Hayek's Contribution to a Reconstruction of Economic Theory

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January 26, 2011

In his penetrating essay, "Theory and Experiment," Vernon Smith observes that in behavioral economics experiments, subject behavior often diverges from game theoretic predictions and asserts that minor fudging with theory is unlikely to solve our problems because "circumstances unknown to us" are responsible for the explanatory failures of neoclassical economic theory (Smith 2010). I deal precisely with these issues in *The Bounds of Reason* (2009a). My remarks here draw upon several themes from this book relevant to specifying a refocused research agenda for the study of human strategic interaction.

The core of economic theory is the rational actor model, which holds that individuals have preferences over outcomes, beliefs (called "subjective priors"), linking choices to the relative probability of alternative outcomes, and they maximize their expected payoffs given these preferences and beliefs, subject to whatever material, informational, and other constraints they face. Many observers consider the experimental work of Daniel Kahneman and others (Kahneman et al. 1982, Gigerenzer and Todd 1999) as destructive of the rational actor model. In fact their research has considerably strengthened the rational actor model's explanatory power, albeit at the expense of increasing its complexity (Gintis 2009a, Chs. 1,12). Most important, these studies have shown the value of modeling other-regarding preferences and virtuous behavior,as well as using heuristics that conserve on information processing and of including the current state (physiological, temporal, ownership) of the individual as an argument of the preference ordering.

1 The Rationality Assumption

Like other members of the Austrian school of economics, Friedrich von Hayek was a bitter critic of the German historical school, whose members eschewed the study

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of individual choice behavior in favor of grounding economic theory in higher-level social constructs. Hayek's opposition was methodologically individualist, but he stressed throughout his work that social outcomes, while the product of rational action, are nonetheless generally distinct from the intentions of the actors themselves. Hayek's position is, I believe, quite correct and of essential importance in assessing the value of alternative economic institutions and the role of economic planning in fostering economic growth and ecological balance.

By contrast to Hayek, modern economic theory in general, and game theory in particular, hold to a much stricter and I believe indefensible form of methodological individualism in which all social phenomena above the level of the individual must be explained as Nash equilibria in a game played by self-regard, amoral, rational actors. So ingrained in economic theory is this principle that it is not usually even explicitly articulated. Rather, it is simply embraced as "tacit knowledge" (Polanyi 1966,1974). How did this situation come about? .

Early work on game theory culminated in Luce and Raiffa's (1957) tour-de-force, after which interest in game theory abated. Renewed interest was sparked in the 1980s, the year 1982 alone seeing the publication of Rubinstein's famous game-theoretic model of bargaining, Milgrom and Weber's theory of auctions, Bengt Holmström's game-theoretic microfoundations of organizations, and the famous "gang of four" (Kreps, Milgrom, Roberts, and Wilson) explanation of cooperation in the finitely repeated prisoner's dilemma.

Game theory became the fundamental microeconomic approach in the following decade, with textbooks by Tirole (1988), Rasmusen (1989), Kreps (1990), Myerson (1991), Fudenberg and Tirole (1991), Osborne and Rubinstein (1994) and culminating in the current industry standard Mas-Colell et al. (1995). The Nobel prize in economics was awarded to a game theorist in the years 1994, 1996, 2001, 2005, and 2007. The early textbooks promoted two basic principles that are now accepted uncritically by most economists and have become the profession's received wisdom. The first principle is that is that *rational agents play subgame perfect Nash equilibria*. In fact, this principle is not even approximately true even in extremely well-behaved cases, such as when such an equilibrium is the unique equilibrium of the game. The conditions under which rational agents choose subgame perfect Nash equilibria is an important, but unsolved problem.

Though widely known to experts in epistemic game theory, this message has not filtered through to the textbooks and hence is generally ignored by working economists. Not surprisingly, the, when experiments show that subjects often do not play subgame perfect Nash equilibria (Camerer 2003), the natural response is that subjects are not rational. It is important to note that contemporary game theory is not falsified by such experimental findings. Rather, in most cases, game theory and the rational actor model are too weak to predict anything at all.

