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Role of Market Microstructure in Price Convergence: A Meta Analysis

Maaz Javed
Ph.D. Scholar
Pakistan Institute of Development Economic (P.I.D.E)
Islamabad
Maazjaved_16@pide.edu.pk (CA)

Saud Ahmad
Assistant Professor
Pakistan Institute of Development Economic (P.I.D.E)
Islamabad

Abstract

This study aims to revisit the assumptions of economic theory that lead to the predictions of competitive equilibrium theory. Extensive work has already been done to answer how well these assumptions of microeconomic theory approximate the real-world market. In this context, two kinds of tools can be found in the literature that tries to answer this question. One is experimental economics (EE) where individuals are involved in a simplified market that mirrors the real-world markets. Human behavior is observed here under an alternating set of rules. The second tool is agent-based Modeling (ABM) which approximates the real-world markets with artificial agents where every agent possesses unique characteristics and the market comprises a diverse set of decision rules. In ABM, computer simulations imitate human behavior. Our results, however, state that with Zero Intelligence agents, the market is not even closer to the level of prediction of a theoretical competitive market. It also makes sense as random number generations should not lead the market to a level of efficiency higher than human agents and we cannot rule out the importance of rationality possessed by humans to bring more efficient results than ZI agents with no rationality.

Keywords: Competitive equilibrium, rationality, agent-based model, zero-intelligence agents, review

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Background

Debate on the rationality of market participants in bringing the market to equilibrium is not new in economics. Equilibrium in itself and its attainment through market mechanisms has been part of the lively discussion to date. The oldest of the theories is the microeconomic theory of supply and demand stating that the market equilibrium is an indigenous characteristic of the market itself. Equilibrium is considered an implicit characteristic as markets always reach back to their equilibrium whenever it got diverted. How the market reaches equilibrium is the question to ponder.
Over time various theories tries to explain the phenomenon regarding how the market learns about and reaches equilibrium. The explanation to answer this question can be traced back to Adam Smith (1962) and his theory of the invisible hand. It is still considered a well-established theory in economics. According to this classical economic theory, the forces of supply and demand helps the market to achieve equilibrium. Whenever a market gets distracted from its equilibrium the demand and supply forces come into action and provide incentive to market participants to act in a way that their behavior ultimately leads the market to equilibrium. The theory of demand and supply considers that there are few conditions applied on the market and the participants necessary to achieve equilibrium. These conditions are described here.

1. Market participants involved in buying and selling are rational and always make best possible decision.
2. Every individual who participated in the market has perfect information about the market.
3. There is no transaction cost involved.

When the market meets all there conditions the economic theory considers it a competitive market. Microeconomic theory predicts that when these assumptions are fulfilled, the markets always achieve an equilibrium price level, individuals maximize their surplus and markets are efficient.

This study aims to revisit the assumptions of economic theory that lead to these predictions. Extensive work has already been done to answer how well these assumptions of microeconomic theory approximate the real-world market. In this context, two kinds of tool can be found in the literature (Smith, 1962; Becker 1962; Gode and Sunder, 1993; and Dhami, 2017) that tries to answer this question. One is experimental economics (EE) where individuals are involved in a simplified market that mirrors the real-world markets. Human behavior is observed here under an alternating set of rules. The second tool is agent-based Modeling (ABM) which approximates the real-world markets with artificial agents where every agent possesses unique characteristics and the market comprises a diverse set of decision rules. In ABM, computer simulations imitate human behavior.

Through human experiments in the double auction market, Smith (1962) reaches to the conclusion that the market with a very small number of traders approximates all the characteristics predicted by economic theory about equilibrium and allocative efficiency. Even the need for a Walrasian auctioneer is no more there to bring up the market results closer to the prediction of economic theory. In a double auction market, the results of the market are dependent on microstructure, market environment, and behavior of agents involved in trading. Microstructure is defined as rules of exchange, the market environment is a set of information available to each trader, and behavior refers to the trading strategies among the agents.

