RAND Journal of Economics
Vol. 32, No. 4, Winter 2001
pp. 657–666

Information and the market for lemons

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This article revisits Akerlof's (1970) classic adverse-selection market and asks the following question: do greater information asymmetries reduce the gains from trade? Perhaps surprisingly, the answer is no. Better information on the selling side worsens the "buyer's curse," thus lowering demand, but may shift supply as well. Whether trade increases or decreases depends on the relative sizes of these effects. A characterization is given. On the other hand, improving the buyer's information—i.e., making private information public—unambiguously improves trade so long as market demand is downward sloping.

1. Introduction

■ Since Akerlof's (1970) seminal article, adverse selection has come to be seen as a fundamental cause of market failure. Resale markets, housing markets, and markets for corporate securities probably all suffer to some extent from the problem that some market participants have better information than others about the value of the good being traded. In such markets, theory suggests that only a fraction of the potential gains from trade are realized.

This article investigates a basic question about adverse-selection markets: do greater information asymmetries reduce the potential for realizing gains from trade? It looks for an answer in the classic asymmetric-information setting, Akerlof's (1970) market for lemons. Sellers have some amount of private information, while buyers are uninformed. There is no potential for screening or signalling, nor any mechanism for bargaining—a price is posted and buyers and sellers decide whether or not to enter the market. I consider how the expected amount of equilibrium trade depends on the quality of the seller's information relative to the buyer's, and hence the degree of information asymmetry between the two sides of the market.

I first observe that as the quality of seller information increases, trade may decrease *or* increase—the relationship between information asymmetries and trade is not monotonic. Instead, there are two competing effects: for a fixed supply curve, the demand curve will shift down as the seller becomes better informed—the "buyer's curse" intensifies; however, the supply curve shifts as well. Information sorts sellers: roughly, more information drives some sellers away from the market, but it also drives some sellers toward the market. Following a change in the information structure, it may be possible to find a new price at which the latter effect dominates and the possibilities for trade improve vis-à-vis the earlier situation.

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I am grateful to Bengt Holmström for suggesting that I look into this problem. Discussions with Susan Athey have contributed greatly to my understanding of these and related issues. I would also like to thank Raymond Deneckere and two referees for helpful suggestions, as well as Glenn Ellison, Jerry Hausman, Richard Levin, Steve Tadelis, and particularly Marco Ottaviani. An earlier version of this article appeared as a chapter in my MIT Ph.D. dissertation.

For partition-information structures, a very sharp characterization is obtained: when new information arrives on the market margin, it may drive some sellers out of the market and reduce trade; if the new information is deep in the market, the price remains unchanged and trade is unaffected; and if sellers who are out of the market acquire new information, trade may increase as sellers who get bad news are pushed toward the market. I extend this result to richer information structures, using an appropriate notion of "more information." Here, I make use of some recent decision-theoretic work by Lehmann (1988) and Athey and Levin (1998). In addition, a weaker, but quite general, result is obtained: if first-best trade is not feasible given a particular information structure, it will not be feasible if the seller's information improves.

I then ask how the potential for trade changes if some of the seller's information is released to the buyer—if private information becomes public. Because market prices can be contingent on public signals, public information effectively creates new markets. While the expected amount of equilibrium trade may again increase or decrease, a positive result is available provided the market is sufficiently well behaved. If demand is downward sloping (in a sense to be made precise), the release of public information unambiguously enhances the potential for trade.

A few articles have studied related issues. Most pertinent is Kessler (1996 and 2001), who considers a lemons market where the seller is either perfectly informed or could be uninformed with some probability. She shows that welfare may be higher or lower in the partial-information case.[1] Our articles take different approaches to modelling information that lead to distinct characterization results. Here, the seller may have a rich set of beliefs about quality, but I assume these beliefs can be stochastically ordered (in her model they cannot be). This leads me to focus on the probability that trade will occur, as opposed to the set of feasible prices, and allows a fairly general description of the buyer's curse and sorting effects of information. I also consider the effect of public information, and its sharp contrast to the case of private information.

A difference between making information public and limiting private information also arises in models where the seller can make discriminating offers to the buyer. Lewis and Sappington (1994) show that such a seller may or may not benefit when the buyer becomes more informed, while Ottaviani and Prat (forthcoming) demonstrate that the seller always benefits from the release of public "affiliated" information.[2] Although I focus on changes in the expected amount of trade, one can use the results here to obtain welfare implications for the competitive seller that are similar to the monopolistic screening case. Such results are immediate if the buyer's valuation differs from the seller's by a fixed amount and one assumes that the market clears at the highest feasible price. The seller then captures all welfare gains, which are proportional to the amount of trade.