2 Social Norms

Hayek clearly recognized the centrality of unintended consequences of rational behavior, and deployed this notion in critiquing the socialist position that central planning could displace decentralized competition on private markets as the instrument of social progress. But Hayek's methodological individualism is much less embracing that of modern economic theory. Indeed, Hayek's evolutionary approach to social organization and dynamics directly admits social institutions above that of the individual. Cultural institutions, according to Hayek, are the product of history, not of individual intentionality, although they are constituted and transformed only through the coordinated actions of individuals. In Hayek's words (Hayek 1967, p. 67):

> The genetic (and in a great measure the cultural) transmission of rules of conduct takes place from individual to individual, while what may be called the natural selection of rules will operate on the basis of the greater or lesser efficiency of the resulting order of the group.

What Hayek did not accept, yet is a major finding of contemporary behavioral economics, is that individuals can internalize social norms that bid them to behave in altruistic and virtuous ways even when these are personally costly. For a theory of social norms, which cannot be explained as the Nash equilibria of games played by rational self-regarding agents (Gintis 2009a), we must turn to sociological action theory.

According to this theory, termed *role theory* in sociology (Linton 1936, Parsons 1967), upon encountering a social interaction, individuals first infer from social cues the nature of the interaction and deduce the social norms appropriate to this interaction. Individuals then use this information to constitute their *beliefs* concerning the likely behaviors of others on the one hand, the payoffs they attach to alternative actions, and the behavior appropriate to role-performance. Moreover, they use this information to constitute their *preferences* over these payoffs, because human agents have a socially constituted genetic predisposition to treat conformity to legitimate social norms as personally valuable and hence represented in their preference orderings.

The concept of social norms is not absent from standard game theory. Several researchers have developed the notion that social norms are Nash equilibria of social games (Lewis 1969, Binmore 2005, Bicchieri 2006). This approach, despite the many insights it offers, nevertheless remains bound to methodological individualism: social norms are explained as the product of the strategic interaction of rational agents. The psycho-social theory of norms goes beyond this to claim that social norms are not simply *coordinating* devices, but also *motivating* devices, inducing individuals to sacrifice on behalf of compliance with norms because they are intrinsically valued. In this manner, social life is imbued with an ethical dimension absent from standard game theory.

It follows from the psycho-social theory of norms that individuals' probability distributions over states of nature and their preferences are not the purely personal characteristics (subjective priors and preference orderings) of the standard rational actor model, but rather are the product of the interaction of personal characteristics and the social context. This is why experimentalists have had such difficulty in modeling strategic interaction: the parameters of the preference function are situation-dependent.

According to the neoclassical model, rational actors are self-regarding unless expressing social preferences allows them to build reputations for cooperation in the future. An extensive body of experimental evidence supports the fact that individuals exhibit other-regarding and virtuous preferences even in one-shot anonymous interactions. The standard interpretation in behavioral game theory of this ostensibly bizarre behavior is that subjects have a cognitive deficit. In fact, other-regarding behavior in one-shot interactions is a daily commonplace. Life in modern society would be intolerable but for the kindness of strangers, and most of us go to great lengths in public to avoid incurring even a disapproving glance.

A more compelling explanation of other-regarding behavior is that individuals bring their personal values to bear even when reputational considerations are absent, and are more or less inclined to behave in socially acceptable and morally approved ways, even when there is no material gain to be had by doing so. People often do what they do, quite simply because they believe it is the right thing to do.

One example of this propensity is strong reciprocity (Gintis 2000), according to which individuals are predisposed to cooperated in a social dilemma and to punish free-riders, even at net personal cost. Another example is respect for character virtues such as honesty and trustworthiness, to which individuals conform not out of regard for others, but because virtuous behavior is its own reward (Gneezy 2005).