Literature provides two strands with different factors that affect the market equilibrium in a double auction. One of these results shows that demand and supply functions play a vital role in bringing the market outcomes that approximate the theoretical predictions of a competitive market (Becker, 1962). The other viewpoint revolves around the agent's behavior to maximize the profit. As per Smith (1962), it is the profit-maximizing behavior of agents in double auction experiments that mirrors the predictions of economic theory. Then there is Gode and Sunder (1993), who try to see the impact of demand and supply functions as well as the profit-maximizing behavior of market participants on market efficiency. Market efficiency is mirrored in two ways. One is through the surplus earned by individual participants. Second, by observing if the surplus decreases over the trades and leads the market towards equilibrium. Results of Gode and Sunder (1993 and 1997) show that even when agents do not possess rational behavior the markets lead to competitive outcomes across varying functions of supply and demand. In their seminal work, the results of both (Becker, 1962; and Smith, 1962) are proved to be true. Instead of human experiments, Gode and Sunder (1993) use ‘zero intelligence’ agents with non-profit maximizing characteristics, unlike human participants. It helps to control the behavior of individuals in terms of their expectations, learning, preferences towards money, risk preference, and ability to understand and participate in experiments.

To study the market behavior concerning the microstructure of the market, ABM provides considerable autonomy and freedom in controlling different factors simultaneously. In the literature, several studies could be found that applied the ABM tool to study the impact of market microstructure on the market efficiency, price behavior, and trend of trader surplus. By applying the tools of ABM, the researchers found that in some cases even if these assumptions are not fulfilled, the market outcomes are very much close to predictions of a competitive market (Becker, 1962; Smith, 1962; Plott, 1982; and Gode and Sunder, 1993, 1996 and 2018). For instance, according to Becker (1962) “the households may be irrational and yet the markets quite rational”. Gode and Sunder (1993) also reach the same conclusion “Market mechanism such as a double auction, may generate aggregate rationality not only from individual rationality but also from individual irrationality”. How these results are derived is a question here to explore.

Market Setup

This section is dedicated to market characteristics including the microstructure of the market, the behavior of ZI traders, and market parameters.

a. Market Microstructure

The market has a double auction microstructure, with no Walrasian auctioneer, having buyers on one side and sellers on the other. Here instead of human traders, the ZI traders are created in a computer program. These artificial traders do not possess any intelligence, do not pursue profits, have no memory, and are not eligible to learn.

Buyers and sellers are selected randomly one by one to enter the market and shout their bid and ask prices, respectively. These bids and asks are randomly generated and distributed independently, identically, and uniformly over the feasible range of trading price between 1 and the maximum limit. The bid price of the buyer is selected randomly between the redemption value and 1 of the buyer. Similarly, the asking price of sellers is selected randomly between the cost of the seller and the maximum limit. These lower bound for buyers and the upper bound for sellers are borrowed from Gode and Sunder (1993a and 1993b).

The double auction market for all the outstanding limit orders (bids or asks) stays active unless the corresponding bids or asks are matched with any existing limit order. Double auction markets are chosen because all the major exchange markets (stock, currency, and other markets) follow this market microstructure. Another reason for selecting double auction markets is that, in literature, it exhibits the results very close to predictions of classical economic theory regarding the market surplus, profit maximization, and equilibrium. In a double auction market, any buyer or seller, when entering the market announces the bid or ask price. Here we are assuming that all the buyers and sellers possess only one unit of homogenous product (Gode and Sunder, 1993b).

The matching of bids and asks is done when any buyer of a bid greater than the ask of any of the sellers enters the market then they both become eligible for trade. Trade happens at a trading price equal to the earlier the bid of buyer or the ask of the seller or who enters first.

b. Market Parameters

Two types of demand and supply schedules are taken based on the redemption values and costs allocated to buyers and sellers. These two markets differ only in terms of how the bid and ask prices are selected across the buyers and sellers. In the double auction market, the demand and schedule from Gode and Sunder (1993b) is followed by a range of redemption values between 90 and 112 and a range of cost between 74 and 96. In market_1, the bid prices are selected randomly between the redemption value and 1. Similarly, ask prices are selected randomly from the list between the cost and 186. The market consists of 42 traders, divided equally between buyers and sellers. All the zero intelligence agents face these budget constraints. The demand and supply schedule for the double auction market is symmetric and is illustrated on the left side of Figure 1. To make it simple, every zero-intelligent trader possesses only one unit to trade. Unit values and costs allocated to buyers and sellers respectively are provided in Table 1. Theoretical profit is the surplus that could be earned if the ZI agents transact at a competitive price level. For this market, the competitive equilibrium price is 93 and the maximum total surplus is 102. The competitive equilibrium quantity for this market is between 12 to 15 trades. These parameters are also used for market_2 where bid and ask prices are selected with 10 percent profit margin for each side of traders i.e. buyers shout the bid price 10 percent less than their redemption values and sellers shout the asking price 10 percent larger than their costs.

