What Can We Really Know about Economics?

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Albert Einstein is considered to have had one of the most innovative minds of all time. His discoveries changed the world. Still, he believed that even the most profound breakthroughs are firmly rooted in the foundations of our cultural heritage. *Ideas and Opinions*, a collection of Einstein's essays published in 1954, a year before his death, includes his famous passage on what he called the "modernist's snobbishness":

> Somebody who reads only newspapers and at best books of contemporary authors looks to me like an extremely near-sighted person who scorns eyeglasses. He is completely dependent upon the prejudices and fashions of his times, since he never gets to see or hear anything else. And what a person thinks on his own without being stimulated by the thoughts and experiences of other people is even in the best case rather paltry and monotonous. There are only a few enlightened people with a lucid mind and style and with good taste within a century. What has been preserved of their work belongs among the most precious possessions of mankind. We owe it to a few writers of antiquity that the people of the Middle Ages could slowly extricate themselves from the superstitions and ignorance that had darkened life for more than half a millennium. Nothing is more needed to overcome the modernist's snobbishness. (Einstein 1994, p. 70)

The question is much debated whether human affairs, history, and (what interests us most in this discussion) economics can be understood in rational terms. So, it is not surprising that, given the current economic crisis, a renewed debate is going on as to whether economics and finance lend themselves to mathematical and computer modeling—one of the current flavors of rationality. Taking Einstein's advice, let us take a look backward at what our predecessors thought about our ability to understand the economy from the perspective of rationality.

A Look at the Classics

To review the history of economics in the context of rational thought, we will start with the ancient world and move to the modern world.

The Ancient World. The ancient Greek world had a fundamentally integrated view of human knowledge and learning. In the Greek world, a learned man was fluent in the seven arts: grammar, rhetoric, logic, arithmetic, geometry, astronomy, and music. Philosophy (back then a word meaning no more and no less than "the love of knowledge") came to embrace all branches of learning, including literature, science, technology, metaphysics, and even sports. The Greek games were an important component of the culture, and gymnastics was an integral part of a learned man's education. According to Dicaearchus of Messana, the great fifth century B.C. philosopher Plato was also a famous wrestler; he participated in matches at the Isthmian Games. The Greeks were not only great thinkers on abstract subjects; they were also interested in understanding physical phenomena, leading them to develop many innovative technologies to solve practical problems. In today's parlance, they were problem solvers. Take, for example, Archimedes, who invented the cochlea (Archimedes' screw) to pump water from a ship's hold (the lower part of the center of a ship's hull). The ancient Greeks even engineered and built the Diolkos, a primitive but effective railway that allowed ships to transit inland across the Isthmus of Corinth.

The ancient Greeks had a notion of physical causation and of philosophical necessity. They believed that the world was governed by causation and necessity and that human affairs were understandable. This belief is particularly evident in the writing of the "father of history," Herodotus of Halicarnassus.[1] Herodotus believed in a fundamental rationality in human affairs and, with the objective lucidity of a physical scientist, sought to explain events as seemingly inexplicable as the Trojan War.

Still, the ancient Greeks thought that humans were subject to the whims of capricious gods and to unknown fate (personified by three goddesses), to which even the gods had to bow. Ancient Greek tragedy is a literary representation of their beliefs as regards human affairs. Their heroes typically have some character fault, often excessive pride, that morally justifies their fall. Behind the plot of the tragedy is fate, the overarching scheme that ultimately governs human affairs. Fate is not irrational, but it is mysterious. In the Greek mind, there are two levels of rationality: (1) the rationality of physical causation and of necessity and (2) the mysterious rationality of fate, often cryptically revealed by oracles. Note that the Greeks were sailors, and although the sea is governed by physical principles, it is still unpredictable; a storm could sink a ship.

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[1] Halicarnassus (presently known as Bodrum) was a Greek city on the southwest coast of present-day Turkey. It was famous in antiquity for its Mausoleum, considered one of the Seven Wonders of the Ancient World.

As we move on to the ancient Roman world, we see a slight change in attitude, perhaps because of the fact that Romans were people of the land, not of the sea. For Romans, the objective in life was to be *compos sui*—that is, to be *master of yourself*. This notion reflects a positive attitude regarding our ability to shape our own future. The Romans created a formidable organization capable of constructing buildings, roads, bridges, aqueducts, and defensive walls on an unprecedented scale. No wonder they had some faith in the ability of humans to shape their own destiny. Although fate, the unpredictable element, still played a role in Roman thinking, it was identified more closely with the gods than with an overarching mysterious rationality.

