Endogenous Market Segmentation for Lemons*

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Abstract

Information asymmetry between sellers and buyers often impedes socially desirable trade. This paper presents a new mechanism that mitigates the inefficiencies caused by information asymmetry. It is shown that markets under severe adverse selection can be endogenously segmented and such segmentation improves social welfare. Endogenous segmentation is driven by low-quality sellers' incentive to attract more buyers by separating from high-quality sellers. The mechanism helps us understand the roles of several real-world institutions, such as multiple marketplaces, costless advertisements, and non-binding list prices.

JEL Classification Numbers: C72, D82, D83.

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1 Introduction

Since Akerlof (1970), it is well-understood that information asymmetry between sellers and buyers may impede socially desirable trade and, in its extreme, the market may completely break down. Various market and non-market innovations have been identified as sources to alleviate the inefficiencies implied by adverse selection. Those innovations fall into two categories: signalling from informed agents (for example, warranties, costly advertisements, and posting prices) and screening by uninformed agents (for example, early discounts and deductibles).

This paper presents an alternative mechanism that mitigates the inefficiencies resulting from information asymmetry: *endogenous market segmentation.* The theoretical novelty is, different from signalling or screening, it necessitates neither money burning nor commitment from agents. Instead, it counts on equilibrium incentives: the incentive for sellers to sort themselves is endogenously generated by buyers' behavior, and vice versa. On the applied side, it helps us understand the roles of several real-world institutions.

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I consider a decentralized version of Akerlof's original model. In a market with many buyers and sellers, each buyer randomly selects a seller and makes a take-it-or-leave-it offer.[1] This model has been employed in several other contexts and maintains the gist of Akerlof's competitive model. A high price will be accepted not only by high-quality sellers, but also by low-quality sellers. Being aware of this adverse selection, unless the proportion of high-quality sellers is sufficiently large, buyers offer only low prices. Then, high-quality units do not trade, even though there are always gains from trade.

Different from Akerlof, sellers communicate with buyers before trading takes place. Communication may be explicit or implicit. Sellers may send some messages to buyers (explicit). Or, they may take some actions (implicit). For instance, sellers may choose different marketplaces to set up their stands or different platforms to post their units. Whether explicit or implicit, communication is costless (no money burning) and non-binding (no commitment), and this is the point of departure from the existing signalling or screening models. A non-trivial issue is how a low-quality seller can be induced to honestly reveal the quality of her unit, even though there are no direct costs in mimicking a high-quality seller.

The main result of the paper is markets under severe adverse selection can be endogenously segmented and such segmentation improves social welfare. High-quality units, that cannot trade without segmentation, do trade with segmentation, and low-quality sellers are also strictly better off. To put it differently, (some) low-quality sellers voluntarily reveal the quality of their units. The consequent reduction of information asymmetry allows trade of high-quality units and leads to Pareto improvement.

Figure 1 illustrates how endogenous segmentation works. The measure of sellers is normalized to 1 and $\widehat{q}$ is the proportion of low-quality sellers in the market. In equilibrium, the measure $\tilde{q}$ of low-quality sellers reveal their quality (by announcing message L or joining submarket L). Other low-quality sellers and all high-quality sellers claim to have a high-quality unit (by announcing message H or joining submarket H). The measure α^* of buyers are attracted to sellers who revealed the low quality of their units, while the other buyers visit sellers who claim to have a high-quality unit. In this structure, agents face the following trade-offs: Low-quality sellers enjoy a higher probability of trade (due to relatively more buyers) but suffer from a lower price in submarket L than in submarket H. Buyers face less quality uncertainty but more severe competition in submarket L than in submarket H. In equilibrium, these trade-offs of buyers and low-quality sellers are exactly balanced, that is, they are indifferent between H and L. High-quality sellers, due to their high reservation price, strictly prefer H to L. In this equilibrium, high-quality units also trade, because the proportion of low-quality units in submarket H is smaller than $\widehat{q}$.

Endogenous segmentation is driven by low-quality sellers' incentive to *separate* from high-quality sellers. To see this, first consider a buyer who is about to make an offer to a seller. If he knows the quality of the seller's unit is high (low), he would offer a high (low) price. When there is uncertainty

[1] The results do not crucially depend on this specific exchange process. See Section 5.

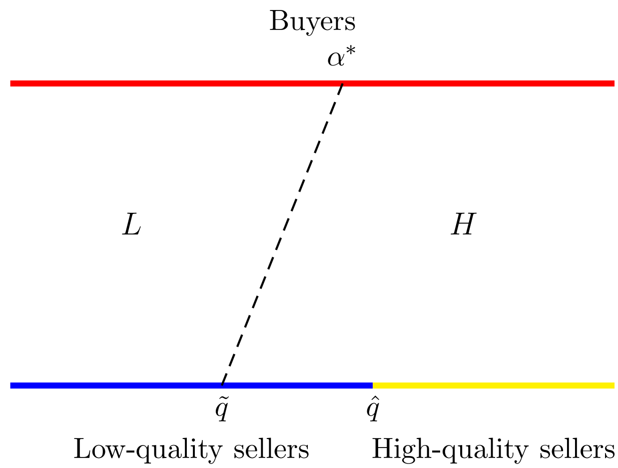

Figure 1: Endogenous segmentation in the two-type case.

over the quality, however, a low price will be rejected with a positive probability, while a high price runs the risk of overpaying for a *lemon.* Therefore, (risk-neutral) buyers are averse toward quality uncertainty. Low-quality sellers' separating incentive stems from here. If a seller reveals the low quality of her unit, her unit becomes more attractive to buyers, because now they face no quality uncertainty. Relatively more buyers will be interested in the seller's unit, which will increase both her probability of trade and expected price.

