Market Theories Evolve, And so Do Markets

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Abstract.

Responding to Mirowski's target article, this paper discusses some intellectual currents of the 1970s to 1990s and offers suggestions on measuring market performance, on including automated agents as market participants, on evolving new market formats, and on dealing with highly differentiated goods.

Acknowledgments.

I am grateful to Associate Editor Rosser for inviting me to participate in this symposium and to Philip Mirowski for writing a timely and engaging target article. Some of the material comes from a recent NSF proposal co-written with James C. Cox. The paper mentions many other intellectual debts. Of course, I retain sole responsibility for lapses of style and substance.

1. Introduction

Mirowksi's "Markets come to Bits" describes an important slice of recent intellectual history. It recounts how researchers in several disciplines have theorized about market formats and market participants, and sketches a synthesis focused on computational issues and evolutionary perspectives. I am no intellectual historian, but I personally encountered several strands of thought that Mirowski mentions, especially those active at Berkeley, UCLA, Arizona and the Santa Fe Institute. In this note I offer my impressions and some suggestions for future research on markets.

Mirowski's title "Markets come to Bits" hints that new information and communications technologies are transforming markets. This note ties these changes in market practice to changes in market theories.

2. Intellectual Currents

My initial exposure to theorizing about markets was at Berkeley in the mid 1970s. My advisor, mathematician Stephen Smale, had recently collaborated with his economics colleague Gérard Debreu in re-examining general equilibrium theory through the analytical lens of differential topology (e.g., Smale 1974). It was natural for Smale (but less natural for Debreu) to consider general equilibrium as the rest point of some sort of market dynamics (e.g., Smale 1976a). As an active participant in mineral bourses (weekend markets whose participants included many of the world's leading rock collectors), Smale had some personal intuition about how mutually beneficial trades and consistent prices could emerge over time from an initially diverse set of participants. Smale (1976b) formalized his intuition, and my dissertation extends his ideas to a somewhat more concrete market format. Inspired by Clower (1967), I conjectured that markets might still converge asymptotically to a general competitive equilibrium even if traders had to use money in every trade rather than direct barter. Much to my surprise, it turned out that money actually helps markets to converge (Friedman 1979).[1]

[1] The paper to some degree foreshadows the Zero Intelligence result that Mirowski emphasizes, and puts it in a different perspective. The 1979 paper shows that monetary exchange among persistent traders subject to a no-loss constraint leads to Pareto Optimum.

This finding didn't surprise most economists, but some appreciated its generality and welcomed a fresh approach to what they called non-tâtonnement processes. Thus my impression is a bit different than Mirowski's: theorists of the mid-20th century such as Arrow, Hahn and Hurwicz were actually quite interested in market dynamics (including trade logistics as well as price formation) but were hamstrung by the Cowles foundation doctrine of "institution-free theory." At UCLA around 1980, and as a visitor at the Berkeley Business School a few years later, I encountered an opposing doctrine: the market format (or "microstructure") matters, it varies greatly depending on "transactions costs," and it shapes an evolutionary process from which optimization and perfect competition may emerge. Besides the research that Mirowski highlights, one should note earlier articles such as Alchian (1950), Ostroy (1973), Garman (1976) and Jones (1976). From Robert Clower I learned to appreciate the role of inventory-carrying middlemen traders (e.g., Clower and Friedman 1986) in the evolution of market formats. Richard Day, the longtime editor of *Journal of Economic Behavior and Organization*, was especially interested in theoretical accounts of market evolution, and published several, including Friedman (1986). Clower's approach had roots in John Hicks' later work (e.g., 1967), and major contributors included Leijonhufvud (e.g., 1967) and Howitt (e.g., 1984).

