

Chapter 2

Crisis

Realism and Rigor

The task of predicting the future to ensure the livelihood of the people, entrusted to the Maya astronomer-priests, is now given to those who intend to interpret the great movements of a society, organizing its economy and orienting its policies accordingly. This should therefore be the task of social scientists and, in particular, of economists. Some do it extremely well, while many others seem to belong to a kind of caste similar to the priest-astronomers, with the difference that the power derived from the role is not supported by the ability to make useful predictions for the community. This caste consists of a particular subset of economists working in universities, and very often appointed to the boards of public and private companies, in politics, in international organizations, etc. We can often see them on talk shows, we can read their editorials in major newspapers, we meet them in politics as senior officials and ministers and they are accredited by public opinion for their technical expertise: as holders of the knowledge of a discipline that should provide evidence-based answers to the great problems of modern societies.

Too often, this apparent technical-scientific knowledge does not correspond to their ability to understand the society. Indeed, it seems that considering economics as a science able to unambiguously answer the various issues affecting a country, a company or an individual's economic life is an artificial way to transform political choices into technical and scientific problems, and so instead posing them as neutral issues. These priest-astronomers of the twenty-first century apparently study any aspect of human life, while trying to quantify some form of value and optimize the relative efficiency. From national economic policy to the organization of universities, from stock market behavior to the definition of the job market, from how to manage cuts to the public health system to reorienting entire industries, etc., it seems that there is no field of human knowledge and action that cannot be reduced to the same simple applicable model able to optimize and make more efficient any situation.

However, what is most critically important, is that economic theories have a very significant impact on our everyday lives and since some decades, and that the neo-classical one has been practically unquestioned. It has become dominant in academia, in politics and in the public debate, and has been used to consistently boost deregulation and liberalization of the economy with the argument that any regulation prevents markets from reaching their perfect equilibrium and their state of maximum efficiency. The key point of the impact of this economic doctrine on policy is insightfully explained by physicist Mark Buchanan, in his comprehensive book on the subject.¹ During the last half-century, neo-classical economic theory has provided the theoretical basis for the idea that, in order to increase market efficiency, governments should privatize their industries and deregulate the markets themselves. This result would be proven by sophisticated economic theories, which, through logical-deductive procedures, characterized by a formal mathematical rigor, would provide a series of mathematical theorems to support these conclusions. However, considering the assumptions underlying those mathematical theorems used in this economics, there is a remarkable difference between the conditions in which they can be applied and reality; here, realism, unlike rigor, takes a back seat. Unlike physics theories, such as the theory of special relativity and quantum mechanics, which have been subject to intensive validation through experiments, it seems that neo-classical economics was not subject to a similar pressure to test the theory against empirical evidence.

The French theoretical physicist, an expert in the study of financial markets, Jean-Philippe Bouchaud, in his 2008 *Nature* editorial entitled “*Economics needs a scientific revolution*”,² published in the aftermath of the failure of Lehman Brothers, expressed a similar concern, comparing advances in economic theory with the advancement of knowledge in physics that has enabled the extraordinary technological development we have witnessed in the last fifty years, from the conquest of the Moon to the spread of those technological discoveries condensates that we have in our pockets in the form of smartphones. The key question concerning economics is

What is the flagship achievement of economics?³ Only its recurrent inability to predict and avert crises, including the current worldwide credit crunch.

The Mayan “*ilhuica tlamatilizmatini*” knew how to predict the seasons: are the modern priest-economists actually able to interpret the behavior and movements of men, markets, economies, and states and predict their future? Can public opinion, the people, and the policy makers can really trust the recommendations and forecasts of the priests-economists to pursue their personal and general well-being? To answer these questions, we will examine below, without going into great detail,

¹Buchanan [1].

²Bouchaud [2].

³Bouchaud refers to neo-classical economics.

the various aspects of neoclassical economic theory that are relevant to the issue of forecasts in economy.

The Queen's Question

On September 15, 2008, the financial services firm Lehman Brothers filed for bankruptcy: it was the largest bankruptcy in US history given that Lehman held more than \$600 billion of bank debt. This important event, which can be considered the culmination of a turbulent series, had started a few years earlier, triggering a global financial crisis, the biggest since the Wall Street crash of 1929, which in turn led to a recession that even extends until now, after eight years, in many countries. Between September 2007 and February 2009, the stock market indeed lost 50 % of its value and the consequences of these dramatic events have not yet been exhausted.

A few months later, on November 5, 2008, Queen Elizabeth and the Duke of Edinburgh visited the most important academic institution for economic studies in the United Kingdom, the London School of Economic (LSE), to inaugurate a new building. During the opening ceremony, Her Majesty asked what is now known to history as 'The Queen's question'. According to the British newspapers,⁴ Queen Elizabeth, after discussing the global financial crisis which at the time was exploding in all its virulence, asked several LSE professors: "Why didn't anybody notice?" In fact, although some economists had predicted that a global financial crisis was coming, most economists, and in particular the adherents to the neo-classical school, by far the majority at the LSE, had failed to predict it; indeed many of them had denied that there was the risk of an occurrence of a severe financial crisis.

The Queen's question focuses on the issue of forecasts in the economy. In the first chapter we distinguished two types of predictions: those useful to falsify a scientific theory and those which, taking for granted the knowledge and the validity of the system's dynamic laws, through the combination of large amounts of observational data, numerical simulations and phenomenological models, aim to provide the predictive elements of open and complex systems that can be helpful to policy makers for different purposes, e.g., from the anticipating of natural disasters to civil protection. In the case of economics, as we shall see, forecasts should be characterized by having elements of both categories: on the one hand, in fact, we are dealing with a complex and open system so that the predictions are useful for obvious reasons of policy planning; on the other hand the forecast can be used to falsify the theoretical models from which they are derived.

Unlike the prediction of earthquakes, extreme weather events, or even ordinary weather, where one does know the deterministic evolution laws, economic laws are

⁴The Telegraph, The Queen asks why no one saw the credit crunch coming, November 2008.

neither known nor have the universal and immutable character of the laws of nature. Therefore, theoretical models must be based on some assumptions in order to describe the behavior of economic systems and their agents. From these models one can obtain a number of indications both of their future behaviors and on how to intervene, for example, to implement a certain economic policy: in both cases, the assumptions of the model play the key role. Therefore, the comparison of the models and of their basic assumptions against reality, which can be the macroeconomic performance of a country or product prices or the value of shares etc., should provide the ultimate feedback of the validity of the theoretical hypotheses used.

Moreover, while for natural phenomena it is not possible to change the laws regulating their dynamics, for economics these laws are the result of human decisions and therefore can be changed through public policy. For this reason, policy makers, as well as public opinion as a whole, should be very attentive to the issue of forecasts and to the ability of theoretical models to explain reality. Unlike the case, for example, of earthquakes, in economics there is much many data characterizing the system that can be considered and used. Hence the question is: is such data sufficient to understand the validity of the assumptions of theoretical models?

Which Crisis?

Several prominent economists have reacted in the opposite way to the debate that has emerged over the issue of lack of foresight of the crisis in 2008. For example, two well-known English economists, Tim Besley and Peter Hennessy, drafted a letter to the Queen summarizing the positions that emerged during a forum sponsored by the British Academy to answer the “Queen’s question”. They write⁵:

So in summary, Your Majesty, the failure to foresee the timing, extent and severity of the crisis and to head it off, while it had many causes, was principally a failure of the collective imagination of many bright people, both in this country and internationally, to understand the risks to the system as a whole.

Even Paul Krugman, winner of the Nobel Prize of Economy in 2008, acknowledged the failure of economists’ forecasts and emphasized a very interesting point⁶

Few economists saw our current crisis coming, but this predictive failure was the least of the field’s problems. More important was the profession’s blindness to the very possibility of catastrophic failures in a market economy [...].

⁵The Global Financial Crisis—Why Didn’t Anybody Notice? British Academy Forum. See the web page: <http://www.britac.ac.uk/events/archive/forum-economy.cfm>.

⁶Paul Krugman, How did economists get it so wrong? New York Times, 2 September, 2009.

Five years later and maintaining the same position, Krugman⁷ argued that the predictive inability corresponded to an intellectual defeat for neoclassical economists:

... Hardly anyone predicted the 2008 crisis, but that in itself is arguably excusable in a complicated world. More damning was the widespread conviction among economists that such a crisis couldn't happen. Underlying this complacency was the dominance of an idealized vision of capitalism, in which individuals are always rational and markets always function perfectly.

Many other economists have instead interpreted the 2008 crisis in a completely different way, and therefore they have very different opinions on the role of economic doctrines. For example, there is the case of Robert Lucas, a prominent member of the School of Chicago, known for being critical of Keynesian economics, author of the approach of "rational expectations", winner of the Nobel Prize in Economics in 1995, and, according to Wikipedia,⁸ "constantly indexed in the top ten in the ranking of economists Research Papers in Economics". To understand the origin of his judgment on the failure of the predictions during the Great Depression, it is possible to start from a passage in his presentation made at the conference of the American Economic Association in 2003⁹:

My thesis in this lecture is that macroeconomics in this original sense has succeeded: Its central problem of depression prevention has been solved, for all practical purposes, and has in fact been solved for many decades.

In the following years, facing the pressure of events that later led to the global crisis, Lucas continued to retain a certain confidence in the functioning of the economic system: on September 19, 2007, in a letter to the Wall Street Journal, he wrote¹⁰:

I am skeptical about the argument that the subprime mortgage problem will contaminate the whole mortgage market, that housing construction will come to a halt, and that the economy will slip into a recession. Every step in this chain is questionable and none has been quantified. If we have learned anything from the past 20 years it is that there is a lot of stability built into the real economy.¹¹

Prevention and stability are therefore related: because the economy is stable, then one can prevent crises. On August 6th, 2009, after the failure of Lehman

⁷Paul Krugman, How to get it wrong, New York Times, 14 September 2014.

⁸https://en.wikipedia.org/wiki/Robert_Lucas,_Jr.

⁹Lucas [3].

¹⁰Robert Lucas Jr., Mortgages and Monetary policy, Wall Street Journal, 19 September 2007.

¹¹Many neoclassical economists shared the Lucas' position. For instance, Italian economist Alberto Alesina in an interview to La Stampa on 20th August 2008 was of the opinion that "There will be no a crisis as 1929 [...]: what is happening is just a correction as there were many others, and Central Banks are reacting in an appropriate manner". Similarly Italian economist Francesco Giavazzi wrote August 4th, 2007 on the Corriere della Sera that "the crisis of the US mortgage market is serious, but it is difficult that it turns into a generalized financial crisis". Exactly the opposite of what happened.

Brothers, Lucas so expressed his position with respect to the debate on the predictive power of economics¹²:

One thing we are not going to have, now or ever, is a set of models that forecasts sudden falls in the value of financial assets, like the declines that followed the failure of Lehman Brothers in September. This is nothing new. It has been known for more than 40 years and is one of the main implications of Eugene Fama's "efficient-market hypothesis", which states that the price of a financial asset reflects all relevant, generally available information. If an economist had a formula that could reliably forecast crises a week in advance, say, then that formula would become part of generally available information and prices would fall a week earlier.

Therefore according to Lucas, in the context of the economic theory resting on the efficient markets hypothesis developed by Eugene Fama, which we will discuss below, the crisis was not predicted simply because these events cannot be predicted. How can this consideration be compatible with the statement made above, that the problem of depression prevention has been solved, as the economy has become stable, if a depression has occurred totally unexpectedly?

Lucas also refers to a "formula" which in reality cannot exist and that reveals a rather unrealistic perspective about mathematics. At most, there might be several "formulas" that, with some approximations, could provide some ranges of probability for a crisis: of course the problem would be to figure out which model works better. However, it is not at all clear in what sense the "markets" would react to the results of these "formulas".

Interestingly, Lucas focuses on the specific event, the failure of Lehman Brothers, and completely ignores the condition represented by the seismic risk to the system: the accidental nature of the single event is more important than systemic fragility—an opposite point of view to that, for example, of Krugman as quoted above. In addition, it is worth noticing that both Lucas and Krugman agree on the unpredictability of the Lehman Brothers failure. As for Lucas, there is nothing to add; according to Krugman the most important aspect on which to focus attention is the fragility of the system.

In any case, the position of Lucas about the role of forecasts in economics, seems quite different from that expressed some years ago, by Milton Friedman, one of the leading exponents of the Chicago School, awarded the Nobel Prize in Economics in 1976. According to Friedman, in fact, economics should have scientific standards similar to those of physics¹³

Truly important and significant hypotheses will be found to have "assumptions" that are wildly inaccurate descriptive representations of reality, and, in general, the more significant the theory, the more unrealistic the assumptions (in this sense). The reason is simple. A hypothesis is important if it "explains" much by little, that is, if it abstracts the common and crucial elements from the mass of complex and detailed circumstances surrounding the phenomena to be explained and permits valid predictions on the basis of them alone.

¹²Robert Lucas Jr., 'The 'unforeseeable shock' was the bankruptcy of Lehman Bros.', *The Economist*, 6 August 2009.

¹³Friedman [4].

