When A Lemon Market Emerges?

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Abstract

The 'Market for lemons' has been a focus of heated interest in economics and related fields since the seminal work in 1970 by Akerlof. Since the unique equilibrium of the *total market failure* identified by Akerlof was the result of the specific assumptions on the unitility functions of traders and quality distribution of goods, other possibilities of the market with information asymmetries have been studied. Proliferation of Internet and e-Commerce has brought diverse marketplaces with more information asymmetry. Markets have devised work-around mechanisms to cope with the "lemon" problem by basically manipulating the level of information asymmetry. Then, according to prior studies such as Wolinsky (1983), different equilibria (a competitive market, a lemon market or in between) can arise because of the degree of information asymmetry in a market and interaction between the market and its participants. It will also be possible that such manipulation makes one equilibrium transition to another one. This could be a concern of grave importance to market makers. Hence, we are interested in *dynamics* and *emergence* of markets with information asysmmetry. This study present a stylish analytical model focusing on the possibility of different equilibria and transition among them. An agent-based modeling approach is employed to extend our findings in a more realistic setting.

1   Introduction

The 'Market for lemons' has been a focus of heated interest in economics and related fields since the seminal work in 1970 by Akerlof[1]. The "lemon" problem caused by *information asymmetry* results in either dominance of low quality products or dwindling trade volume that leads to *adverse selection*. Since the unique equilibrium of the *total market failure* identified by Akerlof was the result of the specific assumptions on the utility functions of traders and quality distribution of goods[36], other possibilities of the market with information asymmetries have been studied including Wilson[50][51] and Ross[43]. The existence of a "lemon" market has been tested experimentally and empirically as well. Lynch et al.[34] measured the efficiency of market with information asymmetry. Like Holt and Sherman[22], they showed that information asymmetry lowers market efficiency. Real world evidence was also sought, for example, for the used car market (Bond[5], Pratt and Hoffer[41], Genesove[14]), for the labor market (Gibbons and Katz[15]), and even for the slave market (Greenwald and Glasspiegel[18][17]).

More relevant to our study, Wolinsky[52] examines the role of the imperfect quality information on the formation of equilibria and their prices. He showed that a near perfect quality signal (information) brings up the competitive solution of the market while an extremely imperfect one results in the total market failure identified by Akerlof. This is consistent with the result obtained by Kim[25]. In the two stage model, he investigated an adverse selection where a seller can incur maintenance cost to improve the quality of the goods to be traded in the second period.

On the other hand, proliferation of the Internet and e-Commerce has called for more attention to market design problems than ever. This frictionless online space had created many new market mechanisms. Herschlag and Zwick [21] proclaim that "unlike the real world, the diversity in shopping on the Internet lies not in the difference in selection but in the multiplicity of methods of purchasing." It was claimed that these are extraordinary times for economists who study markets since they have caused the costs of many kinds of market interactions to plummet (Borenstein and Saloner[7]). In fact, creating markets is a mainstay of the business models of dotcoms (Kambil and van Heck[24]). Among them, the online auction seems to be an apparent winner. The Internet economy has demonstrated a growth rate far beyond most analysts' projections. According to Bajari, P. and Hortaçsu[3], more than 632 million items were listed for sale on the behemoth eBay alone in 2002, a 51% increase over the previous year. This generated gross merchandise sales of more than $15 billion. While such extensive listings of goods for trading and powerful search technologies make markets liquid, the electronic media connecting trading participants and passing quality information still remains lean. In the electronic market, only limited ways of description are possible, so the difficulty of quality discovery is higher than that in the traditional market for 'experience goods' defined by Nelson [37], which are hard to describe. As a result of their increasing popularity, coupled with increased claims of fraudulent conduct (Wall Street Journal[4]) in online auctions (Forrester Research 1998), the

problem of information asymmetry has been manifested as the 'winner's curse'. This issue is thoroughly reviewed by Borenstein and Saloner[7]. However, it appears that this generalization underestimates the evolution of economic mechanisms via efforts to internalize transaction costs of these new markets. In fact, electronic markets, especially in online auctions, have employed various combinations of remedies to the 'market for lemons' suggested by earlier economics literature. They include reputation (Heal[19], Lynch et al.[34], Kreps et al.[27]), advertising (Lynch et al.[34]), and selective serving through credit-rationing (Stigliz and Weiss[46]). A more frequently employed measure is the sellers' reputation feedback mechanism. In other words, online markets have devised work-around mechanisms to cope with the "lemon" problem. Online market makers with these measures are basically manipulating the level of information asymmetry. Then, according to prior studies such as Wolinsky, different equilibria (a competitive market, a lemon market or in between) can arise because of the degree of information asymmetry in a market and the interaction between the market and its participants. It will be also possible that such manipulation makes one equilibrium (for example, a lemon market with extreme information asymmetry) transit to another one (competitive one with no information asymmetry). This could be a concern of grave importance to market makers. In other words, we are interested in the *dynamics* and *emergence* of online markets with information asysemmetry. To the best of our knowledge, prior studies have focused on the possibility of different equilibria but they have not studied transition among them. This study is an attempt to fill this void.