Experimental Economics began to take shape in the early 1980s and, along with several other young theorists, I was enticed by the prospect of dissecting market dynamics in the laboratory. Friedman (1993) is in the tradition of Plott and Smith (1978); it exploits laboratory control over market formats and traders' private information to compare the performance characteristics of various market formats. The introduction discusses a Mirowskian theme, the evolutionary implications of coexistence of differing formats. See Chapter 2 of Friedman and Cassar (2004) for a brisk history of experimental economics and Chapter 15 for a brief survey of laboratory experiments with old and new market formats.

Santa Fe Institute workshops in 1990 and 1991 brought together leaders from four of Mirowski's five literature areas. Examples contained in the proceedings volume (Friedman and Rust 1993) include chapters by "mechanism designer" Robert Wilson (Chapter 5), Zero Intelligence agent pioneers Shyam Sunder and Dan Gode (Ch 7),

microstructure researchers Tim Bollerslev and Ian Domowitz (Chs 2, 8), and early engineers McCabe, Rassenti and Smith (Ch 11). Several chapters are crossovers of these categories; for example, David Easley helped shape market microstructure research and John Ledyard helped shape mechanism design, but their joint chapter 3 is a contribution to the pure economic theory of markets, as is the following chapter by Mark Satterthwaite and Steven Williams.

Sadly, I agree with Mirowski that these early efforts did fully cohere or shape the research agendas of most economists. Other preoccupations took center stage, especially rational expectations equilibrium for macro theorists and games of incomplete information for micro theorists. But theorists do respond to developments in the world as well as to the vagarities of professional fashion. Thus the great spectrum auctions, trends towards globalization, and especially the rise of the internet may well herald a new age of theorizing about markets. Surely they herald a new and fascinating set of actual market formats.

3. Measuring Market Performance

In considering alternative market formats, theorists as well as entrepreneurs and policy makers need objective ways to compare performance. Mirowski is skeptical about the traditional welfare measures of static efficiency, particularly when goods are highly differentiated.

In laboratory studies with induced preferences, static efficiency can be measured directly: it is simply the salient earnings of all participants as a fraction of the maximum feasible such earnings. In principle the same static definition applies to field markets as long as the set of participants is well defined and each has a way of assessing profit or surplus gained from participation. Of course, private information will prevent an outside investigator from implementing the definition directly. Some sorts of estimates are required, but presumably estimates of differences across formats or time are more accurate (and more important) than estimates of levels. Normally one measures static efficiency after the market settles down, that is, after prices have converged. One can disaggregate static efficiency into gains by sellers and by buyers, etc.

Thus I have nothing new to say about static efficiency, but I would like to advertise two other performance measures. Learning (or dynamic or transitory) efficiency measures loss of potential surplus before the market settles down. Some market formats (such as the oral double auction) seem to reach a settled state faster than others, and this should be taken into account. I am agnostic on precisely how to decompose static and dynamic efficiency, but the distinction seems useful.

The other new performance measure, call it evolutionary stability, would somehow quantify the observation that some market formats are more corrosion resistant than others. For example, it seems empirically that various sorts of double auction formats (and I'd include dealer markets as a subspecies) have tended to displace call markets and bilateral negotiation over time as transactions demand increases; witness the development of the New York Stock Exchange in the 19th century, for example (Schwartz 1988). Recent theoretical and laboratory support for such observations includes Kugler, et al. (2005). Proper measures of relative corrosion and corrosion resistance must take into account a size externality: other things equal, sellers will tend to favor a market that already has lots of buyers, and likewise buyers will favor a market that already has lots of sellers. Hence there is a strong incumbency advantage that could confound naïve corrosion measures.

4. Positive Intelligence Agents.

The next several sections suggest promising ways to study markets in the laboratory and in the field. Such studies are of great interest in their own right and will provide the empirical grounding for better theorizing.

Begin by considering market participants. Traditionally these are all humans, whom theorists usually presume are automatically present while the market is open. The internet encourages us to consider also automated agents and intermittent participation in the market.

