Where does Econophysics fit in the Complexity Revolution?

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Abstract

A revolution is occurring in economics that is changing its scope and method. I call it the complexity revolution. The question I explore in this paper is: Where does econophysics fit in that revolution? I argue that the changing methods generally associated with the term econophysics are occurring because of advances in analytic and computational technology, and are not uniquely attributable to integrating physics and economics. Thus, using the term "econophysics" is likely to mislead people as to the nature of the complexity revolution. That complexity revolution involves an exploration of envisioning the economy as a complex evolving system driven by often unintended consequences of actions by purposeful agents. It is a vision that is more related to biology than to physics, and, at this stage of its development, is better thought of as an engineering revolution than a scientific revolution.

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A revolution is occurring in economics. I call it the complexity revolution. Almost twenty years ago (Colander 2000) I predicted that in 50 to 100 years when historians of economics look back on the millennium, they would classify it as the end of the neoclassical era in economics and the beginning of the complexity era of economics. I stand by that prediction. The question I address in this paper is: Where does econophysics fit in that revolution?[1]

Before I turn to that question, let briefly summarize what I mean by the complexity revolution in economics.[2] It is an expansion of the scope of economics to consider issues, such as complex dynamics, and semi-endogenous tastes and norms, that previously were assumed fixed. It is a movement of economics away from a primary focus on issues of allocation, and toward a focus on issues of formation. As is true of many revolutions in academic fields, in real time, complexity economics is as much an evolution as a revolution. By that I mean that it does not negate the current standard economics but instead expands on it, formally considering issues that earlier economists found too difficult to deal with scientifically. Complexity economics incorporates standard economics; it sees what are often called neoclassical models as relevant under appropriate circumstances.

The revolutionary aspect of the ongoing changes in economics that make up the complexity revolution will only become apparent over long periods of time. They involve a broadening of assumptions and methods--a broadening that has been made possible by advances in computational and analytic technology. As analytic and computational technology improved economists found it possible to move away from the holy trilogy of rationality, selfishness, and equilibrium, and replace it with a broader, but much more difficult to formally analyze, foundation of purposeful behavior, enlightened self-interest, and sustainability.

The evolutionary nature of the complexity revolution is highlighted even more because the ideas behind the complexity revolution are not new ideas. Economists, from Adam Smith on, have long believed that the economic system evolves in complex ways, and that that evolution needs to be taken into account in both theory and policy. It isn't surprising that Darwin got the inspiration for biological evolution from Malthus and that complexity themes can be found throughout Classical economists' writing. The question Classical economists faced was: how does one reasonably study that complexity within economic science, given the limited analytic and computation and statistical tools available. Classical economists resolved the problem by

[1] Most economists don't recognize the revolution because, looked at in real time, it is almost impossible to see since it, like most revolutions is actually a collection of numerous small changes, that seem to be almost imperceptible natural evolutions from the (changing) perspective of an economist at the time. The revolutionary nature of evolutions only becomes apparent when looked at from a distant perspective. It is only 50 or 100 years from now that the aggregate combination of the small changes will come into focus, and show themselves as a major shift in thinking worthy of being called a revolution.

[2] I do not call the complexity revolution a paradigm shift, because I do not see standard economics as having a paradigm organized around general equilibrium theory, which is the way it is usually presented. Complexity is not an alternative to general equilibrium; it is a complement to it. One can believe that general equilibrium theory is a useful model, and the best that we can analyze formally, and also believe that the economy is a complex evolving system, and that we should be working on developing other models that capture various aspects of that evolution.

dealing with complexity issues verbally, placing much of economics—including all aspects of economics dealing with policy--outside of the pure science of economics but inside of the broader study of economics. So Classical economists saw different branches of economics each with their own methodology (J. N. Keynes, 1891).

That Classical era ended in the beginning of the 20 century, as economists discovered a way of formally modelling highly complicated (but far from formally complex) systems using multivariate calculus. As they did, they became enamored with the enormous power of the constrained optimization model to shed light on economic problems of allocation, and in thinking about the workings of an interconnected economy. Neoclassical economics centered economic thinking on that model and pushed Classical economics' broader complexity themes to the periphery.[3] Over the next century, economics explored that constrained optimization optimal control model, eventually arriving at modern dynamic stochastic optimal control models, behavioral game theory models, and algorithmic models that currently form the basis of modern economic theory. In that period the constrained optimization model became economic theory, rather than just one of the many models that economics used. Unfortunately, the usefulness of the constrained optimization models to policy was limited by their strict assumptions—if the interactions became too complex for an analytics or the computational methods available to researchers, as they often did, good theorists admitted that the model could not be applied. They admitted that, however, generally in footnotes that were too often forgotten in the textbook economics that lay people and undergraduates learn, and in policy discussions.

