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The Origin of Wealth: Evolution, Complexity, and the Radical Remaking of Economics. By Eric D. Beinhocker. Boston: Harvard Business School Press, 2006. xvi, 527. $29.95. ISBN 1–57851–777–X.

In this broad-ranging book, Eric Beinhocker defends a vision of the economy as a *complex adaptive system.* The theory that explains the operation of the economic system he calls Complexity Economics. The *Origin of Wealth* is a frontal attack on neoclassical economic theory. Beinhocker recognizes the successes of this theory, but locates them in the past. The combined aridity of classical game theory, in which there have been no new insights for almost twenty years, and general equilibrium theory, which has produced nothing of general interest since the consolidation of existence theorems in the 1950s, accounts for the current eclipse in the status of pure theory in the eyes of many contemporary economists. For such-minded individuals, Beinhocker has a message. “Economics can do better,” he says, “it’s time to move on” (p. 23). Some will dismiss this book because Beinhocker does not provide a workable analytical alternative to the neoclassical model. He should not be dismissed since the market economy is, in fact, a complex adaptive system, a fact that materially alters the analytical tools best deployed to model economic behavior. Indeed, some of the appropriate tools remain to be invented.

From its characterization as a complex adaptive system, it follows that the market economy follows an *evolutionary dynamic.* It is well known in evolutionary biology that one can treat genetic and cultural evolution using the same analytical tools (including the same set of differential equations, the so-called replicator equations), and even combine them creatively in gene-culture coevolution (Luca L. Cavalli-Sforza and Marcus W. Feldman 1973; Peter J. Richerson and Robert Boyd 2004). Beinhocker adds that institutions, including firms, also evolve, as does technology and business culture.

Complexity Economics

Complexity economics is in a sense a mirror inversion of neoclassical theory. Beinhocker favorably quotes Axel Leijonhufvud, who remarks that neoclassical theory models “smart people in unbelievably simple situations,” while the real world involves “simple people [coping] with incredibly complex situations” (p. 52). What is the complex economy? For one thing, the complex economy is never in equilibrium, but is constantly subjected to shocks, both exogenous and endogenous, that affect its short-term movements. There are frequent local nonlinear resonances that lead to significant deviations of economic variables (prices, quantities, wages, asset prices) from their equilibrium values even in the absence of strong or systematic perturbations to the system. We see such deviations in many economic time series, which often have the characteristics of the power laws of complex systems, as opposed to the Gaussian distributions of neoclassical theory (J. Doyne Farmer and Fabrizio Lillo 2004).

Beinhocker stresses a second characteristic of the complex economy: the Law of One Price fails (pp. 61–62). For instance, Beinhocker notes that in the European Union, the standard deviation of prices rose from 12.3 percent in 1998 to 13.8 percent in 2003, despite the extensive dropping of trade barriers and movement to a common currency over this period.

A third characteristic of complex adaptive systems is that they rarely, if ever, achieve the sort of optimality that can be attained in simple engineered systems. For instance, since economies are rarely in equilibrium, most production, trade, and consumption takes place out of equilibrium and, hence, is Pareto-suboptimal, at least when measured against a complete information Walrasian economy that has somehow attained equilibrium.

There have been notable contributions to complexity economics in other areas in recent years. These include W. Brian Arthur’s work on increasing returns (Arthur 1994); H. Peyton Young and

Mary A. Burke's analysis of crop sharing (Young and Burke 2001); evolutionary models inspired by Richard R. Nelson and Sidney G. Winter (1982) and Geoffrey M. Hodgson (1998); William A. Brock and Stephen N. Durlauf's study of social interaction (Brock and Durlauf 2001); Edward L. Glaeser, Bruce Sacerdote, and Jose A. Scheinkman's treatment of crime (Glaeser, Sacerdote, and Scheinkman 1996); Samuel Bowles's treatment of institutional evolution (Bowles 2004); Robert Axtell's study of firm size (Axtell 2001); Alan Kirman and his colleagues models of financial markets (Hans Follmer, Ulrich Horst, and Kirman 2005); and models of the evolution of other-regarding preferences (Herbert Gintis 2000b; Bowles, Jung-Koo Choi, and Astrid Hopfensitz 2003) and the agent-based simulation of general equilibrium and barter exchange (Gintis 2006a; Gintis, 2006b). Leigh Tesfatsion and Kenneth L. Judd (2006) is a comprehensive overview of computational methods in complexity economics.

Five Big Ideas in Complexity Economics

Beinhocker offers the following useful summary of the differences between neoclassical theory and Complexity Economics (p. 97).

(A) Dynamics: The complex economy is thermodynamically open, dynamic, nonlinear, and generally far from equilibrium, whereas the Walrasian economy is thermodynamically closed, static, and linear in the sense that it can be understood using algebraic geometry and manifold theory.

(B) Agents: In the complex economy, agents have limited information and face high costs of information processing. However, under appropriate conditions, they evolve nonoptimal but highly effective heuristics for operating in complex environments. There is no assurance that when faced with novel environments, individuals will shift efficiently to new heuristics. In the neoclassical economy, by contrast, agents have perfect information and can costlessly optimize.

(C) Networks: Agents in the complex economy participate in sophisticated overlapping networks that allow them to compensate for having limited information and facing formidable information processing costs. In the Walrasian economy, agents do not interact at all. Rather, each agent faces an impersonal price structure.

