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The Evolution of Equilibria in Irrational Markets

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Abstract

This paper reviews the articles with the focus on the validation of the notions of different equilibria in irrational markets. In all those articles, the evolutionary idea of natural selection is used to explain the eventual occurrences of different equilibria in different market processes where individuals are irrational. The future research direction in this area is also mentioned.

Keywords

Evolution, Market Rationality, Natural Selection, Market Efficiency, Irrationality

1. Introduction

In the traditional economic theory, equilibria are derived from optimal choices made by perfectly rational economic agents. The reality is that due to their computational capabilities and limited access to the sources of information, economic agents simply are not able to maximize their objectives (profits or utilities). The economic agents can be quite unsophisticated. The questions to ask are as follows. Can any equilibrium be established when economic agents are irrational? Is any equilibrium notion still valid after the individual rationality is assumed away?

This paper reviews the articles addressing these questions. The approach used in these articles is based on the evolutionary idea of natural selection. That is the "survival of the fittest". In the market environment, natural selection is replaced by market selection where the economic agents with the most wealth survive and others disappear or become unimportant.

Although there is a large literature (e.g., Biais, B. and R. Shadur [1], Hirshleifer and Luo [2], and B. De Long, A. Shleifer, L. Summers, R. Waldman

[3]) examining the market selection hypothesis, few papers devote their attentions to the validation of the equilibrium notions. The articles reviewed here focus on justifying the equilibrium notions of perfect competition, monopolistic competition and informationally efficient equilibrium by using the evolutionary approach.

The remainder of this paper consists of three sections. The next section discusses the articles supporting the notions of perfectly competitive equilibrium and monopolistically competitive equilibrium. In addition, it also briefly discusses articles addressing the market selection over firms. Section 3 focuses on justifying the equilibrium notion of the informationally efficient equilibrium in financial markets. The last section provides some concluding remarks.

2. The Notion of Perfect Competition and Monopolistic Competition

I begin with the article of Luo [4] who examines whether perfect competition would evolve in an industry when firms are totally irrational. The notion of perfect competition is established with profit maximization assumption placed on the firms' behaviour in an industry where there are free entry and exit and the resources are completely mobile. Luo [4] assumes away this profit maximization assumption on firms' behaviour. The firms in Luo [4] are assumed to be completely irrational in the sense that firms enter the industry regardless of profit opportunities, exit the industry when their wealth are negative and they choose their outputs randomly. With this totally irrational behaviour of the firms, perfect competition in the industry is obtained in the long run. The detailed model is as follows.

Consider an industry where all the firms produce a single homogeneous good. All the firms enter the industry sequentially over a discrete infinite time horizon. For simplicity, only one firm is assumed to enter the industry in the beginning of each time period. Firms' outputs are randomly and independently drawn from any given continuos distribution upon their entry. In addition, a fixed cost is incurred upon entry. It is paid once and only once during the period of entry. This cost of entry can be interpreted as including costs of building a plant and installing equipment and any registration fees. All firms have the same average variable cost function. The demand function facing the industry is downward sloping. The wealth of each firm at the end of each period is computed as the accumulated profits by the end of that period. If a firm has a positive wealth, then this firm will continue to produce the same quantity of the output determined at its entry period; otherwise, this firm will exit the industry. In this simple setup of an industry, where firms randomly choose their outputs, continually enter the market and leave when their wealth becomes negative, Luo [4] proves rigorously that the industry converges in probability to perfect competition as firms gets infinitesimally small relative to the market, as the cost of entry gets sufficiently small and as time gets sufficiently large. The only surviving firms are those that happen to produce at the minimum efficient scale (which is the profit

maximizing output). In other words, the "as if" profit maximizing firms are the only long run survivors.

Luo [5] present a similar model of infinite time horizon describing an industry where firms produce differentiated products with the identical average cost functions but symmetric demand functions. The market process is very similar to Luo [4]. The equilibrium notion in this industry is the monopolistically competitive equilibrium. Luo [5] proves that this industry also converges in probability to this equilibrium as firms gets infinitesimally small relative to the market, as the cost of entry gets sufficiently small and as time gets sufficiently large. The only surviving firms are those that happen to produce profit maximizing output. Luo [6] further extends the above model to reflect the fact that with differentiated products, firms must have their own average cost functions or technologies and face their own market conditions (or their own demand functions). With different average cost functions and demand functions, in the similar market process, Luo [6] proves analytically the eventual occurrence of monopolistically competitive equilibrium. The only long run survivors are the "as if" profit maximizing firms with the most efficient technology and facing the most favourable market conditions.