Friedman, unlike Lucas and Fama, therefore, argued that forecasts were the main test of the theoretical hypotheses. Probably he was not aware of the efficient markets hypothesis, according to which forecasts are not possible by definition: paradoxically a confirmed prediction falsifies the efficient market theoretical hypothesis. Curiously this possible falsification of the theory has not been just considered in the literature about neoclassical economics.

We should note that correct predictions about the possibility of a financial collapse were actually formulated—see the discussion below. However they did not have the form of the type “a financial collapse will occur next week”, but rather: “if interventions along these lines will not be taken, a major financial collapse will happen most likely in the coming years”. These predictions were correct but generally ignored, as, for example, by the Queen of England when she posed the famous “Queen’s question” did not mention them. Perhaps this was another clear sign of the cultural hegemony of the neoclassical doctrine, and we will return to this point below.

As we discussed in the first chapter, when one formulates a scientific theory, it is necessary to assume some working hypotheses, to outline the problem, identify what are the relevant variables of the problem and which ones can be ignored. In its essence, it is precisely a scientist’s job and art, to understand which, of the many variables of a phenomenon, are the key ones and which approximations are the ones that better describe it. Faced with a tangled skein of facts to explain, physicist Richard Feynman argued that one should only choose one and try do his best to understand it in depth, with the hope that the theory that emerges is then powerful enough to explain many more observations. In any case, as we discussed in the first chapter, the possibility that a theory can be confirmed, that is the ability to acquire a certain degree of support by comparing its predictions with empirical observations, is a good criterion of demarcation between science and non-science.

However the efficient markets hypothesis seems to provide a new perspective: theoretical predictions affect reality and change it, with the result of invalidating the forecasts themselves, a situation that by definition implies markets’ unpredictability. An economist¹⁴ recently has even elevated this fact to a principle:

It is a fundamental principle that there can be no reliable ways to predict a crisis.

This singular fact is the reason why equilibrium and unpredictability should be the two sides of the same coin. Therefore, arise the relevant questions: Is the economic system in a stable equilibrium—as Lucas implicitly assumes? What are the signs that should prove it? Is the occurrence of a crisis in contradiction to stable equilibrium? And if it is, what are the consequences for theoretical models, and, above all, for the hypothesis and assumptions on which they are based?

¹⁴David K. Levine, Why Economists Are Right: Rational Expectations and the Uncertainty Principle in Economics, The Huffington Post, 26 January 2012.

There Will Be Growth in the Spring

Richard Portes, professor of economics at the London Business School in 1995, was the longest-serving general secretary of the Royal Economic Society from the time of John Maynard Keynes, and has been decorated as a Commander of the British Empire in 2003. In 2006, because of some turbulence in financial markets, doubts began to arise about the solvency of Icelandic banks as various rating agencies assigned them ratings lower than those in other Nordic countries. For this reason, a higher risk premium was placed on their debt. Richard Portes was then appointed to investigate the solidity of the Icelandic financial sector, which he did with Icelandic economist Fridrik March Baldursson. In their report entitled “*The internationalization of the Icelandic financial sector*”,¹⁵ published in November 2007, they wrote

Overall, the internationalization of the Icelandic financial sector is a success story that markets should better recognize.

Less than a year after the publication of the report by Portes and Baldursson, all major Icelandic banks collapsed; they were among the first victims of the Global Financial Crash initiated by the bankruptcy of the Lehman Brothers. Interestingly the Iceland report was commissioned, and paid for, by the Iceland Chamber of Commerce. The Chamber was concerned about the low-ratings and therefore needed an authoritative report that proved stability. In any case, Richard Portes also, as Robert Lucas, did not understand what the “seismic risk” to the system as a whole was, and of course he has not been able to predict what would happen in a short time.

Neither Lucas nor Portes are isolated cases, nor are the failed forecasts limited to the 2008 crisis. American economist Irving Fisher, president of the American Economic Association in 1918, the American Statistical Association in 1932, and founder in 1930 of the International Econometric Society, remains famous for having said, three days before the big crash of 1929, that

[...] Stock prices have reached what looks like a permanently high plateau.

Similarly, the Massachusetts Institute of Technology economist Rudiger Dornbush in 1998 predicted that the US economic expansion would have no end:

[...] The US economy will not see a recession in the coming years. We do not want, do not need it and we will not [...] we have the tools to keep the pace of the expansion.

Instead, the “dot-com” bubble exploded only two years later. Given this alarming and frequent inability not only to make successful predictions but also to simply interpret reality, two International Monetary Fund (IMF) economists, Hites

¹⁵Richard Portes, Fridrik Mar Baldursson, Frosti Olafsson, *The Internationalisation of Iceland's Financial Sector*, Iceland Chamber of Commerce, November 2007.

Ahir and Prakash Loungani¹⁶ have systematically investigated the quality of economic forecasts. To this end, they considered the predictions of 88 recessions, in about 50 countries, that took place between 2008 and 2012 (where by recession it is meant the decline of the Gross Domestic Product (GDP) on an annual basis in a particular country). Their conclusion is that, according to the consensus forecasts, an average for each country of the forecasts of a number of prominent economic analysts, none of the 62 recessions in the 2008–09 period had been predicted a year in advance.

However, once the magnitude of the Great Recession became apparent, the consensus forecasts predicted, by September 2009, that eight countries would have entered into recession in 2010, but this forecast was correct in only three cases. Even recessions during 2011–12 were again negative surprises for forecasters. Finally it was noted that reducing the advance timing of the forecast does not improve significantly its quality; also the use of a more precise definition of recession based on quarterly data does not change the results. The inability to predict recessions is therefore not only limited to the Great Recession and the following period, but it also applies to previous periods. In summary, the evidence accumulated over the past two decades, shows that, for the sub-group of economists and organizations considered:

The record of failure to predict recessions is virtually unblemished

as the Loungani himself¹⁷ had also concluded on the basis of the data of the 1990s. However, as discussed below, some economists, not considered in these studies, made correct predictions. Were they just lucky or were they using better theories?

The official sector forecasts, of both national and international institutions and agencies, are no better than those of the consensus forecasts. Let us recall, for example, what Ben Bernanke,¹⁸ at that time chairman of the Federal Reserve (FED), the central bank of the United States, said that in March 2007

At this juncture, however, the impact on the broader economy and financial markets of the problems in the subprime market seems likely to be contained. In particular, mortgages to prime borrowers and fixed-rate mortgages to all classes of borrowers continue to perform well, with low rates of delinquency. We will continue to monitor this situation closely.

Another FED chairman, Alan Greenspan, told his colleagues at the end of August 1990—a month from another recession—which

[...] those who argue that we are already in a recession I think are reasonably certain to be wrong.

¹⁶Hites Ahir and Prakash Loungani, *Fail Again? Fail Better? Forecasts by Economists during the Great Recession*, George Washington University Research Program in Forecasting Seminar, 2014. Hites Ahir and Prakash Loungani, *Predicting economic turning points*, *voxeu.org*, 14 April 2014.

¹⁷Loungani [5].

¹⁸See the web site: <http://www.federalreserve.gov/newsevents/testimony/bernanke20070328a.htm>.

During the Great Recession, the forecasts of Consensus Economics and of the official organizations were very similar: this conclusion applies to the forecasts of the Organization for Economic Cooperation and Development (OECD) and to those of the IMF. For the latter, a recent independent evaluation showed that¹⁹

The accuracy of the IMF in the short-term forecasts is comparable to that of private forecasts. Both tend to overestimate GDP growth significantly during regional and global recessions, as well as during the crisis in the individual countries.

Not being able to predict some recessions may be bad luck, but not being able to predict even one must raise a major problem. On the one hand, it could be concluded that those economic models on which forecasts are based are not able to predict correctly and therefore require a fundamental reassessment. On the other hand, according to the modern neoclassical view expounded by Lucas, the reason for the failure is inherent to the efficient markets model: if markets were efficient and it is known with certainty (as we noticed above, it is unclear what this means!) in advance what will happen in the near future, the market would change itself just to cancel the forecast. Finally, behavioral reasons of forecasters can be important: for example, if a forecaster fails like everyone else, the damage to his reputation would be less than if he was mistaken alone.

We discuss below these different possibilities. In any case, these priest-economists, with some exceptions that we will point out, seem therefore able to predict only the obvious. As the resounding character Chance-Peter Sellers in the unforgettable film *“Being There”* opined, it is possible to predict that “there will be growth in spring”, while the ability to predict a sudden hurricane seems to be rather limited. The problem becomes more pressing if one is convinced of it being in the middle of the summer and a snowstorm occurs. If it is, therefore, easy to predict that there will be growth in the spring, perhaps the lingering question is: when does spring arrive? The Mayan astronomer-priests knew the answer to this question: do the modern priest-economists have at least the same capacity?

The Disappearance of the Time

As highlighted by the passage of Robert Lucas reported earlier, neoclassical economics is based on the notion of stability, i.e., on the idea that markets will spontaneously balance because any change in prices would be quickly absorbed so that markets tend naturally towards an equilibrium state. Physics teaches us, however, that equilibrium can have various forms and that the achievement of a stable equilibrium configuration is not generally found in nature.

For instance, if a ball lies at the bottom of a valley, by applying a small perturbation through a small displacement, it will find in a short time, spontaneously—

¹⁹IMF forecasts: process, quality, and country perspectives, International Monetary Fund, Washington D.C., 2014.

without external intervention—an equilibrium position in the same valley's bottom. If we bring the ball to the top of a mountain, this may still be in an equilibrium state, but just a small perturbation may cause a significant change in its status. While the valley's bottom corresponds to stable equilibrium state, the mountain's top is an unstable equilibrium configuration, since in this case a small perturbation may cause a great effect.

A gas in a well-insulated container represents an example of a physical system composed by many particles (e.g., a macroscopic system) in stable equilibrium. In this case, the opposing forces are the pressure exerted by the gas molecules on the container walls and by the mechanical resistance of the latter. If the gas is heated up in a part of the container, the momentary temperature difference created can be quickly redistributed: the gas molecules collide with each other, exchanging energy until the gas finds a new stable equilibrium at a temperature slightly higher than the initial one. The overall equilibrium will not be altered as long as the pressure of the molecules on the walls does not exceed its mechanical strength. If the gas were to be heated more and more, at the end, the pressure exerted on the container walls would become too large with the consequent breaking of the equilibrium configuration (and of the walls!).

The physical characterization of a system close to a stable equilibrium condition has been studied for over a hundred years through the techniques of thermodynamics²⁰ and then with those of equilibrium statistical mechanics.²¹ The example of the gas in equilibrium is paradigmatic. This is an important research field because it provides insight into many behaviors and properties of the matter around us, in its different phases (gas, liquid, solid), and on its chemical and physical modifications. However, a physical system is not always close to a stable equilibrium state even if it seems to have temporarily reached a state that almost does not change with time—an almost stationary state that seems to be as quiet as a stable equilibrium, but that instead may change in a sudden and abrupt manner. In fact, as we shall see in the following, many physical systems, such as compounds of many constituents in interaction between each other, are often characterized by being inherently unstable. Consequently, the concept of stable equilibrium is therefore not relevant for the understanding of their dynamics.

Many economists have interpreted the 2008 crisis as due to entirely unpredictable causes, as was the failure of Lehman Brothers. However, since neoclassical economists assume that free markets tend to stability, so that any perturbation through them would be neutralized by the dynamics that can bring them back to the equilibrium state, just as a small local injection of heat in an isolated container is quickly redistributed in the gas, they concluded that there would be no repercussions on the real economy.

The existence of an equilibrium state allows us to use a kind of magic trick with respect to the theoretical treatment wherein the time variable is eliminated from the

²⁰Fermi [6].

²¹Amit and Verbin [7].

description of a macroscopic system. This is possible, as we mentioned in the first chapter, thanks to the passage from a deterministic microscopic description, in which one focuses on the knowledge of each single particle trajectory, to a probabilistic description of an ensemble composed of a large number of particles (such as a gas). This approach considers the global properties of the ensemble without characterizing the motion of each particle. Despite that every particle follows a trajectory deterministically determined by the forces that are exerted on it from all other particles, in order to calculate the behavior of a huge number of particles, one must abandon the single-particle description and switch to that of an ensemble of particles.

A global property of a gas, such as its pressure or its temperature, is, in fact, an average on the physical status of all its particles; to calculate it, one should know the initial conditions and the temporal evolution of all these particles, whose number for typical real physical systems is greater than the sum of all the grains of sands of all beaches around the entire world! This is not possible in practice, and therefore the idea, firstly suggested by Ludwig Boltzmann in the second half of the 19th century, was to replace the time average with another type of average, that of all the dynamic states of the microscopic system compatible with its macroscopic equilibrium configuration. For instance, the system's state does not change by interchanging the position of only two particles: it is possible, but in general not easy, to count all the microscopic states sharing the same macroscopic properties.