3 Social Norms and Rational Action

The naive notion promoted in the textbooks, and dutifully affirmed by virtually every professional economist, is that rational agents play Nash equilibria. The repeated prisoner's dilemma shows that this is not the case, even in two player games with a unique Nash equilibrium, and where this equilibrium uses only pure strategies. For instance, consider a prisoner's dilemma played repeated until a player defects or 100 rounds have been played. Backward induction dictates defection on the first round, but rational players (and real world players) will normally play many rounds, usually 95 or more, before one player defects. If there are more players, if there are multiple equilibria, as is the general case in the sorts of repeated games for which some version of the Folk Theorem holds, or in principal agent models, or in signaling models, the presumption that the rationality assumption implies that agents play Nash equilibria is simply untenable. Of course, this fact is widely known, but there appears to be a "professional blindness" that bids us ignore the obvious.

Perhaps the most egregious, yet ubiquitous, example of ignoring the questionable status of the Nash equililbrium is that of mixed strategy Nash equilibria. For instance, suppose that Alice and Bonnie can each bid an integral number of dollars. If the sum of their bids is less than or equal to $101, each receives her bid. If the total is exceeded, they each get zero. All symmetric equilibria have the form $\sigma = ps_x + (1-p)s_y$, where $x + y = 101$, $p \in (0,1)$, and $x = py$, with expected payoff x for each player. In the most efficient equilibrium, each player bids $50 with probability $p = 50/51$ and $51 with probability $p = 1/51$.

But, if Alice plays the latter mixed strategy, then Bonnie's payoff to bidding $50 equals her payoff to bidding $51, so she has no rational incentive to play the mixed strategy. Moreover, Alice knows this, so she has no rational incentive to play any particular strategy. Thus, while it is intuitively plausible that they players would choose between bidding $50 and $51 and would choose the former with a much higher probability than the latter, this is certainly not implied by the rationality assumption.

Despite their apparent reticence to communicate this embarrassing truth to students, game theorists recognized that rational agents have no incentive to play strictly mixed strategy Nash equilibria many years ago. One attempt to repair this situation was Harsanyi (1973), whose analysis was based on the observation that games with strictly mixed strategy equilibria are the limit of games with slightly perturbed payoffs that have pure strategy equilibria, and in the perturbed games, the justification of Nash behavior is less problematic. However, Harsanyi's approach does not apply to games with any complexity, including repeated games and principal-agent interactions (Bhaskar 2000). The status of mixed strategy equilibria is restored in evolutionary game theory because every equilibrium of an evolutionary dynamical system is a Nash equilibrium of the underlying stage game (Gintis 2009b, Ch. 11), but this fact does not help us to understand the relationship between rationality and Nash equilibrium.

In fact, the Nash equilibrium is *not* the equilibrium concept most naturally associated with rational choice. Robert Aumann (1987) has shown that the *correlated* equilibrium is the equilibrium criterion most worthy of this position. The concept of a correlated equilibrium of a game $\mathcal{G}$ is straightforward. We add a new player to the game whom I will call the *choreographer* (more prosaically known as the 'correlating device') and a probability space $(\Sigma, \tilde{p})$ where Σ is a finite set and $\tilde{p}$ is a probability distribution over Σ, which we call the *state space*. We assume also that there is a function $f:\Sigma \rightarrow S$, where S is the set of strategy profiles for the game $\mathcal{G}$. In effect, in state $\sigma \in \Sigma$, which occurs with probability $\tilde{p}(\sigma)$, the choreographer issues a directive $f_i(\sigma) \in S_i$ to each player $i = 1, \ldots, n$ in the game, where S_i is player i's pure strategy set. Note that $f_i(\sigma)$ may be correlated with $f_j(\sigma)$, so the choreographer can issue statistically correlated directives. For example, the system of red and green lights at a traffic intersection may be the choreographer, which simultaneously directs traffic in one direction to go (green) and in the other to stop (red). We say this configuration is a *correlated equilibrium* if it is a best response for each player to obey the choreographer's directive, providing all other players are likewise obeying.