Of course, as is familiar in the literature, low-quality sellers also have an incentive to pool with high-quality sellers in order to receive a high price. The equilibrium structure in Figure 1 is the consequence of the collision of the two opposing incentives. Suppose the two types of sellers are fully separated. In this case, buyers would offer high (low) prices to sellers who claim to have a high-quality (low-quality) unit. Then the pooling incentive is strongest, while the separating incentive is negligible. This unravels the full separation. Now suppose sellers are completely pooled. In this case, information asymmetry prevents trade of high-quality units, and thus buyers would offer only low prices. Then, the pooling incentive is vacuous, while the separating incentive becomes operative. In order to attract more buyers, low-quality sellers would reveal the quality of their units. In equilibrium, these two forces are exactly balanced and result in the partial resolution of information asymmetry.

The result helps us understand the roles of several real-word institutions. I discuss three straightforward applications. Each application differs in the form of communication.

First, communication may occur through agents' choices of locations or platforms (implicit). Under this interpretation, the result provides another explanation as to why it is beneficial to have multiple marketplaces or platforms for a single good. Different from the existing papers,[2] the result in this paper is concerned with information asymmetry in markets and illustrate how the mere

[2]See, for example, Armstrong (2006) and Rochet and Tirole (2006)

existence of multiple marketplaces can help mitigate the inefficiencies resulting from information asymmetry. Furthermore, the result provides a particular prediction on the arrangement of multiple marketplaces or platforms: relatively more buyers join low-quality submarkets, and high-quality submarkets entail more quality uncertainty. Interestingly, the prediction in the model matches some recent empirical findings on housing sales. Bernheim and Meer (2008) compared housing sales with and without agents, while Hendel, Nevo, and Ortalo-Magné (2007) compared housing sales through off-line dealers and through on-line website. They found that transaction prices are higher without agents or through on-line website (submarket H), while sales are faster with agents or through off-line dealers (submarket L). These differences may be driven by the difference of network sizes or by the inherent difference of platforms. This paper suggests an alternative theory that is based on information asymmetry in markets and explains the differences as an equilibrium market phenomenon.

Second, communication can be interpreted as costless advertisement (explicit). Then the result challenges a conventional wisdom in industrial organization. In his classic papers (1970, 1974), Nelson argued that costless and non-binding advertisements cannot convey any information about the quality of experience goods. He reasoned that if sellers' claims are costless and unverifiable, all sellers would claim to have a high-quality product. This was in fact one of the reasons why many researchers have studied costly advertisements and other payoff-relevant devices.[3] The result of this paper, however, implies that even costless advertisements can be informative about the quality of experience goods.

Last, more specifically, messages can be interpreted as non-binding list prices, which sellers announce before trading but do not commit to. In several markets (for example, used cars, housing, and online posting sites), sellers post prices, but it has been observed that a transaction price is often different from the list price. This suggests that list prices are non-binding and thus have little intrinsic meaning. Nevertheless, correlations between list prices and economic outcomes (conditioning on all observables) have been reported: a transaction price is typically lower, but sometimes higher, than the list price, and a lower list price tends to induce a smaller number of interested buyers and a longer duration on the market.[4] The result in this paper provides an alternative theory of non-binding list prices that emphasizes their information transmission role.[5] Furthermore, it provides an intuitive reason for the aforementioned stylized facts. The higher a list price is, the

[3] Nelson's own suggestions were repeated purchases (1970) and costly advertisements (1974). Kihlstrom and Riordan (1984) refined Nelson's idea on costly advertisements. Another prominent device considered in the literature is price (or pricing schedule). Wolinsky (1983), Bagwell (1991), and Taylor (1999) showed that price can serve as a signal of quality in various contexts. Milgrom and Roberts (1986) considered both price and costly advertisements.

[4] See, for example, Horowitz (1992) and Merlo and Ortalo-Magné (2004) for housing markets and Farmer and Stango (2004) for an online used computer market.

[5] Despite many empirical efforts to identify the determinants of list prices, there has been only one theoretical explanation for the correlations between list prices and economic outcomes, which was provided by Arnold (1999), Chen and Rosenthal (1996), and Yavas and Yang (1995). They focused on the fact that a transaction price is typically lower than the list price and postulated that list prices are ceiling prices that sellers commit to accept. The crucial idea is that if a seller commits to a lower list price, buyers expect greater gains in the event that their valuations turn out to be high, and consequently they are more interested in the unit.

more uncertain the quality of the unit is, and therefore there are fewer interested buyers. This tends to delay trade, but once there is an interested buyer, he believes that the quality is high and thus the transaction price tends to be higher.

The remainder of the paper is organized as follows. The next section links the paper to further literature. Section 3 introduces the model and Section 4 analyzes it. Section 5 concludes by discussing several relevant issues.