Table 1: Redemption values, costs, and theoretical profits

Buyer ID	Value	Theoretical Profit	Seller ID	Cost	Theoretical Profit
1	112	19	22	74	19
2	112	19	23	74	19
3	107	14	24	79	14
4	107	14	25	79	14
5	102	9	26	84	9
6	102	9	27	84	9
7	98	5	28	88	5
8	98	5	29	88	5
9	96	3	30	90	3
10	96	3	31	90	3
11	94	1	32	92	1
12	94	1	33	92	1
13	93	0	34	93	0
14	93	0	35	93	0
15	93	0	36	93	0

16	92	0	37	94	0
17	92	0	38	94	0
18	91	0	39	95	0
19	91	0	40	95	0
20	90	0	41	96	0
21	90	0	42	96	0

Based on these theoretical redemption values and costs the theoretical profits for each of the buyer and the seller is also provided. Total theoretical surplus is the sum of an extractable surplus of all the traders i.e. 204. From the difference between the maximum theoretical attainable surplus and the actual total surplus, the allocative efficiency can be calculated as below.

$$\text{Allocative Efficiency} = \frac{\text{Actual total surplus}}{\text{Maximum theoretical surplus}} * 100$$

Here, redemption values and costs are private information and not known to other agents. When the trade happens in the market, the buyer and seller earn profits from the trade. Their respective profits are equal to redemption value (v_i) minus the transaction price (p_i). Similarly, for the sellers, the profits are calculated by subtracting the cost (c_i) from the transaction price (p_i) for that specific trade. These profits for buyers and sellers and transaction prices are then recorded. The total surplus of the market is the aggregate surplus of all the successful traders.

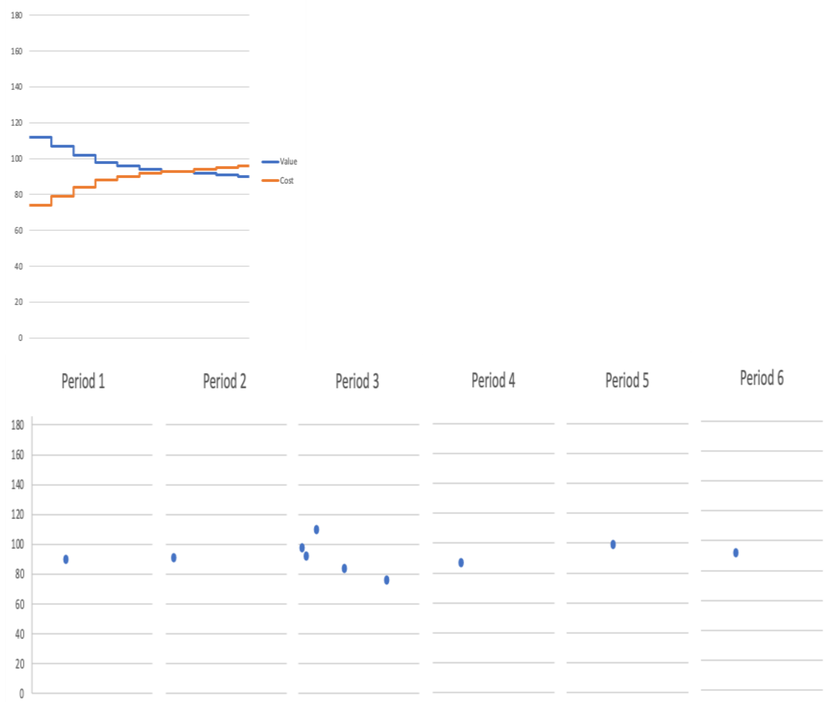
The simulation for artificial agents is repeated for six periods and demand and supply schedules with all related details remain the same across the periods.