(D) Emergence: In the complex economy, macroeconomic patterns are emergent properties of micro-level interactions and behaviors in the same sense as the chemical properties of a complex molecule, such as carbon, is an emergent property of its nuclear and electronic structure or that thermodynamics is an emergent property of many-particle systems. In such cases, we cannot analytically derive the properties of the macro system from those of its component parts, although we can apply novel mathematical techniques to model the behavior of the emergent properties. In the case of the complex economy, these higher level modeling constructs are currently largely absent, although agent-based modeling may provide the data needed to develop the appropriate mathematical tools. By contrast, the Walrasian economy has no macro properties that cannot be derived from its micro properties (for instance, the First and Second Welfare Theorems).

(E) Evolution: In the complex economy, the evolutionary process of differentiation, selection, and amplification provides the system with novelty and is responsible for the growth in order and complexity. In the Walrasian economy, there is no mechanism for creating novelty or growth in complexity.

Evolutionary Economics

Joseph Schumpeter (1934) and Nelson and Winter (1982) are among the several leading economists who have proposed an evolutionary theory of institutional development. Such approaches have been slighted by neoclassical theorists. Beinhocker stresses that in Complexity Economics the treatment of organizations, markets, and economies as subject to an evolutionary process is not meant to be an *analogy* with biology, but rather a *literal description* of dynamical processes in the economy (p. 187). "Evolution," he concludes, is "a process of sifting from an enormous space of possibilities . . . There is no foresight, no planning, no rationality, and no conscious design. There is just the mindless grinding out of the algorithm" (p. 198).

This description applies well to institutional and organizational development, cultural change, and even scientific discovery. The evidence for this view is that almost all attempts at technical or institutional innovation fail, and few individuals are responsible for more than one successful innovation. How, then, are great thinkers possible? When asked how he was able to make so many discoveries, Linus Pauling replied: "You must have lots of ideas and just throw away the bad ones." Great thinkers for the most part simply are attuned to generating mutant ideas, they evaluate more effectively the prospects for a new mutant idea, and discard more rapidly the defective mutations. A similar argument likely obtains for technical change, institutional innovation, and product innovation.

Imitation and Learning

Imitation is at the very center of biological evolution since offspring inherit the genes of their parents. Imitation is also at the heart of cultural evolution. Indeed, the replicator equations for cultural evolution—the same equations that hold for genetic evolution—are derived by assuming individuals with low-payoff strategies switch with some positive probability to the strategies of more successful agents, with a probability that is increasing in the difference of the payoffs (Gintis 2000a). While there have been a few contributions to the economic literature on behavioral change through imitation (John Conlisk 1988; Sushil Bikhchandani, David Hirshleifer, and Ivo Welch 1992), and technological diffusion is included in macroeconomic modeling, neoclassical theorists considers the notion nonstandard. Rather, economics has traditionally treated learning as process of individual data gathering and experimentation. The most plausible explanation of this bizarre prejudice is simply disciplinary cultural inertia. In fact, the human capacity to imitate is one of the most important and virtually unique aspects of human cognitive ability (Michael Tomasello et al. 2005).

Imitation acquires its importance from the fact that in an evolutionary context most mutations are deleterious. An agent is thus more likely to improve his position by imitating a successful other, rather than experimenting personally. "Technological evolution," says Beinhocker, "is not a mere metaphor. It is the result of humandkind's deductive-tinkering search through the near infinite possibilities of Physical Technology space. The nature of the process of differentiation, selection, and replication in this substrate is different from that of biology, but is an evolutionary process nonetheless" (p. 259).

A New View of Markets

Neoclassical theory has a genius for hijacking terms from everyday discourse and turning them analytically into their virtual opposites. Consider, for instance, the term *competition*. The American Heritage dictionary give several meanings to the term: the act of competing, as for profit or a prize; a test of skill or ability; rivalry between two or more businesses striving for the same customer or market; the simultaneous demand by two or more organisms for limited environmental resources, such as nutrients, living space, or light. In the perfectly competitive Walrasian model, all agents are price-takers, so there is no competition at all in the Walrasian economy in any of the above senses. Indeed, perfect competition is precisely a situation in which individuals have *no* effect on market outcomes.

Similarly, a *market* in the Walrasian model is precisely *not* a market in the ordinary sense of an institution mediating the exchange of goods. Rather, the Walrasian market consists of a centralized pricing agent (the "auctioneer") who calls out prices, determines how much of each good would be forthcoming given these prices, and adjusts the prices until excess supply in all markets is zero. Only at this point does exchange occur, and it apparently takes the form (I say "apparently" because the process of reallocating goods once prices are set is never described) of agents dumping their supply goods a certain collection points and picking up their demand goods at other collection points. In no sense, then is the "market" of general equilibrium theory akin to the markets in which agents engage in real competition and exchange. One of the ironies of history is that, if the Walrasian model were plausible, there would be no need for real markets, real competition, or even capitalism itself. Socialism, consisting of a bureau of technocrats implementing the Walrasian auctioneer, could harness the general equilibrium system to a system of public ownership of wealth. This aspect of the general equilibrium model was clearly understood by Oskar Lange, F. M. Taylor, and Enrico Barone in their famous defense of market socialism (Barone 1935; Lange and Taylor 1938). This defense was so successful that it induced Josef Schumpeter to predict the imminent demise of capitalism (Schumpeter 1942), and led Friedrich von Hayek to rethink, and finally abandon, his commitment to neoclassical theory (Hayek 1945).

