in consequence of the neoliberal policies, the financial system had undergone quantitative and qualitative modifications that had progressively enhanced its vulnerability to unexpected destabilising events and to contagion propagation.

Moreover, in the neoliberal era the weight of finance on the economic system had greatly increased. Goldsmith's FIR that measures the ratio between financial and real assets increased from a value of about 1 to a value exceeding 3 in the most developed countries. In the US, the share of the financial industry over the GDP increased from about 4% to more than 8% (Philippon, 2007); the contribution of finance, insurance, and real estate (FIRE) to GDP rose from 15% to 20% (Palley,

[9] See, for example, Vercelli (2009).

2007), while the share of financial profits exceeded 40% of overall profits just before the crisis. In addition, the weight of finance greatly increased in the non-finance business sector as well. The same is true with households as the share of wealth detained in financial assets (including housing) steadily increased, while pensions, after their privatisation, were linked to the financial performance of pension funds.

This quantitative growth of the financial sector has been accompanied by very significant qualitative changes. The first and most important has been the development of shadow banking.[10] These financial institutions are non-bank in the sense that they do not hold deposits like a commercial bank and are subject to different, much weaker, regulations. Within the 'alphabet soup' of the shadow banking system we have to distinguish, on one side, autonomous (from commercial banks) shadow FIs (Financial Institutions) such as investment banks and hedge funds, on the other side shadow-dependent FIs, such as structured investment vehicles (SIV) and conduits, directly or indirectly controlled by commercial banks. The autonomy of investment banks from commercial banks had been set by law in 1933 by the Glass-Steagall Act in order to prevent conflict of interest and fraud believed to be a factor of the 1929 financial breakdown, until it was partially repealed by the Gramm-Leach-Bliley Act in 1999. Controlled shadow FI, such as SIVs and conduits, were established by commercial banks in order to fight back the competition of autonomous shadow FI. To this end, commercial banks shifted part of their activity off balance sheets to earn higher profits by eluding the constraints of regulators. The development of shadow banking has greatly increased the instability of the financial system as its substantial freedom from regulation allowed it to pursue aggressive strategies characterised by very high leverage and incautious financial innovations. This produced high profits during the years of financial boom and huge losses and widespread defaults in critical years. The five big US investment banks have been all swept away by the crisis. Hedge funds underwent severe losses but most of them managed to survive, although downsized, and to recover, together with enduring shadow FI, in the new wave of speculation that began in mid-2009.

[10] As is well known, Paul McCulley of PIMCO is reported to have introduced this neologism at the 2007 Jackson Hole conference where he defined 'the shadow banking system' as ' the whole alphabet soup of levered up non-bank investment conduits, vehicles and structures' (McCulley, 2007).

The development of shadow FIs was the cause and effect of the parallel development of shadow financial markets that trade unregulated or weakly regulated securities, in particular OTC derivatives. The dimension of these markets propelled by the process of securitisation swelled progressively. This technique transformed non-traded assets and liabilities, or a combination of them, in tradable securities. This implied the transfer of the evaluation of expected cash flows from a few specialised analysts (in the originating FI) to the market, namely to an undefined and variable set of traders. The first experiments of securitisation were performed in the 1970s but the process started to spread only in the 1980s, becoming important in the 1990s and crucial in the 2000s. Its outstanding value reached in the second quarter of 2008 an estimated amount of more than \$10 trillion in the US, and more than \$2 trillion in Europe. The systematic use of securitisation transformed the model of banking from the traditional 'originate and hold' to the new 'originate and distribute'. Two kinds of asset-backed securities (ABS) played a crucial role in the subprime crisis: the MBS bundling mortgages of increasing low quality that transmitted the housing crisis to financial markets, and the credit default swaps (CDS) that greatly aggravated it. The first were issued to avoid the risk of holding subprime mortgages and to increase liquidity. The CDS were issued to insure the risk of credit from party A to party B by paying a premium to the insurer in exchange for a promise to pay money to A in the event B defaulted. Contrary to widespread expectations, the market proved unable to price correctly these securities. This should have been understood much before the crisis by taking into account their complexity, opacity, and the systemic risk involved. In particular, the fundamental principle of commercial insurance that excludes the possibility of insuring a collective risk was ignored. The widespread faith in the market, corroborated by models of pricing based on the equilibrium method of mainstream economics, led market participants astray.

15.6 The Crisis of New Classical Economics

The Long Recession that began in 2007 amplified the divergence between different schools of thought, breaking the fragile consensus reached in more tranquil times. This divarication of paradigms is typical of periods characterised by the Great Crises, as we have seen in the Great Depression of the 1930s and the Long Stagflation of the

1970s. For example, in monetary theory the era of financial shocks that began in 1998 deeply questioned the New classical indistinction between short- and long-term neutrality and reopened the debate on the significance of the QTM and its limits. The recent empirical findings are not favourable to the QTM. For example, De Grauwe and Polan, using a sample of 160 countries for the preceding thirty years, say,

> First, when analysing the full sample of countries, we find a strong positive relation between the long-run growth rate of money and inflation. However, this relation is not proportional. Our second finding is that this strong link between inflation and money growth is almost wholly due to the presence of high-inflation or hyperinflation countries in the sample. The relation between inflation and money growth for low-inflation countries (on average less than 10% per year over 30 years) is weak, if not absent (De Grauwe and Polan, 2005, 256).

The recent Long Recession dramatically confirmed the unreliability of the monetarist approach. For example, Koo (2011) showed that, although during the Great Recession Central Banks increased the monetary base at an unprecedented rate by resorting to massive quantitative easing measures, the money in circulation remained stagnant in consequence of the breakdown of the money multiplier, while also credit money did not increase notwithstanding near-zero interest rates.

The Long Recession has triggered a hot debate whether the financial crisis and its subsequent real consequences have been brought about by market failures or policy failures. Keynesian economists typically blamed market failures that were neglected, or played down, by market fundamentalists, while New classical economists defended the invisible hand by putting the blame on the failure of the policy strategies adopted, particularly those inspired by Keynesian economists. I maintain that both markets and policymakers made substantial mistakes. In any case, both categories of failure undermined the soundness of the neoliberal paradigm from the viewpoint of policy, macroeconomic theory (the New classical view in all its versions including the most recent ‘New Consensus’ version), and facts (shortcomings of the neoliberal or ‘turbo’ capitalism).