Simulation Results

The results of simulations with zero intelligence agents are explained in this section. Here an effort is made to examine if the market surplus decreases with each trade, if the transaction price converges to a predictive equilibrium price level and how efficient is the market. The market structure is observed with symmetric supply and demand schedules.

Figure 1: Results of double auction with ZI-agents (market_1)

Panel A: Supply and demand schedule *Panel B: Transaction prices*



The predictive competitive equilibrium price level, competitive level of quantity of units expected to be traded and expected total surplus are given in table 2 below.

Table 2: Results of double auction (Market 1)

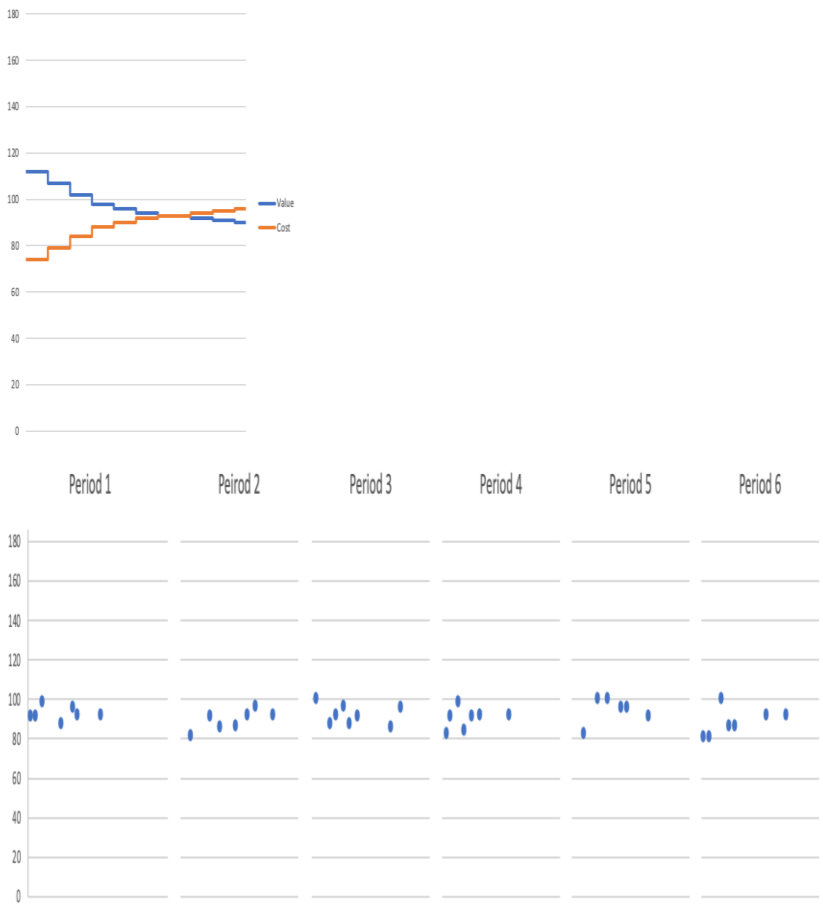
Competitive equilibrium price	93	Average actual equilibrium price	91.9
Competitive equilibrium quantity	12 to 15	Average actual equilibrium quantity	1.67
Total theoretical surplus	204	Maximum surplus attained	40
Average theoretical surplus	204	Average actual equilibrium surplus	12.7
Maximum allocative efficiency	100 %	Actual average allocative efficiency	6.2 %

These results show that the average actual equilibrium price level (91.9) is close to predictions of competitive equilibrium price level (93). But in terms of units being traded, surplus gained and allocative efficiency the performance of Market 1 is way lower than what the classical competitive economic theory predicts and what is offered in literature also (Gode and Sunder, 2003).

The results of market_2 are presented in figure_2 where the bids and asks are set with 10 percent profit margins for buyers and sellers respectively. So, instead of selecting bid and ask prices randomly every buyer and seller makes the trade at least a profit margin of 10 percent. It can be seen in the graphs below that the number of units being traded now increased to a much larger extent as compared to market_1.

Figure 2: Results of the double auction with ZI-agents (market_2)

Panel A: Supply and demand schedule *Panel B: Transaction prices*



A comparison of market results with theoretical predictions is done in Table 3 below. By just changing the rule of how bids and asks are selected, the average traded quantity is increased, the maximum surplus gained is also enhanced, and actual average allocative efficiency is also increased (19.2%) as compared to market_1.