The fact that this substitution is valid is a working hypothesis, the famous ergodic hypothesis, and at all evident to determine in which circumstances this can be successfully applied. Even today, there are studies in the field of statistical mechanics to understand whether this hypothesis actually applies in a given physical system. According to the ergodic hypothesis, the future evolution of a certain system can be calculated from the knowledge of the probability distribution compatible with the system state, which is immutable in time just by virtue of the fact that the system is in thermodynamic equilibrium. An important consequence of this assumption is, therefore, that one can calculate the probability of future events from past data. In neoclassical theory, thanks to the assumption that the system is close to stable equilibrium, one can make use of such an approximation. For this reason the ergodic hypothesis has thus become an essential foundation for all models of risk management developed by the Wall Street "quants".²² Obviously the problem is to verify that this hypothesis is verified in the financial market data. Can we really assume that the time dependence of the probability distribution is constant? In fact, the ergodic hypothesis, although rarely discussed in all its profound implications, is the basis used throughout the discussion of equilibrium economics.²³

²²A quantitative analyst or, in the financial jargon, a quant, is a person who is specialized in the application of mathematical and statistical methods to financial issues and risk management.

²³Paul Davidson, *Is economics a science? Should economics be rigorous? Real-world economics review*, issue no. 59, March 2012.

In practice, a system in equilibrium can be found in different possible states, each characterized by a very precise probability that can be calculated once assigned global conditions, such as whether the system is isolated, if it is in contact with a heat source etc. In these conditions, the problem becomes analogous to that of a die for which there are six possible states each having probability $1/6$ independently of time. The difference is that the states accessible to a macroscopic system are very many, the calculation of their different probabilities rather complicated, and the equilibrium state corresponds to the one with the highest probability.

The statistical mechanical treatment of equilibrium is based on the ergodic hypothesis that, therefore, is the backbone to determine the macroscopic properties from microscopic dynamics. As we first mentioned in the opening chapter, the relationship that provides the bridge between thermodynamics and the microscopic world is the Boltzmann equation of entropy, one of the greatest achievements of all times. Is it really possible applying such a hypothesis to describe a real economic system?

The Three Pillars of Equilibrium

We can now outline the theoretical model of “general equilibrium”. This is built on the work of an engineer, Léon Walras, and of a physicist, Jean Baptist Louis Bachelier, who, in the late 19th and early 20th century, built the three conceptual pillars of modern neoclassical economics. Both were influenced by the great scientific ideas of their time, which we have already briefly discussed.

The first pillar is provided by Newtonian mechanics that could explain, with unmatched precision at the time, planetary trajectories in the sky. The discovery of Neptune was, in fact, such a spectacular success for Newton’s theory that the rest of science, if it wanted to be of equal dignity, should have been inspired by the perfection of planetary motions and of Newton’s celestial clock. In addition, the Newton’s laws of motion were constantly used for practical and technological purposes in chemistry as in engineering, and therefore have been the foundation for the advancement of science and technology that took place from the eighteenth century to the present.

The second pillar in the foundations of neoclassical economic theory is the description of a macroscopic system in thermodynamic equilibrium. This description, which assumes stable equilibrium between opposing forces, was drafted in the second half of the 19th century hand in hand with the formative development of thermodynamics, which was interwoven with the progress of the steam engine that, in turn, gave the main impetus to the industrial revolution. It is important to emphasize the fact that thermodynamics does not purport to describe how and why a system, initially out of equilibrium, reaches equilibrium. From a phenomenological point of view, it is known that systems that convert heat into work (thermal machines such as a refrigerator, a steam locomotive, etc.), can be viewed as operating in a situation close to equilibrium, and this justifies the thermodynamic

treatment that is able to describe in a quantitative and very accurate way processes involving the transformation of mass and energy. The principles of thermodynamics are, in fact, taken as assumptions based on experience and are used without considering the merits of the mechanism that gives rise to a particular phenomenon. Other and, as discussed below, much more complicated problems, concern the understanding of whether a particular system with a given dynamic and prepared in a certain initial state reaches or not a state of thermodynamic equilibrium.

The third pillar is linked to the discovery of the existence of atoms, which occurred with the theoretical explanation of the erratic motion of a pollen particle dipped in a liquid by the work of Albert Einstein, the Brownian motion that we discussed in the first chapter. In particular, the keystone was the abandonment of Laplace's deterministic view and the introduction of probability calculus to explain physical phenomena. This was a turning point so important for physics as for the rest of the sciences, including economics, because it allows one to go from a dynamic description of a myriad of particles to a probabilistic description of a macroscopic system. The description of fluctuations in the prices of products, companies, etc., as we shall see below, is modeled precisely on the same ideas of the Brownian motion, which is still the paradigm universally used to calculate them.

To simplify: Newtonian mechanics teaches us how to find an equilibrium configuration when there are two opposing forces acting on a system. What else is an economic system if not the result of the action of many agents that can be described by the equilibrium between supply and demand? If the system is at equilibrium, it is not necessary to understand the temporal dynamics that led to this situation, so the time-dependent dynamical description comes out of the theory. On the other hand, in this situation, the probabilistic description that follows from the Brownian motion of the particle in a liquid in thermodynamic equilibrium is suitable to describe the fluctuations—in this case the variations in the prices of products; in other words, how the relevant quantities of the economic system move under the action of the myriad of agents and the causes that determine the trend. In the description of a macroscopic system in equilibrium, the temporal dynamics may be replaced by a static probabilistic analysis thanks to the ergodic hypothesis. When a macroscopic system is at thermodynamic equilibrium, such as a gas in an isolated container, fluctuations must necessarily be small, because large fluctuations would break the equilibrium situation. So this is definitely a precise forecast of type I to be verified in the real data of financial markets. In fact, because of the simultaneous actions of a myriad of individuals that correspond to the effect of equal but of opposing forces, the economic system is hypothesized to tend to a stable equilibrium state. For this reason, large variations are not, therefore, either possible or conceivable by that type of theoretical approach.

This is, in a nutshell, the reassuring vision of neoclassical economics theory that was established in the early 20th century. The problem that we will discuss below is just that, despite the technical and conceptual developments that have occurred since then, the foundations of neoclassical economics, modeled on the concepts of the 19th-century physics, evolved except for a more-or-less baroque refinement of

those concepts. In the light of the knowledge developed during the century, it is therefore natural and necessary to critically discuss precisely these conceptual foundations.

The Myth of Equilibrium

Léon Walras in 1874, the son of a French economist, who had studied engineering, illustrated how the notion of mechanical equilibrium could be the pivot for the construction of a theoretical economic theory inspired by the celestial clock governed by Newtonian theory, which, at the time, was the most admired and accurate scientific theory ever developed. In particular, Walras' purpose was to provide a quantitative mathematical expression for the idea of equilibrium between supply and demand, just as two forces balance themselves to maintain, for example, a planet in a stationary orbit around the Sun: stability is the resultant of equal but opposing forces. So in economy, when this equilibrium is achieved, manufacturers do not produce too much, creating surpluses, nor too little, leaving dissatisfied buyers, while, at the equilibrium point, the supply is equal to demand and the economic forces are balanced. Walras himself wrote in a letter to a friend²⁴:

All these results are marvels of the simple application of the language of mathematics to the quantitative notion of need or utility [...] you can be sure that the economic laws that result from it are rational, just as precise and just as incontrovertible as were the laws of astronomy at the end of 17th century.

The general equilibrium approach introduced by Walras has become the core of the neoclassical paradigm. This explains why the neoclassicists have had to introduce a large amount of math in their models: mathematically the equilibrium corresponds to finding the maximum point of an appropriate function.²⁵ In practice, it is not possible to consider the maximization of quantities with certain constraints without the use of relatively advanced computational techniques, at least in Walras times. In fact, Walras himself tried to represent this economic model as a system of simultaneous equations, but he was unable to prove that these equations have a solution. The search for a solution has remained a problem bequeathed to his successors.

From the work of Walras, neoclassical economists conceptualize agents, which can be households, businesses, etc., as rational entities who seek the “best” results, i.e., the highest possible earnings, a situation that, from a mathematical point of view is equivalent to finding the maximum of a suitable utility function. To study further the problem, years later, economists Kenneth Arrow and Gerard Debreu²⁶

²⁴Letter from Walras to Lurent; see Buchanan [1].

²⁵The point of relative maximum is where a curve stops growing and starts to decrease. Mathematically it is a point where the first derivative vanishes.

²⁶Arrow and Debreu [8].

introduced a series of quite unrealistic theoretical assumptions, such as the perpetual possibility of exchange of goods between people in different economies and in different centuries, the absence of barriers of any type for any conceivable trade, etc. In this way they were able to prove not only the existence of equilibrium in the market, but also showed that the perfect “competitive equilibrium” of supply and demand for all goods to be “efficient”. This means that all resources realize their most productive use in meeting consumer demand. This equilibrium configuration would correspond to what economists call “Pareto optimal”²⁷: no other conceivable arrangement of products price or quantity, even managed by an infinitely intelligent central planner, would lead to a better outcome without losses for at least one manufacturer or company.

Although the model of Arrow and Debreu was elaborated half a century ago, it is still considered the obligatory reference for the problem of the existence of a competitive equilibrium. Indeed, the evidence of a competitive equilibrium should provide an understanding of the way market economy works, in which everyone acts independently of any other one. In other words, this should be the mathematical proof of what Adam Smith, in his *“The Wealth of Nations”* (1776), conjectured: in a decentralized economy and in conditions of competition, the market plays the efficient role of coordination of individual decisions (the famous myth of the invisible hand of the market). However, it must still be established that a competitive equilibrium exists, that is unique and that is also stable. Indeed, Arrow and Debreu did not show that their equilibrium was stable and wrote

Neither the uniqueness nor the stability of the competitive solution is investigated in this paper. The latter study would require specification of the dynamics of a competitive market as well as the definition of equilibrium.

At about the same time as Arrow and Debreu published their paper, American mathematician John Nash, Nobel Prize in Economics winner in 1994, while he still was a student, proved an important theorem in game theory. In particular, Nash mathematically demonstrated that the so-called Nash equilibrium occurs when each member of a group of agents, each of them taking the most rational strategy possible, aims to maximize his profit, in light of the opponent agents choices. If any player chooses the optimal strategy to him and he is aware that the other players do the same, then the Nash equilibrium is formed. In this situation, no player can improve its position by unilaterally changing its behavior, while others continue to persevere in their behavior. Even in this case, game theory problem does not capture (but certainly that was not Nash’s objective!) the complexity of real world behaviors, and therefore it is not at all granted that this may be relevant in real cases: Do a large enough group of men, or of economic agents, behave in such a way that each of

²⁷ According to the Italian economist Pareto Vittorio, one can show that, when initial resources are given, a perfectly competitive market ensures optimal allocations. We have a Pareto optimum when it is not possible to reorganize production in a way that that improves the condition of at least one person without diminishing those of others.

them adopts the more rational approach as the players hypothesized by Nash? How should the dynamics driving a system to such an equilibrium state be?

Efficiency and Unpredictability

In the neoclassical theoretical framework, as we have seen, one of the ideas to explain the lack of success of forecasts is that markets should regulate themselves to make invalid any prediction about future price changes: if investors act rationally using all available information, then their actions would change the dynamics of the market defeating any prediction. In 1965, American economist Paul Samuelson of the Massachusetts Institute of Technology, Nobel Prize in Economics winner in 1970, put in mathematical form this thesis in his essay titled “*Proof that properly anticipated prices fluctuate randomly*”²⁸: if people always act in a rational manner, that is maximizing a certain utility function, the market movement would be unpredictable.

This idea was further developed, during the 1960s, in the so-called “information efficiency” by American economist Eugene Fama of the University of Chicago and Nobel Prize in Economics winner in 2013, in his famous article entitled “*The Behavior of Stock Market*”.²⁹ According to Fama, the market is efficient in terms of its use of information: the more the latter flow quickly and efficiently, the more efficient is the market and the most random is the sequence of price changes generated by this market. Markets are therefore unpredictable because of their efficiency.

Robert Lucas, later formulated the synthesis between Fama “information efficiency” and Arrow and Debreu competitive equilibrium³⁰: individuals use all the information efficiently, that is, in the best way possible to make forecasts and policy choices. While individuals may make mistakes, it is assumed that the community as a whole cannot make wrong predictions and have corrected expectations so as to make the economic system efficient. Efficiency automatically implies Pareto optimal effects, that is, the most efficient and convenient price arrangement. From these results it follows, as we will discuss below, the Bachelier description of stock prices changes: small variations around a mean value, with almost no possibility of big jumps.

This theoretical framework becomes the paradigm generally used to make important policy choices. For example, the so-called dynamic stochastic general equilibrium (DSGE) model, used by the European Central Bank to predict the economy, contains equations that completely match the micro-foundations of

²⁸Samuelson [9].

²⁹Fama [10].

³⁰Lucas and Sergent [11].

rational expectations assumed by Lucas theory. In particular, the model mathematically describes what is believed to be the typical behavior of the “family man” who works, earns and spends and of companies that sell, hire and invest. The resulting behaviors are calculated by complex optimizations of future profits, but each agent behaves as an optimizer independently of all the others. Therefore, it is assumed that on average, people and companies have rational expectations and that it is not possible to have interactions that influence their behaviors, such as mechanisms of imitation, the engine, as we shall see, of large fluctuations in the financial markets. It is therefore not surprising that DSGE models have failed to predict the financial crisis: large fluctuations caused by coherent behaviors of large sets of agents are neither admitted nor conceived in these models.³¹

According to this theoretical framework, markets would optimally function if any kind of deal were possible and if there were no impediments to operate any type of trade or bet at any time. This perspective provides the justification for the massive financial deregulation in the eighties and nineties and the corresponding rapid growth of the financial derivative products. On the one hand, one gets closer to the efficient market ideal only by removing any legal barrier that prevents any person from undertaking trade freely. On the other hand, the growth of financial instruments is functional to implement any kind of exchange, and it can thus making the market more efficient and stable and, therefore, according to this model, reduce the risk of recessions.