Although a perfectly competitive equilibrium or monopolistic competitive equilibrium are derived based on the profit maximization assumption on the firms' behaviour, the above three articles prove that even if the firms behave completely irrationally, the industry can arrive at the same perfectly competitive equilibrium or monopolistically competitive equilibrium. The market process described above is in the spirit of Nelson and Winter [7], with respect to their evolutionary treatment of the firm. Firms select their output levels randomly on entry and routinize their own output levels at the fixed levels thereafter. Using biological language, one may interpret the fixed level of each firm's output as its genotype. As in biology, success is rewarded and failure is punished. Here, whether a firm succeeds or fails is indicated by whether that firm passes the survival test of making nonnegative wealth in the market. In other words, if a firm makes a nonnegative wealth, it survives; otherwise it disappears. Darwinian "survival of the fittest" applies. In addition, as in biology, the theory of natural selection requires competition (e.g., see Enke [8] and Penrose [9]). Here, competition takes the form of continuous entry of new firms across time. Thus, whatever routines are adopted by firms, competition among the firms drives prices down, causing all but the fittest firms to make negative wealth and to exit the market, and leaving in the market only surviving firms that happen to produce at the minimum efficient scale or the tangency output. The surviving firms are the ones that act like long-run profit-maximizers.

Other papers addressing the survival of firms (but not the eventual occurrence of an equilibrium) are Winter [10] [11], Nelson and Winter [7], Dutta and Radner [12], and Blume and Easley [13]. Although they are not the focus of this review paper, for the sake of the comparison with the above evolutionary models, I briefly discuss them here. Winter [10] [11] and Nelson and Winter [7] ex-

amine this market selection argument in the context of retained earnings dynamics. They found that the retained earnings of profit maximizers will grow fastest and eventually those firms will dominate the market. Nelson and Winter [7] present a partial equilibrium model where prices are fixed and all firms have access to the same technology; it shows that "as if" profit maximization describe the long run steady state of firms' behaviour. Dutta and Radner [12], and Blume and Easley [13] examine whether natural selection favours profit maximizing firms in models where firms can grow through retained earnings or through financing in the capital markets. Dutta and Radner [12] show that all surviving firms are not profit maximizing firms. Blume and Easley [13] show that the market selection favours profit maximizing firms, but the long-run behaviour of evolutionary market models is not well described by the equilibrium models based on the profit maximization hypothesis.

The next section discusses the articles that support the notion of informationally efficient equilibrium in financial markets when traders are irrational.

3. The Notion of Informationally Efficient Equilibrium

In financial theory, the derivation of an informationally efficient market is based on the presence of traders' rational expectations, strategic usage of market information or adaptive learning behaviour where uninformed traders gradually become informed traders (e.g., see Grossman [14] [15], Feiger [16], and Hellwig [17]). However, traders cannot possibly solve the complex optimization problems due to their limited access to the sources of information and their limited computation capacities. As a result, the achievement of market efficiency in financial markets is questionable. Using the evolutionary idea of natural selection, Friedman's conjectures [18] that because noise traders will sooner or later lose money to the informed traders, the informed traders will come to dominate the market and drive the asset price toward the fundamental value. Friedman's conjecture supports the informational efficient equilibrium even though the market participants are irrational and uninformed. Furthermore, Friedman's conjecture does not rely on the rationality of individual market participants but it replies on the market selection to transfer the wealth among irrational traders.

In the spirit of Friedman's conjecture [18], Luo [19] builds an alternative framework to examine whether the informationally efficient equilibrium would occur when traders are irrational. In this alternative framework, traders cannot possibly learn or adapt their behaviour. Hence, market selection among irrational traders is the only forces that could promote market efficiency. In Luo [19], traders are assumed to make systematic errors in predicting the spot price. Such systematic errors take the form of consistent patterns of predicting biases, which are captured by the probabilities of overpredicting and underpredicting the fundamental value. These predicting probabilities are used to model traders' behaviour in Luo [19]. In an evolutionary sense, each trader is genetically preprogrammed with its own inherent and fixed probabilities of overpredicting, underpredicting and predicting correctly the fundamental value.

Specifically, Luo [19] considers a dynamic model of a commodity futures market where producers sell contracts in the futures market to hedge against the risk in the spot market. The spot price is predetermined each time period but unknown to all market participants. Traders enter the futures market sequentially with positive initial endowment of wealth. For simplicity, one trader enters the markets at the beginning of each time period. Each trader can either buy futures contracts with the hope of selling at a higher spot market price (acting as a buyer) or short sell futures contracts with the hope of buying at a lower spot market price (acting as a seller). In addition, the fraction of wealth allocated for trading activities differs across traders. Furthermore, the abilities to predict the future spot price also differ across traders. A trader's ability to predict the future spot price is modeled as inherent and is characterized by the probabilities of overpredicting, underpredicting and predicting correctly the spot price. Each trader is characterized according to his or her trading type (buyer or seller), his or her fraction of wealth allocated for trading activities, and his or her inherent probabilities of overpredicting, underpredicting and predicting correctly the spot price, which are all randomly determined upon his or her entry period and are fixed thereafter. One trader is said to be more informed than another trader if this trader's probability of predicting the spot price correctly is higher than another trader.