2 Related Literature

Two papers studied endogenous segmentation in different contexts. Mailath, Samuelson, and Shaked (2000) considered a labor market model where both workers and firms search for each other. They showed that "color" can create inequality endogenously. Firms search "green" workers because they are more likely to acquire a skill than "red" workers. On the other hand, "green" workers are more willing to acquire the skill than "red" workers because in equilibrium it takes less time for them to find a firm, and thus their return on skill investment is higher. Fang (2001) considered an economy where the informational free-riding problem is so severe that a socially efficient technology cannot be adopted. He showed that in such environments "social activity" can emerge as an endogenous signaling instrument. Firms pay more to workers who perform a seemingly irrelevant "social activity" because those workers are more likely to acquire a new skill. On the other hand, skilled workers are more willing to do the "social activity" because they expect a higher wage.

Farrell and Gibbons (1989) and Matthews and Postlewaite (1989) examined whether cheap talk can be informative in bilateral bargaining situations in which each party has private information about his or her own value. They showed that allowing for cheap-talk communication enlarges the set of equilibria in double auctions. This paper shows that cheap talk can also be informative in decentralized markets when sellers possess private information regarding the quality of their units, that is, when sellers' private information concern both their own costs and buyers' values.

There is a fairly large literature that studies adverse selection in decentralized markets. Among many, particularly close to this paper are Inderst and Müller (2002), Guerrieri, Shimer, and Wright (2010), and Menzio (2007). The first two papers studied competitive search equilibrium under adverse selection. In those papers, either informed players (Inderst and Müller (2002)) or uninformed players (Guerrieri, Shimer, and Wright (2010)) commit to prices or mechanisms before matching, while commitment is not allowed in this paper. The consequence is that both papers found fully separating equilibria, while this paper finds no fully separating equilibrium but a partially separating equilibrium. In Menzio (2007), informed players send cheap-talk messages, as in this paper. He focused on the case where informed players' private information does not directly affect uninformed players' utility (in the context of this paper, a seller's type determines only her own cost, not buyers' value), and thus the lemons problem never arises. More importantly, in his setup, prices are determined through alternating offer bargaining. This difference has several substantial implications.

For example, his model is hard to generalize beyond the private value case, because of the equilibrium multiplicity inherent in alternating offer bargaining with incomplete information. Even in the private value case, the two models deliver very different predictions. When there is a continuum of types, there can exist at most finite submarkets in his setup, while with the trading mechanism used in this paper, there is a fully revealing equilibrium and every non-trivial equilibrium has a continuum of submarkets.

The particular exchange process used in this paper has been employed in other papers. For example, Butters (1977) used it to generate price dispersion in environments with homogeneous buyers and sellers. Wolinsky (1988) examined a similar model with one-sided private information to study the impact of bidding competition on decentralized trading outcome. Satterthwaite and Shneyerov (2007) considered the case of two-sided private information and showed that the decentralized trading outcome converges to the competitive outcome as market frictions vanish.

3 The Model

3.1 Environment

In a market for an indivisible good, there are a continuum of sellers, whose measure is normalized to 1, and a continuum of homogeneous buyers, with a fairly large measure. Each seller possesses a unit of the good, whose quality is either high or low. A unit of low quality costs $c_L(\geq 0)$ (or reservation utility) to a seller and yields utility v_L to a buyer. The corresponding values for a unit of high quality are $c_H\,(> c_L)$ and $v_H\,(> v_L)$. There are always gains from trade ($v_H > c_H$ and $v_L > c_L$), but the quality of each unit is private information to each seller. It is commonly known that the proportion of low-quality sellers is $\widehat{q} \in (0, 1)$. All agents are risk neutral.

I focus on the case where adverse selection is particularly severe. Formally, I make use of the following two assumptions:

Assumption 1 *(Larger social surplus with trade of high quality)*

$$v_H - c_H \geq v_L - c_L.$$

In words, trade of a unit of high quality is socially more desirable than that of low quality. Note that $v_H > v_L$ is necessary but not sufficient for this assumption.

Assumption 2 *(No trade of high quality)*

$$\widehat{q}v_L + (1 - \widehat{q})v_H < c_H.$$

This inequality is a familiar one in the adverse selection literature. The left-hand side is the maximum price that buyers are willing to pay to a seller who is randomly selected from the population (or the expected value to buyers of a randomly selected unit), while the right-hand side is the minimum price that high-quality sellers are willing to accept (or the reservation price of high-quality sellers). When the inequality holds, no price can yield non-negative payoffs to both buyers and high-quality sellers. Therefore, only low-quality units can trade in the competitive benchmark.

3.2 Trading Process

The market proceeds in four steps. First, each seller announces a cheap-talk message.[6] The set of feasible messages is given by $\{L, H\}$.[7] Second, all buyers observe all messages and decide whether to incur an entry cost $k \in (0, \widehat{q}(v_L - c_L))$ or not.[8] Third, each participating buyer selects a seller and makes a take-it-or-leave-it offer to her. Buyers do not observe the number of competitors. Fourth, sellers who have received at least one offer decide whether to accept the highest offer or not. If a seller accepts p, then her payoff is $p - c_q$ and the buyer's payoff is $v_q - p$, where q denotes the quality of the seller's unit. Sellers who did not receive any offer or rejected the highest offer and buyers whose offer was not accepted obtain 0 utility.