We approach this problem using an analytical model and agent-based modeling. The organization of this paper is as follows. In the ensuing section, we present an analytical model which is very general in describing markets with information asymmetry. The merits of our modeling are explained later. Section 3 explains equilibria, and proves that the market may exhibit a few tipping points where radical transitions of equilibria take place. In the following section, we attempt to confirm our theoretical findings through the agent-based modeling approach and to extend them with more realistic and complex settings. Few agent-based models have as of yet made their way into the mainstream of management literature[42], but they appear to gain more attention because of analysis tools of complex systems exhibiting the emergent behavior caused by the interactions between a large numbers of agents. We believe that our case reaffirms the usefulness of this approach. The directions of future research and the conclusion are presented in the last section.

2   Model

We first consider a single-period model of the market with the possibility of information asymmetry, which is the basis for a multi-period simulation model in Section 4. Following Akerlof[1], we use the used the automobile market as a typical example to illustrate the concept of the market for lemons, but our model can be applicable to any market with multiple grades of

quality.

A certain number of people, normalized to one, come to a used car market for trade. The number of buyers is v ($0 \leq v \leq 1$) and that of sellers is $1 - v$. Each seller carries one car whose quality is either of high quality or of low quality. The probability that a car is of high quality is x ($0 \leq x \leq 1$)[1]. People are distinguished by their preference for car quality. The number of high-preference types, H, is w ($0 \leq w \leq 1$) and that of low-preference types, L, is $1 - w$. We will assume that $v \geq \frac{1}{2}$ and $w \geq \frac{1}{2}$. Let $V_{ij}(i, j = H, L)$ represent utility a person of preference type i derives from a car of quality j. Clearly, $V_{HH} > V_{HL}, V_{LH} > V_{LL}$.

Information about car quality is asymmetric between buyers and sellers. That is, buyers have no way to infer quality while sellers know the quality of their own car. Inspection of a car does not reveal any information about its quality while its owner knows the quality. We assume that all buyers form expectations about quality in the same manner. Let y be their common expected quality. Then, the bid price of a buyer of preference type i, U_i^B is given by

$$
\begin{aligned}
U_H^B &= yV_{HH} + (1-y)V_{HL} \\
U_L^B &= yV_{LH} + (1-y)V_{LL}.
\end{aligned}
$$

The offer (reservation) price of a seller of preference type i with a car of quality $j, U_{ij}^O = V_{ij}$, is of course, unobservable to buyers in the auction market[2].

An auctioneer is responsible for making trades. He holds the stock of cars consigned by sellers and matches each car randomly to a buyer whose bid price is greater than or equal to the offer price attached to the car. The matching process continues either until car supply lasts or until all buyers are assigned a car. Our model is different in a few ways from prior studies. First, we reflect some of the nature of the electronic market. In Wolinsky[52], a buyer's effort to 'shop' for the better deal accrues additional cost and however, in computer-mediated markets, such cost may be negligible since transactions are made by the market maker's 'matching' rather than potential buyers' search efforts. In addition, we do not assume any specific form of quality distribution function that is the central dispute between Wilson[50][51] and Ross[43].

3   Equilibrium

We first introduce some definitions. Let PQ denote a set of sellers of preference type P and with a car of quality $Q(P, Q = H, L)$. Also let R denote a set of buyers of preference type

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[1]Note that the choice of dichotomy in goods quality levels is just for simplicy of illustration. Proposition 1 in the next section is essential in characterization of equilibria, which can be easily generalized to any number of quality degrees.

[2]There may be some online markets where sellers signal or misrepresent the quality levels of their goods. For example, One may set up her minimum reservation higher than the market price of the true quality of her goods. However, this is not within the scope of our main research interest here.

$R(R = H, L)$. Finally PQR is a set of pairs of a seller and a buyer who succeed in trading where the seller is of preference type P with a car of quality Q and the buyer is of preference type R. For example, HHL is a set of pairs of a seller of high-preference type who sells his low-quality car to a buyer of low-preference type. N_{PQ}, N_R, and N_{PQR} represent the size of respective sets. With some abuse of notation, PQR also denotes a pattern of trade made between pairs of agents in PQR.