Ironically, however, the neoclassical has generally been an unrelenting defender of capitalism, and by casting his lot with real-world "competition" and real-world "markets," it has thereby made a strategic choice that ensured victory over the Socialists, the Syndicalists, the Institutionalists, the Populists, the Anarchists, the Communalists, and the other various movements that proposed alternatives to capitalism. Nevertheless, neoclassical theory is quite incapable of explaining what role "competition" and "markets" in fact play in a successful economy since the terms refer to completely different concepts in Walrasian theory and in economic reality.

Game theoretic modeling of market competition comes close to explaining why this economic institution is so central to the success of an economy. "Competition among agents," noted Bengt Holmstrom (1982), "has merit solely as a device to extract information optimally. Competition *per se* is worthless." In other words, it is only when we have *incomplete* information that real markets are valuable; in the complete information context of the general equilibrium model, they are otiose.

Beinhocker does not make the game theoretic argument, but it is implicit in his evolutionary defense of market competition. "An evolutionary view of the economy leads one to agree . . . that markets are good, but for some very different reasons [from those of Walrasian Economics]" (p. 294). Markets are, in his view, "an evolutionary search mechanism. Markets provide incentives for the deductive-tinkering process of differentiation. They then critically provide a fitness function and selection process that represent the broad needs of the population . . . Finally, they provide a means of shifting resources toward fit modules and away from unfit ones, thus amplifying the fit modules' influence." He explicitly recognizes that the *differentia specifica* of markets cannot be captured by neoclassical theory: "Markets win over command and control, not because of their *efficiency* at resource allocation in equilibrium, but because their *effectiveness* at innovation in disequilibrium" (p. 294).

Politics and Policy

Throughout much of the world, the pitched ideological and political battles between Right and Left over economic policy are a thing of the past. On the Left, there is no serious movement for the abolition of private property or even the nationalization of basic industries. Unionionism is increasingly confined to the government sector, and socialist policy is espoused only in a couple of oil-rich countries. Liberal Keynesianism is dead in an era where conservatives are prone to run deficits and liberals to piously admonish such policy as reckless and short-sighted. On the Right, the notion that the state should be limited to protecting private property is maintained, against all evidence, only by a radical fringe. Complexity Economics is not responsible for defusing Right- Left polarities in policy circles. Ineffectiveness was probably the real culprit.

Nevertheless, as Beinhocker stresses (p. 416), there remain deep ideological divides of a Right–Left nature that are affected by the considerations analyzed in The Origin of Wealth. One concerns human nature. "If one digs deeply into the Left–Right divide . . . one finds two conflicting views of human nature. On the Left is the view that human beings are inherently altruistic; that greed and selfishness stem . . . from the construction of the social order; and that humans can be made better through a more just society. . . . On the Right is the view that human beings are inherently self-regarding and that the pursuit of selfinterest is an inalienable right. The most effective system of government is one that accommodates rather than attempts to change this aspect of human nature" (p. 418). Beinhocker asserts that behavioral game theoretic findings defuse this polarity by showing that both sides are wrong, and give us the materials for a far more nuanced and effective set of policy options than are envisioned in the Left–Right dialogue.

The second Left–Right divide is over the proper weight to be afforded to markets versus state intervention, the Left stressing market failure and favoring widespread state intervention, the Right stressing state failure and favoring strict constraints on intervention. The historical fact that strong states and strong market economies have coevolved suggests that *state intervention is an aspect of the economy as a complex adaptive system*, and the idea of a minimal state is simply a conservative fantasy. Conversely, the notion that the state can successfully supplant the market is incompatible with the importance of competition in the economy's evolutionary dynamic. However, a proper understanding of economic dynamics and human nature hold out the possibility of rendering state interventions, for instance in addressing poverty and environmental problems, considerably more effective and politically popular than hitherto possible.

Human Nature and Strong Reciprocity

Beinhocker stresses that behavioral economic research, in work pioneered by Ernst Fehr and Simon Gächter (1998), extended by Joseph Henrich et al. (2004), and summarized in Gintis et al. (2005) and Henrich et al. (2005), supports the notion that most individuals are not purely self-regarding in their social interactions within a group, but rather are a combination of *conditional cooperators,* who prefer to sacrifice personally on behalf of other group members, and *altruistic punishers,* who prefer to punish other group members who violate the group's cooperative norms. The case of both cooperation and punishment, individuals are willing to so behave even when there is no possibility of future material reward stemming from their actions—as is the case, for instance, in one-shot anonymous games in the laboratory and in the field. This has come to be known as *strong reciprocity* (Gintis 2000b), the adjective indicating that this goes beyond the sorts of mutual reciprocity based on enlightened long-term self-interest stressed in the theory of repeated games (Drew Fudenberg and Eric Maskin 1986).