This theoretical construction has certainly fascinated many people: for example, the University of Chicago economist Luigi Zingales writes in his “*A Capitalism for the People*”³²:

The history of physics in the first half of the twentieth century was an extraordinary intellectual adventure: from the intuition of Einstein in 1905 on the equivalence of mass and energy to the first controlled nuclear reaction of 1942. The development of finance in the second half of the twentieth century shares similar characteristics.

We have already mentioned that physics has had a spectacular series of experimental tests that have made possible an amazing, and sometimes unfortunate, series of applications of these findings. In the next chapters, we will discuss other discoveries in modern physics that have had an important impact in our everyday life. However, one cannot say the same about finance, and more in general neo-classical economic theory, where, as we discussed above and will see in more detail in the next section, it is not at all clear which are the successful predictions and which the discoveries found in the empirical data. In fact, it seems clear to an outside observer that markets are not efficient, men tend to be overly focused on the short term and blind in the long term and, ultimately, they are subject to collective irrationality, panic and instability. The 2008 crisis dramatically showed the fragility

³¹Volker Wieland, Maik Wolters, Macroeconomic model comparisons and forecast competitions, voxeu.org, 13 February 2012.

³²Zingales [12].

of this theoretical construct, based on concepts developed on the 19th century physics. Indeed, the equilibrium models do not contemplate even simple cooperative behaviors as those that can be triggered as a result of a simple dynamic interaction between agents. Physicists Jean-Philippe Bouchaud notes,³³ with specific reference to the financial crisis of 2008, then becoming a worldwide economic crisis, that the models used to determine prices, and thus the risk of financial products related to subprime mortgages, were basically wrong because they underestimated the probability of the occurrence of a coherent large-scale event, originated by the fact that most borrowers, instead of acting independently of each other, had developed a relationship based on potential defaults on their loans at the same time. These models have thus overlooked the very possibility of a global crisis, even if they have contributed to triggering one.

From a theoretical point of view, it would not be worth mentioning Arrow-Debreu general equilibrium, along with generalizations of rational expectations derived from Lucas and others, if there was no reason to consider it stable, so that an economy is able to reach by itself this special state and then to remain close to it. However, despite the effort to simplify the problem by using a number of unrealistic assumptions in the model, there is no proof of the stability of the Arrow-Debreu equilibrium, and therefore there is no reason to believe that there is stability in the real economy thanks to markets efficiency. The next questions that arise are: Can neoclassical models be falsified in any way? Can it be taken for grant that the assumptions of the neoclassical model have been falsified by the data?

Mathematics as Ornament

One of the founders of neoclassical economics, William Stanley Jevons, thought that economics should be a mathematical science, and this is why, even today, most neoclassical economists use a large amount of mathematics in their work. The father of rational expectations theory, Robert Lucas, claimed, in a lecture³⁴ at Trinity University in 2001, that: “Economic theory is mathematical analysis. Everything else is just talk and pictures”. Motivated, among other things, by these positions, British philosopher of science Donald Gillies wrote an interesting article on the comparison of the use of mathematics in physics and in neoclassical economics.³⁵

Gillies first recalled that physicists have learned to critically consider each theory within the precise limits that are dictated by the assumptions used and by the experiments available. From the times of Galileo and Newton, physicists have, therefore, learned not to confuse what is happening in the model with what instead

³³Jean-Philippe Bouchaud, *ibidem*, 2008.

³⁴<http://www.wiu.edu/cbt/eds/quotes.php>.

³⁵Gillies [13].

is happening in reality. Physical models are compared with observations to prove if they are able to provide precise explanations: an example of this type is represented by the procession of the perihelion of Mercury, which we discussed in the previous chapter. Otherwise, theoretical models can provide successful predictions. For example in 1887, Hertz generated the electromagnetic waves postulated by Maxwell in 1873. The question is therefore: can one argue that the use of mathematics in neoclassical economics serves similar purposes? Otherwise, this usage is reduced to a mere rhetorical exercise, which employs the flaunted use of a relatively refined tool to precisely calculate irrelevant quantities. Gillies's conclusion is that, while in physics mathematics was used to obtain precise explanations and successful predictions, one cannot draw the same conclusion about the use of mathematics in neoclassical economics in the last half century. This analysis reinforces the conclusion about the pseudo-scientific nature of neoclassical economics we reached previously given the systematic failure of the predictions of neoclassical economists.

To show this, Gillies has examined the best-known works by a selection of the most famous neoclassical economists (Paul A. Samuelson, Kenneth J. Arrow, Gerard Debreu and Edward C. Prescott) in the period from 1945 to the present. The most famous work of Samuelson is one of the classics of mathematical economics, "*Foundations of Economic Analysis*".³⁶ Gillies notes that Samuelson, in his book of over 400 pages full of mathematical formulas, does not derive a single result that can be compared with the observed data. There is even no mention of any empirical data in the book Samuelson!

As for the seminal work of Kenneth Arrow and Gerard Debreu,³⁷ published in 1954 and previously discussed, Gillies highlights that the general equilibrium models considered by the authors are based on such simplistic assumptions of reality that they cannot be compared with the observed data. In fact, as Samuelson, they do not derive any result that can be compared with the empirical data, which are indeed absent in their work.

Finally, Gillies takes into account the article by Edward C. Prescott called "*The Equity Premium. A Puzzle*",³⁸ written in collaboration with Rajnish Mehra. In this article, the authors try to compare the general equilibrium model of Arrow-Debreu with theoretical data obtained from a real economy, namely the US economy in the period 1889–1978. In this case, there is no agreement between the theoretical results and empirical data. In conclusion, neoclassical economics, unlike physics, has not achieved either precise explanations or successful predictions through the use of mathematics. Thus, this is the main difference between neoclassical economics and physics.

³⁶Samuelson, Paul A., 1947, Enlarged ed., 1983. *Foundations of Economic Analysis*, Harvard University Press.

³⁷Arrow [8].

³⁸Rajnish and Prescott [14].

One Hundred Years of Solitude

Abandon the classical description of commodity prices and stock-price fluctuations (that we will later see is based on Gauss statistics) to accept that extreme variations have not a negligible probability. Move from a static description to a dynamic and evolutionary one, where the core is the possibility of changes in historical time (and not in the mathematical one) of economies and of market properties. Consider the enormous amount of data generated every day by different economical observables as for instance financial markets ones as an ideal laboratory to compare the different theoretical concepts with the observations, such as: is the price really such that supply meets demand? Or is it true that prices move mainly due to new information? The answers to both questions seem to be clearly no.³⁹ In any case, these should be the first steps to begin the long and arduous journey that, taking as a basis a continuous nagging comparison between theoretical hypotheses and empirical data, proposes to build a model that can explain observations and then describe reality. Yet this is not what happens in neoclassical economic theory because of the unquestionable dogma of market stability, agents' rationality and the subsequent description of prices fluctuations on the model of Brownian motion.

In neoclassical economics, we thus find a paradoxical situation: on the one hand, the idea was affirmed, supported by mathematical theorems, that markets are machines with wonderful properties of self-regulation and stabilization of the economy; on the other hand, the neoclassical theory is not benefiting from the most important scientific ideas of the last fifty years. Actually what happened is the change of economics into an axiomatic discipline, where the assumptions and hypotheses have become indisputable dogmas, which no longer require any empirical verification: the rationality of economic agents, the invisible hand and the financial markets efficiency. These concepts have become strong enough to replace the empirical reality: an inconceivable fact for a natural scientist.

If one of the biggest problems confronting the academic teaching economics, as we shall see in more detail below, is seemingly overlooking the economic theories different from the "mainstream" one, on the other hand, a deeper knowledge of the methods and concepts of the natural sciences developed in the last century could be useful to frame the economic problem in a less ideological way. For example, one of the greatest innovations to have occurred in theoretical physics about half a century ago, which has laid the foundation of the interdisciplinary field of complex systems and further expanded the conceptual revolution started from the study of chaotic phenomena, pioneered by meteorologist Edward Lorenz, does not seem to have been assimilated into the field of neo-classical economics.

Phil Anderson, Nobel Prize for Physics in 1977, summed up this revolution in his 1972 paper titled "*More is different*".⁴⁰ The basic idea is the following: in

³⁹Bouchaud and Potters [15].

⁴⁰Anderson [16].

physics the traditional approach considers the simplest systems and studies them in detail. This approach, known as reductionism, focuses on the “building blocks” that make up matter and is successfully applied to many phenomena. From this approach, one can derive the general laws that extend from the scale of the atomic nucleus to that of galaxies. It is easy, however, to realize that, as soon as the degree of complexity of the structures and systems is increased, and when these are composed of many elements *in interaction with each other*, there is a new situation, in which the knowledge of the properties of the individual elements (for example, particles, atoms, planets, etc.) is no longer sufficient to describe the overall system as a whole. The point is that, when these elements interact with each other, they form complex structures and develop collective motions that have a little to do with the properties of individual isolated elements. The individual components have a relatively simple behavior, but their interactions lead to new emerging phenomena. For this reason, the behavior of the whole is fundamentally different from that of any of its sub-elementary parts. We can represent this as the study of the “architecture” of matter and of nature, that in some ways depends on the properties of the “building blocks”, but that then shows characteristics and laws that are unrelated to those of the individual elements.

According to Phil Anderson, reality thus has a hierarchical structure and, at every level of the hierarchy, it is necessary to introduce concepts and ideas different from those used in the previous level. In simple words, the knowledge of the fundamental laws that govern the interaction between elementary particles is simply not enough to understand the formation of many of the phases of condensed matter and, *a fortiori*, of increasingly complex systems to arrive at biological systems and social aggregates. This situation leads to an interesting epistemological consideration: while reductionist physics is usually deductive, understanding a phenomenon of collective organization hardly occurs through deduction. The logical deductive process thus shows its fundamental limit when applied to complex phenomena.⁴¹

Out of Equilibrium

Since more than thirty years, it is known that, for many complex systems, even if an equilibrium state exists in principle, this may be totally irrelevant in practice, because the time it takes to reach it is too long. In addition, there are systems that are intrinsically fragile with respect to the action of small perturbations, thus evolving intermittently with a succession of stable periods interspersed by rapid and unpredictable changes. In other words, for many physical systems equilibrium is not a naturally reached configuration: different systems instead attain a situation of meta-stability and not a true equilibrium such as that of a gas in an isolated room or a ball in the bottom of a valley, but rather a temporary stationary but potentially

⁴¹Laughlin [17].

unstable configuration, so that a small perturbation is sufficient to cause great effects.⁴² For example, we discussed in the first chapter chaotic systems showing behaviors that become very different as a result of very small disturbances—the famous “butterfly effect”. To understand the unstable nature of complex systems, various conceptual models were introduced with the aim of capturing the essential aspects of the dynamics of intermittent phenomena. These are clearly idealized models developed to capture the main qualitative feature of relatively simple physical systems. Nevertheless, they can give some useful idea to understand the complexity of an economic system.

The most famous is the sand-pile model formulated by Danish physicist Per Bak⁴³ in the 1990s, and that can be considered as a metaphor of phenomena such as earthquakes, avalanches, and many others. Quite simply, the model consists in adding, slowly enough, sand grains on an already formed sand pile. The exact place in which individual grains are placed affect the way in which the height of the pile can successively grow: in this way the growth of the pile depends on its past history and for this reason the system acquires a memory. Occasionally the addition of a new grain triggers an avalanche that does not have a given size, but may be limited to a few grains or may involve all the grains of the pile. So the addition of a single grain can have dramatic effects despite that the pile seems to have reached a quasi-equilibrium configuration and despite the fact that the influence of a single grain is localized in space and limited to its immediate neighbors.

Here we find again power-law behaviors: indeed, for the sand-pile model, the size of avalanches follows a power-law behavior of the same type as the Gutenberg and Richter law for the intensity of earthquakes, for the law Omori of aftershocks and, as we shall see better in what follows, for price fluctuations in the financial markets. This fact means that extreme variations, as in very large avalanches, are not very rare events.

The metaphor of the pile of sand captures the properties of a class of systems that exhibit the so-called self-organized critical behavior: these systems are naturally attracted by their own dynamics, which consists of a feeding and dissipation process of material and/or energy, to an almost steady state—almost independent of time, and in this sense in quasi-equilibrium—but with so-called “critical” properties. In general, the process of dissipation is manifested through events like avalanches (of matter and/or energy) that occur on very fast time scales with respect to the time scale of the process of accumulation of matter or energy in the system (such as the addition of a grain to the pile in the previous example). The critical behavior of a quasi-stationary state is manifested in its extreme instability that gives rise to fluctuations (such as avalanches) of arbitrary magnitude.