Since physicists had explored similar constrained optimization models, this period has been described as a period of the importation of physics into economics. Phillip Mirowski (1989) describes the early importation as being driven by physics envy. He argues that neoclassical economics showed contempt for the history of economics, uncritically applying models and attempting to upgrade the scientific status of economics by using models developed in physics to describe economics. This description colors many economists' interpretation of the term, econophysics. They see it as the wholesale importation of physics theory into economics, whether it fits or not.

I see this period differently from Mirowski. Yes, there were some economists who tried to closely connect physics' models with economic theory. But this was not a majority of the economists, who had little concern for a formal theory of value. They were happy with an informal theory of price. Following Marshall, they saw economic theory and models as simply tools for thinking about policy problems, not as rigid statements of truth. Policy used formal theory, but was not based directly on formal theory, because they knew the assumptions didn't match. It was for that reason that they separated economic policy analysis from economic science. These Marshallian economists used the general equilibrium model, and the physics model related to it, as a way of capturing the connections between sectors of the economy, but otherwise making little difference to their wider worldview, which was evolutionary and

[3] The consistency of neoclassical economic models with complexity was not recognized by many economists of the period, which is why many observers talk about a neoclassical paradigm. In my view, that is a mistake, While, as often happens, in that development many economists became a bit too enthralled with Walrasian general equilibrium model, applying it where it didn't apply, many did not; they saw it as useful in some instances, not as a description of reality. The history of 20th century economics is a struggle to discover where the constrained optimization model fit and where it didn't.

institutional. Most economists of the time had little concern about the science in the formal sense that Mirowski is describing.

The limitations of the general equilibrium model were quite well known and understood by these theorists. For appropriately structured functions, the model worked, but there was no formal claim that those functions chosen for tractability purposes matched the real world. These limitations were listed in the footnotes, which provided numerous rabbit holes down which the economy could slide, pushing it into uncharted territory.[4] The complexity scientific revolution is in many ways simply the exploration of the implications of these footnotes for economic theory; it involves the charting of these rabbit holes and the integration of insights gained by their exploration into policy.

Throughout both the classical and neoclassical period, the idea that remained central to economics was that incentives are important—that the appropriate methodology is to develop models of purposeful agents and to use those models to both understand, and design policy for the economy. The neoclassical Walrasian general equilibrium model guided not only the science of economics, but also applied policy thinking. The constrained optimization model provided a policy framework that was useful in thinking about policy on the firm level (management theory), and at the societal level (market failure theory). But there was a negative side effect of that discovery—as opposed to seeing the constrained optimization policy frame as one of many policy frames, the constrained optimization policy frame became the only frame that economists used— policies that didn't fit that frame were not explored or discussed. This left out significant types of policy—for example, policies that involved endogenous tastes; policies designed to deal with transitional problems in non-linear dynamic systems, policies that involved significant distributional effects, or policies that relied on people's civic nature. The complexity revolution changes that. It opens up economics to the exploration of a much wider set of policies. That expanded scope is what I see as one of the most important aspects of the complexity revolution.

In many ways complexity economics can be seen as a return to those parts of Classical theory that were comfortable with viewing the economy as a complex evolving system. What's different is that the questions that Classical economists had to deal with verbally can now be approached formally because we now have better analytic and computational tools.

Econophysics

What today goes by the name econophysics is part of that complexity revolution. Econophysics has a number of different, but interconnected, strains. One involves the expanded use of statistical mechanics in economics, which leads to using non-linear models to think about both the workings of the economy and about policy. It is the exploration of the rabbit holes that previously were assumed away in footnotes. Its goal is to provide a much richer understanding of dynamical systems, and the fine line between chaotic and self-organized systems. This strain of econophysics is a natural evolution of standard economics made possible by advances in analytical and computational techniques. Like the earlier connection between physics and

[4] The rabbit holes were especially important when dealing with macro theory issues; in macro rabbit holes were everywhere, which is why many economists, and all complexity economists, were dismissive of DSGE macro, which assumed away rabbit holes, and related far too simple general equilibrium models to applied macro policy analysis.

economics, it relates to physicists because they have faced similar issues in their exploration of complex systems.