The prevalence of strong reciprocity effectively undermines the Hobbesian view of human nature so dear to conservatives. But it conflicts with the notion of unconditional altruism favored by liberals on two counts. First, strong reciprocators are *conditional* cooperators who, in repeated but anonymous interactions, will generally withdraw cooperation if it appears that others are not reciprocating. Second, strong reciprocators will generally revert to self-interested behavior if the cost of cooperation becomes sufficiently high (James Andreoni and John Miller 2002; Uri Gneezy 2005). Moreover, both Left and Right have generally ignored the altruistic punishment aspect of strong reciprocity. Indeed, only carefully controlled laboratory studies have succeeded in isolating altruistic punishment as a "pure" motive rather than simply a statistical aberration or an attempt to establish a reputation as a hard bargainer. These studies suggest, by contrast with traditional political philosophies of both Right and Left that altruistic punishment may be the most potent enforcer of prosocial norms, both in the evolution of our species and in contemporary social life. Informal, decentralized sanction will normally be more effective in motivating prosocial behavior than bureaucratic juridical sanctions. "Leges," wrote Horace in the Third Ode, "sine moribus vanae" (laws without morality are useless).

Strong Reciprocity and Social Welfare Policy

Gintis et al. (2005) recently edited a volume the first part of which established the nature and modeled plausible evolutionary origins of strong reciprocity, and the second applied this model of human strategic interaction to several spheres of economic policy, including public support for the welfare state (Christina M. Fong, Bowles, and Gintis 2005). Beinhocker draws upon this example to illustrate the possible uses of strong reciprocity preferences in framing social policy.

The most widely accepted model of the demand for redistribution in neoclassical economics is the *median voter model,* which holds that each voter chooses a redistribution schema that maximizes his personal wealth (Kevin W. S. Roberts 1977). It follows that the redistribution implemented by majority-rule voting is that preferred by the median-income voter. Because the distribution of income is generally skewed to the right, voters and will therefore demand a positive level of redistribution. By contrast, a strong reciprocity voter will choose to redistribute towards individuals who are needy and deserving, and away from individuals who are rich or nondeserving. Fong, Bowles, and Gintis (2005) provide evidence strongly supporting the latter model of voter behavior.

Beinhocker concludes that to mobilize rather than offend "reciprocal values," redistributive policies should be contingent upon the moral standing of the recipients. For instance, to the extent that persistent poverty is the result of low wages and lack of educational opportunity, or is due to mental or physical defect beyond the control of the individual, a large majority of voters in the United States are prepared to redistribute in their favor. Similarly, a majority of individuals approve of policies that insure individuals against bad luck but not against the consequences of their own actions.

Many traditional projects of egalitarians, such as land reform and employee ownership, are consistent with reciprocity norms, as they make people the owners not only of the fruits of their labors, but more broadly of the consequences of their actions (Bowles and Gintis 1998, 1999 provide overviews based on principal–agent models). The same may be said of more conventional initiatives such as improved educational opportunity and policies to support home ownership. There is evidence, for example, that home ownership promotes active participation in local politics and a willingness to discipline personally those engaging in antisocial behaviors in the neighborhood (Robert J. Sampson, Stephen W. Raudenbush, and Felton Earls 1997). An expansion of subsidies designed to promote employment and increase earnings among the poor, suggested by Edmund S. Phelps (1997), would tap powerful reciprocity motives. Similarly, social insurance programs might be reformulated along lines suggested by John Roemer (1993) to protect individuals from risks over which they have no control, while not indemnifying people against the results of their own choices, other than providing a minimal floor to living standards. In this manner, for example, families could be protected against regional fluctuations in home values—the main form of wealth for most people—as Robert J. Shiller (1993) has shown. Other forms of insurance could partially protect workers from shifts in demand for their services induced by global economic changes.

The Philosophy of State Intervention

There are three philosophies of state intervention in America. Liberals generally believe that markets wreak havoc with people's lives and generate extreme income inequality, state intervention being the appropriate remedy. Conservatives believe that the market almost always produces efficient and just outcomes, so the state should be limited to protecting the rules of the game. Economists generally believe that both market and state failure are serious problems, and any proposed intervention must be thoroughly analyzed in terms of costs, benefits, and feasibility. Beinhocker argues that Complexity Economics offers a philosophy of state intervention that is distinct from all of the above.

"A complexity perspective," he asserts, "would distinguish between two types of government action. Policies that get the government involved in differentiating, selecting, and amplifying Business Plans would be seen as interfering in economic evolution . . . In contrast, policies that *shape the fitness environment* while leaving Business Plan selection and amplification to market mechanisms" are useful and even necessary (p. 426). This position is closest to that of the neoclassical economics view, except that Beinhocker's approach is more ecological in that many of the parameters involved in assessing the effect of an intervention on the fitness environment of the economy are interdependent. His conclusion that the "economic role of the state is to create an institutional framework that supports the evolutionary workings of markets" (p. 427) suffers from a certain vagueness, but may be workable in practice.

Economics for our Grandchildren

Since Beinhocker's wide-ranging intellect appears to touch on all subjects, it is surprising that he does not reconsider the model of personal well-being implicit in neoclassical economic theory. This model, based on the neoclassical utility function, proposes that happiness is getting more of what you want, and expending the least possible effort to do so. Both sides of this assertion are doubtful. A long line of economists, including Robert E. Lane (1993), Richard A. Easterlin (1995), Andrew J. Oswald (1997), Daniel Kahneman (1999) and Kahneman, Edward Diener, and Barry Schwartz (1999) have documented the negligible effect of material wealth on personal well-being for individuals above the poverty line. Similarly, there is a strong political economy tradition asserting the centrality of work in personal well-being and self-esteem (Bruno Frey, 1997).