Financial markets seem to function in a similar manner as disordered systems, in which the equilibrium is very fragile and is, in fact, never reached. Their evolution

⁴²Jean-Philippe Bouchaud, *The (unfortunate) complexity of the economy*, *Physics World*, pp. 28–32, April 2009.

⁴³Bak [18].

is indeed characterized by a series of quasi-equilibrium states that are very unstable with respect to the effect of small perturbations. The evolution shows, in this way, a succession of rather stable epochs marked by rapid, unpredictable and large variations. During periods of relative stability, as in the case of earthquakes, the potential energy is accumulated, and it will subsequently be released at the time of the shock.

This type of behavior has been observed in many systems out of equilibrium both in physics, and in a wide range of disciplines such as geophysics (in fact, earthquakes), biology, ecology, neuroscience, and even the social sciences such as sociology. In economics, this kind of conceptual model can be useful to understand the limits of neoclassical theory based on the concept of equilibrium that seems to be missing a description, even a very simple one, of the structure of the interaction between agents.

The Flight of Bird Flocks and the Market's Panic

Different physical materials have been studied showing a global collective behavior that emerges from simple localized interaction rules, without the need for any centralized coordination. The best-known example is provided by a magnetic material, which can be schematized as a set of small magnetic needles (spins). If the temperature is low enough, so that the thermal motion is reduced, each marking needle shows a tendency to align in the same direction of its neighbors. In this way, a spontaneous overall magnetization can rise, when all the needles are aligned, even in the absence of an external magnetic field. When a sufficiently large set of needles is oriented in the same direction due to a spontaneous and random fluctuation, they can induce the rest of the needles of the material to orientate consistently, thus giving rise to a total magnetization different from zero. This is one of the most known and studied models to pass from disorder (needles each oriented differently from each other) to order (needles all pointing in the same direction), as a result of simple local interactions—the magnetic attraction in this case.⁴⁴

Such a collective phenomenon can also be found in social and animal collective behaviors and it can be understood by extending the concept of local interaction (between the magnetic needles) to individuals. For example, birds in a starling flock show complicated in-flight changes made with a surprising coordination so that the flock seems something fundamentally different than the simple sum of its parts, as the birds become a kind of holistic phenomenon.⁴⁵ As for the magnetic needles, the collective behavior is the result of simple rules: in this case the tendency of birds is

⁴⁴Amit and Verbin [7].

⁴⁵William Bialek, Andrea Cavagna, Irene Giardina, Thierry Mora, Edmondo Silvestri, Massimiliano Viale, and Aleksandra M. Walczak, Statistical mechanics for natural flocks of birds, *Proceedings of the National Academy of Science*, vol. 109 no. 13, 4786-4791.

to align their speed to that of their nearest neighbors. This phenomenon can be mathematically described by very similar equations to those used in magnetic systems, which serve to study the alignment of the needles. The difference is that, instead of magnetic forces, there are the “forces” shaped by natural evolution that have been optimized to ensure the best chance of survival and thus a greater adaptability to the environment. So each bird interacts only with those individuals close to it in space, without having any knowledge of the overall group structure and therefore without any centralized control, as it could arise when the flock is led by a leader. All decisions of the group are collectively determined through a mechanism of amplification of a local fluctuation: if a sufficiently large number of birds suddenly change direction, this fluctuation spreads within the flock, resulting in an overall change of direction.

In nature one can easily find other examples of animals showing self-organized behaviors with global coordination generated by a local dynamic between first neighbors.⁴⁶ For example, fish such as sardines, herrings and cods forming huge shoals are all gregarious species that can give rise to cohesive groups with very highly coordinated movement. Cases of collective behavior occur even among some species of land animals like zebras and buffalos as well as among the swarms of insects, such as flies, locusts, bees, and ants.

Dispersion of thousands of people from a rock concert or from a major demonstration, pedestrian and automobile traffic, the applause at the end of a concert, the Mexican hola of sport fans and panic propagation in crowds are examples of similar collective phenomena involving people. As in the case of groups of animals, each individual acts on the basis of a purely local and limited information in space, without having any notion of group behavior.

Collective social phenomena, in which the tendency to imitation of other individuals is very strong, can also happen in financial markets, such as the formation of trends, flows of opinion and, more generally, of the so-called herd effects in social behavior. In this case, quite simple rules of interaction give rise to the collective behavior as a whole. In particular, imitative mechanisms in financial market can be the origins of speculative bubbles, during which financial operators buy (sell) only on the basis of what most of the others do, thus pushing the price higher and higher (or lower and lower). However, these behaviors are in no way described or considered by the theory in which hypothetical rational agents, based on full information, optimize their gain, while this type of collective behavior may underlie the extemporaneous formation of large fluctuations in the markets, whose latest causes, however, have a political nature as we will argue below.

A whole society can develop global behaviors through interaction between its elementary components. This is the field of study of the macro-economy, and the discussion above, although simplified, makes clear the difficulty of the transition from the micro-foundations description to a macro-economic one.

⁴⁶Camazine et al. [19].

The Wild World of the Financial Markets

If what Robert Lucas says is true, that price fluctuations cannot be predicted by the efficient markets hypothesis, then this same theoretical model provides accurate forecasts based on the assumption that the economic system is close to a stable equilibrium so that any perturbation would be quickly absorbed. Correspondingly, fluctuations of the prices of stocks and goods should therefore be random, independent and with small amplitude. However, this prediction seems to be blatantly contradicted by observations. Large, sudden, unexpected and unexplained changes occurred very often in financial markets in recent years: the so-called flash crash, when the stock market lost significant percentages within a few minutes, to specific events such as the recent financial crisis, the Internet bubble at the end of the nineties, the Black Monday of 1987, when markets around the world suffered a sudden collapse in a very short time and the Dow Jones record loss of 22 % in one day. In order to clarify what can we learn from these fluctuations, we discuss in more detail an aspect related to the data provided by the financial markets, the statistics of price changes.

Lack of information prevents us from making a precise forecast of the future, such as the price of a certain good. For this reason, it is necessary to abandon the deterministic view immortalized by the famous exchange between Laplace and Napoleon, which we discussed in the first chapter, according to which by knowing the status of a system today we can predict its future behavior. We should look for the appropriate tools to develop a new form of predictability, which is no longer deterministic but statistical. Predicting trends in stock prices is, in fact, certainly too difficult a task, but their statistical variations can be mathematically described. The financial markets offer an ideal example for the development of a statistical approach because the fact that a large number of agents, with conflicting interests, are simultaneously present in these markets leads to unpredictable but statistically quantifiable behaviors.

The statistical approach consists of using observations of past behaviors or theoretical models to derive information about the frequency of possible price changes. In other words, to develop a statistical risk theory, we must firstly define what kind of description we assume: if this is determined by theoretical considerations on the markets functioning or whether this is measured in the available data. Difficulties do not end here since, unlike what happens when rolling a die, for which the probability of getting a number between one and six is always the same and equal to $1/6$, the statistical properties of market goods can change with time in a way that we do not know how to determine. A crucial problem is to understand in which time interval variations of price changes can be considered approximately to have the same statistical properties, so that the signal can be considered stationary.

For example, it is well known⁴⁷ that emerging markets behave differently from the more mature ones. For this reason the empirical statistical description of

⁴⁷Bouchaud and Potters [15].

financial fluctuations, certainly imperfect, is based on the idea that any evolution occurs slowly enough (on the scale of several years) so that the observation of the recent past is useful to describe a not-too-far distant future, by implicitly using the method of analogues that we discussed in the first chapter. On the other hand, many economists (in particular, those adherents to the neoclassical school) have adopted a very different point of view: they have assumed some theoretical hypotheses on markets functioning from which they derived the description of the risk. These assumptions, as does the theory from which they are derived, do not depend on time and, like the laws of nature, are assumed to be universal and unchanging. It is quite amazing to use this hypothesis in the socio-economic context, and therefore it should be carefully verified empirically.

French physicist Jean Baptiste Louis Bachelier, universally considered the father of financial mathematics, first postulated the fundamental theoretical assumption used to describe price changes. In 1900, Bachelier applied the same probabilistic ideas used by Einstein, that we briefly discussed in the first chapter, to explain the random motion of a grain of pollen in a liquid, the Brownian motion, to evaluate stock-price changes. The mathematical model developed by Bachelier in his 1900 doctoral thesis “*Theorie de la Speculation*”⁴⁸ assumed that the price changes were random and independent, that is they could go up or down with equal probability, just as when flipping a coin one gets heads or tails.

This type of change is described by the statistics introduced in the early 19th century by the mathematician, astronomer and German physicist Johann Carl Friedrich Gauss to characterize the measurement errors in astronomical observations, the so-called Gauss curve. This has special mathematical properties that allow it to describe fluctuations in an astonishing number of phenomena, those in which fluctuations may be regarded as independent, e.g., the fluctuations in the height of a population and those of school marks. Because of its universal characteristics, the Gauss function is ubiquitous not only in natural sciences but also in social ones. The most remarkable properties of the Gauss curve are that the more likely event coincides with the average value and that the dispersion around the mean is very limited: this implies it is extremely unlikely to observe values very different from the average.

The work of Bachelier in 1900, was forgotten until the 1960s, when it finally became one of the tools of finance theory with the studies of the two economists Fischer Black and Myron Scholes who, in an article in the 1973,⁴⁹ proposed a model for the time behavior of financial instruments, in particular of options, based on Brownian motion. Since then the Brownian-motion model for financial stocks prices, and thus the Gauss curve that describes its statistical properties, has become the key element for defining the price of all financial assets. This description, however, leads to paradoxical conclusions, such as, for instance, that price changes so great as those we have already seen repeated many times in the recent past

⁴⁸Bachelier [20].

⁴⁹Black and Scholes [21].

(Black Tuesday in 1987, the Asian economic crisis of 1997, etc.) that should take place only once every hundreds of thousands of years or more. To explain these anomalies, then, one can invoke external anomalies that change all expectations, or that make unlikely events to happen frequently: these are the unpredictable external factors. On the other hand, there is evidence that the hypothesis of Gauss is contradicted by stock market data even in the absence of particularly dramatic events, and that we need (among other things!) a different statistical treatment, and interpretation, of the data.

Mathematical Monsters

Trees, mountains, clouds, are few examples of irregular structures that are as common as impossible to describe through the regular shapes of Euclidean geometry—circles, squares, spheres, cylinders etc. Benoit Mandelbrot, a mathematician of Polish origin, who was educated in France and then joined IBM in the United States, was awarded in 1993 the prestigious Wolf Prize for Physics, “for turning our vision of nature”. Mandelbrot, with his famous book “*The Fractal Geometry of Nature*”,⁵⁰ founded a new branch of mathematics that is capable of providing tools to identify mathematical regularity in the apparent irregularity of natural shapes. This is a fundamental geometry for the natural sciences as it is able to identify quantitative elements to, for instance, model the weather, study rivers flow, analyze brain waves and seismic tremors and to characterize the distribution of galaxies.⁵¹

These irregular shapes were considered as a mathematical curiosity until the seventies, and they were relegated to a sort of horrors gallery inhabited by those curves that are intractable with the methods generally used to describe continuous functions. Fractal geometry (from the Latin *fractus*: broken or fragmented) has therefore opened a new window on nature allowing us to identify mathematical regularity in the seemingly irregular structures in physical space. This regularity is manifested by scale invariance, i.e., changing the scale (zooming) of a fractal leaves it statistically the same. From a scientific point of view, one can use therefore a tool that completely changes our perspective on natural forms: for example, by observing a cloud one not only identifies a indefinite and indescribable shape but a fractal structure characterized by a single specific number, the fractal dimension.

Many rightly consider Lewis Fry Richardson as the grandfather of fractals and the father of modern meteorology. He was, in fact, the first to ask “How long is the coast of Britain?”; the same question Mandelbrot formulated in his famous 1967 article.⁵² Richardson had, in fact, measured the length of the border between Spain

⁵⁰Mandelbrot [22].

⁵¹Gabrielli et al. [23].

⁵²Mandelbrot [24].

and Portugal, the length of the coast of Australia and of South Africa and he had noticed, well before Mandelbrot, that the measurements depended on the used scale.⁵³ By increasing the resolution, the perimeter increases because the curve is not smooth, and further irregularities appear by zooming, which are instead neglected when a rougher resolution is used. For an irregular curve, the perimeter instead of being constant with the map resolution shows an inverse power law trend so that it increases when the resolution becomes finer.

Fractals are ubiquitous in nature: who has never noticed the surprising regularity of the Roman broccoli in which the same conical shape is repeated at ever-smaller scales? Even human anatomy offers wonderful examples of fractal structures, such as the arteries and bronchial tubes in the lungs. The latter have been designed by nature to have an effective surface area, through which oxygen is absorbed, corresponding to about two tennis courts. This feature is made possible by the presence of fractal structures that, maximizing the ratio between surface and volume, were chosen by nature, through evolutionary selection, for the optimization of the physiology of biological structures.