There are eight possible trade patterns summarized in the table below. To read the table, for example, the first row indicates trades in which a seller of high preference type sells his high-quality car to a buyer of high-preference type. Given y, the difference between the bid price and the offer price is

$$\Delta_{HHH} = -(1 - y)(V_{HH} - V_{HL})$$

which is 0 only when $y = 1$. That is, such trades occur only when buyers expect that all cars offered in the market are of high-quality. Similarly, the second row is for trades between a seller of high-preference type selling a high-quality car to a buyer of low-preference type. In this case, it is obvious that Δ_{HHL} is always negative so that such trades never happen.

Patterns	Sellers	Number of sellers	Buyers	Bid-Offer (Δ)	
HHH	HH	$(1-v)wx$	H	$\Delta_{HHH} \leq 0$	Trade if $y = 1$
HHL	HH	$(1-v)wx$	L	$\Delta_{HHL} < 0$	No trade
HLH	HL	$(1-v)w(1-x)$	H	$\Delta_{HLH} > 0$	Trade always
HLL	HL	$(1-v)w(1-x)$	L	$\Delta_{HLL} \gtreqless 0$	Trade if $y \geq y_1$
LHH	LH	$(1-v)(1-w)x$	H	$\Delta_{LHH} \gtreqless 0$	Trade if $y \geq y_2$
LHL	LH	$(1-v)(1-w)x$	L	$\Delta_{LHH} \leq 0$	Trade if $y = 1$
LLH	LL	$(1-v)(1-w)(1-x)$	H	$\Delta_{LLH} > 0$	Trade always
LLL	LL	$(1-v)(1-w)(1-x)$	L	$\Delta_{LLL} \geq 0$	Trade always

where $y_1 = \frac{V_{HL} - V_{LL}}{V_{LH} - V_{LL}}, y_2 = \frac{V_{LH} - V_{HL}}{V_{HH} - V_{HL}}$, and
$\Delta_{HHH} = -(1-y)(V_{HH} - V_{HL})$,
$\Delta_{HHL} = -(1-y)(V_{LH} - V_{LL}) - (V_{HH} - V_{LH})$,
$\Delta_{HLH} = y(V_{HH} - V_{HL})$,
$\Delta_{HLL} = yV_{LH} + (1-y)V_{LL} - V_{HL}$,
$\Delta_{LHH} = yV_{HH} + (1-y)V_{HL} - V_{LH}$,
$\Delta_{LHL} = -(1-y)(V_{LH} - V_{LL})$,
$\Delta_{LLH} = y(V_{HH} - V_{HL}) + V_{HL} - V_{LL}$, and $\Delta_{LLL} = y(V_{LH} - V_{LL})$.

Table 1: Possible Trade Patterns

Patterns of particular interest are HLL and LHH. As the table indicates, such trades occur only when y is greater than or equal to certain values, y_1 in the former pattern and y_2 in the latter pattern respectively. It is clear that $y_1 > 0$ and $y_2 < 1$. Furthermore, we have the following

Equilibria	Expected Quality	Possible trades
Low Quality	$0 \leq y < y_1$	HLH, LLH, LLL
Mixed Quality	$y_2 < y < 1$	LHH, HLL, HLH, LLH, LLL
High Quality	$y = 1$	$HHH, LHH, LHL, (HLH, HLL, LLH, LLL)$

Table 2: Three Possible Equlibria

relations:

$$y_1 \gtreqless 1 \Longleftrightarrow V_{HL} \gtreqless V_{LH} \Longleftrightarrow y_2 \lesseqgtr 0.$$

Therefore, there are three possible cases depending on values of y_1 and y_2:

$$
\begin{aligned}
y_1 &\geq 1 > 0 \geq y_2 \\
1 &> y_2 \geq y_1 > 0 \\
1 &> y_1 > y_2 > 0
\end{aligned}
$$

From the table above, we can easily sort out the possible trade sets according to the range of expected quality of goods in the market, summarized in Table 2. These three cases will be analyzed later in sequence.

In order to characterize the equilibria, we have to derive the frequencies of each trade type. For that end, the following preliminary results prove useful.