Real markets confirmed their limits, pointed out since long by economic theory, that henceforth no honest observer should underestimate. First, the neoliberal era confirmed that markets are unable to deal with income distribution in a satisfactory way. It is well known from pure theory (including that based on GE models) that, in a perfectly competitive market, income distribution evolves on the basis of the existing allocation of wealth and resources (given technology and preferences). Therefore, there is no reason why it should comply with a given distributive standard considered as desirable or at least acceptable. In the real markets, that are characterised by significant asymmetries in discretional economic power, in the absence of redistributive economic measures, the distribution of income tends to become more unequal as the most powerful decision makers eventually succeed in distorting market choices in their own favour. In addition, the increase of poverty and malnutrition in the last two decades, even in developed countries, showed that the trickle-down argument works only in part.

The policies pursued in the market of labour were able to establish a flatter Phillips curve, curbing the inflationary bias of real Keynesianism and establishing a regime of price stability (the so-called Great Moderation). However, this result could be obtained only at the cost of reducing the purchasing power of real wages and salaries, as well as the stability of jobs. This had negative implications not only for the wealth and well-being of a great part of society, but also for the aggregate consumption financed by current income. Effective demand had to be sustained by the increasing debt of households promoted by private financial firms (bank and non-bank companies) and public institutions (as Fanny May and Freddy Mac in the mortgage sector). In this way, however, also the households became fragile finance units. This explains why the increase in cost inflation in 2007, due to the spike in the oil price and the consequent increase in the rate of interest, triggered the crisis of the subprime mortgages sector that started the financial crisis.

These examples of huge market failure contradict the basic assumptions of New classical Economics: that agents do not make systematic errors and have rational expectations, that uncertainty is week and symmetric, and so on.[11] The inability of these models to 'mimic' the empirical evidence has been often observed in the past. The method of calibration adopted for habilitating New classical models to empirical research is often used in such a way to make impossible the falsification

[11] I developed these arguments in more depth in Vercelli (2017, 2019).

of the model. Moreover, in principle, as recognised by the founding father of the school himself (Lucas, 1981), these models are based on a crucial postulate of 'regularity' of economic phenomena that prevents sound application to irregular phenomena such as the subprime crisis. The possibility of an event of this kind was altogether outside the conceptual horizon of the theory that was by definition unable to forecast, prevent, and control it.

The new model of finance that emerged in the neoliberal era greatly increased the intrinsic instability of the financial system. The new 'originate and distribute' model of banking led to a generalised delegation of responsibilities about financial decisions to an inexistent, or very weak, invisible hand. Shadow banking, being much less constrained by regulation and being protected by information opacity, greatly increased the attitude of responsibility relief in financial markets. Shadow markets approached the ideal model of unfettered markets that have always been dear to old and new exponents of laissez-faire. This did not strengthen the self-regulating virtues of markets and further clarified that the deregulation of real markets does not imply a better approximation to a perfectly competitive market. The way in which the regulation of financial markets was weakened or eluded, greatly reduced the completeness and reliability of information that is a crucial requirement of a competitive market.

Let's now consider the nature and effects of policy failures. The market failures that we have rapidly recalled have been induced or permitted by neoliberal policies. A crucial role has been played by Central Banks. They continued to react promptly to any danger of accelerating inflation as is clearly shown by their restrictive interventions in 2007 and first half of 2008, although the financial crisis had already started. This is by itself questionable as it shows an undervaluation of the gravity of the emerging crisis. However, the crucial point is the lack of reaction to financial inflation and the refusal to prick the bubbles. According to Greenspan, the market knows better than any single individual when it is the case of pricking the bubbles and deflating financial assets. This clarifies that the failures of monetary policy are strictly related to the market fundamentalism of New classical Economics and neoliberalism. The same is true with the lax supervisory controls that allowed extravagant leverage ratios, the development of huge derivatives markets outside any control, and of an abnormal shadow banking sector. Also, the policy mix of privatisation and deregulation did not reach its goals but produced unexpected devastating collateral effects. In the end, the declared crucial objective entertained by neoliberalism of reducing the share of public expenditure over GDP was not reached. The only success that very few countries may possibly claim is the stabilisation of this share. However, in most countries there has been a radical change in the structure of public expenditure: fewer public services and more expenditure for security and defence. In any case, there is no evidence of enhanced competition in markets. On the contrary, the vicious circle between the exponents of powerful private interests and policymakers deteriorated also in the most developed countries. As for taxation, the progressive burden on personal incomes was weakened if not reversed, and this contributed to the growing inequality of income distribution. As we see from these examples, the policy failures were the direct consequence of the same philosophy of market fundamentalism underlying orthodox macroeconomics and the neoliberal turbo capitalism.

15.7 The Coevolution of Economy and Economics

As our reconstruction suggests, the Interaction followed a fairly regular qualitative pattern in the last century or so (see Figure 15.1). We had in industrialised western countries three major crises: the Great Depression in the 1930s, the Long Stagflation in the 1970s, and the Long Recession that began in 2007. In each of these cases, the existing economic policy regime was considered as a crucial factor contributing to the outbreak and persistence of the state of crisis leading to a policy paradigm shift. The new macroeconomic theory was meant to overcome the policy failures observed during the crisis and provide apt foundations to a new policy strategy: Keynesian full employment policies since the 1930s and neoliberal policies since the 1970s. The new policy strategy starts to be applied after a fairly long and variable lag required to allow its advantages to percolate at the level of public opinion and policymakers. The new policy paradigm in its applied version is typically simplified and distorted to make it appealing and to serve better the specific interests of policy makers and their great electors and supporters. We have to distinguish between an 'ideal' policy paradigm as worked out by the intellectual leaders of the revolutions in macroeconomic theory, and its 'real' application that depends on many other, often distorting, factors. As we routinely