Mandelbrot⁵⁴ showed that modeling price changes through the analogy with the Brownian motion, the key assumptions of Bachelier, is unable to describe the sudden and extremes price changes actually observed, and which seem to be the norm in the financial markets and not aberrations that can be neglected, just because they are scale-invariant—i.e., fractals:

A year earlier, the Dow had fallen 7.7 per cent in one day. (Probability: one in 50 billion.) In July 2002, the index recorded three steep falls within seven trading days. (Probability: one in four trillion.) And on October 19, 1987, the worst day of trading in at least a century, the index fell 29.2 per cent. The probability of that happening, based on the standard reckoning of financial theorists, was less than one in 10^{50} —odds so small they have no meaning. It is a number outside the scale of nature. You could span the powers of ten from the smallest subatomic particle to the breadth of the measurable universe—and still never meet such a number.

It all started in the early 1960s when Mandelbrot,⁵⁵ by studying changes in the cotton price, observed that they follow a very similar law to that observed for the number of earthquakes with a certain intensity, the Gutenberg-Richter law: larger fluctuations are rarer than smaller ones, as in the case of earthquakes of small intensity are more frequent than those of great intensity, but these occur much more frequently than one might expect if the phenomenon was described by a toss of a coin, as Bachelier suggested. The exponent of the power law is the key number of fractal geometry (simply connected to the fractal dimension).

Mandelbrot's result was confirmed by several other studies including the one conducted by American physicist Eugene Stanley⁵⁶ who, at the end of the 20th century, along with his collaborators, analyzed hundreds of millions of price

⁵³Vulpiani [25].

⁵⁴Mandelbrot and Hudson [26].

⁵⁵Mandelbrot [22].

⁵⁶Gopikrishnan et al. [27].

changes of 16,000 thousand companies and many financial indices in various countries over a period of 30 years. The qualitatively different element observed in the data compared to the Bachelier's hypothesis is the presence of memory: the volatile prices have memory of the past.⁵⁷ As in the case of earthquakes, a great shock leaves a trace in the system's memory that lasts for a long time, manifesting itself in a power law similar to that of Omori, according to which the probability of having aftershocks is directly proportional to the time passed after the main shock. From a mathematical point of view, memory is equivalent to the presence of scale-invariant temporal correlations, and thus of fractals, that are described by power laws. This situation makes the Gaussian curve, derived theoretically by assuming the independence of different random events, to be unable to capture the distribution properties of the observed fluctuations, which are instead described by functions characterized from having a "long tail": events that are far from the most likely one, and occur much more frequently than in the Gaussian case.

Why, then, are there such great price changes (or fluctuations)—rare and unpredictable events that the Lebanese essayist (naturalized American) Nassim Nicholas Taleb called the "Black Swan"⁵⁸ to symbolize the occurrence of an unforeseen event of great importance? They happen because they are correlated events due to the fact that many brokers are simultaneously doing the same thing: sell (or buy) the same stocks at the same time, very often for the same reason—as birds flock in their spectacular and coordinated flights. Because what happened in the past affects what happens in the present and what will happen in the future—such as earthquakes showing a memory over time. In other words, because coherent phenomena can occur, that means in technical terms, because long-range correlations are formed. The presence of these correlations is not, and cannot be, explained by neoclassical economic models that are based on equilibrium and independence of the events—the Brownian motion, the toss of a coin, the Gaussian statistics—and that do not consider the structure of interactions between individuals. Correspondingly, from a dynamical point of view, it is necessary to understand and to model the forms of interaction between agents that can give rise to these correlations. Interactions and correlations are thus two sides of the same coin.

The standard description of price fluctuations, therefore, not only is not able to predict, or even to describe what happens in reality as shown by the analysis of time series of price changes. On the contrary, as noted by French physicist Jean-Philippe Bouchaud,⁵⁹ the theoretical preconceptions used in the standard risk assessment may have, and in fact they have had, the catastrophic effect of triggering a cascade process. In 1987 the stock market fell by 22.61 % in one day just because of wrong models of risk assessment. The key role was played by the Black-Scholes model, invented in 1973 to price options assuming that their changes have a Gaussian distribution. That is, a model that neglects the probability of large fluctuations.

⁵⁷Bouchaud and Potters [15].

⁵⁸Taleb [28].

⁵⁹Bouchaud Nature, 2008 *Ibidem*.

Paradigms and Predictions

The Governor of the Central Bank of Australia Glenn Stevens has captured the reaction of neoclassical economists to the recent financial global crisis as follows⁶⁰

I do not know anyone who predicted this course of events ... What we have seen is truly a 'tail' outcome — the kind of outcome that the routine forecasting process never predicts.

Not one neoclassical economic model had, in fact, anticipated the great crisis: in 2007 these were all in line with the OECD's observation that

the current economic situation is in many ways better than what we have experienced in years.

In the wake of these drastically erroneous forecasts, the crisis continues to be considered by neoclassical model makers as an inherently unpredictable event, caused by unforeseen external shocks that cannot be modeled by the economic theory. In contrast, the 2008 crisis was an expected result for a number of economists, adherent to other theoretical paradigms that properly identified the factors of fragility and instability of the financial and economic systems.⁶¹

Steve Keen,⁶² from the University of Sydney, has compiled a list of economists who, through theoretical models, mathematical or theoretical qualitative analysis, predicted the possibility of a major financial crisis. Generally, the prediction was not deterministic—that the crisis will be on a specific day—but concerned the conditions of systemic instability of the economy of industrialized countries. Despite the differences of approach between different authors, we can find a common root in the critique of the concept of equilibrium, its role and its possible spontaneous and natural achievement thanks to the action of de-regulated markets. For example, American economist Hyman Minsky⁶³ developed a theory of financial fragility according to which economic systems cannot be understood through the equilibrium theory, because markets are recurrently susceptible to spontaneous instabilities for reasons that are endogenous to the markets themselves. The mechanism proposed by Minsky recalls the self-organized criticality that we discussed earlier: a mechanism by which the time scale of energy storage, with the

⁶⁰Glenn Stevens, *Interesting Times*, Reserve Bank of Australia Bulletin, Sydney, pp. 7–12, December 2008.

⁶¹Sylos Labini [29]. In this article several similarities have been identified between the situation in the United States in the twenties, a period culminated with the most serious depression in the history of capitalism, and the situation that has emerged during the nineties. In particular, the similarities are: (1) the importance of the innovations (electricity and cars in the twenties, information technology and telecommunications in the nineties), (2) the high and increasing profits, (3) growing speculation in financial markets, and (4) short- and long-term indebtedness of families and companies.

⁶²Keen [30].

⁶³Minsky [31].

subsequent formation of a state of instability, is very long compared to the time scale during which the energy release (avalanche or shocks) occurs.

On the other side of neoclassical paradigm, we find its opposite: that is, those who think that financialization of the economy, liberalization of markets, accompanied by the deterioration of workers protections and conditions and a significant growth in the income distribution disequilibrium had determined the conditions for the crisis to happen. In this perspective, the causes of the crisis are not accidental endogenous events, but they are determined exactly by those policies inspired by the neo-classical doctrine. As we noted, the last 30 years have been characterized by confidence in the ability of the financial instruments to make markets more efficient and stable: a vision based on the idea of equilibrium. On the contrary the proliferation of financial instruments has often increased the market instability leading it to a disaster.⁶⁴

The “free market fundamentalism”, that is the blind faith in the market-rebalancing mechanisms, the hostility towards binding rules, which favored the enormous growth in finance, is the ultimate cause of the conditions that have made the system unstable. For this reason, many would welcome a thorough review of the rules and institutions that must act to prevent new crises in the near future.

Economic Complexity

In the absence of a reliable theoretical model, there is another way to make predictions: the essential idea is to apply to some specific economic data the method of analogues. As we discussed in the first chapter, this enables one to infer the system’s future state⁶⁵ from the knowledge of the state of the system up to a fairly remote time in the past. In other words, the aim is to discover some regularities from the data series, so that, by finding a past situation “close” enough to that we observe today, we can infer the evolution of the system tomorrow. It is not always possible to successfully use the method of analogues. For example, all attempts to forecast the weather based on the method of analogues have been disastrous. The reason is that for the atmosphere, the time sequence in which to look for the analogue is too long for any possible big data that will be available even in distant future, because it is “too” chaotic.

⁶⁴More recently computerized high-frequency trading became the latest threat to the stability of financial markets. In fact, many physicists and mathematicians are currently working in financial institutions to develop sophisticated computer methods and algorithms to operate in the financial markets, especially in the high frequency trading—from a few hours to fractions of a second. This automated trading can be effective, in a situation of relative stability, to profit from small price changes. Obviously this is a very specialized job that does not consider longer timescales, or to the complexity of the economic system. If there are big changes like the huge price fluctuations related to the crisis, the automated methods amplify them causing greater instability in the markets.

⁶⁵Cecconi et al. [32].

However this is an average result, and already common sense suggests that the weather forecast in the Sahara desert is simpler and more stable than that in the Alps, where many micro-conditions are difficult to monitor and some physical phenomena are too complicated to be modeled. One must therefore understand if chaos is homogeneous over the system or whether it shows heterogeneous variations, as in the case of the desert and mountains that we have just mentioned.

A group of scientists from the Institute of Complex Systems⁶⁶ of the Italian National Research Council and of the University of Rome “Sapienza”, led by Italian physicist Luciano Pietronero, has introduced a new method, called the “selective predictability scheme”, to make predictions in economics that is inspired by the method of analogues.⁶⁷ This method is based on data regarding the flow of exports of each country between 1995 and 2010. The economic development of every nation is graphed within a two-dimensional plane, where one compares a monetary variable—GDP—with a non-monetary variable—the fitness—for a period of about 20 years.

The fitness is a variable that takes into account the economic competitiveness of a nation by measuring, at the same time, the level of diversification and of complexity of the products exported from a certain country.⁶⁸ Its definition is inspired by the Google Page-Rank algorithm, which we will discuss later, even though it has some important differences. In this way, one can extract from a complex economic system, like that of an industrialized country, comprehensive information describing a specific quality of it. In particular, a country with high fitness produces many products that are technologically complex, and a product is complex if only a country with high fitness produces it. The two definitions are self-consistent and therefore one can use the data of the global exports to calculate, through the mathematical algorithm, the fitness of each country and the complexity of each product. For this reason, the fitness can be defined as the ability of a country to compete in the global market.

The time evolution of countries, in the plane fitness-GDP, shows that there are two main areas. On the one hand, we find a non-chaotic (or laminar) area where the trajectories corresponding to the nations evolving in a linear fashion lie. Therefore these are predictable trajectories in the sense of the method of analogues: this is an area of very low chaos. This predictability is the sign that the fitness is the major factor that led to the growth of the GDP. Instead, very intricate trajectories lie in the chaotic area of the plane. Countries for which the evolutionary trajectories are found in this area experience unpredictable and very chaotic economic changes. In this case, their economic development is not driven by the variable fitness, but by exogenous factors that are difficult to measure, such as the lack of an industrial policy, civil wars, natural disasters, or excessive dependence on exports of raw materials. This huge difference between countries shows that the evolution of the

⁶⁶See the web site <http://e-complex.info/>.

⁶⁷Cristelli et al. [33].

⁶⁸Cristelli et al. [34].

economies results in a very heterogeneous manner, even when the initial conditions, in terms of GDP, are identical.

The conclusion of this study is that the nations that will grow more in the next decade are those that are actively concerned with increasing their fitness, before their GDP, as shown by their past trajectories. These are those countries that have better structured their industrial, research and innovation systems, enriching the basket of their export business with complex, highly-technological products but which have not yet collected all the revenues arising from such diversification of goods. For this reason, as a result of a substantial increase of fitness, such nations have had access to more and more exclusive, and therefore more and more profitable, markets. This means that at some point even the GDP, firstly low compared to the value of the fitness, has started to grow by continuing to do so until a sort of balance between the value of GDP and the fitness is reached. The countries that will continue to grow for at least another decade are therefore those who have amassed a bonus in terms of economic competitiveness that still has not translated into a proportional increase in the GDP.

We will discuss in more details the concept of fitness in the last chapter; but for the moment, we simply note that these predictions are the result of a very innovative work in which elements coming from complex systems studies have been applied to economics. The underlying idea is to introduce the techniques based on the analysis of big data that are able to provide more pragmatic methods, inspired by the natural sciences rather than by theoretical dogma, for the analysis of the economy. But we must emphasize the fact that this type of prediction is very rough and it does not allow a fine resolution of the evolution of developed countries over time, even though it is able to identify quite clearly the temporal evolution of developing countries. A refinement of this analysis would therefore be necessary to understand how the major economies of the industrialized countries do change.

The Neoclassical Dictatorship

The “Queen’s question” is the key test to show that there was a fundamental problem in the current development of economic research. At the same time, when this question was asked, in autumn 2008, the results of the evaluation for research in economics in the United Kingdom, carried out under the Research Assessment Exercise, the periodic assessment of the “quality” of scientific research in that country,⁶⁹ were published. The result was surprising: economics as a discipline, not only got a good result, but had the best academic evaluation of all disciplines in the UK. The British philosopher of science Donald Gillies as formulated the question⁷⁰

How could such an erroneous assessment have occurred?

⁶⁹See the website: <http://www.rae.ac.uk> and the discussion in Chap. 3.