3.1 Preliminary Results

Suppose there are two groups of urns. In the first group, there are n_1 urns and urn i ($i = 1, 2, \cdots, n_1$) can contain N_i^I balls. In the second group, there are n_2 urns urn i ($i = 1, \cdots n_2$) can contain N_i^{II} balls. Let $n = n_1 + n_2$. There are M balls, wM red balls and $(1 - w)M$ white balls where $0 \leq w \leq 1$. A ball is chosen at random and a replacement is put in the urn. If a white ball is chosen, it is put only in an urn of the second group. If a red ball is chosen, it can be put in an urn of either group. The probability that a chosen ball is put in a particular urn is determined by the ratio of the size of the *remaining* space of the urn to that of the remaining space of all other urns. The experiment is over when one of the urns become full.

For analytic simplicity, the experiment is deemed to be done continuously in time. Let $R_i^I(t), R_i^{II}(t)$ and $W_i(t)$ represent the (expected) number of red balls in urn i of the first group, that of red balls in urn i of the second group, and white balls in urn i of the second group at time t. (In what follows, all the relevant variables are interpreted in expected sense.) The rate

of change in time of respective variables is defined as

$$
\begin{aligned}
\dot{R}_i^I(t) &\equiv \frac{dR_i^I(t)}{dt} \\
\dot{R}_i^{II}(t) &\equiv \frac{dR_i^{II}(t)}{dt} \\
\dot{W}_i(t) &\equiv \frac{dW_i(t)}{dt}.
\end{aligned}
$$

Also we let R^I be the total number of red balls in urns of the first group at time t. Similarly, we define

$$
R^I(t) \equiv \sum_{i=1}^{n_1} R_i^I(t) \tag{1}
$$

$$
R^{II}(t) \equiv \sum_{i=1}^{n_2} R_i^{II}(t) \tag{2}
$$

$$
W(t) \equiv \sum_{i=1}^{n_2} W(t) \tag{3}
$$

$$
N^I \equiv \sum_{i=1}^{n_1} N_i^I \tag{4}
$$

$$
N^{II} \equiv \sum_{i=1}^{n_2} N_i^{II} \tag{5}
$$

$$
\bar{N} \equiv N^I + N^{II}. \tag{6}
$$

Finally, we define

$$
\begin{aligned}
m_i &= \frac{N_i^{II}}{N_{n_2}^{II}}(i = 1, 2, ..n_2) \\
m &= \sum_{i=1}^{n_2} m_i.
\end{aligned}
$$

Clearly, $m_{n_2} = 1$.

Proposition 1 *(i) All urns of the second group become full at the same time, more quickly than*

the first group. (ii) Let t^0 be time at which a urn in the second group becomes full. Then

$$R_i^I(t^0) = N_i^I \left(1 - \left(\frac{N^I}{\bar{N}} \right)^{\frac{w}{1-w}} \right), (i = 1, 2, \cdots, n_1) \tag{7}$$

$$R_i^{II}(t^0) = \frac{m_i(wN^{II} - (1-w)R^I(t^0))}{m}, (i = 1, 2, \cdots, n_2) \tag{8}$$

$$W_i(t^0) = \frac{m_i(1-w)(N^{II} + R^I(t^0))}{m}, (i = 1, 2, \cdots, n_2) \tag{9}$$

$$t^0 = R^I(t^0) + N^{II} \tag{10}$$

3

Below, we will extensively utilize Proposition 1 in characterizing various types of equilibria. To this end, we regard a red ball as a buyer of high-preference type and a white ball as a buyer of low-preference type. We also identify a seller set as an urn. Then, to which group a particular seller set belongs is determined by trade patterns associated with the seller set in an equilibrium. Suppose that there are three types of potential trade patterns in an equilibrium, say, HLH, LLH and LLL. (This is in fact the low-quality equilibrium discussed below shortly.) Then, HL belongs to the first group and LL to the second group because a buyer of high-preference can be matched with both HL and LL (or a red ball can be put in HL and LL urns) while a buyer of low-preference is matched only with LL (or a white ball can be put only in LL urn.).

3.2   Characterization of equilibria

Now we investigate the three possible equilibria summarized in Table 2.

3.2.1   Low quality equilibrium

This is the case where the expected quality of traded goods is below a certain threshold, y_1 (possible only when $V_{LH} < V_{HL}$). In this case, as the above table indicates, there are potentially three types of trade patterns in equilibrium, which include HLH, LLH and LLL. That is, only lower quality goods are traded. Adopting the interpretations above, we can see easily that

$$N^I = N_1^I = N_{HL} = (1-v)w(1-x)$$
$$N^{II} = N_1^{II} = N_{LL} = (1-v)(1-w)(1-x)$$
$$\bar{N} = N_{HL} + N_{LL} = (1-v)(1-x).$$

---

[3] The proof of the proposition above is omitted due to the space limitation but available from the authors.