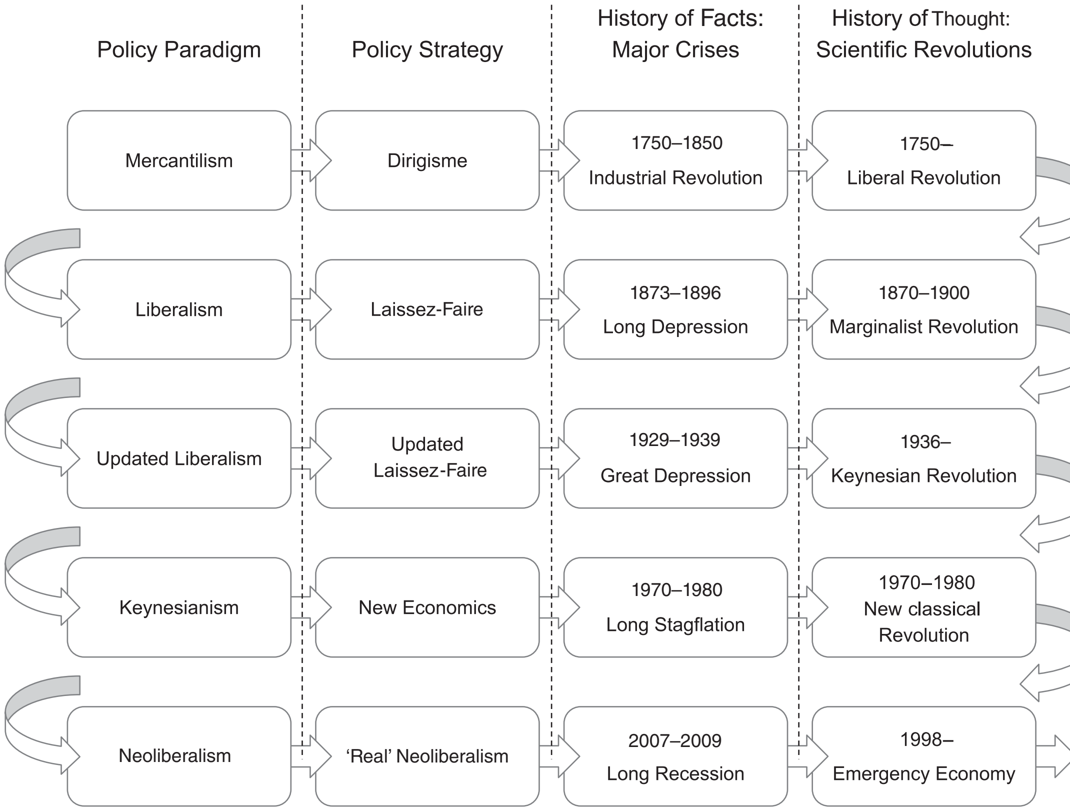

Figure 15.1 The Interaction's spiral

distinguish between socialism and real socialism, analogously we have to distinguish between liberalism and real liberalism, as well as between Keynesianism and real Keynesianism, and finally between neoliberalism and real neoliberalism. The real version of these policy paradigms tends to degenerate under the pressure of particular interests contributing to the outbreak of a new great crisis that determines a radical redirection of theory, policy, and behavioural practices.

The analogies that we have emphasised (as summarised in Figure 15.1) should not blur the differences between the historical episodes here sketchily reconstructed. In particular, we may notice that the reaction of macroeconomics to the Great Depression of the 1930s went in the direction of a much enhanced awareness of the complexity of the real world. As Keynes maintained '… the classical theorists resemble Euclidean geometers in a non-Euclidean world … there is no remedy except to throw over the axiom of parallels and to work out a non-Euclidean geometry' (Keynes, 1936, 16). On the contrary, the reaction of macroeconomics to the Long Stagflation of the 1970s went in the opposite direction of systematic compliance with first principles believed to be universally true, regardless of their counterfactual appearance and their appropriateness for the problem studied. Also, in this occasion there were serious attempts to redirect macroeconomic theory in a direction that takes account of the complexity of the real world. Simon's theory of bounded rationality, Clower and Leijonhufvud's theory of disequilibria (or temporary equilibria), and Minsky's theory of financial instability were some of the most serious attempts that attracted a great interest from many macroeconomists in the 1960s and early 1970s and seemed to point to a new revolution in the direction of enhanced awareness of complexity. However, the New classical Revolution succeeded in the 1970s to defeat in mainstream quarters the alternative attempts to reform macroeconomics. The success of the New classical scientific vision derived from a host of factors, such as the simplicity and elegance of its models, their suitability for quantitative analysis, the feelings of reassurance to a profession in deep crisis. But none of these alleged advantages could have been reaped without a robust protective belt meant to isolate the theory from the falsifications stubbornly iterated by the empirical evidence. This protective belt favoured the use, or abuse, of the New classical mainstream as an ideology of market freedom that was much cherished by whomever believed, rightly or wrongly, that laissez-faire was in their own interest.

What will be, on this occasion, the reaction to the Long Recession? We believe that we cannot further postpone a systematic effort in the direction of a more satisfactory complexity science. Differently from the Long Stagflation, in the Long Recession it is much more difficult to exclusively blame policy mistakes and exogenous shocks for macroeconomic failures. The pathological inefficiency of the invisible hand in fully liberalised and weakly regulated financial markets questions all the basic postulates of mainstream macroeconomics: persistent equilibrium, systematic efficiency, unbounded rationality, and so on. The subprime crisis provided a particularly evident confirmation of a significant empirical regularity: the majority of financial crises are preceded by financial liberalisation. We need a different kind of economics that starts from assumptions consistent with the properties of real markets. In particular, we have to liberate macroeconomics from the straitjackets of classical microfoundations and the equilibrium method. Whatever are the merits of these two basic methodological features for the study of an ideal market of perfect competitions, macroeconomics has to address the problems of real markets. To study the latter, we need a more appropriate approach to individual decisions and a higher awareness that in real markets disequilibrium and instability play a crucial role. Only a macroeconomics of this kind may guide us to understand and control the behaviour of real markets, contributing to avoid or mitigate major crises.

15.8 Is Dirigisme Coming Back?

Figure 15.1 and the underlying narrative summarised in the previous sections do not pretend to be more than a didactic device to stress some analogies between successive coevolution stages of the economy, economics, and policy rules since the industrial revolution. For the sake of simplicity, this representation ignores the conspicuous differences that qualify the historical episodes mentioned in the figure. Notwithstanding its extreme simplicity, the figure shows that after the Long Recession, the broad regularity of the recurrent stages has so far been somewhat interrupted. First, the reaction to the crisis did not promote the birth of a new research programme that takes account of the failure of mainstream economics in all its variants and tries to build up a more promising research programme. The first reaction seemed to favour a revival of the original radical anticlassicism of

Keynes as cultivated by some of his most uncompromising followers such as Minsky. However, in the early 2010s the equilibrium method of the pre-crisis consensus recovered a tight control of the practice of normal science similar to that pursued before the crisis. As for the policy paradigm, substantial changes of a great moment silently materialised, independently of the evolution of economic theory. After the Long Recession of 2007–2009, the loss of prestige of laissez-faire economics facilitated a progressive coming back of political dirigisme that exploited technological and institutional changes. This time the motivations for the policy change often did not pretend to be rooted in the failure of economic theory. On the contrary, the rulers of the new policy regime struggled to motivate why the usual economic rules have to be occasionally suspended. The first and foremost excuse was the breakout of an emergency requiring urgent and unorthodox measures. In the last decades the emergencies emphasised by policymakers became increasingly frequent. After the stage dominated by an alleged regularity of economic time series hallmarked as *Great moderation* in the economy and *Washington consensus* in economic policy, most countries entered in a stage dominated by what may be called *emergency economics* relying on ad hoc measures rather than on policy rules. These measures did not hesitate to limit both economic and personal liberties, with the argument that temporary deviations from orthodoxy were necessary to counter the ongoing or expected emergency. The recent epidemics and wars offer many examples. In addition, the environmental emergency was evidenced long ago but commenced to be emphasised only after the Long Recession.[12] Deep financial crises offered further pretexts for measures that limit the liberty of individuals. The dirigiste measures that characterise emergency economics are usually not inspired by economic arguments but forced by policymakers on economic policy to orientate it towards desired objectives.[13] Mainstream economics after Adam Smith has always been against any form of dirigisme. This is true not only of the classical stream (old and new) but also of the Keynesian

[12] See, for example, Borghesi and Vercelli (2008).