The trading process can be interpreted in two ways. From a seller's viewpoint, it is equivalent to her running a first-price auction with a private reservation price and a stochastic number of bidders. From a buyer' viewpoint, it is equivalent to the bargaining game in which he makes a take-it-or-leave-it offer to a seller who has a private and stochastic outside option.

3.3 Matching Technology

As is common in the decentralized trading literature, I introduce anonymity into the trading process. Formally, I assume that buyers condition only on sellers' messages in both matching and bidding stages. Each buyer selects sellers who announced an identical message with equal probability. In addition, buyers' bidding strategies depend only on sellers' messages, that is, they are independent of their own as well as sellers' identities. These restrictions probably can be best interpreted as *coordination frictions*: in large markets, it seems implausible to assume that each agent knows what every other agent would do. Interested readers are referred to Burdett, Shi, and Wright (2001) and Shimer (2005) for insightful discussions.

Suppose a measure s_L of low-quality sellers and a measure s_H of high-quality sellers announced an identical message and a measure b of buyers would select those sellers. As in directed search models, this essentially creates a submarket. Denote by λ the ratio of buyers to sellers in the submarket, that is, $\lambda = b/(s_L + s_H)$. In addition, let q denote the proportion of low-quality sellers in the submarket, that is, $q = s_L/(s_L + s_H)$.

By the standard argument, the probability that a seller is selected by k buyers, π_k, follows a

[6] An alternative but essentially equivalent setup is the one in which there are two submarkets, say submarket L and submarket H, and each agent chooses a submarket to join.

[7] It will be shown that the two-message restriction has no loss of generality.

[8] The condition $k < \widehat{q}(v_L - c_L)$ ensures that the market never breaks down. It is not crucial for any qualitative result in the paper.

Poisson distribution with parameter λ. Formally,

$$\pi_k(\lambda) = \frac{\lambda^k}{k!e^\lambda}, k = 0, 1, ...,$$

where λ is the ratio of buyers to sellers.[9] In addition, by the conditional independence property of Poisson distribution, the probability that a buyer is competing with k other buyers is also given by $\pi_k(\lambda)$.[10] These properties imply that the submarket outcome will depend only on the ratio of buyers to sellers, λ, and the proportion of low-quality sellers, q. In other words, the matching technology exhibits constant return to scale, and thus each submarket can be characterized by λ and q.

4 Characterization

I first characterize submarket outcome and then endogenize buyers' participation and sellers' communication strategies.

4.1 Submarket Outcome

Consider a submarket that is identified by (q, λ) where q is the proportion of low-quality sellers and λ is the ratio of buyers to sellers. Denote by $U(q, \lambda)$ the expected payoff of buyers in the submarket. Similarly, let $V_L(q, \lambda)$ and $V_H(q, \lambda)$ denote the expected payoffs of low-quality sellers and high-quality sellers, respectively.

Buyers' Expected Payoff The following two observations pin down buyers' expected payoff:

1. In equilibrium, buyers play a mixed bidding strategy. Let a distribution function $F : \mathcal{R}_+ \to [0, 1]$ represent buyers' symmetric bidding strategy.

2. Let $\underline{b}$ be the minimum of the support of F. Then $\underline{b}$ is equal to the offer of the monopsonist to a randomly selected seller.

To see the first, suppose buyers' bids are deterministic. The equilibrium bid must be lower than their expected value of a unit. Then a buyer would be strictly better off by bidding slightly above the equilibrium bid. His expected payment would increase slightly but he would always win. A similar reasoning also reveals that F has no atom in its support. To see the second, notice that, since F has no atom, a buyer who offers $\underline{b}$ wins only when he is the only bidder. Therefore, his offer $\underline{b}$ must be optimal conditional on him being the only bidder.

[9] Suppose there are λN buyers and N sellers and each buyer selects sellers with equal probability. As N tends to infinity, by the Poisson convergence theorem (see, for example, Billingsley (1995), Theorem 23.2.), the probability that a seller is selected by k buyers converges to $\pi_k(\lambda)$. This matching technology is known as "urn-ball" in the literature.

[10] For an elementary exposition, see Satterthwaite and Shneyerov (2007), p. 173.

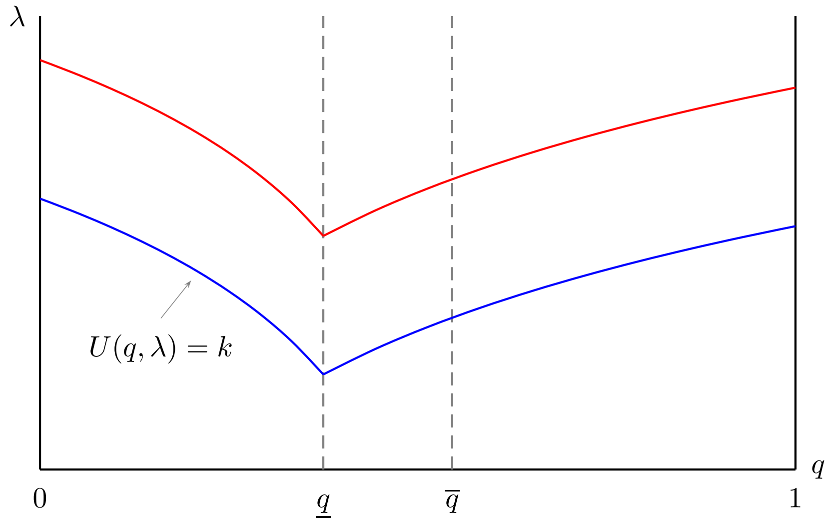

Figure 2: Buyers' indifference curves

Lemma 1 ***(Buyers' Expected Payoff)***

$$U\left(q,\lambda\right)=e^{-\lambda}\max\left\{q\left(v_L-c_L\right),E_q\left[v\right]-c_H\right\},$$