A second related, but more distinctive, strain involves a challenge to economists' method of building models based on purposeful agents. This strain of econophysics replaces purposeful agent models with non-purposeful agent models, in which agents are similar to atoms; they might have determinant behavioral characteristics, but they do not have purposeful behavior. This strain of econophysics explores system properties that do not depend on the purposeful actions of agents within the system. This way of integrating physics thinking about the economy and the social system into economics actually developed long before the term econophysics developed, and can be traced back to Aguste Comte and St. Simone who talked about social physics (Iggers, 1959). More recently social physics has been explored by Serge Galem, under the name *sociophysics*, (Galem, 2012) which he defined as "the use of concepts and techniques that are taken from statistical physics to investigate some social and political behavior" (Galem; xviii). In these non-purposeful agent models, aggregate results will be the same independent of agent's purposeful actions, including policy actions. Aggregate results are determined by statistical properties of systems not by the decisions made by agents in the model.

There are numerous phenomena that seem to fit such models. For example, in earthquakes, there are aftershocks that can be predicted with reasonable certainty. Similarly, after a financial crisis, there are aftershocks, suggesting that certain aspects of financial crises are systemic, and independent of specific individual agent actions. This strain of econophysics is quite distinct from neoclassical economic thinking, although not from economic thinking considered over a longer period of time.[5]

A third strain of research that is often included under the name econophysics is agent based modeling. This approach is quite different than the non-purposeful agent approach. Instead of assuming nonpurposeful agents, it assumes purposeful agents, and offers a way to understand how complex systems of purposeful interacting agents evolve from the bottom up over time creating complex systems when one might expect chaos. Whereas zero intelligent agent models are statistical models without purposeful agents, agent based models are inherently game theoretic models exploring how purposeful agents' interactions leads to unintended results.[6]

Concerns about the Econophysics Moniker

I see each of the three strains of econophysics as important branches of the complexity revolution, but I shy away from using the econophysics moniker for a number of reasons. The first is that econophysics will likely be misunderstood by many because of its early connotations emphasized by Mirowski. To many economists, the term, econophysics, conveys an attempt by

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[5] Earlier economists noted empirical regularities that seemed to occur in numerous distinct systems, and that could be captured by power laws. For example, Pareto observed that income distribution seemed to follow certain patterns, and what came to be known as Pareto's Law--the conclusion that 80% of the wealth was held by 20% of the people--was part of Classical economic thinking. This was simply an observation, and he did not extend the reasoning to conclude that economist's core models should not include purposeful agents.

[6] As purposeful agents explore and learn to control a system, it is possible that the systemic importance of purposefulness is reduced, as developed systemic intelligence (what is generally called artificial intelligence) reduces the systemic role of purposeful behavior. The end state of evolutionary models of purposeful agents may be a system that can be best captured by models of non-purposeful agents.

economists to ape physics; they associate it with a goal of reducing economics theory to a set of fundamental equations similar to the fundamental equations of physics. That is not the complexity revolution. The complexity revolution is the opposite; it sees understanding of complex systems coming about from a bottom up study and explores how simple behavioral rules can lead to highly complex seemingly ordered systems.

A second reason I shy away from the econophysics moniker is that it conveys a sense that physics and economics are more related than they are. For economists, intention and the purposefulness of agents are important; for most of physics, its fundamental building blocks do not have intention. Atoms are not assumed to have free will. Thus, physicists may be exploring agent based models, but that exploration has little connection to the fundamental equations of physics, nor to the attempt of theoretical physicists to capture physical reality in a set of simple equations. In a complex evolving system the goal is to capture an evolving reality in a set of simple behaviors that agents follow.

If anything, agent based modeling represents economist's, not physicist's, thinking about reality—purposeful agents are the driving force. If physicists are using agent based models, it is economics influencing physicist's thinking not the other way around. What if those strings that underlie matter have purpose—it would make theoretical physics much harder to do. Von Neumann and Morgenstern (1944) developed a new math—game theory—to study systems involving purposeful agent behavior. Agent based models are an attempt to study the aggregate implications of games. Agent based modeling is much more economics borrowing from evolutionary biology, than it is borrowing from physics. So, thinking of agent based modelling, a better term than econophysics would be econobiology.

A third reason why I shy away from the term, econophysics, is that it conveys a sense that economics is being uniquely affected by the complexity revolution. That isn't true; as I stated above, all social sciences are part of the complexity revolution. This means that a better name for the changes that are occurring would not refer to economics, but would refer to all the social sciences. So the more appropriate moniker would be sociophysics, not econophysics. Combining these two objections together, and we arrive at the moniker, sociobiology, as a more descriptive term to describe the historical roots of the complexity revolution in economics.