Occasional studies going back to (J.) Friedman and Hoggatt (1980) used simple trading agents in the same market as humans. The original motivation was to simulate demand in oligopoly settings, but studies such as Cason and (D.) Friedman (1997) use agents to provide a more stable structure for learning equilibrium behavior. Several recent

laboratory asset market studies (e.g., Plat, 1995) use simple money-losing agents as "noise traders" to encourage human traders to become active. In an influential article, Gode and Sunder (1993) use Zero Intelligence (ZI) agents to demonstrate rapid convergence to competitive equilibrium.

Recent work studying agents more sophisticated than ZI in two-sided markets includes Gjerstad and Dickhaut (1998), Das et al. (2001), Zhan et al. (2002), Cliff (2003), and Gjerstad (2005). (Their agents are in principle exploitable by experienced human traders, but some of the studies show that the agents can outperform inexperienced humans in some settings.) The idea generally is that rather than bidding randomly as in ZI, the agents take into account recently observed market events to generate more profitable bids. The agents may be completely autonomous or tuned by humans. A popularly known example is the "proxy bidder" for eBay's one-sided auction. The user sets only the agent's reservation price, and the agent monitors the auction. It places a slightly higher bid whenever the current highest bid is held by another bidder and is below the reservation price.

An instructive study of human controlled agents is reported in Rust et al. (1993), who analyze the results of a market tournament sponsored by the Santa Fe Institute. Smart agents designed by contestants competed in a newly created market format called a synchronized double auction (SDA). The winner was a strategic but relatively simple agent that waits in the background while others negotiate and then jumps in at the last minute to "steal the deal" (i.e., what now is called a sniping agent). However, as such agents gain market share, their profitability plummets, and so does market efficiency. Rust et al. interpret this finding as an unstable market ecology or, in our terminology, ineffective learning in the SDA. A careful reading of their study suggests an alternative interpretation. The strict separation of "buy/sell" steps from "bid/ask" steps in the SDA allows the winning agent to exploit the information revelation of more forthright agents. Integration of these steps, as in the standard continuous double auction market format (CDA, specified below), apparently would disable the parasitic agent and restore efficiency. It also seems clear that the SDA is evolutionarily unstable: exploited traders would move from the SDA to a CDA where their deals couldn't easily be stolen.

The moral of this story is that market performance (static efficiency as well as learning efficiency and evolutionary stability) can turn on seemingly minor details of the market format. Careful theoretical and empirical studies are essential to understanding and predicting market outcomes.

5. Market Formats.

Already there are at least four major formats for two sided markets.[2]

- Posted offer (PO) allows one side (say sellers) to commit to particular prices that are publicly posted and allows the other side to choose transaction quantities. PO is ubiquitous in the modern retail sector.
- Bilateral negotiation (BLN or haggle) requires each buyer to search for a seller (and vice versa); the pair then tries to negotiate a price and (if unsuccessful) resumes search. BLN markets are prevalent in pre-industrial retail trade, in modern B2B contracting, and in some retail Internet sites such as Priceline.com and MakeUsAnOffer.com. Laboratory research with BLN markets goes back to Chamberlin (1948) and generally shows PO markets to be more efficient than BLN.
- The continuous double auction (CDA) allows traders to make public committed offers to buy and to sell and allows traders to accept offers at any time during a trading period. Variants of CDA markets prevail in modern financial exchanges such as the New York Stock Exchange (NYSE), NASDAQ, and the Chicago Board of Trade and are featured options on B2B Internet sites. Numerous laboratory studies beginning with Smith (1962) show that CDA markets without endogenous entry are more efficient (i.e., produce a larger total of buyer and seller trading surplus) than BLN or PO markets in a wide variety of environments.
- The call market (CM) is the best understood theoretically; see for example Satterthwaite and Williams (1993). The CM requires participants to make simultaneous committed offers to buy or sell, and the offers are cleared once each period at a uniform price. It is used to set opening prices on the NYSE and

[2] Both buyers and sellers actively participate in two-sided markets. Most auctions are one-sided, the seller choosing only the format (e.g., first price sealed bid) and afterwards being passive, while the buyers actively make bids.

elsewhere. Laboratory studies show that the CM is almost (but not quite) as efficient as the CDA when all buyers and sellers are present from the outset.