To state Aumann's theorem, note that since each state ω in epistemic game $\mathcal{G}$ specifies the players' pure strategy choices $\mathbf{s}(\omega) = (\mathbf{s}_1(\omega), \ldots, \mathbf{s}_n(\omega)) \in S$, the players' subjective priors must specify their beliefs $\phi_1^\omega, \ldots, \phi_n^\omega$ concerning the choices of the other players. We call ϕ_i^ω i's *conjecture* concerning the behavior of the other players at ω. A player i is deemed *rational* at ω if $\mathbf{s}_i(\omega)$ maximizes $\pi_i(s_i, \phi_i^\omega)$, where

$$\pi_i(s_i, \phi_i^\omega) =_{\text{def}} \sum_{s_{-i} \in S_{-i}} \phi_i^\omega(s_{-i})\pi_i(s_i, s_{-i}), \tag{1}$$

where s_{-i} is a strategy profile of players other than i, S_{-i} is the set of all such strategy profiles, and $\pi_i(s_i, s_{-i})$ is the payoff to player i who chooses s_i when the other players choose s_{-i}.

We say the players $i = 1, \ldots, n$ in an epistemic game have a *common prior* $p(\cdot)$ over Ω if there, for every state $\omega \in \Omega$, and every $i = 1, \ldots, n$, $p_i(\cdot; \mathbf{P}_i\omega) = p(\cdot|\mathbf{P}_i\omega)$; i.e., each player's subjective prior is the conditional probability of the common prior, conditioned on i's particular information $\mathbf{P}_i\omega$ at ω. We then have

Theorem 1. *If the players in epistemic game $\mathcal{G}$ are rational and have a common prior, then there is a correlated equilibrium in which each player is directed to carry out the same actions as in $\mathcal{G}$ with the same probabilities.*

The proof of this theorem is very simple and consists basically of identifying the probability space Σ of the correlated equilibrium with the state space Ω of $\mathcal{G}$ and the probability distribution $\tilde{p}$ with the common prior $p(\cdot)$.

This theorem suggests a direct relationship between game theory and the rational actor on the one hand, and the psycho-social theory of norms on the other.

The common prior assumption, key to the association between Bayesian rationality and correlated equilibrium, is socially instantiated by a *common culture*, which all individuals in a society share (at least in equilibrium) and which leads them to coordinate their behaviors appropriately. Moreover, the choreographer of the correlated equilibrium corresponds to the *social norm*, which prescribes a particular behavior for each individual, according to the particular social roles the individual occupies in society.

It is important to note that this theorem holds even for self-regarding agents, which appears to imply that social norms could be effective in coordinating social activity even in the absence of a moral commitment to social cooperation. This may indeed be the case in some situations, but probably not in most. First, there may be several behaviors that have equal payoff to that suggested by the social norm for a particular individual, so a personal commitment to role performance may be required to induce individuals to play their assigned social roles. Second, individuals may have personal payoffs to taking certain actions that are unknown to the choreographer and would lead amoral self-regarding agents to violate the social norm's directive for their behavior. For instance, a police officer may be inclined to take bribes in return for overlooking criminal behavior, or a teacher may be inclined to favor a student of one ethnic group over another of a different background, thus ignoring the norms associated with their social roles. However, if the commitment to the ethic of norm compliance is sufficiently great, such preferences will not induce players to violate the duties associated with their roles.

The psycho-social theory of norms is a formal representation of Vernon Smith's suggested explanation of behavior in anonymous one shots. Smith says,

> Why should a real person see no continuation value across stage games with different but culturally more or less similar strangers? Can we ignore the fact that each person shares cultural elements of commonality with the history of others?... Is not culture about multilateral human sociality? These empirical extra theoretical questions critically affect how we interpret single play observations.

It is not hard to see, however, that these are deeply theoretical, not "empirical extra theoretical" questions. Indeed, widely observed ethical behavior dramatically reveals the standard game theory's error in embracing not just the self-regarding actor model, but the whole philosophy of methodological individualism. Individuals often behave ethically because it is the right thing to do, whether or not they will be rewarded in the future for their prosocial behavior. Moreover, individuals are predisposed to consider an action to be the right thing to do when it conforms to a legitimate social norm. An adequate theory of human behavior must successfully incorporate these facts.