Table 3: Results of double auction (Market 2)

Competitive equilibrium price	93	Average actual equilibrium price	91.6
Competitive equilibrium quantity	12 to 15	Average actual quantity traded	7
Total theoretical surplus	204	Maximum surplus attained	47.9
Average theoretical surplus	204	Average actual equilibrium surplus	39.1
Maximum allocative efficiency	100 %	Actual average allocative efficiency	19.2 %

Although Market 2 outperforms Market 1 it still underperforms when compared with the predictions of the theoretical competitive market. Results of simulations show that the market_1 and Market 2, give results that are not in line with the literature and the predictions of classical economic theory. Results of Gode and Sunder (1993a, 1993b, 1997, and 2003), Shersttyuk et al. (2020), Cliff and Bruten (1997), Plott et al., (2013), Jamal and Sunder (1996), List (2004), Parson et al., (2006), Plott, Roy, and Tong (2013), Vytelingum (2006), and Attansai *et al.*, (2016) shows that the allocative efficiency of ZI agents is usually near to 100 percent. But results of this study for the double auction market with ZI agents show that these results are sensitive to every minor detail. By changing these minor details of the simulation, the results vary significantly.

The result of this study shows that the double auction market is not as efficient as it is thought but agents with zero intelligence are unable to learn about the market characteristics, supply and demand in the market, trading strategies, and a lot of other details.

Conclusion

Since the last three decades, the importance of zero intelligent agents has been so vast and significant that a whole branch of economics can be dedicated to it. The role of simulation in economics becomes very significant when the predictions of classical economic theory are supported with evidence from computer-based simulations. It is seen that computer agents with no intelligence, no decision-making power, absence of learning abilities, and no memory achieved market efficiency irrespective of the market microstructure, trading strategies, and market rules. In literature, the results of double auctions with ZI agents are overgeneralized than what they represent. For instance, Gode and Sunder (1993) conclude that a double auction market populated by ZI agents generates 'aggregate rationality not only from individual rationality but also from individual irrationality'. All the variations of the ZI-populated market of Gode and Sunder (1993) revolve around varying supply and demand schedules, while all the other factors remained constant. Secondly, a market populated by ZI agents does not mean that all the results are in the absence of profit-maximizing behavior of agents, but it also shows that many other factors could play an even stronger role than the profit motives of agents. Our results with a simple illustration of a simulated market show the same as a market with ZI agents does not approximate the results predicted by classical economic theory.

Similarly, the absence of a profit-maximizing motive by populating the market with ZI agents does not mean that the market itself is rational enough to be allocatively efficient. For instance, Sunder (2003) states that there an aggregate phenomenon of the market may not depend on the individual characteristics of agents involved in the market. Even if individuals are not rational, the market may lead to approximately rational results as classical theory describes. In Sunder's words 'if creation without creator and design without a designer is possible, we need not be surprised that market can exhibit elements of rationality absent in economic agent'. This entirely subjective analogy makes very little sense as all three claims can be refuted depending on the type of evidence one gathers and on the predominant beliefs of individuals. These claims of market rationality go even one step beyond what the classical economic theory describes. Competitive market theory states that it is individual rationality and the supernatural decision-making power of the individual in a complex situation that makes the market perfect and leads to the maximum allocative efficiency. But the ZI literature even removes these supernormal conditions that are pre-requisite for efficient markets. Literature on double auction markets with ZI agents shows that no rationality of individuals is required for the markets to be efficient. If we generalize these results, then humans with relatively high rationality in the real market should bring the market to an efficient allocative level. Our results, however, state that the ZI agents' market is not even closer to the level of prediction of a theoretical competitive market. It also makes sense as random number generations should not lead the market to a level of efficiency higher than human agents (of course some amount of rationality possessed by humans should bring more efficient results than ZI agents with no rationality).

Where it is advised in literature to revisit the critique on the rationality of humans by behavioral economics and believe in market efficiency without rational agents (Gode and Sunder, 1992), this study proposes to rethink the role of ZI agents in bringing market efficiency with assumption mirroring the real world phenomenon.

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