2. The model

■ An indivisible good, with quality $\omega \in \Omega$ (Ω a measurable subset of $\mathbb{R}$), can potentially be traded between a buyer and seller who have (weakly) increasing values $b(\omega)$ and $s(\omega)$. The prior distribution of quality $H \in \Delta(\Omega)$ is commonly known; the seller also observes a private signal X. When $X = x$, she updates her beliefs to arrive at a posterior distribution $F(\cdot \mid X = x) = F(\cdot \mid x) \in \Delta(\Omega)$. I make two assumptions: first, gains from trade (GFT) always exist; second, the seller's signal is positively related to the true quality.

Assumption 1 (GFT). $b(\omega) \geq s(\omega)$ for all ω.

Assumption 2. $F(\cdot \mid x')$ first-order stochastically dominates $F(\cdot \mid x)$ for any $x' > x$[3] (FOSD).

[1] Kessler's (1996) working paper is the first to observe the nonmonotonicity of trade in information. Private information can also have ambiguous welfare consequences in contracting environments where there is signalling (Crocker and Snow, 1992) or screening (e.g., Kessler, 1998).

[2] Other related work includes Persico (2000) on information acquisition in auctions, and Sarath (1996) on disclosure of information to market participants. There is also research, dating back to Hirshleifer (1971), on how public information affects the ability of agents to share risk (Schlee (2001) is an elegant recent contribution).

[3] Recall that $H_1 \succ_{FOSD} H_2$ if and only if $H_1(\omega) \leq H_2(\omega)$ for all ω.

The first assumption is essentially for convenience, but the second is important. It says that the signals are stochastically ordered so that observing a higher signal is favorable news about quality—this allows me to proceed without specific functional forms for $b(\cdot)$ and $s(\cdot)$ and, later, to use a definition of information that "fits" the problem.

The market structure is minimal: I consider the possibility of trade at a posted market price p. Having received a signal $X = x$, the seller will sell at price p if and only if

$$E\left[s(\omega) \mid x\right] \leq p. \tag{1}$$

The buyer, taking into account the seller's decision, will buy at p if and only if

$$E\left[b(\omega) \mid E\left[s(\omega) \mid x\right] \leq p\right] \geq p. \tag{2}$$

Trade is *feasible* at p if the buyer enters the market. Let P be the set of feasible prices. In terms of a demand schedule, demand is one if (2) is satisfied, and zero if it fails, and P is the set of prices at which there is positive demand. It is well known (Wilson, 1980) that demand need not be downward sloping.

Denote by $\alpha(p)$ the *ex ante* probability that a seller will enter the market at price p (or with a large number of buyers and sellers, the proportion of sellers in the market at p):

$$\alpha(p) = \sup\left\{\alpha : E\left[s(\omega) \mid F_X(X) = \alpha\right] \leq p\right\}.$$

Here $F_X(x) = \int_\Omega \Pr[X \leq x \mid \omega] dH(\omega)$ is the marginal distribution of the signal X. So $E[s(\omega) \mid F_X(X) = \alpha]$ is the seller's expected value conditional on receiving a certain signal realization $X = F_X^{-1}(\alpha)$, such that the *ex ante* probability of receiving a lower signal realization is α.

The function $\alpha(p)$ can be thought of as a supply curve. By FOSD, it is increasing in p. The (maximum) extent of trade given information structure F is $\alpha^* = \sup_{p \in P} \alpha(p)$, which will be my measure of market performance.

Let me make two observations. First, the measure of trade is *not* the price at which trade occurs, but rather the maximum probability with which the good can be traded. If $b - s$ is constant, this is proportional to the expected welfare gains. Second, the possibility of upward-sloping demand in this model means that market equilibrium need not be unique (see Wilson (1980) or Mas-Colell, Whinston, and Green (1995)). The highest feasible price (at which the maximum extent of trade is realized) is the constrained Pareto-efficient equilibrium.