4 Conclusion

Behavioral economics has vastly increased our knowledge of basic economic behavior. In so doing, it has strengthened our appreciation for game theory and the rational actor model because behavioral methodology is firmly grounded in these two analytical constructs. On the other hand, behavioral economics has demonstrated that both beliefs and preferences are functions of social context, individuals embrace social norms even when this requires personally costly altruistic or virtuous behavior. In line with Hayek's reasoning, these findings do not suggest that we abandon the rational actor model, but rather that we adopt a more complex version thereof. This more complex version includes non-self-regarding behavior, the social constitution of beliefs, and imitating others in making choices without complete information.

It would have been nice if strategic interaction could be explained by charting the logical implications of juxtaposing a number of Bayesian rational actors, as contemporary game theorists have attempted do. But, as Hayek has stressed, it cannot be done. Neoclassical economics' strong form of methodological individualism is, for better or worse, contradicted by the evidence. Our species developed by imbuing its members with a deep, but not irrational, substrate of sociality (Boyd and Richerson 1985, Brown 1991). Behavioral economics has shown us that the challenge is to model this substrate and chart its interaction with self-regarding objectives. We must enrich economic theory with analytical insights of Friedrich von Hayek, Talcott Parson, and other greats from a variety of disciplines, bu no single thinker from the past has a monopoly on truth.

5 Hayek, Decentralized Information, and Market Dynamics

The most momentous event in Hayek's brilliant career was doubtless his break with neoclassical economics over the way information is to be modeled. The neoclassical model generally assumes that the price system in a market economy is public information and is common knowledge. In the great socialism debate of the 1930s, the market socialists Fred M. Taylor (1929), Oskar Lange (1938), and Abba Lerner(1934) argued that a state-run economy could at least be as efficient as a capitalist economy, provided government planners used the price system as if in a market economy. The Austrian school, led by Ludwig von Mises and Hayek, was no match for this high-tech argument, which convinced even so stalwart a champion of capitalism to predict the eventual triumph of state socialism (Schumpeter 1942). Several years elapsed, his research hampered by World War II, before he published his definitive break with neoclassical economics in his Hayek (1945). In this paper he asserted that information is extremely decentralized in a private property market economy, and a central planning agency simply will not have the information to perform the massive number and range of calculations necessary to run an efficient and innovatory economy. Hayek wrote (1945) p.519:

> What is the problem we wish to solve when we try to construct a rational economic order? If we possess all the relevant information,... the problem which remains is purely one of logic.... This, however, is emphatically not the economic problem which society faces.... The problem of a rational economic order is determined precisely by the fact that the knowledge of the circumstances of which we must make use never exists in concentrated or integrated form, but solely as the dispersed bits of incomplete and frequently contradictory knowledge which all the separate individuals possess.

As it turns out, dropping the assumption that prices in a market economy are public information allows us to correct one of the great failures of neoclassical economics: its inability to specify a dynamical counterpart to the Walrasian general equilibrium system Gintis (2011).

Adam Smith (2000[1759]), heavily influenced by the French Physiocrats (Quesnay 1972[1758]), gave us the vision of a decentralized economy that leads to an efficient allocation of resources through the "invisible hand" of market competition. This vision was given explicit analytical formulation by Léon Walras in 1874, and a rigorous proof of existence of equilibrium for a simplified version of the Walrasian economy was provided by Wald (1951 [1936]). Soon after, Debreu (1952), Arrow and Debreu (1954), Arrow and Hahn (1971) and others provided a fairly complete analysis of the existence of equilibrium in decentralized market economies.

One might reasonably have thought at the time that the problem of dynamic stability of Walrasian economies would have be relatively quickly solved, but surveying the state of the art some quarter century after Arrow and Debreu's contributions, Franklin Fisher (1983) concluded that virtually no progress had been made in this direction. It is now more than another quarter century since Fisher's assessment, and his conclusion remains. Despite the centrality of the general equilibrium model to economic theory, we know nothing systematic about market dynamics.