⁷⁰Gillies [35].

It is, in fact, evident that there is a fundamental problem with the current course of economic discipline if the greatest global crisis to have ever occurred since 1929 exploded while leaving most economists surprised. To understand Gillies's interpretation of these facts, it is necessary to make a brief excursion into the epistemology of science, because it is in this context that the (apparent) technical-scientific and depoliticized appearance of economics plays a key role.

As we discussed in the first chapter, Thomas Kuhn in his masterful *"The Structure of Scientific Revolutions"*⁷¹ has developed a vision of natural sciences, which has become well known and widely accepted. In short, according to Kuhn, mature natural sciences grow for most of the time in the way that he describes as "normal science". During the period of normal science, almost all researchers who work in a certain scientific field accept the same structure of assumptions, which Kuhn calls the "paradigm". However, these periods of normal science are, from time to time, interrupted by scientific revolutions during which the dominant paradigm in the field is overturned and replaced by a new paradigm. The fundamental difference between natural sciences and social sciences is generally that in the natural sciences, except during revolutionary periods, almost all scientists accept the same paradigm, while social science researchers are usually divided into competing schools. Each school has its own paradigm, but these paradigms are often very different from each other. The contrast is thus between a situation with, substantially, only one paradigm and a multi-paradigm situation, in which different paradigms coexist in a conflicting way.

For example, all theoretical physicists accept the paradigm whose core consists of the theory of special relativity and quantum mechanics. This does not mean that contemporary physicists are too dogmatic: rather they think that, at some point in the future, there will be another revolution in the field, originate from some new experimental discovery, which will replace special relativity and quantum mechanics with other theories. However, they think, having large experimental evidence that relativity and quantum mechanics work very well, in the sense that they can explain natural phenomena, it is reasonable to accept them for the time being.

An examination of the research community in economics has made it clear that it is divided into a number of different schools of thought, each with its own paradigm. The members of each of these schools share the same paradigm, but the paradigm of a school can be very different from that of another. In addition, members of a school are often very critical of members of another school. The different schools, which for simplicity we can identify in the neoclassical, which has the largest number of members at this time, in various versions of Keynesianism and in the Marxist school, are associated with different political ideologies. In particular, these schools are placed on a political spectrum that goes from right to left.

⁷¹Kuhn [36].

Generally, the members of each school have a low opinion of the research of the other schools. Now the question is: what will be the result when a system of research evaluation is applied to this type of community? The thesis of Gillies, resulting from the analysis of what happened in the UK over the last 20 years, is that the research work of the members of any school that has the largest number of members, will receive the best evaluation. In this case, the dominant school is the neoclassical one. With the affirmation of a mainstream school, the others are marginalized so that it is increasingly difficult for them to obtain research funds. A vicious cycle is thus created that goes to the benefit of the dominant school. The British case is not isolated and the research evaluation is a battleground for supremacy in academia in other countries as well.⁷² For example in Italy, the national evaluation research agency has appointed a group of experts for evaluation in economics that are not only closely linked one to each other⁷³ (for instance as co-authors of scientific articles) but who are also the founders, candidates and supporters of the same political party.⁷⁴ Even in France, the schools of thought different from the neoclassical one are undergoing a tough battle not to be stifled.⁷⁵

This kind of social dynamic in an academic field, then, tends to suppress both the teaching and the research pluralism of ideas and doctrines. The struggle for pluralism seems to be felt not only by economists belonging to numerically smaller schools,⁷⁶ but also by students; for example, the Post-Crash Economics Society⁷⁷ is a group of economics students at the University of Manchester, but also similar associations were founded at the University of Cambridge and the University College London. These associations argue that neoclassical economic theory should no longer have a monopoly within the economics courses. Students see the problem simple: students, graduates or professional economists could easily go through their careers without knowing anything substantial about other schools of thought, such as Sraffian, post-Keynesian, Austrian, Marxist, etc., which are considered inferior or irrelevant to the “science” of economics.

The academic domain of neoclassical theory is linked to another issue that deals with the “mathematization” of economics. This endows economics with a technical-scientific appearance so that the economic problem seems to produce, as

⁷²From 2008 to today we have many initiatives in favour of a critical review of economic thought. For instance, the “Manifesto on Freedom of Economic Thought Against the dictatorship of the dominant theory and a new ethic” promoted by Paolo Sylos Labini Association. See the web site: <http://www.syloslabini.info/online/wp-content/uploads/2010/02/Manifesto-ingl.pdf>.

⁷³Alberto Baccini, Gli esperti di valutazione all’italiana, Roars.it, 16 dicembre 2011.

⁷⁴Francesco Sylos Labini, L’Oscar della garanzia, Roars.it, 8 marzo 2013.

⁷⁵Laura Raim, Police de la pensée économique à l’Université, Le Monde Diplomatique, 16 July 2015.

⁷⁶For example, the World Economics Association aims to promote pluralism of different economic theories and, for this purpose, coordinates the work of various scientific journals, organizes conferences, etc. See the web site: <http://www.worldeconomicsassociation.org>.

⁷⁷Zach Ward-Perkins and Joe Earle, Economics students need to be taught more than neoclassical theory, The Guardian, 28 October 2013.

in physics, a solution that is unique and has been derived according to the scientific method. This transformation, in the eye of public opinion, of a social science, with extensive political aspects, into a technical science is sealed by the “Nobel Prize for Economics” which, like the one in the hard sciences, seems to affix the final quality mark on the discoveries in the field.

The Theft of a Successful Brand

There is a “strange loop” characterizing the field of economics: very often a successful academic is also a columnist for a major newspaper and a political advisor. Academia, policy makers and the media are three vertices that, in addition to being closely related, support one another. Public opinion can be very confused by these overlapping roles: economics is one of the few fields in which these three roles are so closely interconnected.⁷⁸ A fundamental pillar that holds up the “strange loop” is the “Nobel Prize in Economics.”

Every year prizes are awarded according to the will of Alfred Nobel:

“[...] the capital, invested in safe securities by my executors, shall constitute a fund, the interest on which shall be annually distributed in the form of prizes to those who, during the preceding year,⁷⁹ shall have conferred the greatest benefit on mankind. [...]”

In short, Alfred Nobel established in his will that the prizes for physics and chemistry were to be awarded by the Swedish Academy, the one for medicine by the Caroline Institute in Stockholm, that for literature by the Academy in Stockholm, and finally the one for peace by a committee of five people elected by the Norwegian parliament.

The Nobel Prize, from 1901, has become a successful brand that was awarded to great persons related to important discoveries.⁸⁰ While some of the winners are little known by the general public, the most famous scientist of the 19th century, Albert Einstein, is definitely one of those figures that everyone instinctively associate with the word “Nobel”. The winners of this award are generally acclaimed: sometimes

⁷⁸For example in the general election in Italy in 2013, the journalist Oscar Giannino, leader of the movement to Make Stop the Decline (Fermare Il Declino—FID) and candidate for prime minister, just before the election resigned from the presidency of the movement, but not as candidate for prime minister, because he acknowledged not to have a degree in law, economics and did not take the master’s degree in economics at the University of Chicago. Both he had previously said publicly. Surprisingly none of the promoters and sponsors of the movement FID, which were mostly academic economists with Italian professorships in various countries around the world and members of the neoclassical school, was aware of such an inconsistency. FID has thus represented the first political party entirely motivated by and consisting of neoclassical economists. In any case, the election result was laughable.

⁷⁹This role was not always respected.

⁸⁰Even though one could compile a long list of scientists and writers that did not receive the Nobel Prize while widely thought to deserve one.

one counts a country's Nobel Prizes like medals at the Olympic games. This occurs, for instance, in the case of university rankings, as we shall see in the next chapter. There is thus no doubt that every year every newspaper in the world reports on the winners of these prizes. The media attention on the winners, and consequently to what they say and think, is certainly higher than any other award: this is so thanks to the prestige of a successful brand.

In 1969 the Central Bank of Sweden (the Sveriges Riksbank) established what is commonly treated as the sixth Nobel Prize, the one for economics, but that is called "The Sveriges Riksbank Prize in Economic Sciences in Memory of Alfred Nobel". Of the 75 economists who have been awarded the "Nobel Prize in Economics", 28 or 37 %, were affiliated with the University of Chicago. Moreover, 80 % of the winners are from the United States (by birth or by naturalization). Only the 7 % of the winners came from outside of North America or Western Europe. Only one woman has won the award.⁸¹

Recently Peter Nobel, a lawyer and a descendant of Alfred Nobel, has disassociated the Nobel family from the "Nobel Prize in Economics" stressing that, in his original will Alfred Nobel had not specified that there must be a prize in economics, and that the prize for economics was funded at a later time by the Bank of Sweden⁸²:

What has happened is an unparalleled example of successful trademark infringement. [...] But something must be wrong when all economics prizes except two were given to Western economists, whose research and conclusions are based on the course of events there, and under their influence. I can imagine Alfred Nobel's sarcastic comments if he were able to hear about these prize winners. Above all else, he wanted his prizes to go to those who have been most beneficial to humankind, all of humankind!

Many others, including some members of the Swedish Academy, have shared this view.⁸³ Recently⁸⁴ Bo Rothstein, a prominent member of the Royal Swedish Academy of Sciences, proposed an immediate moratorium on the Nobel Prize in Economics in the name of Alfred Nobel and of the Nobel Foundation since the awarding of this prize is in direct conflict with what Alfred Nobel decreed in his will.

A different way for organizing a prize was indeed possible. Alfred Nobel did not write in his will either to set up a prize for economics, or for mathematics. To avoid repeating the confusion created by economists, mathematicians established the Abel

⁸¹Lars. P Syll. The Nobel prize in economics is a disgrace. Dump it! Si veda: <https://larspsyll.wordpress.com/2015/10/11/the-nobel-prize-in-economics-is-a-disgrace-dump-it/>.

⁸²The Nobel family dissociates itself from the economics prize, Real-World Economics Review blog, 22 October 2010. See the web page: <http://rwer.wordpress.com/2010/10/22/the-nobel-family-dissociates-itself-from-the-economics-prize/>.

⁸³Joris Luyendijk, Don't let the Nobel prize fool you. Economics is not a science, The Guardian, 11 October, 2015.

⁸⁴The Real-World Economics Review Blog, 1 ottobre 2015. Si veda: <https://rwer.wordpress.com/2015/10/11/key-member-of-swedish-academy-of-sciences-calls-for-immediate-suspension-of-the-nobel-prize-for-economics/>.

Prize. This should be a kind of “Nobel Prize for mathematics” and is awarded by the Norwegian Science and Literature Academy, which attributes it after a selection made by a committee composed of famous mathematicians. The winners are undoubtedly scholars who have achieved fundamental results in the discipline. There should, however, be noted a difference between the two awards: no announcements appear on newspaper front pages, every year, of the winners of the Abel Prize (or even other awards such as the Fields Medal, the Dirac Medal, etc.) as it happens for the other five Nobel laureates, real plus the one for economics. It seems clear that the key factor is that the promoters of the prize of the Bank of Sweden, knowing the basic principles of marketing, have managed, with this “violation of a successful brand”, to advertise at no cost.

Economics Is Politics

The problem of pluralism of thought in economics is not only a purely academic issue, but the presence of a “neoclassical dictatorship” is the reason why the mind-set in dealing with the crisis in recent years has not changed. Mass media are subjected to the same kind of cultural hegemony, and therefore they often offer a distorted representation of reality that does not allow the consensus opinion and understanding of important events. For example, in the mainstream media, the policy choices of European governments and of the European Commission itself have been presented as forced by a crisis caused by excessive generosity of pay levels and of the public welfare systems. This representation reflects a well-defined point of view (that of the neo-liberal economic theory), and it is not at all a true representation of what happened beginning in 2008 onwards.

The economic crisis, in fact, initially broke out as a banking and financial crisis triggered by a crisis of private debt due to the uncontrolled creation of “money out of nothing”, in the form of financial instruments, by banks both in Europe and the United States. The enormous growth in financial markets and instruments has thus entwined in the last 30 years with the explosion of private debt, creating the basis for the great global crisis. The financial sector pushed the debt increase because banks derive high interest from third-party debts. Moreover, in a system with growing inequalities, low income and precarious jobs, normal people can buy a house or a car or go on vacation only by borrowing money. So there was pressure on both the supply and the demand side, and the whole mechanism has given rise to an increased financialization of the economy.

When this house of cards collapsed, with huge cost for millions of people, the US government acted to support the banks for almost 30 trillion dollars, in the form of loans and guarantees, while at the end of 2010 the European Commission had authorized aid to banks for more than four trillion dollars. With these actions the financial crisis, which until early 2010 was a crisis of private banks and had not turned yet into a worldwide catastrophe, was loaded on to public budgets that have thus saved private ones. For a few years, most discussions in the media were focused

on the failure of the financial system and the need to reform it. Many economists—including some neoclassical ones—joined in blaming the financial sector and easy credit without guarantees to those who “cannot afford it”. After about a year, the discussion had started to move on to different topics, e.g., too much public debt because of the excessive public spending and of inter-generational issues—it was the fault of the older generation that had everything, leaving the young hopeless. The slogans spread by the mainstream media have evolved in a short time to, for instance, the over-indebtedness of states, excessive public spending, unsustainable pensions, and education spending “that we can no longer afford”. And as a result, the message was communicated, without much difficulty that the state spends too much and therefore it is necessary to cut public expenditure such as kindergartens, schools, health care, education, research, and pensions. While this narrative has opened the doors to the austerity measures, the role of the financial sector and the need to reform it appear to have been completely forgotten.