There is a model of human well-being compatible with the notion that we humans are complex adaptive systems, endowed by our genetic constitution with certain capacities—cognitive, affective, psychomotor, aesthetic, and spiritual—and an individual well-being depends on the extent that we have developed these capacities and have the means of exercising them. Happiness, in this view, is not what you have, but what you are. Societies are judged, then, not on what material comforts they generate, but on the extent to which they foster the development of human beings fully capable of exercising their personal capacities.

Agent-Based Modeling of Market Exchange

My own foray into modeling general equilibrium as a complex adaptive system suggests that the Walrasian model will emerge delimited but enriched rather than replaced as a result of such research (Gintis 2006a; Gintis 2006b). General equilibrium theory captures important long-term historical aspects of a market economy, and many of the basic insights of the Walrasian model will be retained, albeit modified. Even in the long run, there will be a strictly positive rate of unemployment, supply will exceed demand, efficiency will be considerably less than 100 percent, and there will be other deviations from equilibrium due to incomplete information and other "frictions" amplified by local nonlinear resonances. Moreover, the Walrasian assumption that agents are price-takers, that complete contracts can be written for all important exchanges and can be costly enforced by a third party, are all unrealistic. Hence, the Walrasian system is a poor guide to micro-modeling economic transactions. In particular, the Walrasian assumptions concerning labor markets, capital markets, and consumer goods markets are misleading (Bowles and Gintis 1993; Gintis 2002).

My own recent work has taken the form of developing an agent-based model of a general equilibrium system with many sectors, firms and consumers, capital and labor, in which there is no public information (Gintis 2006a). The results are well described by Beinhocker. Prices in this system are private information, in the sense that each firm generates its own prices and must engage in costly search to discover the pricing strategies of its competitors. Moreover, each worker has his own private discount rate, disutility of labor, and reservation wage. and consumers discover favorable goods prices through using a search strategy. Major forms of change in this economy are that agents experiment with their own parameters and assess the results, and agents copy the behavior of others that have been more successful than themselves.

Perhaps surprisingly, my dynamical model of general market interdependence, which is clearly a complex adaptive system in the sense of Beinhocker, stabilizes rather quickly to a stationary distribution in which prices are *approximately* at their market-clearing values, profits are a*pproximately* zero, and the unemployment rate averages about 4 percent. But the devil is in the details. My economy exhibits "fat tails" with many large excursion from equilibrium, even in the absence of any systemic shock (see figure 1). Moreover, as Beinhocker describes in his discussion of the "Law of Supply and Demand," (p. 60), the general case is one in which firms experience excess supply for their product and have generally positive excess demand for labor, even while labor is in aggregate excess supply. This is illustrated in figure 2 for one of the sectors in my agent-based model of the economy. In effect, firms evolve by developing reaction functions to changing economic conditions that maximize profits, but not by solving complicated maximization problems with extensive knowledge of demand and supply conditions in all input and output markets, but simply by "muddling through" with judicious jiggling of their reactive behavior and occasional switching to a strategy of a better-performing competitor.

Like complex adaptive systems in general, my agent-based model does not achieve optimality. Average consumption reaches about 75 percent of Pareto-optimal consumption after about two hundred periods, and oscillates thereafter at between 72 percent and 80 percent efficiency (figure 3).

Finally, my model clearly exhibits the failure of the Law of One Price, as shown for a ten-sector economy in figure 1. Note that after about 100 periods the standard deviation of prices settles to an average level which persists throughout the 3,000 period run, punctuated by frequent price excursion of as much as 50 percent of the equilibrium price (which is unity for all goods, by construction). These excursions are not due to any systematic disturbance applied to the underlying model. Rather, they are local resonances that account for the some of the "fat tails" of stochastic variables in a complex economy.

The Economy is a Biological System

Beinhocker's critique of neoclassical theory includes the assertion that the economy is a biological system subject to the same sort of evolutionary dynamic as other sociobiological systems, but neoclassical theory models the economy as the solution to a set of equilibrium conditions. No one has successfully modeled a bee hive as the solution to a set of equilibrium conditions. Modeling the market economy, orders of magnitude more complex than a bee hive, as the solution to a set of equilibrium conditions is that much less likely to succeed. Neoclassical theory lacks explanatory power because it uses the theoretical tools of mathematical physics while ignoring those of mathematical biology, seeking the sorts