New information technologies enable new market formats and hybrids. For example, eBay's "buy it now" option allows a seller to transform a one-sided auction into a PO format (Anderson et al, 2005).

These technologies also create new environments in which performance should be compared (e.g., agents can be part of the trading population). Unpublished work by Sunder and others suggests that ZI agents can exploit human traders (by virtue of their greater speed) in the CDA but are easily exploited by humans in the CM. Rankings of market formats established in the lab (and field) might fail in the new environments. For example, pre-specifying agent behavior is a commitment device for the human users, as Fershtman and Judd (1987) famously demonstrated in the traditional context of Cournot competition. Cason and Friedman (1999) show that a major reason for the CDA's efficiency is its push towards full revelation of willingness to transact, but pre-specified agents could easily resist the push. Hence the CM or the BLN format might be more efficient in the new environments.

Tournaments will be especially helpful in assessing the evolutionary stability. Already, agent-only tournaments have been conducted that require complete pre-specification, notably the Santa Fe Institute CDA tournament (Friedman and Rust) and the Trading Agent Competitions noted by Mirowski. The basic idea is straightforward. In each simulation run, a selected subset of agents interact in a given market environment, and the economic outcomes (especially individual profitability and market efficiency) are recorded. A balanced set of simulation runs ensures that every agent has been paired against all other agent types over a range of relevant market conditions. Thus one can identify the agent strategies that deliver consistently-high individual or market performance in each fixed market format. Beyond this are evolutionary tournaments, in which one alters the set of active agents after each round. Agents with better performance will become more prevalent, and various sorts of mutant and hybrid agents will be introduced in small proportions each round. The idea is to identify the agent strategies that survive evolutionary competition and to evolve newer

and perhaps more sophisticated agents. One can also imagine tournaments across market formats. One would see which formats and variants emerge from direct evolutionary competition.

6. Differentiated Goods

Mirowski's section 4.4.2 notes a "counter-trend to individuate and differentiate that which may have previously been treated as uniform and homogeneous." I agree that there is a major emerging issue here. Endogenous and composite goods and services are increasingly prominent in industry but have not yet seen much insightful new theorizing. For example, IBM, HP and other major corporations increasingly see themselves as being in the services industry, "co-producing value with clients" as they build highly individuated integrated systems for clients' inventory control, human resources, marketing, information technology, and so on. IBM in particular has called for the creation of a new "services science" (e.g., Chesbrough 2005).

Consider, for example, a market for wireless network connectivity. A consumer (running some particular application such as voice transmission or data streaming) has a personal tradeoff between price and attributes such as bandwidth, latency and jitter, and the consumer needs a connection between specific geographical locations over some specific time interval. How could a market function for such a multi-attribute customized service?

The easiest format to imagine is a monopolist posting prices. The seller could build an algorithm to estimate marginal cost for each dimension and use a pre-established markup factor to quote an attribute-price menu to the consumer. Absent entry barriers, a profitable monopolist will attract rival sellers and so the PO is the first two-sided market format one might expect to emerge. But other market formats might perform better once a sufficient number of buyers and sellers are present.

The conceptual problem for service markets is that different participants will demand or supply different varieties and so it might seem that these markets will never become thick enough for the CM and CDA formats. However, the same problem arises even for agricultural commodities, the most traditional of products, and was overcome in the 19th century by a device that I will refer to as the benchmark variety. For example, a

thick market evolved for hard red winter wheat #2 delivered at a particular rail junction on the seventh business day following the last trading day of March each year. Indeed, more than 50,000 futures contracts, each for 5,000 bushels, were outstanding for precisely this benchmark variety in mid-February 2004 at the Chicago Board of Trade (CBOT).[3] Most contracts are ultimately generated by producers and consumers of slightly different varieties of wheat at locations all over North America for dates several weeks earlier or later. They all trade the benchmark contract, but each wheat producer delivers his particular variety at a known price differential determined by the cost of storage and transportation. Similarly the consumers pay the price of the benchmark variety plus or minus a known price differential for the chosen variety. Most transactions do not require actual transformations into and out of the benchmark variety; active traders (the arbitrageurs) ensure that costly transformations are kept to a minimum.