3. Private information and trade

■ Consider an example in the spirit of Akerlof. A buyer and a seller can potentially trade a good of uncertain quality; the good is equally likely to be a lemon ($\omega = L$), a melon ($\omega = M$), or a peach ($\omega = H$). The buyer and seller have values

$$b = \begin{cases} 14 & \text{if } \omega = L \\ 28 & \text{if } \omega = M \\ 42 & \text{if } \omega = H \end{cases} \qquad s = \begin{cases} 0 & \text{if } \omega = L \\ 20 & \text{if } \omega = M \\ 40 & \text{if } \omega = H \end{cases},$$

where the buyer always has higher value than the seller, and both like higher quality.

If buyer and seller are equally uninformed, then

$$E[b] = 28 > 20 = E[s]$$

means that full trade can take place at any price between 20 and 28.

Suppose now that the seller is partially informed. She knows a lemon when she sees one, but can't distinguish a melon from a peach. It is now impossible to find a price at which lemons, melons, and peaches can all be sold, since

$$E[b] = 28 < 30 = E\left[s \mid \omega \in \{M, H\}\right].$$

Only the market for lemons is active, at a price between 0 and 14. As in Akerlof's model, adverse selection reduces the amount of trade.

What if the seller becomes still more perceptive and can identify quality exactly? Peaches cannot be traded at any price, but at a price between 20 and 21, both lemons *and* melons can be exchanged:

$$E\left[b \mid \omega \in \{L, M\}\right] = 21 > 20 = E\left[s \mid \omega = M\right].$$

The market has expanded in the face of greater information asymmetry! Evidently, the relationship between information asymmetry and trade is nonmonotonic. But as I now demonstrate, it is nonmonotonic in a very intuitive way.

The story about lemons, melons, and peaches is an example of a (noiseless) partition-information structure. The seller learns for certain that the type of good she owns is from some subset of possible types, but she learns nothing new about the relative likelihoods within this subset. Better information means a finer partition. Refining the seller's information spreads out her reservation price in a specific way: it lowers her reservation price if she has a low value among some set of previously indistinguishable values, and it raises her reservation price if she has a high value in this set. In the example, the first partition affects the seller when she is *on the market margin*: this reduces trade by driving her out of the market when her value is above the market price. On the other hand, the second partition affects the seller when she is *out of the market*: this increases trade by lowering her reservation price if she owns a melon and bringing her into the market.

A general result to this end is possible. Let the set of possible signal realizations be $\mathfrak{X} = \{x_1, \ldots, x_n\}$, where $X = x_i$ corresponds to $\omega \in \Omega_i$. Assume that the subsets Ω_i are ordered, $\Omega_{i+1} > \Omega_i$ (meaning that any element in Ω_{i+1} is greater than every element in Ω_i), and that they form a partition: $\Omega = \cup_{i=1}^{n} \Omega_i$, and $\Omega_i \cap \Omega_j = \emptyset$. Let $\alpha^*(\mathfrak{X})$ be the maximum amount of trade given this information structure, where $\alpha^* = \Pr[\omega \in \cup_{i=1}^{I^*} \Omega_i]$. A seller with a signal $x_1, \ldots, x_{I^*}$ is active in the market, one with a signal $x_{I^*+1}, \ldots, x_n$ is not. Suppose $\mathfrak{X}' = \{x_1, \ldots, x_k', x_k'', \ldots, x_n\}$ is identical to $\mathfrak{X}$, except that for some k, Ω_k is partitioned into $\Omega_{k'}, \Omega_{k''}$ with $\Omega_{k''} > \Omega_{k'}$. If $k < I^*$, this is additional information *in the market*; if $k = I^*$, this is information *on the margin*; and if $k > I^*$, the information is *out of the market*.

Proposition 1 (private information and trade). More information in the market cannot affect the maximal amount of trade. More information on the margin can only reduce trade. More information out of the market can only increase trade.

Proof. For α^* to be the maximal amount of trade given $\mathfrak{X}$, it must be that

$$E\left[b \mid X \le x_i\right] \ge E\left[s \mid X = x_i\right] \qquad \text{for } i = I^* \tag{3}$$

$$E\left[b \mid X \le x_i\right] < E\left[s \mid X = x_i\right] \qquad \text{for } i > I^*. \tag{4}$$

If $k < I^*$, then (3) and (4) hold unchanged under $\mathfrak{X}'$, so the maximal amount of trade is unchanged. If $k = I^*$, then (4) holds, so trade may not increase. But to sustain the same level of trade requires $E[b \mid X \le x_k''] \ge E[s \mid X = x_k'']$, clearly a stronger condition than (3). If it fails, then trade must decrease. Finally, let $k > I^*$. Now, (3) holds identically; trade will increase if and only if $E[b \mid X \le x_k'] \ge E[s \mid X = x_k']$, which is not ruled out by (4). *Q.E.D.*