Noting that t^0 is when the auctioneer has just assigned the last seller in LL to a buyer and defining $N_{PQR}(t_0)$ as the size of PQR at t_0, we see that

$$
\begin{aligned}
R_1^I(t^0) &= N_{HLH}(t_0) \\
R_1^{II}(t^0) &= N_{LLH}(t_0) \\
W_1(t^0) &= N_{LLH}(t_0).
\end{aligned}
$$

Invoking the results in Proposition 1,

$$
\begin{aligned}
N_{HLH}(t^0) &= (1-v)w\left(1 - w^{\frac{w}{1-w}}\right)(1-x) \\
N_{LLH}(t^0) &= (1-v)(1-w)w^{\frac{1}{1-w}}(1-x) \\
N_{LLL}(t^0) &= (1-v)(1-w)\left(1 - w^{\frac{1}{1-w}}\right)(1-x).
\end{aligned}
$$

Since only low-quality cars are traded in low-quality equilibrium, it must be that $y = 0$ for consistency. This equilibrium is robust in that as long as buyers believe that all traded cars are low-quality, only those cars can be traded in the market no matter how many high-quality cars arrive. This is a standard result in this line of research.

Let N_{HLH}^L (N_{LLH}^L, N_{LLL}^L) be the equilibrium size of HLH (LLH, LLL) in the low quality equilibrium and $N^L \equiv N_{HLH}^L + N_{LLH}^L + N_{LLL}^L$ be total trade size. By Proposition 1, it is clear that

$$
\begin{aligned}
N_{LLH}^L &= N_{LLH}(t^0) \\
N_{LLL}^L &= N_{LLL}(t^0).
\end{aligned}
$$

In other words, all sellers in LL have been matched with buyers in some way or other by t_0. This implies that buyers of low-preference type who have failed to buy a car until t_0 has no more chance. Since $N_{HLH}(t_0) < N_{HL}$, some sellers in HL are yet to be matched with buyers of high-preference type. The number of buyers of high-preference type who have bought a car by t^0 is

$$
\begin{aligned}
& N_{HLH}(t_0) + N_{LLH}(t^0) \\
=\ & (1-v)w(1 - w^{\frac{1}{1-w}})(1-x) \\
\leq\ & (1-v)w \\
\leq\ & vw.
\end{aligned}
$$

The last inequality follows from the assumption that $v \geq \frac{1}{2}$. This means that after t^0, buyers of high-preference type who failed to buy a car before t^0 will be assigned to a seller in HL. As a result,

$$
\begin{aligned}
N_{HLH}^L &= \min\left\{N_{HL}, vw - N_{LLH}(t^0)\right\} \\
&= \min\left\{(1-v)w(1-x), vw - (1-v)(1-w)w^{\frac{1}{1-w}}(1-x)\right\}.
\end{aligned}
$$

Let SW^L be social welfare in the low quality equilibrium. Note that gains (or losses) from trades occur only when trades are made between sellers and buyers of different preference types. That is, only trade patterns of HHL, HLL, LHH, and LLH in Table 1 affect social welfare. Hence, we have the following proposition:

Proposition 2 *In the low quality equilibrium, the trade size and the social welfare are given as follows:*

$$
\begin{aligned}
N^L &= N^L_{HLH} + N_{LL} \\
&= \min\left\{ (1-v)(1-x), vw + (1-v)(1-w)\left(1 - w^{\frac{1}{1-w}}\right)(1-x)\right\}
\end{aligned}
$$

and

$$
\begin{aligned}
SW^L &= N^L_{LLH}(V_{HL} - V_{LL}) \\
&= (1-v)(1-w)w^{\frac{1}{1-w}}(1-x)(V_{HL} - V_{LL}).
\end{aligned}
$$

It is easy to see that N^L and social welfare decrease with x. They also show the same trends with v. That is, the larger the number of buyers relative to that of sellers, the smaller the social welfare becomes. In addition, the social welfare also decreases with $w > \frac{1}{2}$. This occurs because an increasing portion of high-quality cars are hoarded from the market or the market for "lemons" shrinks in size.

3.2.2   Mixed quality equilibrium

Suppose $1 > y > y_2$. There are five potential trade patterns, HLH, HLL, LHH, LLH and LLL in which both high- and low-quality cars are traded. In this case, LH belongs to the first group and HL and LL to the second group.