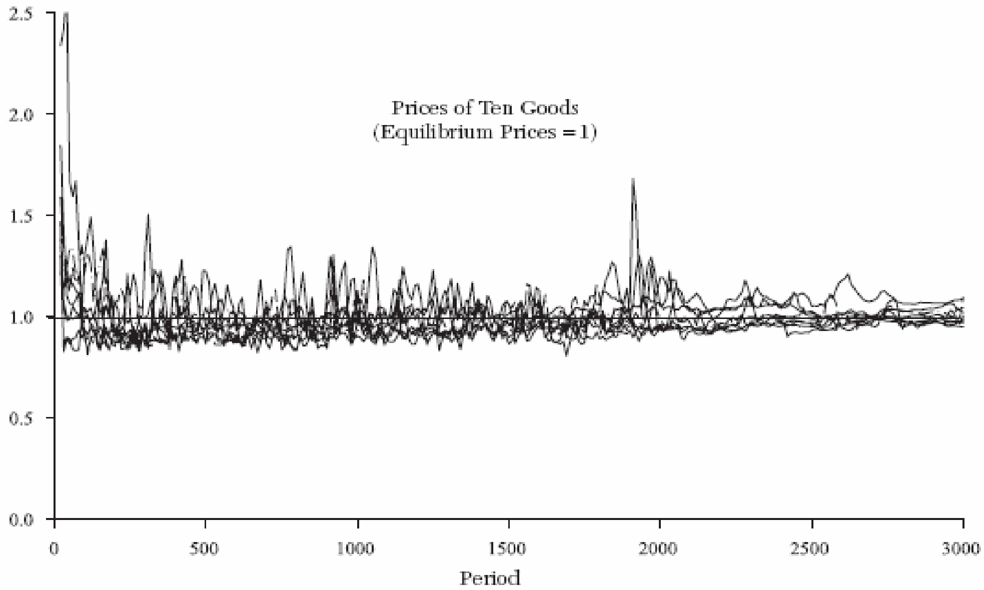

Figure 1. Sectoral Prices

Note that since conditions of production are the same in all sectors, relative prices are unity in equilibrium. Taken from Gintis (forthcoming-b).

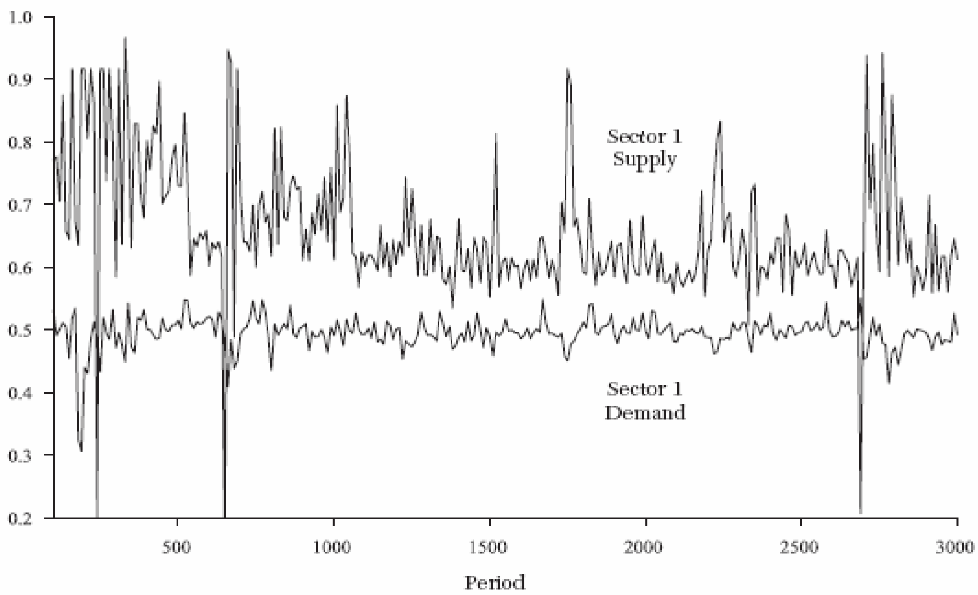

Figure 2. Demand and Supply in Sector 1 of a Multisector Economy

Note that there is considerable period-to-period volatility. Excess supply averages about 8 percent of average supply.

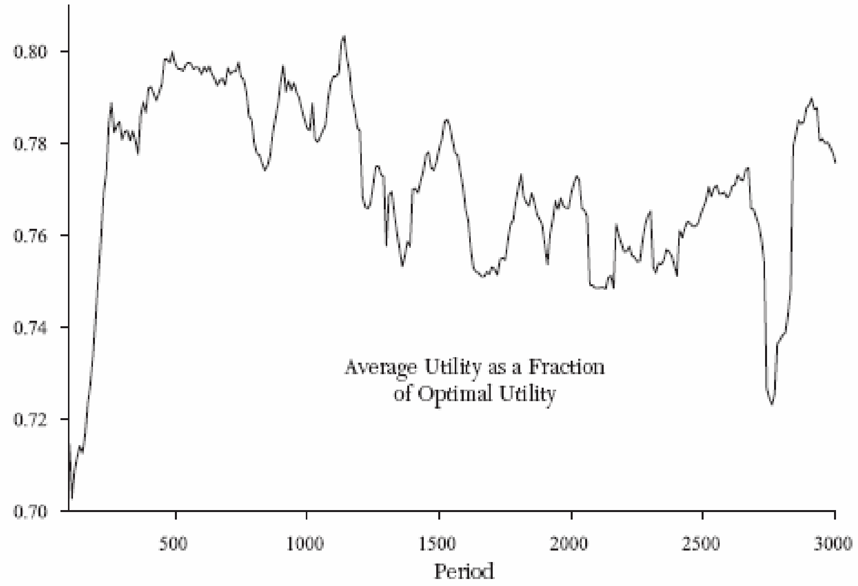

Figure 3. The Efficiency of the Simulated Economy

Note that, after only 100 periods, the system has attained nearly 79 percent efficiency. After 100 periods, average utility appears to be a random walk between 72 percent and 80 percent (the apparent declining trend in the figure is an artifact of truncation to 3000 periods).

of explanations relevant to electro-mechanical systems rather then evolved biological systems. The stunning success of modern physics and chemistry cannot be replicated in economics for one simple reason. Physical theory's success lies in modeling noncomplex, nonadaptive systems. The experimental method in physics is to create highly simplified laboratory conditions, under which modeling becomes analytically tractable. Physics is no more effective than economics or biology in analyzing complex real-world phenomena. The various branches of engineering (electrical, chemical, mechanical) are effective because they recreate in everyday life artificially controlled, noncomplex, nonadaptive, environments in which the discoveries of physics and chemistry can be directly applied. This option is generally not open to economists, who rarely have the opportunity of "engineering" economic institutions and cultures.