where $E_q\left[v\right]\equiv qv_L+\left(1-q\right)v_H$*. (1)* U *is strictly decreasing in* λ*. (2)* U *first decreases and later increases in* q*.*

Proof. In equilibrium, buyers must be indifferent over all bids in the support of F. Therefore, it suffices to know the expected payoff of a buyer who bids $\underline{b}$. Let $M\left(q\right)$ be the expected payoff of the monopsonist who is facing a randomly selected seller. Since the monopsonistic offer is either c_L or c_H, $M\left(q\right)=\max\left\{q\left(v_L-c_L\right),E_q\left[v\right]-c_H\right\}$. Then the result follows from the second observation and the fact that $\pi_0(\lambda)=e^{-\lambda}$. ■

Intuitively, when there are more buyers in the submarket, they compete more severely, which lowers their expected payoff. For the second comparative statics result, consider a monopsonist's problem. When q is small, the risk of overpaying for low quality is small and thus he offers c_H. In this case, a higher q implies a higher probability of overpaying, and thus his expected payoff decreases in q. When q is large, he makes a safe offer, c_L. In this case, a higher q implies a higher probability of trade, and thus his expected payoff increases in q.

Figure 2 depicts buyers' indifference curves. The V shape is due to the two comparative statics results in Lemma 1. When q is small (large), buyers' expected payoff is decreasing (increasing) in q. Therefore, for buyers to be indifferent, as q increases, buyer competition, measured by λ, must decrease (increase).

Sellers' Expected Payoffs To obtain sellers' expected payoffs, the entire bidding strategy of buyers must be derived. It is found from buyers' indifference over all bids in the support of F. For example, suppose $\underline{b} = c_L$. The expected payoff of a buyer who bids $b < c_H$ is given by

$$q\sum_{k=0}^{\infty} \pi_k F(b)^k (v_L - b) = q\pi_0 e^{\lambda F(b)} (v_L - b).$$

If b is in the support of F, buyers must be indifferent between $\underline{b}$ and b, and thus

$$q\pi_0 e^{\lambda F(b)} (v_L - b) = q\pi_0 e^{\lambda F \underline{b}} (v_L - \underline{b}) = q\pi_0 (v_L - c_L).$$

Arranging terms yields the result. All other cases can be derived analogously. The following lemma summarizes all necessary information about buyers' bidding strategy. See the Appendix for the closed-form solution.

Lemma 2 ***(Buyers' Bidding Behavior)***

F is always increasing in λ in the sense of first-order stochastic dominance. Let $\underline{q} = (v_H - c_H)/(v_H - c_L)$ and $\overline{q}(\lambda) = (v_H - c_H)/(v_H - v_L + \pi_0(\lambda)(v_L - c_L))$. In addition, let $\overline{b}$ be the maximum of the support of F.

(1) If $q \geq \overline{q}(\lambda)$, then $\underline{b} = c_L$ and $\overline{b} < c_H$. In this case, only low-quality units trade and F is independent of q.

(2) If $\underline{q} < q < \overline{q}(\lambda)$, then $\underline{b} = c_L$ and $\overline{b} > c_H$. In this case, low-quality units fully trade, while high-quality units partially trade.[11] *F is strictly decreasing in q.*

(3) If $q \leq \underline{q}$, then $\underline{b} = c_H$ and thus both qualities fully trade. F is strictly decreasing in q.

When there are more buyers (λ is higher), they bid more aggressively (F increases). Also, buyers bid more when they believe that the average quality is higher (q is smaller). However, if only low-quality units trade, each buyer's bid must be optimal conditional on him selecting a low-quality seller. Therefore, in (1), F is independent of q.

The second case clearly shows how buyers' bargaining power and competition among themselves interact in the model. If a buyer knows that he is the only bidder, he would offer c_L, and thus trade occurs only when the unit is of low quality. But competition drives up buyers' bids. When competition is strong enough, buyers' bids increase up to the point where they often bid more than c_H. These two forces, together, result in a unique outcome: high-quality units trade, but not always.

Now sellers' expected payoffs can be obtained by applying F to the following formulae:

$$V_i(q,\lambda) = \sum_{k=1}^{\infty} \pi_k \int_{c_i}^{\overline{b}} (b - c_i)\, dF^k(b), i = L, K.$$

[11]"Full trade" means that trade occurs whenever a seller is selected by at least one buyer.