Proposition 3 *In the high quality equilibrium, the trade size and the social welfare are given as follows:*

$$
\begin{aligned}
N^H &= N^H_{HHH} + N_{LH} \\
&= \min\left\{ (1-v), vw + (1-v)(1-w)\left(1 - w^{\frac{1}{1-w}}\right)\right\}
\end{aligned}
$$

and

$$
\begin{aligned}
SW^H &= N^H_{LHH}(V_{HH} - V_{LH}) \\
&= (1-v)(1-w)w^{\frac{1}{1-w}}(V_{HH} - V_{LH}).
\end{aligned}
$$

In the mixed quality equilibrium, $N^M = (1 - v)(1 - w)x$. It is easy to show that

$$(1 - v)(1 - w) < N^H.$$

Therefore, there is a discontinuity at $x = 1$ in terms of market performance. Specifically, trade volume jumps upward when all cars are of high quality. Despite the jump in trade volume, social welfare does not.

A sudden emergence by a small change in a system has been observed in many complex systems[8][16] including technology markets. From Propositions 2-4, two 'tipping' points exist where a market suddenly shifts from the market for lemons to one for mixed qualities and to the market for only high quality. Then, it is clear that market makers can trade goods if they can manipulate the buyers' perceived level of information asymmetry beyond a tipping point. This explains why electronic markets with seemingly magnified information asysmmetry are thriving and the earlier prediction of electronic 'lemon' markets do not hold.

The 'lemon' market is manifested more acutely due to the possibility of sellers' misrepresentation as in Akerlof, and Wolinsky[52]. Wolinsky recognized that buyers' 'search' behavior could prevent sellers' from misrepresentation even though the information buyers are gathering is imperfect. We modeled a computer mediated online market where buyers' misrepresentation is not permitted through a price signal. However, it is interesting that our results still show that the market can be of lemons, or perfectly competitive, or of goods with mixed quality levels. Of course, the existence of information asymmetry, that is, buyers' incapability of distinguishing the quality level distorts the quality distribution of the goods of being traded through the market.

4 Agent-Based Simulation Model

Axtell[2] identify several advantages of agent-based modeling (ABM). One of them is that it "results an entire dynamics history of the process under study. That is, one need not focus exclusively on the equilibria, should they exist, for the dynamics are an inescapable part of running the agent model." More specifically, using ABM, we try to confirm the results of the theoretical model and extend more insights from them as envisoned by Axtell[2]. To take advantage of this methodology, we are able to investigate harder problems which are not easily formulated in a closed form in the theoretical model. They include multiple quality levels and preference types, more realistic settings such as the existence of expertise among buyers and their search efforts.

Tesfatsion[47] also advocates this methodology because it is useful to study complex phenomena associated with decentralized market economies, such as inductive learning, imperfect competition, endogenous trade network formation, and the open-ended coevolution of individual behaviors and economic institutes focusing on the constructive explanation of emergent global behavior. Our analytical model assumed that buyers form their expected quality y from the

market outcome but did not elaborate how it can be determined. By extending in a dynamic framework with adaptive expectations, we can observe what Testfatision[47] suggests.

4.1 Model

The simulation model is the same as the theoretical model except that the former is a multi-period one. In each period, a certain number of buyers and sellers arrive at the market. Buyers know generic quality x,i.e., quality distribution of goods. However, since there is no guarantee that actual quality of traded cars is equal to x, each buyer needs to expect the actual quality, we assume that she expects it as a convex combination of generic quality and average quality in the previous period with the weight attached to generic quality becomes smaller as periods go on

$$q_t^e = \lambda_t x + (1 - \lambda_t)q_{t-1}.$$

One possibility is $\lambda_t = \frac{1}{t}$. In this case, as t grows, q_t approaches a certain value, an equilibrium quality in the theoretical model. Given the expected quality, each buyer submits a bid to the auctioneer, who then randomly assigns a car whose offer is not greater than the bid. For high x, q^e starts with a high value, the market will not collapse or mixed quality equilibrium can be sustained. The simulation is the modeled using *Repast*, a popular Java based ABM tool[4].

4.2 Existence of Tipping Points

One of the main findings of our analytical investigation is the existence of thresholds of buyers' perceptions that determines the equilibrium of the market. Hence, we test it using the same setting as our analytical model except for the multi-period setting. In this simulation, the total number of agents is 100, which is evenly divided between buyers and sellers. As in Example 1, set $V_{HH} = 1.0, V_{HL} = 0.5, V_{LH} = 0.7$, and $V_{LL} = 0.4$. For 100 iterations of the simulation, Figure 1 shows the average quality of the goods traded from the market. It clearly confirms the existence of tipping points of the market. That is, until the proportion of high quality goods, x reaches at around 0.5, the market trades only lemon goods but beyond the first tipping points, market performance sharply improves.