4. Public information and trade

■ The natural counterpart to the above analysis is to ask what happens when the buyer obtains some of the seller's information—private information becomes public—thus lessening the information gap.[4] To see that the answer to this question may not be obvious, consider the following example. Again, the good is equally likely to be a lemon ($\omega = L$), a melon ($\omega = M$), or a peach ($\omega = H$). The buyer and seller have values

$$b = \begin{cases} 10 & \text{if } \omega = L \\ 28 & \text{if } \omega = M \\ 85 & \text{if } \omega = H \end{cases} \qquad s = \begin{cases} 0 & \text{if } \omega = L \\ 20 & \text{if } \omega = M \\ 40 & \text{if } \omega = H \end{cases}.$$

Initially, assume that the seller has perfect information about quality, while the buyer has none. Despite the information asymmetry, full trade is possible, since $E[b] = 41 > 40 = E[s \mid \omega = H]$. Now suppose that the buyer learns whether or not the good is a peach. If the good is indeed a peach, this fact is common knowledge and trade can occur at any price between 40 and 85. But if the good is not a peach, both lemons and melons cannot be traded, since $E[b \mid \omega \in \{L, M\}] = 19 < 20 = E[s \mid \omega = M]$. Thus trade decreases with public information. Finally, observe that a further release of public information that distinguishes between a lemon and a melon makes quality common knowledge and permits full trade.

Again, the example can be generalized. Assume that the seller observes an informative signal X, and that part of this information may become public. In particular, the buyer may observe whether or not $X \leq \bar{x}$ for some fixed $\bar{x}$. The price then may be contingent on the public information.

Absent public information, suppose trade will occur only if the seller has a signal $X \leq x^*$. The equilibrium conditions are

$$E\left[b \mid X \leq x\right] \geq E\left[s \mid X = x\right] \qquad \text{for } x = x^*, \tag{5}$$
$$E\left[b \mid X \leq x\right] < E\left[s \mid X = x\right] \qquad \text{for } x > x^*. \tag{6}$$

Market demand is downward sloping if and only if whenever (5) holds for some $x = x^*$, it holds for all $x < x^*$.

Following the earlier analysis, say the public information is out of the market if without the public information, the seller does not trade if she receives signal $X = \bar{x}$, i.e., if $\bar{x} > x^*$. The public information is in the market if without it, the seller does trade if she receives signal $\bar{x}$, so $\bar{x} \leq x^*$. In the example, the first public information arrived in the market, the second out of the market.

Proposition 2 (public information and trade). Public information out of the market always increases trade. Public information in the market may increase or decrease trade. If market demand under F is downward sloping, then public information can never decrease and may increase trade.

Proof. Suppose the public information is out of the market, $\bar{x} > x^*$. If $X \leq \bar{x}$, (5) and (6) imply that the seller will still be able to trade if she has a signal below x^*. On the other hand, new possibilities for trade will arise when $X > \bar{x}$. Conditional on this positive public information, the buyer knows the value of the item is at least $E[b \mid \bar{x}]$, so at a minimum the seller will be able to sell if her signal is just above $\bar{x}$. Aggregate trade is increased.

Now suppose the public information is in the market, $\bar{x} \leq x^*$. If $X > \bar{x}$, it is certainly possible for the seller to trade if $\bar{x} < X \leq x^*$, since the buyer's expected value in this event would be greater than the left side of (5). And it may be possible for the seller to trade if $X > x^*$. However, the seller may now be unable to trade if $X \leq \bar{x}$. When the public signal reveals that $X \leq \bar{x}$, the earlier equilibrium conditions (5) and (6) do not guarantee that (5) holds for $x = \bar{x}$. For instance, if

$$E\left[b \mid X \leq \bar{x}\right] < E\left[s \mid X = \bar{x}\right],$$

[4] One can also consider the effect of releasing public infomation that is not fully known by either side of the market. In this case, however, it is not *a priori* obvious how the public information affects the degree of asymmetry, and it is easy to construct examples where the presence of public information can increase or decrease trade.

then if the seller has signal $X = \bar{x}$, she cannot profitably trade despite being able to trade in the absence of a public signal. The problem arises because demand fails to be downward sloping. Absent public information, demand is zero at $p = E[s \mid X = \overline{x}]$ despite being positive at $p^* = E[s \mid X = x^*] > p$. If demand is downward sloping, then (5) holding for $x = x^*$ implies the same for all $x < x^*$. So (5) holds for $x = \bar{x}$, and with public information, the seller can always trade with a signal $X \leq x^*$. *Q.E.D.*

With public information, price becomes contingent on the public signal realization, so the original market is partitioned into separate markets. Downward-sloping demand guarantees that trade does not unravel if the public signal reveals that true quality is lower than the marginal quality traded in the initial market.