In this evolutionary model of futures markets, for those buyers (sellers), who predict exactly right the spot price with a low probability and overpredict (underpredict) the spot price with a high probability, their wealth will be frequently reduced. Consequently, their ability to influence the futures price will be overshadowed by buyers (sellers) with a high probability of predicting exactly right the spot price and a low probability of overpredicting (underpredicting) the spot price. Therefore, as time goes by, market selection constantly transfers wealth from less informed traders to more informed traders. Assuming that there is a positive probability each time period that a trader enters the market with a higher probability of predicting correctly the spot price than all previously entered traders, the convergence of the futures price to the spot price eventually occurs.

Luo [20] adds a random shock to the futures market to see if an informationally efficient equilibrium would still occur in the dynamic futures market described in Luo [19]. In Luo [20], the prices are modelled as continuous variables and traders can buy or sell with a single submission of their quotes. Assuming that with a positive probability each time period, a trader enters the market with a higher probability of predicting the spot price than all previously entered traders. Luo [20] proves that with probability one, if the volatility of the underlying spot market is sufficiently small, then the proportion of time that the futures price is sufficiently close to the fundamental value converges to one. However, the interval containing the fundamental value, where the futures price eventually lies, is influenced by the underlying volatility generated from the spot market. In other words, the accuracy of the information for which the market can even-

tually select, depends on the volatility generated from the random shock in the spot market. The more volatile the spot market, the more noisy is the information that gets selected for. As a result, the futures market moves further away from informational efficiency.

Luo [21] builds an evolutionary model of one-sided buyer auction market to examine if the informational efficiency would still occur as a long run outcome. In Luo [21], the supply of the asset is inelastic and also, a random shock to the fundamental value of the asset is present. Similarly, each trader's behavior is preprogrammed with its own inherent and fixed probabilities of overpredicting, predicting correctly and underpredicting the fundamental value of the asset. With similar market process to the one described in Luo [19], assuming that with a positive probability each time period, a trader enters the market with a higher probability of predicting the spot price correctly than all previously entered traders, this article proves analytically that, if each buyer's initial wealth is sufficiently small relative to the market supply and if the variation in the asset's random shock is sufficiently small, then as time gets sufficiently large, the proportion of time, that the asset price is arbitrarily close to the fundamental value, converges to one with probability one.

What is in common in Luo [19] [20] [21] is that with a positive probability each period, a trader enters the market with a higher probability of predicting correctly the spot price than all previously entered traders. In other words, the informed traders with more accurate information will eventually enter the markets and accumulate the most wealth, they will become the dominant force in the markets and drive the asset price to its fundamental value. This is consistent with the view in the literature that the presence of informed traders is necessary for achieving an informationally efficient equilibrium.

Now, the question to ask is that whether the informationally efficient market outcome would still occur if informed traders are removed from the markets. Luo [22] explores this issue in the similar setting (to Luo [19]) of commodity futures market by restricting the probability of predicting correctly the spot price by all traders to be strictly less than a positive fraction. Luo [22] proves analytically that the long-run market outcome is informationally efficient, as long as in every period there is a positive probability that entering traders are more conservative than their predecessors. Conservative traders are those who correctly predict the spot price with a positive probability, and more importantly, who in their mistakes err on the side of caution, and rarely overpredict the spot price as buyers, and underpredict the spot price as sellers. This result does not require entry of traders with better information than their predecessors. This is in contrast with the literature viewing the presence of informed traders with accurate information as the key ingredient in achieving market efficiency.

Note that this paper does not review articles with the focus only on market selection over different behavioural rules and nor does it review articles not addressing the rationality of the aggregate market outcome in irrational markets. However, for the sake of comparison with the articles reviewed above, I briefly

discuss Blume and Easley [23] and Biais and Shadur [1]. Blume and Easley [23] study a dynamic market with wealth flows between traders and they find that economic natural selection does not necessarily select for rational rule. Similarly, Biais and Shadur [1] arrive at the same conclusions using Darwinian dynamics in a non-overlapping generations model of a risky asset. In both papers of Blume and Easley [23] and Biais and Shadur [1], the reason for the rational rules not being selected is that, aside from not allowing traders to enter with better predictive abilities than existing traders, traders' behavioural rules are modeled as being linked to their utility functions. Since utility maximizing rules do not guarantee that traders have accurate predictions, it follows that wealth may not be maximized. Therefore, traders with rational rules do not necessarily dominate the market in the long run. On the contrary, traders with irrational rules may come to dominate the market.

4. Concluding Remarks

In all evolutionary models reviewed above, the evolutionary idea of natural selection is used in different market processes to explain whether the market aggregate rationality can be established in the long run even though the individual market participants are irrational. The models presented here shed some lights on the validation of the concepts of the perfectly competitive equilibrium, monopolistically competitive equilibrium and informationally efficient equilibrium. However, there are still a lot of other equilibria (such as Nash equilibrium) that need to be examined when the rationality of individual market participants is not possible.

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