Exactly the same process is at work with the Brent Crude oil contract traded on the New York Mercantile Exchange, or the 30-year Treasury Bond contract traded on the CBOT, or the new Weather Futures contracts traded on the Chicago Mercantile Exchange. The price differentials for other dates, locations and grades are known to participants, who benefit from trading in a thick market for the benchmark variety.[4] The same pattern may be emerging for new services and solutions such as computons (bundles of CPU time, storage, and system management), utility computing (bundles of consulting, software applications, and computer resources), and even "business on demand" (interoperable service bundles, e.g., for inventory and HR support, or even for manufacturing and R&D). For example, many services are sold at a benchmark rate and additional "levels" of service can be added using a Service Level Agreement (SLA). The SLA in itself provides another stage of benchmarking to simplify the complex sets of services provided (e.g., bronze, silver, gold level service). One can imagine that more

[3] Recent textbooks on futures markets routinely explain the CDA format used on the Chicago exchanges, and also explain some aspects of benchmark varieties and standardization, particularly the mark-to-market feature that standardizes across the dates contracts are written. However we have not yet seen a textbook or article that points out the connection or discusses the general principle that the benchmark variety creates a thick market that can use the CM or CDA format. I first heard the idea in a personal conversation with John Hicks (who alludes to it, but never spells it out, in his later books) and later encountered it as oral tradition at Chicago and UCLA.

[4] In some cases, the markets focus on the price differentials. For example, traditional bank loans to small businesses are priced as prime plus, and banks compete mainly on the "plus" differential to a specific customer rather than on the benchmark prime rate.

detailed and complex service requirements can be priced separately and layered onto these levels.

Thus two powerful and opposing forces shape the evolution of markets for differentiated goods. The logic of arbitrage, supported by consumers and new entrants, tends to unify and standardize via benchmark varieties. Mirowski's countertrend arises from producers' attempts to protect themselves against greater entry, more elastic demand, and thinner profit margins (or "commodification") by distancing their output from those of competitors. It will be quite interesting to see what will emerge in the next few decades, and how theorists will explain it.

7. Concluding Remarks

I neglected Mirowski's discussion of computational aspects of markets simply because I have nothing new to say on the matter. But it clearly is a lively emerging area of interdisciplinary research. Interested readers should read Leijonhufvud (1993, 2006) for some useful perspectives. A series of graduate summer schools at the University of Trento has focused consistently on computational issues in economics, with evolutionary economics and market institutions among the annual themes. Indeed, the summer 2006 program is Agent-Based Computational Economics; see http://www-ceel.gelso.unitn.it/.

I do have a brief comment about fitness landscapes. Mirowski rightly criticizes models of evolution as movement of a point over a fixed landscape and endorses Fontana's proposal to use more abstract topologies than those obtained from the Euclidean metric. In my opinion, the biological dichotomy between genotype and phenotype has little resonance in social science and therefore Fontana's problem and proposed solution becomes less important for economists. But a useful evolutionary theory for social science (as well as biology) must recognize co-evolution. For example, market performance characteristics, and thus the evolution of market formats, interact very strongly with the evolution of market participants, including automated agents. To take this into account, one should consider dynamic fitness landscapes that change as the population of agents (and formats) changes. These ideas are under development at http://www.vismath.org/research/landscapedyn/.

To conclude, Mirowski has raised the right set of issues at the right time. My comments focus on areas of disagreement and areas of relative neglect. The future evolution of markets, and of market theorizing, will doubtless show that I have been off-target in some (and perhaps most) of my remarks. But it seems safe to predict that evolution of market theories will be speeded by the interchange featured in this issue of *JEBO*.

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