In summary, both cultures, the ancient Greek and the ancient Roman, considered human affairs as basically rational processes interspersed with exogenous unpredictable influences.

The Renaissance and Beyond. Following the cultural collapse of the Middle Ages, the Renaissance rediscovered the ancient texts, thereby paving the way for the development of modern science. The beginning of modern science, as we conceive it, can be dated to the publication of Newton's *Principia* in 1687—although Galileo and others can be identified as precursors. With Newton's work, physics became a mathematical science in the sense that all physical phenomena could be described with differential equations. The mathematics of differential equations gave determinism a new flavor. In fact, Newton's differential equations imply that if one knows initial and boundary conditions, the future can be mathematically determined. In 18th century physics, determinism meant that the future is perfectly predictable, conditional on knowledge of the initial state.

Pierre-Simon, marquis de Laplace, one of the greatest mathematicians of all time, expressed his faith in determinism in *A Philosophical Essay on Probabilities* (1814), in which he stated that a supernatural being with infinite computational power and knowledge of all the initial data could correctly compute the future evolution of the entire universe.

The transformation of physics into a mathematical science marked the separation between scientific culture and literary and philosophical culture. From the 18th century onward, the unity of learning that characterized the ancient Greco-Roman world was lost, replaced by a sharp separation between scientific and humanistic knowledge.

It is probably fair to say that, in the 18th and 19th centuries, the global perception of the evolution of historical events was not deeply influenced by the physical sciences. The Enlightenment had a rational view of history deeply influenced by the idea of progress. *The Decline and Fall of the Roman Empire*—with Volume I published in 1776 and the final volume (VI) published in 1788—by Edward Gibbon, the major historian of the Enlightenment, is perhaps the most lucid expression of the rationalistic historical perceptions of that period.[2] The Romantic Movement had a more dramatic and less rational view of history, centered on the heroic struggles of people to defend their identity. Romantic historiography is centered on the role of great individuals. Later, Georg Wilhelm Friedrich Hegel introduced the idea of historical determinism based on dialectical processes. Despite its obscurity, Hegel's view—which asserted that historical events could only be explained by unstoppable social forces, not by the actions of individuals—proved to be very influential: It provided the philosophical basis of Marxism.

Economics—A Quantitative Science?

The ancient Greek world was an explosion of intellectual prowess and enthusiasm. It has been said that in the fifth century B.C., Athens was a city of 20,000 free citizens who spent most of their time passionately discussing and arguing about ideas. Still, despite their achievements, the ancient Greeks did not like arrogance. *Hubris*—a legal term that indicated the humiliation of the adversary and disrespect of the sacred—was considered to be a capital offense.

In Greek myths and tragedy, *hubris* results in the final fall of the hero. Milo of Kroton, the "most illustrious of athletes" according to the ancient geographer Strabo, was a legendary wrestler who won six Olympic Games and successfully participated in all other major games. He enjoyed demonstrating his strength, for example, by holding a pomegranate in one hand and challenging people to take it from him. Despite the struggle during which no one was able to wrench the fruit from his clutch, the pomegranate was never smashed. But one day, later in life when walking in the woods, he saw a trunk split by a wedge. To prove he was still strong, Milo attempted to split the trunk with his bare hands. He succeeded, and the wedge was freed. But his hands were imprisoned by the trunk, and Milo was devoured by wild beasts.

Modern Hubris. A modern form of intellectual hubris is the belief that anything that escapes the formalized mathematical reasoning of the physical sciences must somehow be mysterious. We have come to regard mathematics and the use of computers as the ultimate solution to every scientific problem—so that if a phenomenon cannot be explained with current mathematics, it must be impossible to understand. This "modernist's snobbishness" has now permeated some strains of economics and finance theory, as well as other domains of knowledge.