The recent success of behavioral game theory (Vernon Smith 1962; Charles R. Plott 1979; Colin F. Camerer 2003) suggests the great value of carrying out controlled laboratory experiments in economics, but in the absence of "economic engineers" who can reproduce laboratory conditions in the field, economic policy will surely never rival the scientific accuracy and objectivity of physics and chemistry.

Why is Neoclassical Theory Sui Generis Theorizing?

The unwillingness of neoclassical theory to deal with the complex adaptive nature of economic activity has led a generation of talented theorists to manifest a pervasive indifference to empirical relevance. Beinhocker does not attempt to explain this development, but it is important to do so if we are to move forward in economic theory. Therefore, I shall put forward my own understanding of this phenomenon.

In the natural sciences, theorists appreciate experimentalists because the latter provide the data that allow them to distinguish among competing models. Economic theorists, by contrast, are indifferent, or even actively hostile, to those who do controlled experiments. A typical example is the following opinion of Nobel prize economist Robert J. Aumann (Sergiu Hart 2005): "I have grave doubts about what's called 'behavioral economics' . . . most of behavioral economics deals with artificial laboratory setups . . . true behavioral economics does in fact exist; it is called empirical economics . . . In empirical economics, you go and see how people behave in real life, in situations to which they are used."

Neoclassical theorists are not threatened by "empirical economics" because the lack of controlled laboratory conditions makes it impossible ever to contradict the theory. Empirical economics is theoretically irrelevant, and hence perfectly safe. I call this retreat from explaining the world *sui generis theorizing,* by which I mean that theorists devise their own standards of adequacy that have nothing to do with an encounter with realworld phenomena.

Sui generis theorizing flirts with being unscientific. Some theorists defend their research agenda by claiming to be, or to be like, pure mathematicians. I am sympathetic to this position, but then what they do should not be taught as basic economic theory in Ph.D. programs, and a whole new branch of economic theory that does grapple with the real world should be fostered. This sorry situation of *sui generis* theorizing became clear to me in the summer of 2001, when I happened to be reading a popular graduate text in quantum physics, as well as a leading graduate text in microeconomics. The physics text began with the anomaly of black body radiation which was inexplicable using the standard tools of electromagnetic theory. In 1900, Max Planck derived a formula that fit the data perfectly, assuming that radiation was discrete rather than continuous. In 1905, Albert Einstein explained another anomaly of classical electromagnetic theory, the photoelectric effect, using Planck's trick. The text continued, page after page, with new anomalies (Compton scattering, the spectral lines of elements of low atomic number, etc.) and new, partially successful models explaining the anomalies. This culminated in about 1925 with Heisenberg's wave mechanics and Schrödinger's equation, which fully unified the field.

By contrast, the graduate microeconomics text, despite its brilliance, did not contain a single fact in the whole thousand page volume (actually, there were two references to facts, both in footnotes). Rather, the authors build economic theory in axiomatic fashion, making assumptions on the basis of intuitive plausibility or consonance with the principles of "rational action." This is *sui generis* theorizing at its most pure.

When the world does not conform to the models, microeconomic theory blames the world—information is *incomplete*, competition is *imperfect* or markets are *missing,* there are market *externalities,* or individuals are *irrational.* Implicit in such terminology is that there is another world (akin to the physicists frictionless world) in which information is complete, markets are pervasive, and the costs of information processing are zero. A bounty of excellent economic theory was developed in the twentieth century based on this assumption. But, this is all in the past. There is no such idealized world, nor is there any sense in which the economy "works better" as conditions approximate this ideal. We cannot understand a complex adaptive system by analyzing the system's behavior in the limit as the degree of complexity goes to zero.

Why did economic theory take this *sui generis* turn in the past few decades? The reason, I believe, is because of the phenomenal success of *sui generis* theorizing in the in the early post- WWII period. Let me first note that *sui generis* theorizing can be extremely productive even in the natural sciences. Some of Albert Einstein's greatest discoveries were *sui generis*, including special relativity, which follows from the constancy of the speed of light in inertial frames, and general relativity, which follows from the equivalence of inertial and gravitational mass and a thought experiment concerning the path of a light ray as viewed from an accelerating frame. Indeed, economists themselves developed two stunningly successful *sui generis* theories in the first half of the Twentieth century: decision theory and general equilibrium theory.

Decision theory is an archetypal case of a theory of great explanatory value developed on the basis of abstract theorizing alone. The creators of modern decision theory did not pore over reams of data before discovering their underlying unity. Rather, they drew out the implications of a few intuitively plausible axioms of rational choice (the most important being transitivity over the appropriate phase space). Yet decision theory is highly predictive, and when individuals deviate from its prescriptions, individuals are usually wrong (nonoptimizing) and the theory correct. Nobel prize winning psychologist Daniel Kahneman and his coworkers, among others, have shown that there are ample real-world deviations from the predictions of decision theory (Kahneman and Amos Tversky 2000), but these findings have enriched rather than undermined decision theory which stands as one of the most successful models in the behavioral sciences (Gintis 2006c).