In Walras' original description of general equilibrium (Walras 1954 [1874]), market clearing was effected by a public "auctioneer" possessing knowledge of the excess demand curves of all agents. The auctioneer would call out a price vector for the economy, measure excess demand in each sector, and gradually, through a process of groping around the price space (the famous "tâtonnement") all excess demand would be squeezed from the system and equilibrium attained. It turns out, however, that only under quite implausible assumptions can the continuous 'auctioneer' dynamic be shown to be stable (Fisher 1983, Kirman 1992), and in a discrete period model, even these assumptions do not preclude chaos in price movements as the generic case (Saari 1985, Bala and Majumdar 1992).

An acceptable model of market dynamics may be based on two fundamental facts about market competition. The first, well known in the literature, is that real trades are bilateral with separate budget equations that must be satisfied for each transaction (Starr 1972). The second is conceptually clear but rarely stated in the general equilibrium literature. This is the fact that in a decentralized market economy out of equilibrium, *there is no price vector for the economy at all*. The assumption that there is a system of prices that are common knowledge to all participants (we may call these *public prices*) is reasonable in equilibrium, because all agents can, at least in principle, observe the same prices. However, out of equilibrium there is no single set of prices determined by market exchange. Rather, every agent has a subjective prior concerning prices, based on personal experience, that he uses to make and carry out trading plans.

Hayek's pellucid yet profound observation suggests the futility of assuming a public price adjustment process. The analysis of market disequilibrium must start out with a vector of *private* prices, one for each agent in the economy, that is updated through the exchange experience. The only admissible forms of experience in a decentralized market economy involve producing, consuming, trading, and observing the corresponding behavior of other agents. Recall of one's own trading experience and knowledge of the trading strategies of exchange partners alone can be the basis for updating the system of private prices, and equilibrium can be achieved only if plausible models of inference and updating lead to a convergence of private prices to a system of public prices through market exchange (Howitt and Clower 2000).

It follows from the above reasoning that in a pure market system, all expectations are adaptive. The "rational expectations" notion that agents know the global structure of the economy and use macroeconomic information to form expectations is not plausible in this context.

My first foray into implementing such a model (Gintis 2006) assumed a simple barter economy with fixed-proportions utility functions and production functions constructed so that any public price vector is a market-clearing equilibrium. Shifts in production activity from lower to higher-profit sectors then led to what I term *market quasi-equilibrium* in the long run. A market quasi-equilibrium is a stationary state of a Markov chain representing repeated cycles of production, trade and consumption. Learning occurs in this model by imitiation: an agent A from time to time learns the price vector of another agent B, and if B has had more trading success, A adopts B's price vector, perhaps with some random mutation. In addition, producers adapt by raising prices when they sell out quickly and lowering prices when they experience inventory accumulation. Similarly, consumers raise their offer prices when they failed to make trades in previous periods, and lower their offer prices when they have had previous success.

The main fact flowing from an analysis of this system using agent-based modeling techniques was that a system of private prices, randomly assigned in period one quickly converges to a set of *quasi-public* prices, in the sense that the variance across agents of relative prices moves from very large to fairly small, and this variance has no further secular trend. In the long run the quasi-public prices stabilize at levels entailing market quasi-equilibrium.

Quasi-public prices are conceptually distinct from public prices even when the variance of relative prices across individuals is very small. This is because with truly public prices, a small change in a relative price leads all agents to adjust in a synchronized manner. This synchronization leads to the instability of public prices Gintis (2007).

My two previous papers on this topic have complementary weaknesses. The barter model (Gintis 2006) cannot illustrate the dynamics of price adjustment to equilibrium, because any public price system is a market equilibrium. The full Walrasian model (Gintis 2007) has so much institutional detail that it is difficult separate basics from details and hence to infer the fundamental regularities of market dynamics in a fully decentralized system. The current paper overcomes these two weakness, thus facilitating future work towards a fully analytical model of market dynamics.

In my most recent paper (Gintis 2011), agents are endowed with Cobb-Douglas rather than fixed proportion utility functions, the coefficients of which are drawn from a uniform distribution for each agent. The Cobb-Douglas assumption, together with simplifying assumptions concerning production described below, implies that there is a unique market equilibrium whose market-clearing prices can be calculated. This allows an unambiguous analysis of market dynamics, including the relationship between the long-run performance of the economy, which is the stationary distribution of the Markov process underlying the agent-based model, and the analytically-derived market equilibrium. I have also experimented with more general CES utility functions, finding no significant differences in the nature of market dynamics.