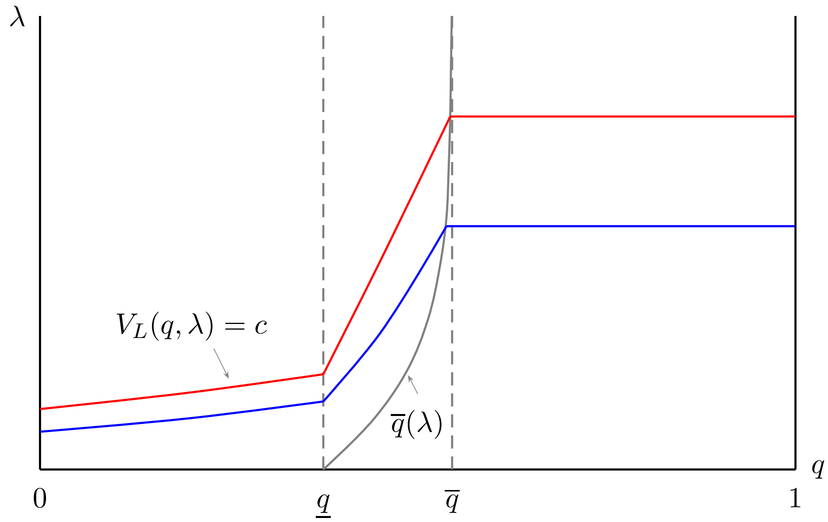

Figure 3: Low-quality sellers' indifference curves.

The closed-form solutions are rather complicated and available in the Appendix. The following lemma summarizes necessary information for further discussion.

Lemma 3 ***(Sellers' Expected Payoffs)***

(1) V_L is strictly increasing in λ. V_H is strictly increasing in λ if $q < \overline{q}(\lambda)$ and constant if $q \geq \overline{q}(\lambda)$.

(2) V_L and V_H are strictly decreasing in q if $q < \overline{q}(\lambda)$ and constant if $q \geq \overline{q}(\lambda)$.

Figure 3 depicts low-quality sellers' indifference curves. They strictly increase up to $\overline{q}(\lambda)$ but are constant after $\overline{q}(\lambda)$. They are particularly steep when $\underline{q} < q < \overline{q}(\lambda)$. This is because in that range an increase of the average quality (decrease of q) induces buyers to shift some of their bids from the interval below v_L to the interval above c_H, and thus sellers' expected payoffs increase fast as q decreases. For sellers to remain indifferent, λ must decrease fast.

High-quality sellers' indifference curves are omitted for clarity, but the curve $\overline{q}(\lambda)$ can be interpreted as an indifference curve of high-quality sellers (on which they obtain zero payoff). As in the figure, high-quality sellers' indifference curves are in general steeper than those of low-quality sellers.

4.2 Buyers' Participation

Suppose buyers believe that the proportion of low-quality sellers is q in a submarket. Then buyers enter the submarket up to the point where $U(q, \lambda) = k$. This implies that buyers' participation behavior can be summarized by a function $\lambda : [0, 1] \to R_+$ such that $U(q, \lambda(q)) = k$. Applying

Lemma 1,

$$\lambda(q) = \ln\left(\frac{\max\{q(v_L - c_L), E_q[v] - c_H\}}{k}\right).$$

This function is similar to the function that relates wages to market tightness in directed search models. In the communication context, wages are replaced by uninformed players' beliefs.

4.3 Equilibrium

Now I characterize market equilibrium by solving for sellers' communication strategies.

Pooling (Trivial) Equilibrium There always exists a trivial equilibrium in which no information is transmitted through cheap-talk messages. This equilibrium corresponds to the "babbling" equilibrium in the standard cheap talk game. If all sellers randomly announce messages, then buyers draw no useful inferences, which in turn makes sellers indifferent between messages. In this equilibrium, due to Assumption 2, only low-quality units trade.

Partially Separating Equilibrium For non-trivial equilibrium, assume that all high-quality sellers announce H. This is without loss of generality for the following reasons. First, switching the roles of H and L makes no difference. Second, one can show that if in equilibrium both types of sellers announce both messages, then it is a trivial equilibrium. Third, in equilibrium, it never happens that all low-quality sellers announce one message, while high-quality sellers use both messages.

A non-trivial equilibrium is characterized by the proportion of low-quality sellers among those who announce H. Let q^* be the proportion. Then, in equilibrium, it must be that

$$V_L(1, \lambda(1)) \geq V_L(q^*, \lambda(q^*)),$$

with equality holding if $q^* > 0$. The left-hand side is a low-quality seller's expected payoff by revealing her quality (announcing L), while the right-hand side is her expected payoff by pretending to have a high-quality unit (announcing H). This condition is also sufficient because the maximum price buyers would possibly offer to a seller who announces L, v_L, is strictly lower than high-quality sellers' reservation price, c_H, and thus high-quality sellers will never deviate to L. If there exists such q^*, then in equilibrium a measure $(1-\widehat{q})\frac{q^*}{1-q^*}$ of low-quality sellers announce H, and the other low-quality sellers announce L.