The second major *sui generis* accomplishment was general equilibrium theory itself. Walras did not derive the building-blocks of his model from close attention to empirical findings. Rather, he noted that there were consumers, producers, products, raw materials, labor and capital, and prices. He put them all together in an appealing package leaving enough puzzles to solve for the next three generations of economists, culminating in the work of Debreu, Arrow, and their colleagues in the early post-WWII period.

It is reasonable to say, then, that an economic theorist coming of age in, say 1970, might have thought that *sui generis* theorizing is the best way to go. In fact, many took exactly this path, including those working on general equilibrium theory and game theory. But it has been virtually a dead end. The logical next step in decision theory was to extend the axioms to strategic interaction, which was the task of classical game theory. What theorists found was that *there is no way to accomplish this extension that has any logical or empirical plausibility.* This fact remains virtually unknown except among game theorists working in the interactive epistemology area, because the major results are of post-1990 vintage, whereas virtually every game theory text is based on earlier theory. Most important, economists expected a rational actor model justification of Nash equilibrium, despite the fact that B. Douglas Bernheim (1984) and David G. Pearce (1984) had shown that rationality justifies at best the iteration of strictly dominated strategies. Aumann and Adam Brandenburger (1995) provided sufficient conditions for Nash equilibrium, but these can be expected to obtain in only the simplest of situations.

The Failure of Sui Generis Game Theory

One of the chief embarrassments of classical game theory was its inability to explain why an individual would ever play a mixed strategy in a one-shot game. Since randomizing must be costly (for elementary information-theoretic reasons), and since all pure strategies in the support of a mixed strategy have equal payoff, a rational agent should never player a mixed strategy. Nor should he expect his opponent to play a mixed strategy. John C. Harsanyi (1973) developed the ingenious notion of "purification" to justify the mixed strategy assumption, but this only applies to a highly specialized set of games, and virtually never to repeated games where agents in a Nash equilibrium must play mixed strategies of the stage game. The current state of affairs is that evolutionary game theory provides a justification both of the Nash equilibrium concept and of the mixed strategy concept, but only in situations where a system has achieved equilibrium through an evolutionary dynamic (Gintis 2000a).

Finally, classical game theorists expected a justification of backward induction on rational actor grounds, and one was provided by Aumann (1995). However, few theorists accept this justification because it depends on implausible off-the-equilibrium-path reasoning. The fact is that human subjects rarely used more that two or three stages of backward induction, and this in no way violates the assumptions of rational action. The substantive achievements of behavioral game theory flow from the fact that it provides facts that can be used to build a theory of strategic interaction, whereas the *sui generis* methodology of classical game theory is powerless to do so.

The Failure of Sui Generis General Equilibrium Theory

Just as a 1970 theorist might have expected decision theory to generalize smoothly to game theory, a general equilibrium theorist might have expected that it would be feasible to add institutional realism to the general equilibrium model, and to flush out the dynamic properties of the model in a theoretically satisfying manner. Both of these expectations failed to materialize. It turns out to be a major mathematical *tour de force* to add even a small degree of institutional complexity to the general equilibrium model, and there has been absolutely no progress in providing a dynamic to a generalized model of production and exchange. Most embarrassingly, attempts to formalize the Walrasian tatonnement process have led precisely to complex nonlinear dynamics in which prices are, unlike in observable economies, generically chaotic.

Of course, if the Walrasian tatonnement process led to stability, this would give little comfort to general equilibrium theory. The idea of calling out prices and asking agents to reveal their demand and supply amounts is not only bizarre but completely lacking in incentive compatibility. Agents have no incentive to lie, of course, since in competitive equilibrium no individual makes a difference. However, they have no incentive to tell the truth either, and they have a strong disincentive to engage in the costly information-gathering required for an informed response.

Franklin M. Fisher (1983), in his masterful summary of the dynamics of general equilibrium, complained that there had been little progress in many years. It is now a quarter century later and there is still little progress (Donald G. Saari 1985, 1995)[1]

Conclusion

Economists are envious of the explanatory power of modern natural science, and rightly so. What we have tended not to notice is that these natural science disciplines base their success on creating conditions in the laboratory that *eliminate* complexity, thus permitting the development of analytical models with high levels of accuracy. The engineering disciplines then recreate these noncomplex conditions in everyday life, which accounts for the success of modern technology. We can partially follow the lead of natural science by studying social life in the laboratory under conditions favorable to analytical modeling. This is the path taken by behavioral game theory and agent-based modeling. We can even transport noncomplexity to the economy in special cases, such as devising sophisticated natural resource and bandwidth auctions. However, in general we must study the economy as a complex adaptive system directly—a formidable task indeed.

The virtue of this book is that it makes clear the nature of the beast, but it does not provide us with the tools to undertake its effective analysis. Developing these tools will be a formidable but exciting task.

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1 There has been progress in obtaining Walrasian equilibrium
as the limit of a barter process, but there are no dynamical implications of this research. See Douglas Gale

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