[13] Some economists tried to provide economic foundations to the severe limitations of individual liberty recently imposed by some strategies of public interventions by resorting to the theory of externalities introduced by Marshall and developed by Pigou (1920). It is arguable, however, that a careful use of this theory is rarely able to justify the excesses of the new dirigisme.

stream that has always cultivated a different, much more cautious and self-restrained, form of liberalism. In consequence of these structural changes, also the internal pluralism of mainstream economics petered out. The dirigiste orientation of Mercantilism ruled when the main problems of national policies were colonial wars and the strictly related foreign commerce and monetary policies. The evolution of international markets and geopolitical relations revived similar priorities. In addition, the evolution of technology and of the industrial structure further weakened the support for genuine liberal policies in politics and society.

15.9 The Fluctuations of Pluralism

I sketched in this chapter a bird's-eye view of the evolution of economic paradigms since the eighteenth century that could be used for teaching an introductory course in economics. It could help providing a preliminary understanding for why we cannot ignore the crucial role of pluralism neither from the descriptive nor from the normative point of view. Periods of scientific revolution characterised by a harsh conflict between competing economic paradigms (as in the 1870s, 1930s, and 1970s) alternated with periods dominated by 'normal science' where the confrontation between competing paradigms was somehow repressed by the mainstream school(s) of thought. The periods of normal science characterised by a broad consensus may be conducive to a significant upgrade of the role of economics in the academia and society but jeopardise the crucial critical role of pluralism. The Marshallian synthesis gave Marshall the strength of introducing for the first time a degree in economics and starting the era of systematic advising of economists to the government, but deemphasised the importance of an unrestrained dialogue between alternative research programmes (external pluralism). The neoclassical synthesis enlarged and strengthened the crucial role of economics in the design and management of mixed economies but watered down the deepest insights of Keynes. The New classical Synthesis played instead a crucial role in the design and management of the Neoliberal Era but was unable to avoid or control the growing structural instability of the economic system. The crisis of the periods of consensus was typically conducive to scientific revolutions that produced a new hegemony and eventually a new consensus. So, for example, the crisis of Classical economics led to the Keynesian Revolution and then to the new consensus of neoclassical synthesis . The crisis of the neoclassical synthesis brought about the New classical Revolution that eventually led to the New classical Synthesis. The subsequent cycle did not follow so far, the same pattern of the preceding cycles. The Long Recession and the subsequent turmoil destabilised the New classical Synthesis but did not generate, at least so far, a new economic paradigm capable of facing the new problems efficiently. In this ambiguous and somewhat anarchist situation, by spontaneous generation or intentional design (or a mix of the two), an unprecedented system of control of research orientation was implemented to buttress a crumbling consensus accompanied by a loss of prestige of economics. This system justified by monistic meritocratic criteria progressively marginalised the alternative research programmes within academia, mass media, and policy-making. The first step was the rating of scientific journals based on the number of citations. This allowed an apparently objective rating of researchers based on the number of publications weighted by the bibliometric prestige of the journals. The bibliometric rating of researchers offered an apparently objective criterion to determine their promotions and their status in the academic career and consulting, but this process of selection proved to be conspicuously biased. The pressure of this alleged meritocratic system on researchers, especially young researchers, exerted a formidable pressure on the choice of research topics and the approach to be adopted. The young researchers were pushed to become clones of their most successful teachers, and the entry freedom of new ideas and methods was severely limited, generating self-energising scientific oligopolies. In addition, in many countries the public money to support academic teaching and research started to be distributed in proportion to the score obtained by the single departments and schools with the systematic application of bibliometric criteria: conform or perish! This new institutional *tunic of Nessus* contributes to explain the difficult emergence of a new paradigm more adequate for the new challenges of an economic and political world in rapid transformation.

16 *Whither Pluralism?*

> *Voltaire:*[1] *Toleration is the prerogative of humanity; we are all full of weaknesses and mistakes; let us reciprocally forgive ourselves. It is the first law of nature.*
>
> *Alfred North Whitehead:*[2] *A clash of doctrines is not a disaster – it is an opportunity.*

In this book I argued that pluralism is an essential requisite of sound science and that its rejection, whether explicit or implicit, is the litmus test of dogmatism. I recalled in the preceding chapters that, from the pre-Socratic thinkers of ancient Greece to the contemporary exponents of quantum gravitation, philosophy and science always adopted an intransigent antidogmatic attitude. I added epigraphs at the beginning of each chapter to recall the firm rejection of dogmatism by famous philosophers and scientists. Explicitly or implicitly, the rejection of dogmatism calls for pluralism, the necessary antidote against authoritarian conformism. In this final chapter, I intend to wrap up a few crucial concepts of my previous arguments. I recall in Section 16.1 that in the western culture pluralism and rationality were born together and coevolved synergically. Rational choice requires plural options, and critical pluralism calls for rational judgement. In Section 16.2, I briefly recall the main insights of post-positivism that greatly contributed to the foundations of contemporary pluralism, although in a questionable way. Section 16.3 discusses what I believe to be the main source of anti-pluralism: the alleged primacy of practical over epistemic reason. Section 16.4 deals with one of the main obstacles to pluralism, namely the incautious use of rigid demarcation lines between sound science and pseudoscience. I discuss in Section 16.5 an emblematic example of the distortions introduced by normative objectives in the age-old, but

[1] Voltaire (2000 [1763]). [2] Whitehead (1926 [1925], 230).

often misleading, debate on the conflictual dichotomy between market and state. These distortions are instrumentally used by the economic and political elites to pursue their own interests in the name of all citizens (Section 16.6). I end this book with a modest and limited proposal that could become one of the many tesserae of a much more extensive and complex mosaic of interventions to revive pluralism and keep it vibrant.

16.1 Coevolution of Pluralism and Rationality

The critical pluralism advocated in this book emerged in Ancient Greece (4–5 century BCE). The origin was a far-reaching shift from the mythological polytheism of the ancient Greek culture to the rational pluralism advocated and practiced by Socrates and his pupils. We can say that critical pluralism and rationality were born together and evolved together. This explains why this book on pluralism focuses so much on the genesis and evolution of rationality as mainspring and counterpart of the evolution of scientific pluralism.