Figure **??** shows the average social welfare. In general, social welfare also improves as does the proportion of high quality goods. However, at the high end, social welfare drops because many of the buyers whose preference is low cannot be served by the market due to the lack of low quality goods. The average trading proportion and average prices of the market are depicted in Figure 2 and 3 respectively. It is noticed that the number of successful trades decreases until the first tipping point as the proportion of high quality goods increases. It is because high quality

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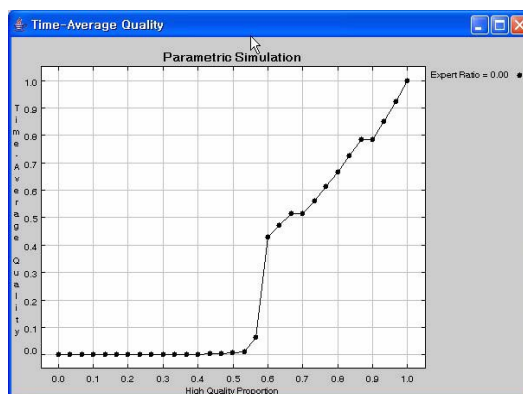[4]Repast is available from repast.sourceforge.net.
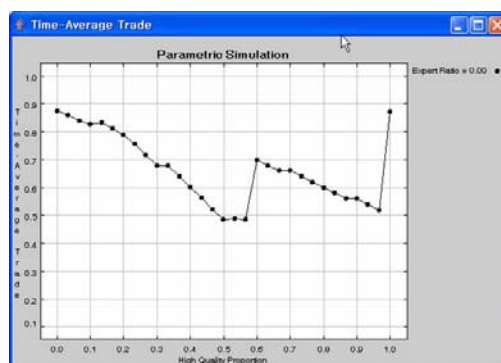
Figure 1: Average Quality of Goods Traded

Figure 2: Trading Portion

goods cannot be traded in this market since the market remains as one for lemons until these points.

4.3   Experts in the market

As an extension to our theoretical model, we allow the possibility of experts among buyers who know the true quality of the goods to be traded. The average quality of the traded goods, their trading portion, the average price and social welfare are shown in Figure 4, 5, 6 and 7 respectively. The ratios of experts to the total number of buyers were increase from 0% by 20% to 100%. Figure 4 shows that the market performance quickly improves with even a small number of experts in the market for lemons but the number of trades decreases with them since they sort out "lemon" trades. It is interesting that social welfare drops with experts if the goods with higher quality exceeds the first tipping point. Therefore, it implies that
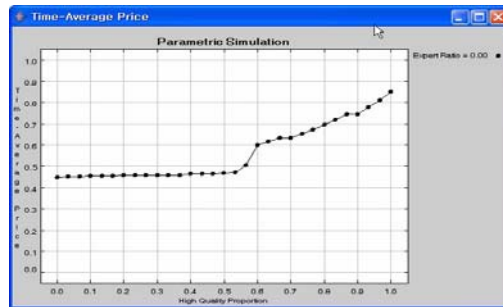
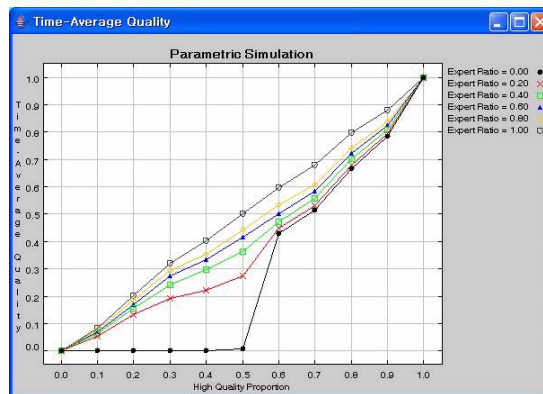Figure 3: Average Price of Goods Traded

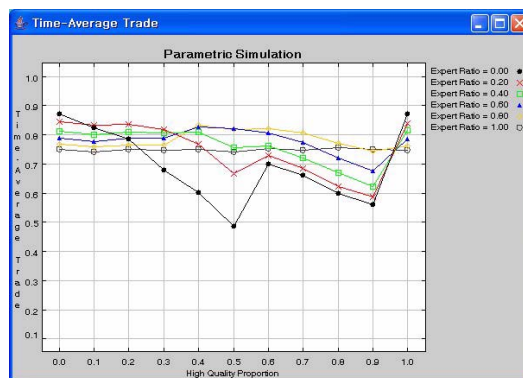Figure 4: Average Quality of Goods Traded with Experts