The science of economics is in an uncomfortable position, somewhere between the physical sciences and the human sciences. Economics is naturally a quantitative science because most observable economic quantities are quantitative. For example, prices, industrial output, and savings are all quantitative. The rules that link these

[2]Gibbon's rationalistic views did not reflect his personal experience. His grandfather had lost most of the family's considerable fortune in the 1720 collapse of the South Sea Bubble.

quantities, however, are ultimately related to human behavior. In other words, in economics, our quantitative observables are driven by unobservables that are not naturally quantitative.[3]

Throughout the 19th century, economics developed along lines that were not quantitative in the sense that the physical sciences are quantitative. Although the work of such economists as David Ricardo had quantitative elements, there was no notion that all economic behavior and outcomes could be, or indeed needed to be, expressed mathematically.

Things began to change in the second half of the 20th century, with the invention of high-speed computers. Ever faster computers allowed economists to handle ever larger amounts of data and thus to explore statistical regularities. The process of transforming economics into an empirical and mathematical science has required, and will continue to require, conceptual innovation, often creating an original synthesis of ideas coming from different disciplines. One should be aware of the objective limits of introducing mathematics in economics and be ready to use setbacks as springboards for innovation.

One strain of economic thinking argues that economics cannot be understood mathematically because it is driven by unpredictable events. Nassim Nicholas Taleb's metaphor of the "black swan" (*The Black Swan: The Impact of the Highly Improbable*, 2007) is perhaps the best-known example of this conceptual attitude. Taleb argues that economics, and history in general, cannot be explained because human affairs are driven by black swans—single unpredictable events that have a large impact. In *Fooled by Randomness: The Hidden Role of Chance in Life and in the Markets* (2001), Taleb suggests that we instinctively try to impose an artificial order on phenomena that are purely random. We are, as the title of the book says, fooled by randomness because those events that are really important in economics are events that cannot be forecast by studying the past. Contrast this point of view with that of Herodotus, who started the study of history 25 centuries earlier under the opposite assumption—that we can, and indeed should, learn from the past.

Taleb's reasoning runs against the scientific spirit and the quest for knowledge that have driven the scientific endeavor for the last 25 centuries. Do we really believe that it was so easy for the ancient Greeks to resist the temptation to see black swans everywhere? They came out with daring hypotheses based on fundamental intuitions. Most of these hypotheses have since been proven wrong, but some of them proved to be very profound. For example, it took 24 centuries to finally vindicate Democritus' atomistic conjecture. And it took 21 centuries to understand the idea of mathematical continuum and to develop calculus, finally resolving Zeno's Paradox of the Tortoise and Achilles.

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[3]Consider that in the human sciences we have observables that are not quantitative, at least not naturally. For example, a facial expression is highly meaningful for another human, but it is difficult to give facial expressions a quantitative value.

In 1960, Eugene Wigner, recipient of the 1963 Nobel Prize in Physics, discussed the "unreasonable effectiveness of mathematics in the natural sciences" in a paper of that very title. The marvel, for Wigner, is that there *is* a natural order that can be mathematically described. But there is no a priori reason why mathematics should be able to describe nature. The very fact that we can use mathematics as the language of science deserves explanation in itself.

The use of mathematics requires profound conceptual thinking. The major achievement of science in the 20th century was not the discovery of new equations but the introduction of new conceptual paradigms. In physics, Einstein's relativity theory violated all previous notions of physical reality by mixing time and space. Quantum mechanics went further, replacing the concept of matter with that of states that can overlap. The notion of determinism progressively gave way to notions of fundamental uncertainty—first with statistical mechanics, then with quantum mechanics, and lastly with chaos theory. If we look at other sciences, we find that attempts to introduce mathematics and computation required fundamental conceptual innovation, typically accompanied by many setbacks.

Success of Mathematics in Economics. We have no a priori reason to assume that mathematics will be "unreasonably successful" in the domain of economics and finance—at least not the type of mathematics that is used in physics and not if the test of success is that mathematics accurately forecast which way the markets or individual stocks will move. For the moment, as argued in Focardi and Fabozzi (forthcoming 2010) in their article "The Reasonable Effectiveness of Mathematics in Economics," mathematics is only *reasonably* successful in explaining financial phenomena, and this success arises by using mathematics that is different from that of physics. It cannot be otherwise: Our economic systems are designed to be uncertain to allow for profit opportunities.