This concept of reason as the fundamental concept that regulates the epistemic and practical activity of human beings emerged in Ancient Greece within the paradigmatic model of dialogue between interlocutors aiming to seek a common agreement on a matter of fact or opinion, or about a choice of action. This paradigmatic example of rationality presupposes the use of a common language, different initial opinions, and a critical attitude aiming at discovering and correcting the errors concealed in the initial opinions of all interlocutors. In this way, the dialogue between them aims at approaching the truth, or at sorting out the right choice in the problem under investigation. In principle, the process of collective learning, namely the convergence of the interlocutors towards the truth, or the right solution of the problem under investigation, is more effective in the function of the variety of viewpoints and the unrestrained critical acumen of the interlocutors. This process of error correction focused on the detection of logical contradictions in the arguments, or of inconsistencies, with empirical evidence. However, if the ultimate milieu of interactive reason is language (*logos*), it cannot focus only on its syntactic structures but must take into account the other dimensions of language, namely semantics and pragmatics, that play a crucial role in interpersonal communication. Rationality is thus in its essence a process of learning that has many dimensions: a syntactic (or formal) dimension aimed at avoiding logical contradictions, an empirical dimension to match in the best possible way the empirical evidence, and a social dimension that implements interactive learning through critical dialogue. Pluralism is thus a necessary condition of reason as it promotes rational learning. This requires a genuine tolerance for different opinions, judgements, and theories and a sincere disposition to learn not only by direct experience and deductive inference, but also from the interlocutors arguments. The critical attitude towards others' opinions and arguments must be as frank as possible but should not violate the requisite of mutual respect. In other words, as Whitehead wittily said, a clash of opinions does not need to be a destructive event as a car crash but should be seen by all interlocutors as an opportunity to learn. The assertion of reason without dialogue is just a dogmatic instrument of persuasion that may easily degenerate in authoritarian imposition. Reason without pluralism is like Othello without the moor of Venice. Plato provided a series of paradigmatic exemplars of rational pluralism in his early dialogues strongly influenced by the teaching of Socrates. However, in his later political dialogues, Plato's avatar betrayed the original critical pluralism of his master by claiming the superior rationality of philosophers. He ended up in a contradictory position characterized by epistemological pluralism and normative monism. In the *Republic*, for example, he developed the famous myth of the cavern that vividly represented the fallibilism that underlies any form of knowledge, but at the same time advocated the republic of philosophers in the unfounded conviction of their superior rationality. In this book I assumed that no one, including Plato himself, is immune from Socratic fallibilism. The late Plato, under the influence of Pythagoreans, started to mathematise natural philosophy. This influence was limited and somehow distorted by his pupil Aristotle who gave great contributions to logic and empirical sciences but introduced a demarcation line that inhibited mathematical research in physics and other earth-based natural sciences. In particular, he maintained that mathematics and geometry, which were already successfully applied in astronomy, could not be applied to the sublunar world where the movements of existing entities were too complex. This inhibition was relaxed only when Renaissance artists and scientists revived the approach promoted by the Pythagoreans and the late Plato. The Scientific Revolution of the late Renaissance began when Kepler, Galileo, Newton, and Huygens advocated and practiced the mathematisation not only of astronomy but also of terrestrial physics. This greatly encouraged a new form of pluralism expressed by mathematical models. This episode shows that highly strict methodological demarcation lines are crucial enemies of pluralism. The inapplicability of mathematics to the sublunar world was one of the demarcation lines advocated by Scholastic Rationalism deeply influenced by Aristotle. Also, the empiricists introduced rigid methodological rules that inhibited pluralism. In particular, the radical assumption that there is nothing in the intellect that was not previously in the senses gave a central role to induction and inhibited other constructive approaches to critical learning. The trouble is that induction cannot lead to universal laws. The contradiction between the two requirements led to the decline of both radical Empiricism and radical Rationalism. Hume demonstrated that, if we aim at certain knowledge, neither empiricist induction nor rationalist deduction can lead to it. At the end of the nineteenth century, Kant elaborated his great synthesis of Rationalism and Empiricism based on the relaxation of the requirement of certain knowledge based on deterministic causes. His critical vision anticipated many aspects of subsequent science and was a turning point in philosophy. His rebuttal of the requisite of certain knowledge provided a new background for a revival of scientific pluralism that found in the nineteenth century more explicit foundations. The success of pluralism was resisted by post-Kantian philosophical streams, in particular Idealism and Positivism. The two philosophical streams reacted to the alleged relativism and scepticism of Kant in different ways. Idealism spelled out the apparent relativism in historical terms. In this view, the specific spirit of historical periods (*weltanschauung*) necessarily affects the prevailing philosophical and scientific vision. This is not wrong in principle. In this book I did not hesitate to give a crucial importance to the historical background of scientific visions to explain meanings, implications, and evolution of science. The trouble is that the influential German historicism interpreted the succession of historical stages as progressive realisation of a metaphysical design. This belief was renewed and revived by subsequent schools of thought and influenced many scientists who interpreted science as a progressive cumulative enterprise approaching a final target. This sort of teleological historicism is inconsistent with the critical pluralism advocated in this book. While teleological historicism revives in new form the metaphysic attitude of rationalists such as Descartes and Leibniz, the logical positivism of Russell and the Vienna Circle put a series of new obstacles to critical pluralism. First, they defined a rigid demarcation line between science and pseudoscience based on the assertion that metaphysical arguments are meaningless. Second, they introduced a radical reductionism meant to solicit methodological agreement among scientists. Finally, they advocated rigid rules of induction in the conviction that their common application should lead to the same conclusions. Therefore, logical positivism corroborated the conviction that mainstream science based on positivist principles proceeded by accumulation of knowledge. This point of view is still influential in natural sciences, although scientific advances, started in the early twentieth century within relativity theory and quantum mechanics, proved inconsistent with this monist belief.