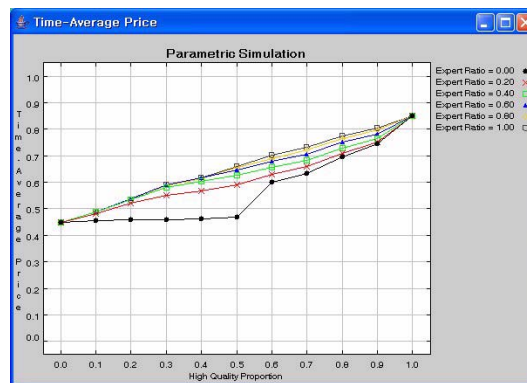

Figure 5: Trading Portion with Experts

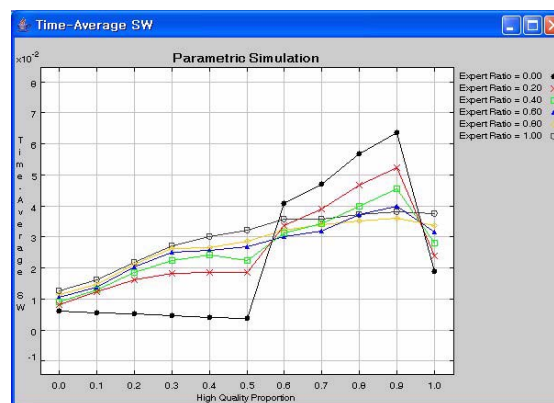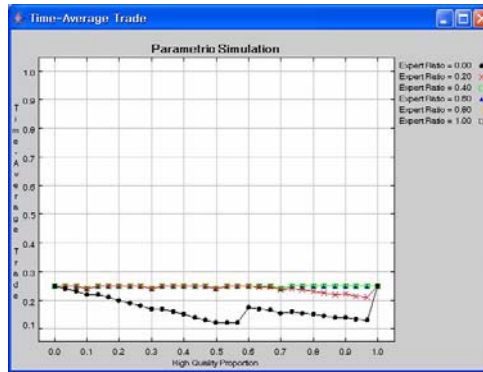Figure 6: Average Price of Goods Traded with Expert Buyers

Figure 7: Social Welfare with Expert Buyers

4.4   Market Thickness

We also test the impact of an imbalance in the numbers of sellers and buyers. From the equal number of agents, now, we test the market with more buyers than sellers (the ratio is 6 to 4). Due to the imbalance between the trading participants, the trading portion depicted in the figure below is much lower than that for the balanced number of participants as in Figure 5. The buyer's market with the reversed ratio results in the similar outcomes.
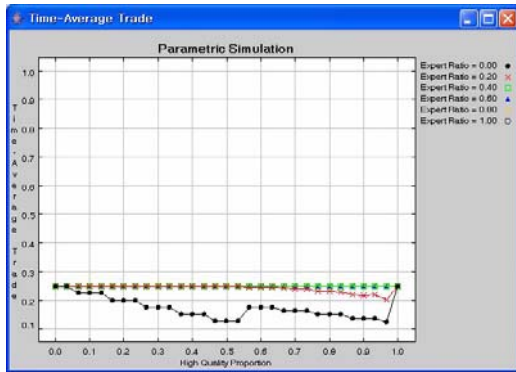
Trading Portion with More Buyers   Trading Portion of Market with More Sellers

5   Conclusion

The existence of multiple equilibria was fiercely debated in the early information asymmetry literature. Reflecting the recent development of electronic markets where sellers and buyers are literally matched via market makers, we develop a very general theoretical model that characterizes different equilibria and transition among them by the extent of information asymmetry. Electronic markets, in particular, are exposed to this problem more directly. Various combinations of the measures to mitigate the information asysmmetry have been introduced. Hence, to a certain extent, such market makers or participants can control the amount of information asymmetry. Since Cyberspace emerges as a viable mainstream distribution channel, prediction and evaluation of market performance with information asymmetry is becoming more relevant and important.

With ABM, we verified our analytical results by observing the dynamics of market emergence. While in this study, we limit our investigation to "information asymmetry" *per se*, it seems that flexibility of this methodology enables us to test more realistic markets. Several limitations or direction of further research are obvious in our study. First of all, the possibility of misrepresentation of the quality by a seller is not incorporated in the model. Secondly, the way buyers infer the quality level of the market should be empirically verified.

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