The next result provides conditions that ensure a well-behaved demand curve.

Proposition 3 (downward-sloping demand). Market demand under F is downward sloping (equivalently, the set of feasible prices P is convex) if

(i) $b(\omega) - s(\omega)$ is decreasing in ω,

(ii) $F(\omega \mid F_X(X) = \alpha) - F(\omega \mid F_X(X) \leq \alpha)$ is decreasing in α for all $\omega \in \Omega$.

Proof. I show that if trade α is feasible, so is trade $\alpha' < \alpha$. If trade α is feasible,

$$E\left[b \mid F_X(X) \leq \alpha\right] \geq E\left[s \mid F_X(X) = \alpha\right],$$

or equivalently,

$$E\left[b - s \mid F_X(X) \leq \alpha\right] \geq E\left[s \mid F_X(X) = \alpha\right] - E\left[s \mid F_X(X) \leq \alpha\right]. \tag{7}$$

By FOSD and (i), the left-hand side of (7) is decreasing in α, and by (ii), the right-hand side is increasing in α. So trade must be feasible at any $\alpha' < \alpha$. *Q.E.D.*

The first condition implies that the gains from trade are lower at higher quality levels. The second implies that progressively larger price increases are needed to induce the seller to enter the market with higher-quality goods. It amounts to a convexity assumption—an alternative requirement is that $E[s \mid F_X(X) = \alpha]$ is convex in α.

5. Private information: a general analysis

■ I now return to changes in the quality of the seller's information, and extend the analysis by considering more general information structures. The general setup is illuminating because it makes clear the two effects of changes in the seller's information. First, better information on the selling side always lowers the buyer's valuation for the "average" quality given a fixed market size. This works to decrease demand. This effect may compete with possible changes in the seller's valuation for the marginal quality given a fixed market size. I give conditions that suffice for either the demand or supply effect to dominate. Finally, I discuss why the special features of the partition model generate such a simple characterization.

□ **Two concepts of information.** I begin with a short foray to describe two notions of informativeness that are appropriate for the general problem: the monotone information order (MIO) studied by Athey and Levin (1998) and the related concept of effectiveness due to Lehmann (1988). Both allow informativeness comparisons to be made between two signals that share the property that "high" signal realizations correspond to "high" posterior beliefs. This is a natural requirement in the context of adverse selection, and exactly what the earlier assumption FOSD entails: if $x' \geq x$, then $F(\cdot \mid X = x') \succ_{FOSD} F(\cdot \mid X = x)$ (where $F(\cdot \mid x) \in \Delta(\Omega)$).

The following definition allows a comparison of X with an alternative signal Y, where $Y = y$ leads to posterior beliefs $G(\cdot \mid y) \in \Delta(\Omega)$ that also satisfy FOSD.

Definition 1. Given a prior $H \in \Delta(\Omega)$, suppose X, Y are signals leading to posterior beliefs

$F(\cdot \mid x)$, $G(\cdot \mid y)$ that satisfy FOSD. Then $G \succ_{MIO} F$ if for all $q \in [0, 1]$,[5]

$$G(\cdot \mid G_Y(Y) \geq q) \succ_{FOSD} F(\cdot \mid F_X(X) \geq q). \quad (8)$$

The condition says that high realizations of Y lead, on average, to higher posteriors than do high realizations of X, where a high signal realization means a realization in the qth percentile or higher. Now by Bayes' rule, for any q, ω,

$$qF(\omega \mid F_X(X) \leq q) + (1 - q)F(\omega \mid F_X(X) \geq q) = H(\omega),$$

and likewise for G, so an equivalent definition is that for all $q \in [0, 1]$,

$$F(\cdot \mid F_X(X) \leq q) \succ_{FOSD} G(\cdot \mid G_Y(Y) \leq q). \quad (9)$$

Or, in other words, low realizations of Y lead, on average, to lower posteriors than do low realizations of X.