16.2 Post-Positivism and Scientific Pluralism

The contributions of post-positivism (in particular those of Popper, Feyerabend, Kuhn, and Lakatos that I have critically reviewed in Chapter 4) have important implications for the issue of scientific pluralism. Popper's falsificationism provided telling foundations for pluralism because it supported the idea that a free and lively dialectic between competing conjectures is instrumental to scientific progress.[3] On the other hand, Popper's strict demarcation between science and pseudoscience excluded from the club of genuine sciences also theories that have a solid scientific status. An emblematic example is the Darwinian theory of biological evolution that Popper himself eventually considered crucial for the development of sound science (Popper, 1963, 1972). Feyerabend (1975 [1965]) reacted to this contradiction by rejecting any demarcation criterion between science and non-science (or pseudoscience). The resulting 'methodological anarchism' eliminated any a priori obstacle to unrestricted pluralism but made it liable to dangerous consequences. If 'everything goes in science', we would lose any defence from arguments that could lead astray any honest search for truth. If unchecked, the opportunist practices of unscrupulous scientists could eventually facilitate the imposition of a dogmatic

[3] In particular, he argued that 'real progress in Science is impossible without toleration, without feeling sure that we can publicly state our thoughts' (Popper, 2012, 324).

scientific monism functional to specific private interests. The introduction of rules that guarantee unadulterated scientific pluralism requires a deeper analysis of its different forms. In Kuhn (1970 [1962]) we find the germs of an analysis of this kind that is, however, in the end, unsatisfactory if not misleading. Appraising Kuhn's point of view on pluralism, we have to distinguish different aspects. First, we have to consider Kuhn's conviction that in normal science the prevalence of one mainstream paradigm is fully justified by the higher efficiency in the puzzle-solving routine of scientists. Second, the late Kuhn seemed to look at the pluralism typical of revolutionary periods as a sort of temporary pathology typical of conflictual times. Moreover, Kuhn's idea that a persisting plurality of competing paradigms may be found only in immature sciences such as social sciences further contributed to undermine the scientific pluralism in economics. This monist bias seems to justify the conformism of normal science that has always had a devastating impact on the teaching of science, its enlightened use in society, and the selection of new researchers. This point of view would greatly repress the critical attitude that underlies the progress of science and a wise application of its advances in society. In particular, its adoption in social sciences would inhibit the necessary creativity of scientists to search truth for the common good. It would be not only obnoxious from the normative point of view but also in sharp contrast with the historical record of sound science. Kuhn conjectured that, given the tendency of scientists to believe in theories that have withstood many tests, science may well enter a phase of permanent 'normalcy,' in which no further revolutions are possible. This scenario is frightening because its implementation would be the end of critical pluralism and could involve the instauration of a technocratic dictatorship supported by scientific monism. However, the persistent plurality of scientific views and the recent evolution of science suggest that this 'end of history' in science is fortunately unlikely unless it is forced on science producers and consumers through repressive methods.

16.3 Scientific Rationality, Practical Rationality, and Pluralism

If we consider at a distance of time the contributions of the early leaders of post-positivism – Popper, Kuhn, Feyerabend, and Lakatos – we perceive in their contributions a deep intellectual kinship. Notwithstanding their turbulent personal connections of friendship, conflict, and emulation, the synergic influence of their contributions played a crucial role in the renovation of epistemology and history of science. The main common message may be summarised by the well-known assertion by Lakatos: 'History of science without philosophy of science is blind. Philosophy of science without history of science is empty'.[4] This point of view was not new as it was already practiced a century earlier by scholars of high standing such as Whewell and Mill. However, post-positivist philosophers developed this approach to an unprecedented level of detail and sophistication. With hindsight, I must point out also a crucial common shortcoming that heavily limited the validity of their message. Lakatos remarked that in Popper there is a disconnection between the game of science, which is based on the dialectic between conjectures and refutations, and the aim of science, which seeks a progressive approximation to truth. Popper was aware of this crucial problem but did not succeed in solving the problem. His analogy between the game of science and trial-and-error learning suggested the viability of a progressive approximation to truth that would render an internalist approach viable. However, the actual convergence to truth of learning processes requires a series of demanding assumptions whose plausibility Popper did not discuss in sufficient depth. To restore the connection between the game of science and its ultimate task is not enough to introduce a 'whiff of inductivism', namely an 'inductive principle which connects realist metaphysics with methodological appraisals'. This alleged solution would emphasise the unsolved contradiction with the radical criticism of inductivism that Lakatos shares with Popper. In the absence of specific inferential rules to ascertain the nature and weight of growing verisimilitude, the suggested solution remains wishful thinking. Therefore, against Lakatos we can address the same criticisms he addressed against Popper as he does not provide a better link between the game of science and its ultimate aim. I may add that we find the same unsolved problem also in Feyerabend and Kuhn although its presence is clouded by their rejection of a scientific rationality theory. The trouble is that, in all their contributions, the game of science and its internal aims are almost completely disconnected from the external, or

[4] This sounds as a reformulation of the famous Kantian assertion that 'Thoughts without content are empty, intuitions without concepts are blind. It is, therefore, just as necessary to make our concepts sensible, that is, to add the object to them in intuition, as to make our intuitions intelligible, that is, to bring them under concepts.' (Kant, 1787, 75)

social, aims of science. This is surprising because in common understanding the ultimate aim of science is that of contributing to the well-being of society by providing epistemic and technological instruments to solve the problems of the human lot. In particular, we cannot grasp the evolution of science and its impact on society without considering its interaction with technology. For example, we cannot understand the innovations in the field of optical instruments without taking into account the progress of optics, while the impact of improved optical instruments greatly contributed to the progress of natural sciences as was altogether clear at the time of Galileo and Huygens. This interaction is evident in many other cases such as thermodynamics and thermic engines (pioneered by Sadi Carnot in the early nineteenth century), hydraulics and construction of better pumps that boosted mining and agriculture in the eighteenth century, geology and exploitation of fossil fuels, chemistry and the development of the chemical industry, radioactivity theory and its use by medicine or nuclear reactors, and so on. The continuous progress of technology and its obvious dependence on science has always been the litmus test of the progress of science and the source of its growing social power. A merely internalist history of science such as that advocated by Kuhn (and, to some degree, practiced also by Popper and Lakatos) is bound to ignore the strict interaction between science and technology, and thus also between science and power – industrial, economic, and political power – which is often considers science mainly to control technology, and through technology nature and society.[5] If one neglects, or plays down, the dialectic between internalist and externalist evolution of science, one is unable to understand the huge impact of the evolution of science on society and vice versa. This is of course particularly true for social sciences, and among them for economics that has always been particularly close to the objectives of the economic and political élites.