As in Gintis (2006, 2007), I find that over a wide range of parameter values (number of agents, number of goods, sector sizes, costs of production, transactions costs) the decentralized market system swiftly (within a few thousand trading periods) attains a set of quasi-public prices, but these are generally not market-clearing. In the same time period, the allocational efficiency of the economy improves considerably. In the stationary price distribution, approximated after several tens of thousands of periods, quasi-public prices closely approximate market clearing prices and the economy approximates the efficiency of market-clearing price equilibrium.

I then illustrate the value of the model by showing, for the first time, that money emerges dynamically from decentralized market exchange with fully endogenous out-of-equilibrium production, trade and price formation.

It is well-known that there is no role for money in the Walrasian general equilibrium mode because all adjustments of ownership are carried out simultaneously through the auspices of the auctioneer once the equilibrium prices are set. When there is actual exchange among individual agents in an economy without aggregated clearing mechanisms, two major conditions give rise to the demand for money, by which we mean a good that is accepted in exchange not for consumption or production, but rather for resale at a later date against other intrinsically desired goods. The first is the failure of the "double coincidence of wants," (Jevons 1875), explored in recent years in this and other journals by Starr (1972) and Kiyotaki and Wright (1989,1991,1993). The second condition is the existence of transactions costs in exchange, the money good being the lowest transactions-cost good (Foley 1970, Hahn 1971, Hahn 1973, Kurz 1974b, Kurz 1974a, Ostroy 1973, Ostroy and Starr 1974, Starrett 1974). We show that these conditions interact in giving rise to a monetary economy. When one traded good has very low transactions costs relative to other goods, this good may come to be widely accepted in trade even by agents who do not consume or produce it. Moreover, when an article that is neither produced nor consumed can be traded at very low transactions costs, this good, so-called *fiat* money. will emerge as a universal medium of exchange.

In sum, attempting to explain market dynamics assuming public prices has been a fruitless enterprise. Hayek would not have been surprised, because out of equilibrium there is no reasonable sense in which public prices exist in a market economy. By modeling market exchange assuming each agent has as set of private prices that is updated through learning and imitation, my research shows that market economies behave in extremely stable and robust ways. Such economies are nevertheless complex dynamical systems that to date cannot be properly modeled using standard analytical techniques, but reveal their basic properties through agent-based models, which treat the system of prices and quantities as a finite Markov chain with a stationary distribution whose properties we can analyze computationally.

What are these properties? First, starting from a state of pure randomness, under the twin influence of learning and imitation, private prices rapidly converge to *quasi-public prices*, which have the property of differing across individuals, but with a very small standard error. Quasi-public prices have much of the virtue of public prices in that they support a relatively high level of economic efficiency, while at the same time acting as shock absorbers in the face of random exogenous perturbations to the economy.

Second, quasi-public prices adjust to their equilibrium levels in the long run, leading to a *quasi-market equilibrium* with approximately constrained Pareto-optimal allocations, at least in the simple case of market exchange in which each agent produces a single good using only personal labor.

Third, individual learning is insufficient to produce market equilibrium. The imitation process is much more powerful that individual learning, but the two in combination are quite powerful even in the case of many goods. The economist's faith in the general equilibrium model is in this sense completely vindicated.

Finally, the resulting economy is extremely robust in the face of exogenous shocks. This contrasts with the extreme fragility of the full Walrasian economy analyzed in Gintis (2007). Apparently there is some point in the passage from simple market to a full Walrasian system at which fragility enters. Identifying this point through agent-based modeling would be a valuable enterprise.

Given the clarity, uniformity, and simplicity of our findings for a market economy, it is perhaps surprising that an analytical model exhibiting the above three characteristics remains to be developed. This should prove a worthy task for contemporary mathematical economists, and might serve as a prologemena to the analytical dynamics of a full Walrasian economy that survives the Hayekian critique.

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