Figure 4 shows the equilibrium. At the equilibrium, $(q^*, \lambda(q^*))$, the indifference curves of buyers and low-quality sellers intersect. The equilibrium point is in the interior. This is because the indifference curve of low-quality sellers is above that of buyers when q is close to $\widehat{q}$, while it is below

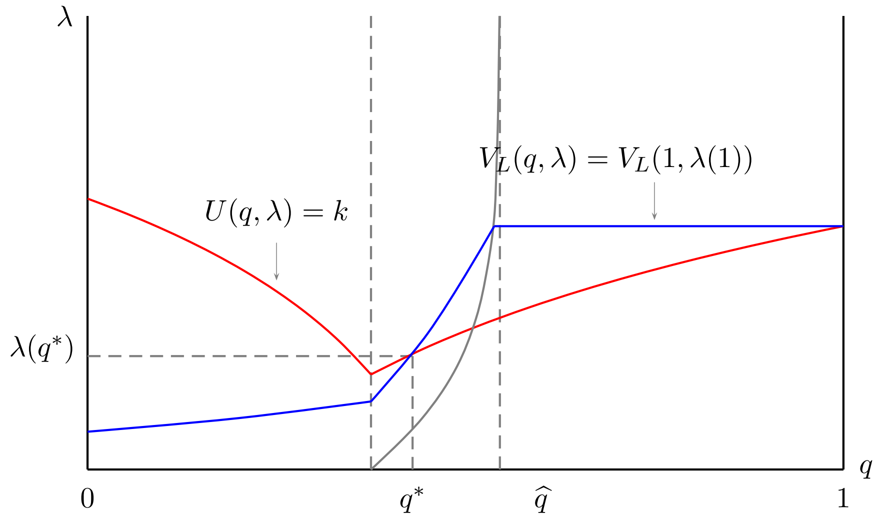

Figure 4: Partially separating equilibrium is characterized by q^* such that the indifference curves of buyers (red) and low-quality sellers (blue) intersect.

when q is close to 0. In other words,

$$V_L\left(q, \lambda\left(q\right)\right) \left\{ \begin{array}{c} < \\ > \end{array} \right\} V_L\left(1, \lambda\left(1\right)\right) \text{ for } q \text{ close to } \left\{ \begin{array}{c} \widehat{q} \\ 0 \end{array} \right\}.$$

To see this, notice that q being equal to 0 and $\widehat{q}$ correspond to the completely separating and completely pooling cases, respectively. If the market would be completely separated ($q = 0$), due to Assumption 1, relatively more buyers would be attracted to sellers who announce H. In this case, a low-quality seller would obviously prefer to be perceived as a high-quality seller ($V_L\left(1, \lambda\left(1\right)\right) < V_L\left(0, \lambda\left(0\right)\right)$). If the market would be completely pooled ($q = \widehat{q}$), due to Assumption 2, buyers would offer only low prices, and thus only low-quality units could trade. Given this, a low-quality seller would be willing to reveal the quality of her unit. By doing so, she could attract more buyers ($\lambda\left(\widehat{q}\right) < \lambda\left(1\right)$), which would increase both her probability of trade and expected price ($V_L\left(\widehat{q}, \lambda\left(\widehat{q}\right)\right) < V_L\left(1, \lambda\left(1\right)\right)$).

The results are summarized in the following proposition.

Proposition 1 *Under Assumptions 1 and 2, there always exists a partially separating equilibrium. In the equilibrium, some, but not all, low-quality sellers reveal the quality of their units.*

While there always exist multiple equilibria, there are at least two reasons why the partially separating equilibrium is more plausible than the pooling equilibrium. In reality, sellers can always convince buyers of the low quality of their products. If this is the case in the current model, then there cannot exist a pooling equilibrium, that is, any equilibrium is partially separating.

Theoretically, one can resort to NITS (no incentive to separate) introduced by Chen, Kartik and Sobel (2008). It was developed in the context of the standard cheap-talk game in which players' utility functions are exogenously given. However, it directly applies to the current model and eliminates the pooling equilibrium.

There may exist more than one partially separating equilibrium, though. This is because both indifference curves of buyers and low-quality sellers increase when $\underline{q} < q < \overline{q}(\lambda)$. When there are multiple partially separating equilibria, they are weakly Pareto ranked: low-quality sellers obtain $V_L(1, \lambda(1))$ in any of those equilibria, while high-quality sellers are strictly better off with smaller q^*.

4.4 Welfare

High-quality units trade with a positive probability in the partially separating equilibrium. When q is larger than $\overline{q}(\lambda)$, the indifference curve of low-quality sellers is flat, while that of buyers is strictly increasing. Therefore, the indifference curves can intersect only at a point where $q < \overline{q}(\lambda)$. Intuitively, some low-quality sellers reveal the quality of their units, and thus the proportion of high-quality sellers among those who announce H is greater than that of the grand market. This potentially provides an incentive for buyers to offer high prices. On the other hand, if high-quality units do not trade, then low-quality sellers would have no incentive to announce H. Since low-quality sellers must be indifferent between H and L in the partially separating equilibrium, high-quality units must trade with a positive probability.

Due to Assumption 2, high-quality sellers cannot trade without communication (or in the pooling equilibrium). Therefore, they are strictly better off in the partially separating equilibrium.

Low-quality sellers also obtain a higher expected payoff in the partially separating equilibrium. Consider a low-quality seller who reveals the quality of her unit. This seller attracts relatively more buyers in the partially separating equilibrium than in the pooling equilibrium, which increases her probability of trade as well as expected price. Since low-quality sellers are indifferent between H and L in the partially separating equilibrium, all low-quality sellers must be strictly better off.