16.4 The Monistic Demarcation between Science and Pseudoscience

The growing subordination of epistemic rationality to practical rationality is the main motive of the hostility against pluralism, especially

[5] The externalist approach advocated by Feyerabend is too generic to contribute to a systematic analysis of the links between science and far-reaching social factors such as technology and power.

external pluralism. Mainstream scientists always tried to defend in this way their hegemony. They did not fight what I suggested to call internal pluralism because, without a minimum of genuine dialectic between different points of view, science cannot even survive: pluralism is for science like oxygen for a human being. However, they always adopted a few strict discrimination criteria between sound science and pseudoscience. Therefore, if one paper trespasses one of these demarcation boundaries, it is immediately expelled from the archives of serious scientific contributions. This leads to the marginalisation of heterodox authors from prestigious academia and top-level consulting. For example, the New classical economists assumed as crucial demarcation lines the microfoundations approach, the efficiency of competitive markets, and the Rational Expectations Hypothesis. These criteria exclude from sound updated science important and influential research programmes including the Keynesian, behavioural, institutional, and Marxian research programmes. Abiding to these criteria left some margin, to a certain degree, of internal plurality in the explanation of the business cycle: these were first connected to unexpected variations of money supply (monetary equilibrium business cycle), then to unexpected technological shocks (Real business cycle), or to specific market imperfections as contended by New Keynesian economists. These sort of variations were expressed in different kinds of models and discussed with different econometric techniques. To superficial observers this variety may give the impression that the evolution of mainstream economics was not lacking the necessary pluralism. The main strategy pursued by the New Keynesian School to defend a consistent share of academic and political power was the introduction in the model of at least one market imperfection that could justify some sort of public intervention to improve the efficiency of unfettered markets. This game was easy to play because it is evident that real markets differ from paradigmatic free markets on many different accounts interpretable as market imperfections. This led to a new phase of convergence towards a broad consensus between New classical and New Keynesian economists. This alleged New Consensus dominated the turn of the millennium until 2007 when the Long Recession disrupted the previous fragile convergence. Although the New classical and New Keynesian models were similar enough to suggest the viability of a basic agreement, the interpretation of their results and policy implications were still significantly divergent because of the residual heterogeneity of their underlying scientific and political vision. In the eyes of a Keynesian economist (even a New one), the identification of a market failure justifies some sort of correcting public intervention, while a New classical economist is rather interested in its elimination, at least in the longer period.

16.5 The Distorting Primacy of Normative Objectives

The alleged primacy of practical reason over epistemic reason professed today by a growing number of philosophers of science, scientists, and economists has strong disruptive effects on the prompt comprehension of the evolving economic system and its implications for policy. In particular, the excessive emphasis on conflicting stylised normative rules disrupts the dialogue between alternative schools of thought, a frank but constructive dialogue that would be essential for the necessary updating of theory and policy. I limit myself to discuss an example of great consequence; the controversial policy primacy of the market over the State. According to the liberal doctrine, this policy bifurcation has played a crucial role in the history of political economy and then economics and economic policy. In my sketch of the evolutionary tree of political economy one finds in the left part of Figure 14.1, the schools supporting free markets and seeking to minimise public interventions, while in the right part of the same figure one finds the schools of thoughts that focus on the limits of markets and the necessity of substantial and systematic public interventions. The conflict between State and market has been conceived in a misleading way as if it were a zero-sum game. In this view, it seems that more State necessarily implies less market and vice versa. This simplistic dichotomic vision degenerated often in a sort of Manichean conflict. Liberalists old and new argued that public interventions affecting the functioning of free markets are destined to reduce significantly their efficiency and capacity of self-regulation. In addition, they claimed that any shift of power from markets to the State reduces the chances of an effective democracy by encouraging economic autocracy. I briefly recall as emblematic examples three of the most influential arguments advanced in the last century. Soon after the October revolution, the liberal critique against the State interventionism turned first against socialism. Mises (1936 [1922]) argued that rational economic activity is impossible in a socialist economy because the pricing system managed by State bureaucracy cannot be fully rational. The main reason is because, if the State owns the principal means of production, the planners are necessarily unable to assign rational prices to the good produced and are in principle unable to allocate resources efficiently. After the success of Keynesianism and its systematic applications to many market economies, the main liberal economists extended and adapted the criticisms of State interventionism to its new forms typical of mixed economies managed according to Keynesian macroeconomics policy rules. Hayek (1944) argued that, although the Keynesian interventionism was much more limited and circumscribed than the socialist one, this first step could easily become the irreversible beginning of a 'road to serfdom' that could lead to authoritarian collectivism. Friedman and Friedman (1962) supported this view arguing that, although a society entirely based on free markets may be impossible, the area of admissible State interventions should be greatly reduced by focusing only on its two basic functions of protecting the nation against foreign enemy and protecting citizens against crime (Friedman and Friedman (2002 [1962]). All these popular arguments, like most other arguments in favour of free markets, presuppose that a free market optimises the allocation of resources and never restricts the personal liberty of citizens. These assumptions, however, are by no means obvious and require several conditions that are by no means trivial. First, such a market must be a perfect-competition market that requires by definition a long list of counterfactual conditions. It is enough to recall one of them: in a perfectly competitive market no agent has the power of influencing relative prices, an assumption that sounds ludicrous in an economic system dominated by multinational corporations and global finance. Second, while the existence of a perfect-competition equilibrium is considered plausible under wide formal conditions, this is certainly not true of its stability and unicity. Third, in any case, the allocation of resources determined by equilibrium depends on the initial allocation and is likely to increase the inequality of income and wealth. This is not only a fundamental ethical issue but jeopardises the institutional stability of the equilibrium model on which the pro-market arguments are tacitly founded. Even if we start from a situation in which all the agents are price takers, the distributive alterations will grant agents increasing power as they grow wealthier. This will start a process of transition from the original perfect competition market to a suboptimal oligopolistic market that no one may pretend to reverse. However, the failure of the liberal arguments from the analytical point of view by no means endorses collectivism nor acritical interventionism. Liberal thinkers are right in claiming that any limitation of the freedom of individuals is potentially dangerous and should always by accurately justified and monitored. I briefly recalled these few fragments of the fundamental debate between classical and anticlassical economic schools on the State–market dichotomy to evoke a bit of its typical flavour before advancing some comments.

16.6 The Misleading Dichotomy between State and Market

The debate on the State–market dichotomy has always been, and still is, too abstract and schematic as if it were a conflict between stereotyped impersonal institutions. As soon as we shift, as Pareto did, to the more concrete point of view of élites conflicting for economic and political power, we uncover a much more complex and interesting dialectic between markets and State.[6] The economic and political élites utilise indifferently the market or the State, as any other public and private institution, to protect and increase their profits and their power. They need freedom of choice within the market to maximise expected profits; but also they need the support of the government to avoid unfavourable taxation, limiting constraints, and damaging sanctions. To this end, they finance generously one or more political parties. Analogously, the political élites act competitively to attract financial support promising specific measures usually justified by the alleged interest of all citizens but often clearly targeted to sectorial interests. Some of the measures may favour a plurality of industrial and financial interests and may produce large and powerful alliances between converging interests but the conflicts are unlikely to disappear. The change of economic and political conditions alters the map of interests, alliances, and conflicts. As a consequence of these changes, the political élites redefine their political objectives and alliances to surf better the chaotic and unpredictable waves of history. If we look at the relation between State and market from the point of view of economic and political élites, such a relation becomes much more fragmented, opaque, and subject to continuous evolution. The distinction itself

[6] See in particular Pareto (1968 [1901]) and (1935 [1916]).

between economic and political élites becomes blurred and variable. This opens a vast and complex area for the external analysis of economics history without which the analysis of pluralism risks to remain confined to the ideological features of schools of thought. In any case, the growing emphasis on Manichean pragmatic objectives has progressively compromised the viability of tolerant and constructive dialogue between different scientific visions. Even the identification of schools of thought and their intertemporal coherence are currently jeopardised as the economic and political élites utilise them in a growingly instrumental and incoherent way. Their references to specific economic paradigms are often just a pretext to endorse the policies they want to pursue in a certain moment in particular fields. They may have paradigmatic foundations radically different from, even opposite to, those of the policies pursued by the same élites in other fields without even seeking adequate scientific justification.