A fourth reason why I shy away from the term econophysics is that it conveys a sense that the complexity revolution came to economics through physics. That, in my view, isn't correct. The complexity revolution in economics would have happened even if physicists hadn't been involved with the economics. Sciences tend to evolve together, because they are influenced by the same advances in analytic and computational technology. The complexity revolution is occurring because of the increase in data and computational methods for extracting information from data, not because economists learned something new from physicists.

While some of the techniques associated with complexity may have passed into economics through physics, that was most likely the result of particular circumstances. Specifically, in the 1980s the governmental defunding of a number of programs in physics as national priorities changed. In an economist's model of purposeful action, it isn't surprising that Santa Fe, where significant initial work in complexity took place, was only a short distance from Las Alamos, which was decreasing its work in atomic energy. As money for physics research dried up, the physicists naturally looked elsewhere where they could use their expertise to earn a living. Economics and finance were obvious areas since they were better funded. It is also not by accident that the initial transfer occurred in the area of finance, not economics. In finance the needed mega data were available, making it possible for physicists to ply their trade. Physicists initially made fewer inroads into other areas of micro or macroeconomics, since the needed mega data did not exist. Only now, is the mega data in other areas becoming available, expanding the ability of physicists to explore economics issues with the data intensive methods used in physics.

A final reason I see the econophysics moniker as not capturing the changes occurring in the complexity revolution is that it suggests that the changes are occurring in the science of economics, whereas I see the largest changes as occurring in applied policy economics. The complexity policy revolution is leading the complexity scientific revolution; it is reducing the role of formal theory in guiding policy. It is seeing policy as more related to biology than physics. Biology doesn't have a formal general theory. It uses evolution as its informal general theory, but there are lots of debates about how, and at what level, that evolution takes place.

Answering the relevant questions scientifically is empirically difficult, so policy analysis often precedes theory, and is based on educated common sense, not theory. Complexity economics, similarly, has evolution at its worldview, and bases policy on educated common sense. It sees general equilibrium theory is as useful in guiding aspects of policy, but not as a foundation for all policy. Thus, a complexity worldview is quite consistent with the continued use of general equilibrium theory as economics' primary formal theory. What complexity changes is the importance given to that formal general theory.

Currently many economists give general equilibrium theory enormous importance. For example, Franklyn Fisher (Fisher, 2011) writes that the welfare theorems of general equilibrium provide "rigorous justification for the view that free markets are desirable." He continues that "It is not an overstatement to say that they are the underpinnings of Western capitalism." … "So elegant and powerful are these results (g.e.'s exploration and proofs of existence, uniqueness, and optimality) that most economists base their conclusions upon them and work in an equilibrium framework—as they do in partial equilibrium analysis."

A complexity economist would fundamentally disagree with those statement. He or she might see general equilibrium as an interesting thought experiment, but not as a complete theory of the economy, or as a guide to much in the way of policy thinking. General equilibrium theory would be seen as close to irrelevant to many policy issues because it doesn't capture the complex dynamic evolving nature of the economy. For a complexity economist, there are multiple models that should be guiding policy, not just one.

This multiple model approach makes the complexity revolution far less related to physics than to engineering. For complexity economists, policy doesn't follow from formal theories, it follows for solving problems practically without a formal general theory. Policy precedes theory, and the complexity revolution is having its biggest impact on economic policy. The econophysics moniker misses this dimension of complexity. If one wanted to capture the policy dimension of the complexity revolution, the complexity revolution would better be better described as revolution in engineering, rather than in science. So perhaps it should be called econoengineering, or socioengineering, not econophysics.

Unfortunately, socio-engineering has negative connotations. It is associated with delusions of control, and all types of grand unworkable schemes. Classical economists from Smith on, were dubious about such control because they saw the economy as a complex evolving system. Complex evolving systems are not controlled by policy; they are only influenced by it. Thus complexity policy is not the economics of control, but the economics of influence. So it involves a quite different type of social engineering than the socio-engineering that earlier economists had in mind. Complexity socio-engineering does not involve attempts to control the economy and society without a recognition of the economy's complexity.[7] Complexity policy is modest in its goals and expectations of what can be achieved. Instead of trying to control, complexity policy is directed much more at creating an environment in which agents are given the freedom to arrive at policy solutions on their own, from the bottom up. (Colander, 2015; Colander and Kupers, 2015)

The bottom line: the changes that are occurring in economics associated with the term econophysics are important, but the term, econophysics, is probably not the best way to classify them.

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[7] Karl Popper (1971) differentiated utopian social engineering from democratic social engineering which he said had to be conducted piecemeal. The complexity approach to social engineering follows Popper, but because it directly recognizes the complex system nature of the economy is even more cautious about implementing policy.