This hoax has been made possible thanks to cultural hegemony and political influence of the orientation of public opinion through both the major newspapers and the core center of culture and education, academia. For instance, the monopoly of information on economical topics is clearly shown by the results of a study in the Italian press⁸⁵ on the complexion of professors of economics: there is a clear predominance of neoclassical economists (teaching at private universities) who write the editorials in the main economic newspapers.

Cultural Hegemony⁸⁶

It's been more than eight years after the demise of Lehman Brothers and in many countries the crisis has deepened, while nothing seems to have changed in the positions taken on the root causes of the great global crisis by those economists in major international institutions and in the governments. The prevailing ideas on the origin of the 2008 crisis and of the failure of its forecasts⁸⁷ are still mostly linked to the belief that the economy may suffer a shock, but it is then able to return to the state of full employment of resources. That it is sufficient to maintain control over turmoil in the financial markets in terms of their regulation to prevent the recurrence of similar events is also practically unquestioned. Instead, one finds little evidence of the view that the financial crisis is the epiphenomenon of a deep crisis in the real economy, a

⁸⁵Francesco Sylos Labini, Furto d'informazione e crisi economica, *il Fatto Quotidiano*, 4 August 2012.

⁸⁶Ideas presented in this section have been developed in the article with Daniela Palma Neoliberalism and cultural hegemony, <http://www.syloslabini.info/online/neoliberismo-e-egemonia-culturale/>.

⁸⁷Simon Potter, *The Failure to Forecast the Great Recession*, Liberty Street Economics, 25 November 2011.

crisis of demand that finance has enhanced, thus generating chronic indebtedness of large sections of the population both in the United States and in Europe.

It is clear that the different interpretation of the causes that gave rise to the crisis influences the remedies that have been put into place for its abatement. In addition it is clear that the outcome of the treatment will be much better if the “model” of interpretation of the crisis is better able to capture its real characteristics and fundamentals. The crucial problem is that one cannot approach economics in the same way as a discipline of natural science, because the object of its study is the society with historically determined characteristics. Considering a certain “model” rather than another one to interpret economic facts does not mean simply introducing alternative assumptions responding to an epistemological status that allows to test their validity—as it happens in the natural sciences—but it means joining different *Weltanschauung*, alternative visions of the world, where the hegemonic component of the dominant culture in any given period plays a decisive role. In this sense, we can say that the genesis of the crisis, its development, our ability to end it and the effects on the economies going through it, are intrinsically linked to a problem of cultural hegemony.

The way the prevailing economic thinking has been compared to the crisis since its inception is typical of the mainstream vision that is rooted in the main references of neoclassical theory as we discussed earlier. In this theoretical framework, economics is conceived as a science that studies the alternative choices of scarce resources, and the market is the place of optimal allocation of resources, guaranteed by rational agents able to use all the available information conveyed by prices, which measure the scarcity of such resources. According to this model, which has have its roots in the work of Walras at the end of the 19th century, the market would “naturally” find an equilibrium that is the meeting point between supply and demand, according to a process that is exclusively logical-deductive and therefore totally independent from the diversities among economies in time and space.

Deviations from market equilibrium must be only temporary because, according to this view, the economy is expected to spontaneously converge towards equilibrium. In this situation, as evidenced by the thought of Robert Lucas that we discussed earlier, the crisis cannot be expected simply because it is not conceivable. So in the face of its manifestation, it is only possible to attribute to it the character of a momentary accident, or trying to identify market imperfections that prevent the achievement of equilibrium, perhaps by proposing to further reduce state intervention.

According to the vision that marked the birth of economics and that is stated in the aftermath of the first industrial revolution with the thought of Adam Smith, economics⁸⁸ is instead a scientific reflection on the society, aimed at examining the characteristics that ensure the conditions of reproducibility and possibly development on the basis of division of labor, in a social, institutional and regulatory context that constrains the role and actions of the various parties in time and space.

⁸⁸Alessandro Roncaglia, *Why the Economists Got it Wrong: The Crisis and Its Cultural Roots*, Anthem Press 2010.

Not surprisingly, one talks about political economics, looking at the market as a complex institutional system of historically determined standards and devoid of any connotation of naturalness: in this situation it is not at all obvious that the market will ensure the full and optimal use of resources. The approach of political economics is therefore inherently predisposed to acknowledge the occurrence of a crisis and the need to impose on the market those correctives that ensure at least the continuation of the economic system. Beyond the different versions and insights that have followed through Ricardo, Marx and up to Keynes, the vision of political economy remains anchored to a representation of the economic system in which the size of the social classes and the diversity of interests determine a basically unstable structure.

In light of this, it is easy to understand how, in the mainstream neoclassical view, any role of politics is seemingly absent, but in fact this view implies that politics is subject to markets, acting at most in a technocratic form in order to facilitate their functioning. The predominance of this vision over the past 30 years has produced a specific cultural hegemony that, despite the on-going crisis, is still dominant both in academia and in the public debate. In fact, the mainstream neoclassical view appears to have an inherent ability to survive. That the economic system is a fact of nature, which can be studied using a method that suits the laws of natural science, is a fundamental aspect that characterizes it and that leads to excluding the existence of any alternative ideological dimension with which we must deal. In this way, the mainstream neoclassical view has enjoyed (and still enjoys) the possibility of close itself through the leads of its axiomatic assumptions. Given this situation the mainstream neoclassical view accept as the only eligible threads those conducted within its conceptual boundaries.

Austerity policies have been inspired by the same ideological paradigm at the basis of the neoclassical perspective: this situation occurred precisely because of the cultural hegemony in academia and politics that we discussed earlier. For example, a famous article by economists Carmen Reinhart and Kenneth Rogoff,⁸⁹ among the most cited in recent years, pointed out the existence, in many countries, of a correlation between a high ratio debt/GDP (greater than 90 %) and low growth. The article by Reinhart and Rogoff has been shown to suffer from serious methodological problems and even to be affected by a simple mistake in the calculation spreadsheet.⁹⁰ Yet this study was among those used to justify austerity policies and the need “to put in order the budgets” in the different countries. Despite the fact that the data, analyzed properly, did not show any correlation between debt and GDP, and therefore did not justify the recruitment of austerity policies, these have not been changed. According to Paul Krugman,⁹¹ despite the fact that the forecasts of

⁸⁹Reinhart and Rogoff [37].

⁹⁰Thomas Herndon, Michael Ash Robert Pollin, Does High Public Debt Consistently Stifle Economic Growth? A Critique of Reinhart and Rogoff Cambridge Journal of Economics, pp.1-23, 24 December 2013.

⁹¹Paul Krugman, How the Case for Austerity Has Crumbled, The New York Review of Books, June 6, 2013.

the pro-austerity faction have been refuted by empirical data, the theory in favor of austerity has tightened its grip on the elite just because the austerity program benefits it.

What the richest one per cent of the population want, become what economics tells us we must do.

In short, there is no need to invoke sophisticated psychological reasons or even guilt—feelings and the reality is much simpler: economic policies, as always, benefit some and disadvantage others. Those who have an interest in pursuing austerity policies have the ability to influence the government's choices and have protected and encouraged those who argued, in academia, in favor of this policy. In this way the hegemony in academia and politics becomes cultural hegemony in the society. As a result of this cultural hegemony exercised in academia, in the media and then in politics, intellectual and cultural references different from those of the dominant economic paradigm have been marginalized. Therefore, the mainstream view plays the role of being the only possible thought.

Thus, in the overall political confusion in which we are living, the right-wing economic ideas have permeated the social democratic parties across Europe, and a policy now devoid of ideas and content adopts the neo-liberal dogma as the only possible solution. As an example of this situation, we will discuss in the fourth chapter that science policy in Europe, both within countries and at EU level, has been largely shaped by the same ideology.

Economics, Politics, Forecasts

We have seen in the first chapter that one of the main task for geologists is to identify a seismic area; similarly economists should identify the conditions for which the occurrence of a traumatic event of exogenous origin becomes more likely so as to understand, accordingly, the conditions of formations of systemic fragility. While a seismic zone remains such for a geological of time, an economic system can be more or less subject to crises for a time scale of a few years. Moreover, while the laws of elasticity underlying dynamics of earthquakes are universal and unchanging, the laws of economics are the result of human actions, they are politically determined and, as such, they can be changed. Finally, while it is not possible to make the relevant observations of the stress level of tectonic plates that are within a few hundred kilometers below the earth's surface, it is possible to measure many aspects of the economic system of a country. The challenge, as we discussed earlier, is to find which are most important ones and what are the relevant variables that describe the state of stress in the economy.

If a seismologist assures us today that “Atlantis is not a seismic areas” and instead tomorrow a devastating earthquake occurs in that region, it would be necessary that the public demand to know why something so fundamental for the public good it was not understood and that those who had made certain statements

should assume publicly their responsibility. This situation would necessarily open a great debate to question the fundamentals of the discipline. It is just that that did not happen between the followers of the neoclassical theory (as was instead the case among members of other schools of economic thinking). This is why we still find today, entrenched in international institutions, in the media and in politics, the same economists who had neither been able to interpret the system instability up to 2008, nor the real extent of the crisis and its implications on the real economy for hundreds of millions of people. Indeed, as we noted, the excessive growth of the financial system, fuelled by the belief that liberalized and deregulated markets tend to a stable equilibrium, was at the root of the outbreak of the economic crisis, and it is still both a threat and a burden that affects the choices in terms of economic policy.

If we want to compare the situation in physics with that of neo-classical economics, as some neoclassical economists suggest doing, we can do it by saying that the laws of physics have been strongly confirmed empirically by successful explanations and predictions, while the neo-classical economic theory has not been confirmed at all, while indeed has been discredited by the empirical evidence. What has happened instead in recent years shows that we would need to shift from an equilibrium treatment towards the consideration of the out-of-equilibrium evolutionary dynamics. The understanding of this should be guided as much as possible from the data. The economic and social ecosystem is composed of several different elements and actors, all of which are coupled together and co-evolve, forming a complex network with multi-layer interdependent interactions, and it looks like the “tangled bank” described by Charles Darwin in his *“On The Origin of Species”*⁹²

It is interesting to contemplate a tangled bank, clothed with many plants of many kinds, with birds singing on the bushes, with various insects flitting about, and with worms crawling through the damp earth, and to reflect that these elaborately constructed forms, so different from each other, and dependent upon each other in so complex a manner, have all been produced by laws acting around us.

Neoclassical economics, not considering the complexity of social aggregates, the structure of interactions between agents, juridical and historical paths that gave rise to modern markets, then follows a trajectory that starts with the aspiration to appear like physics, but ends with becoming instead a real political ideology characterized only by a large dose of dogmatism. And this transformation is clearly demonstrated by the failure of its model predictions. As rightly noted British historian Eric J. Hobsbawm⁹³

[Neoclassical] economics, however, although subject to the requirements of logical consistency, could flourish as a form of theology - perhaps, in the Western world, as the most influential branch of a secularized theology - just because this discipline can be, and usually is, formulated in terms that lack of any empirical verification.

⁹²Darwin [38].

⁹³Hobsbawm [39].

The starting point is the attempt to explain reality by assuming certain special simplified but unrealistic hypotheses. These ideas, in turn, are used to guide the political action by changing the reality itself, but they could not align it with the basic principles of the theory, as shown by the great global crisis occurrence, in obvious contradiction with the equilibrium and stability of economic systems. This is because the heart of the theory lacks a crucial element, the interaction between economic agents which gives rise to the collective behavior of aggregates of individuals. The society is not, in fact, a sum of rational agents seeking to maximize their income in competition with each other, as assumed by the neoclassical theory, but rather it is a complex organization, just like the “tangled bank” described by Darwin, where the collective action of interacting individuals results in new behaviors whose emergence and understanding must be traced with the knowledge of the historical, sociological and legal as well as economic factors.

In economics, this situation can be summarized with the insight that micro and macro systems behave differently. Therefore the policies developed on the basis of micro behaviors do not work at the macro economic level. Market fundamentalism denies that there is the macro-economy and claims that only the micro-sphere is worthy of analysis, proposing to interpret the macro-economic set simply as a consequence of the behavior of individual microeconomic agents, with the idea that individuals in it—be they consumers or businesses—interact, independently of each other, through the market, which does not need an external input. The intervention that may be necessary is just to make markets work better.

On the other hand, when one passes from a description that focuses on the action of the single agent maximizing its benefit, to that of a set of agents who act in interaction with one another, one must necessarily consider the laws that regulate these interactions, how they have developed and what collective behaviors result. In other words, one needs to consider the historical development of social aggregates in combination with the special juridical and sociological conditions. In short one needs to consider that economics is a social science.

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Science and the Economic Crisis

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Sylos Labini, F.

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