16.7 The Machiavellianism of Elites

This dangerous drift towards unrestrained Machiavellianism is supported by a few tactical and institutional transformations. First, the élites implement through mass media the instrumental use of the unavoidable emergencies that often affect the normal economic and political routines to suspend economic freedom. Examples are wars, terrorist attacks, epidemics, environmental catastrophes, and unusual immigration flows. The focus on existing or just expected emergencies leads to the temporary suspension of individual freedom through administrative acts and/or weakening of constitutional safeguards. These episodes of dirigisme are exploited by the ruling élites to introduce unpopular measures that would be otherwise opposed with much more vigour. The sentiments of fear inspired by emergencies make individuals much more passive and docile towards authority dulling their critical sense. The objectives may be temporary but the emerging *disaster economics* shows more ambitious strategic goals including a strict control of the process of evolution of capitalism. Specific sectorial measures may have liberal or neoliberal inspiration or may pretend this sort of justification to render them more palatable. However, on the whole, the general drive of *emergence capitalism* is a new form of dirigisme in disguise. The more decisive adoption of emergence capitalism as a response to the germs of a new great crisis is facilitated by other supporting structural changes that occurred at the turn of the millennium. One is the progressive convergence of most mass media towards similar varieties of group thinking. Notwithstanding the growing formal plurality (format, language, typical arguments) of mass media and their growing apparent differentiation, the convergence of the basic contents increases the persuasiveness of the similar representation of reality communicated by them. As with 3D glasses, the differences between the lenses resolves in a unique sharper relief image, mass media diversity builds an apparently compelling unique reality. In many cases the apparent truth of group thinking could be debunked by readers, but this would require a critical spirit that the educative system proves increasingly unable to build up. One of the reasons is the reform of the education system according to the doctrine that assimilates education institutions to private enterprises. This subordinates education to the objectives of the ruling élites with devastating effects for the critical capabilities of educated people. One of the principal reasons is the loss of awareness of the crucial role of pluralism in research. This is true in many evidence-based scientific disciplines and particularly in economics. This greatly facilitated the role of support by mass media of the desired policies advocated by ruling élites: whenever they need the instrumental support of science, they may just recall the alleged truth of updated science as if it were unique and thus compelling. In the light of this inkling of analysis, we may better understand reasons and consequence of the loss of pluralism.

16.8 Reinforcing Pluralism in Economic Education

The worrying tendencies briefly hinted at in the previous section confirm that pluralism plays a crucial role not only in sound development of science, in particular economics, but also in making possible an effective practice of democracy. As suggested above, the weakening of pluralism crucially depends on the ongoing involution of the education system and contributes to its ongoing deterioration. This negative tendency is often not visible at first sight. The ongoing division of labour has fuelled a continuous amazing improvement of technicism that is reflected by a use increasingly sophisticated of mathematics, statistics, and mathematical models. What is increasingly missing, however, is the critical spirit that is required by genuine science and its thorough use in society. The achievement of these goals calls for the systematic practice of full-fledged pluralism. To stop the ongoing degenerative process and invert the trend, it is thus a priority to revive pluralism in all articulations and levels of the education system. This book was oriented towards the analysis of causes and consequences of the ongoing loss of pluralism rather than on the policies to revive it in the conviction that a thorough plan to relaunch pluralism requires first a full comprehension of its crucial importance in healthy science and democracy. Moreover, an effective plan to relaunch pluralism would require a titanic collective effort that would need the cooperation of a sufficient plurality of committed scholars and policy makers in different fields of science, culture, and politics. However, I want to end this book with a modest and limited proposal that could become one of the many tesserae of a much more extensive and complex mosaic of interventions. My proposal aims to expose undergraduate students to pluralism at the very beginning of their studies of economics before they succumb to the misleading and stubborn illusion of scientific monism. This goal could be obtained by introducing a compulsory teaching unit on the evolution of internal and external pluralism that I have summarised in Chapters 14 and 15. This unit could be a significant part of the basic lecture course in economics, or it could precede it. Its contents could be articulated in four parts. In the first part, the lectures should focus on the internal history of economics by sketching the coevolution of the main alternative scientific visions (see Chapter 14). The second part should introduce the basic principles of the structural approach based on the epistemic matrices of scientific visions (ibidem). The third part should focus on the external history of economics by sketching the coevolution between scientific visions, policy strategies, and history of facts (see Chapter 15). Finally, the fourth part should discuss the normative implications of scientific plurality as a positive value to stimulate the necessary critical attitude in the study and then application of economics. Summing up, the first three parts of the teaching unit would aim to solicit the awareness of the role of plurality of visions, theories, and methodology in the evolution of economics. The use of diagrams similar to those introduced in Chapters 14 and 15 could help students form a first map of alternative schools of thought. The awareness of the existing scientific plurality is likely to support pluralism as a normative attitude aiming at preserving and valorising theoretical and methodological diversity (not less valuable than biodiversity and cultural diversity that enjoy a much wider endorsement.) The fourth part should thus discuss the role of pluralism as crucial value in science and in the democratic dialectics of society. In particular, it may be shown that pluralism is a powerful mechanism of learning and error correction, a necessary condition for a sound critical attitude in scientific research and practice, and thus a fundamental mainspring of constructive creativity.

This teaching unit could not only incentivise the students to adopt a critical attitude in their approach to economics, but also encourage teachers to adopt a more pluralistic approach in all their teaching activity. Analogously, departments could be stimulated to become more pluralist in designing curricula and syllabuses as well as in their recruitment policy. Of course, an efficient strategy to boost pluralism should act on different fronts, including a renewed independence of universities as institutions primarily dedicated to the search and promotion of truth over whatever pragmatic objective is promoted by the financial support of the ruling élites. We have a long and arduous way ahead but we have to find the courage to pursue it.

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