Economic systems, and especially financial systems, are characterized by a high level of uncertainty. Highly uncertain systems cannot be successfully described with the tools of mathematical physics. These tools were designed to describe highly stable systems. Physical reality is very stable, so stable that it allows one to formulate the initial assumption of perfect determinism. Only at the end of the 19th century was the mathematics of uncertainty introduced in physics.

The description of financial systems, however, has followed a different path. The initial hypothesis in the 1960s was that of pure randomness; that is, prices were believed to evolve as random walks. It was later understood that there must be some residual forecastability, otherwise there could be no profit motive for analyzing securities: The entire speculative exercise would be pointless. But it was also realized that the amount of forecastability must be very small, otherwise the system would explode under the pressure of an inordinate amount of profits. One can say: In physics, we have lots of information corrupted by a little noise; in economics, we have lots of noise corrupted by a little information.

No wonder the mathematics of economics and finance is different from that of physics. Physics is formulated through all-encompassing theories, whereas economics and finance theory are formulated through a process of learning and model selection. In practice, both economics and finance theory make recourse to learning methods. Learning methods do not require a priori theoretical knowledge; rather, it is the model that learns patterns by adapting to the data. Learning, therefore, requires models that adapt to new data.

But given the noisy data (i.e., data that include some information but also meaningless noise) that we have in economics and finance, if the models are too flexible, they will try to adapt to noise. A model that adapts to noise will perform well on the sample data but poorly when applied to new out-of-sample data. Learning methods, therefore, include rules that constrain the adaptability of models so that they learn only information, not noise. A simple example is a filter used in wireless communications to extract the meaningful signal from noise by constraining the frequency band of the radio signal.

The only major all-encompassing theory in economics and finance theory is the concept of general equilibrium, which is formulated in a language similar to that of mathematical physics. But when we try to apply general equilibrium to actual economic processes, we run into difficulties because we are unable to specify some of the crucial terms of the theory. To make a physical parallel, general equilibrium theories are the Newtonian dynamics without the specification of force fields. There is no way that we can make predictions with such theories.

Understanding the evolution of economic systems over time and making predictions about them, however, is only one aspect of economic science. The analysis of economic structure (i.e., the understanding of the links and correlations between economic phenomena) is also an important object of study. This is a difficult endeavor that makes use of the mathematics of complexity. A number of important results have been obtained by modeling the economy as consisting of multiple heterogeneous interacting agents. For example, the paradigm of multiple interacting agents can explain the emergence of fat tails in economic and financial variables through processes of aggregation. This type of theory offers explanations as well as estimation methods for some of the extreme events that we find in economic phenomena.

The mathematical representation of human cognitive and creative abilities has proved to be a very difficult task; it will probably require some breakthrough innovation. Since the introduction of computers, we have witnessed a vast scientific endeavor to understand human cognitive capabilities in terms of computations. The fields of artificial intelligence and cognition theory have proposed a number of models of human cognitive capabilities that regard cognition as a computational process. In his Pulitzer Prize–winning 1979 book *Gödel, Escher, Bach: An Eternal*

Golden Braid, Douglas Hofstadter (the son of Robert Hofstadter, recipient of the 1961 Nobel Prize in Physics) gives an explanation of consciousness based on the self-referential capabilities of computational structures.

The ultimate goal is to understand how societies self-organize, in particular, why economies take specific structures. Presently, we can only analyze economic systems with a given structure. For example, Hyman Minsky showed how business conditions could be expected to alternate between boom and bust given some assumptions about the flow of money and credit. We know reasonably well how to perform this type of analysis, but we do not know how to analyze the decision-making process that will lead to economic structures more or less prone to boom-and-bust cycles.

Conclusion

Can economics be rationally understood as a mathematical science based on empirical data (if one assumes that we have gathered the data), or is the evolution of our economy irrational, driven by unpredictable black swans? The answer is threefold. First, we have powerful mathematical and computational tools to use for understanding our economic systems. Second, these tools are ultimately different from those of the physical sciences because economic systems are inherently uncertain; the tools of mathematical physics are not well suited for handling situations where noise prevails over information. Third, we do not yet have the conceptual and mathematical tools for understanding how economies and human societies at large self-organize. Developing this level of understanding will require conceptual breakthroughs. But the challenges involved in the development of human knowledge over the past 25 centuries have been no less daunting, and thinkers will eventually rise to this challenge as well.

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