Proposition 2 *In any partially separating equilibrium, high-quality units trade with a positive probability, and both types of sellers obtain higher expected payoffs than in the pooling equilibrium (or without communication).*

5 Discussion

5.1 Two-Message Restriction

The two-message restriction incurs no loss of generality. This is because with two types there can exist at most two distinct submarkets. As shown in Figure 3, the indifference curves of high-quality sellers are steeper than those of low-quality sellers. Intuitively, high-quality sellers' expected payoff, due to their high reservation price, is more responsive to changes of q than that of low-quality sellers. Therefore, as q decreases, the necessary reduction of buyer competition to keep sellers indifferent is larger for high-quality sellers than for low-quality sellers. In equilibrium, there cannot exist more than one distinct submarket in which both types of sellers participate (the indifference curves of low-quality and high-quality sellers can intersect only once), and thus there can exist at most two distinct submarkets.

5.2 Sensitivity to Submarket Trading Process

All the qualitative results are robust to various perturbations of the trading process. For example, one can allow sellers to use second-price auctions instead of first-price auctions. Buyers may observe the number of competitors before they submit bids. The matching technology can be perturbed as well. The only requirement is that agents' submarket expected payoffs exhibit the same qualitative properties as in Section 4. Rather informally, buyers are averse toward quality uncertainty (their expected payoff first decreases and later increases in the proportion of low-quality sellers, q) and their expected payoff is lower when there are relatively more buyers (their expected payoff is decreasing in the ratio of buyers to sellers, λ). In addition, sellers' expected payoffs are higher when buyers believe the average quality is higher or when there are relatively more buyers (their expected payoffs are decreasing in q and increasing in λ).

5.3 More Than Two Types

It is technically complicated to generalize the results beyond the two-type case. Even with three types, characterizing agents' payoffs would be much more involved, and there may be several kinds of separating equilibria. There is, however, no conceptual difficulty. Sellers trade off between probability of trade and transaction price, while buyers trade off between quality uncertainty and competition among themselves. A single crossing property will hold with respect to seller types. If there are several distinct submarkets in equilibrium, they will be arranged in a monotone fashion: low-quality submarkets entail less quality uncertainty and, therefore, attract relatively more buyers.

Appendix: Closed-form solutions for buyers' bidding strategy and sellers' expected payoffs

Buyers' Bidding Behavior

1. If $q \geq \overline{q}(\lambda)$, then

$$F\left(b\right)=\frac{1}{\lambda}\ln\left(\frac{v_L-c_L}{v_L-b}\right), \text{ for } b\in\left[c_L,\left(1-\pi_0\right)v_L+\pi_0 c_L\right].$$

2. If $\underline{q} < q < \overline{q}(\lambda)$, then

$$F(b) = \begin{cases} \frac{1}{\lambda}\ln\left(\frac{v_L - c_L}{v_L - b}\right), & \text{if } b \in [c_L, v_L - (E_q[v] - c_H)/q], \\ \frac{1}{\lambda}\ln\left(\frac{q(v_L - c_L)}{E_q[v] - b}\right), & \text{if } b \in [c_H, E_q[v] - \pi_0 q(v_L - c_L)]. \end{cases}$$

3. If $q \leq \underline{q}$, then

$$F(b) = \frac{1}{\lambda}\ln\left(\frac{E_q[v] - c_H}{E_q[v] - b}\right), b \in [c_H, (1-\pi_0)E_q[v] + \pi_0 c_L].$$

Sellers' Expected Payoffs

1. If $q \geq \overline{q}(\lambda)$,

$$\begin{aligned} V_H(q,\lambda) &= 0, \text{ and} \\ V_L(q,\lambda) &= (1 - \pi_0 - \lambda\pi_0)(v_L - c_L). \end{aligned}$$

2. If $\underline{q} < q < \overline{q}(\lambda)$, then

$$\begin{aligned} V_H(q,\lambda) &= (E_q[v] - c_H) - q\pi_0(v_L - c_L) - q(v_L - c_L)\ln\frac{E_q[v] - c_H}{q\pi_0(v_L - c_L)}, \text{ and} \\ V_L(q,\lambda) &= \frac{q\pi_0(v_L - c_L)^2}{(E_q[v] - c_H)} - \pi_0(v_L - c_L) - \pi_0(v_L - c_L)\ln\frac{q(v_L - c_L)}{(E_q[v] - c_H)} \\ &\quad + (E_q[v] - c_H) - q\pi_0(v_L - c_L) - q\pi_0(v_L - c_L)\ln\frac{E_q[v] - c_H}{q\pi_0(v_L - c_L)} \\ &\quad (c_H - c_L)\left(1 - \frac{q\pi_0(v_L - c_L)}{E_q[v] - c_H}\right) \end{aligned}$$

3. If $q \leq \underline{q}$, then

$$\begin{aligned} V_H(q,\lambda) &= (1 - \pi_0 - \lambda\pi_0)(E_q[v] - c_H), \text{and} \\ V_L(q,\lambda) &= (1 - \pi_0 - \lambda\pi_0)(E_q[v] - c_H) + (1 - \pi_0)(c_H - c_L). \end{aligned}$$

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