A related, but stronger, notion of information is due to Lehmann (1988). Lehmann strengthens FOSD, requiring that posterior beliefs $F(\cdot \mid x)$, $G(\cdot \mid y)$ have the monotone-likelihood ratio property, i.e., that if $x' > x$, then $f(\omega \mid x')/f(\omega \mid x)$ is increasing in ω, and likewise for G.

Definition 2. Suppose X, Y are signals leading to posterior beliefs $F(\cdot \mid x)$, $G(\cdot \mid y)$ that have the monotone-likelihood ratio property. Then G is more effective than F, $G \succ_L F$, if $G^{-1}_{Y|\omega}(F_{X|\omega}(x \mid \omega) \mid \omega)$ is increasing in ω.[6]

The following result is due to Athey and Levin (1998).

Theorem 1. If X, Y are signals leading to posterior beliefs $F(\cdot \mid x)$, $G(\cdot \mid y)$, then F, G have the monotone-likelihood ratio property and $G \succ_L F$ if and only if for any nondegenerate prior on Ω, F, G satisfy FOSD and $G \succ_{MIO} F$.[7]

The result is useful because Lehmann exhibits many well-known distributions that can be ordered on the basis of effectiveness, and hence satisfy MIO. Moreover, if for a given prior $H \in \Delta(\Omega)$, F and G satisfy FOSD (respectively, have the MLRP), and Y is *statistically sufficient* for X, then $G \succ_{MIO} F$ (respectively, $G \succ_L F$). So the standard idea of "adding noise" reduces informativeness according to both definitions.

□ **General analysis.** The concepts of information introduced above allow some immediate insight into the degree of adverse selection in a market. One can interpret (9) as saying the expected value of the object to the buyer conditional on an *ex ante* probability q that the seller will tender is decreasing in the quality of private information (supposing that if a seller tenders with some signal, she tenders with all lower signals). To see this, recall that the expectation of *any* increasing function of a random variable decreases when the distribution shifts down by FOSD. In other words, fixing the probability that the seller will come to market and increasing the information asymmetry in the sense of MIO causes the quality of available goods to shift down in the sense of first-order stochastic dominance. The "buyer's curse" intensifies!

Thus for a fixed supply curve, an increase in information shifts the demand curve down. However, to compare two market equilibria, one must account for changes in supply. Suppose some amount of trade $\alpha \in (0, 1]$ is exactly feasible at a price $p_{\alpha,F}$ when the seller's information

[5] Athey and Levin (1998) define more generally various monotone information orderings, each relevant for a particular class of decision problem. In their terminology, the notion of informativeness considered here is the supermodular monotone information order (MIO).

[6] Here, $F_{X|\omega}(x \mid \omega) = \Pr[X \leq x \mid \omega]$ and $G_{Y|\omega}(y \mid \omega) = \Pr[Y \leq y \mid \omega]$.

[7] The result that X, Y have the MLRP if and only if they satisfy FOSD for any nondegenerate prior is due to Milgrom (1981). Athey and Levin show the equivalent relationship between effectiveness and MIO.

is poor, i.e.,

$$E\left[b \mid F_X(X) \leq \alpha\right] = p_{a,F} = E\left[s \mid F_X(X) = \alpha\right].$$

If the quality of the seller's information increases, then trade α will not be feasible at any price $p > p_{a,F}$, because

$$E\left[b \mid G_Y(Y) \leq \alpha\right] \leq E\left[b \mid F_X(X) \leq \alpha\right] = p_{a,F}.$$

Nevertheless, the same number of sellers would be willing to enter the market at a *lower* price provided that

$$E\left[s \mid G_Y(Y) = \alpha\right] < E\left[s \mid F_X(X) = \alpha\right].$$

That is, the improvement in information may cause the seller's value for the marginal quality to fall. In this case, there is a horse race between two competing effects—the intensified buyer's curse that lowers the buyer's valuation for the *average* quality in the market (i.e., lowers demand), and the selection effect that lowers the seller's valuation for the *marginal* quality (i.e., might increase supply). Before characterizing when these effects can be unambiguously ranked, I note that it is possible to make a weaker statement about private information and the possibility of realizing *all* the gains from trade.

Proposition 4 (full trade is not restorable). Suppose $G \succ_{MIO} F$. If full trade is not feasible with F, it is not feasible with G.

Proof. If full trade ($\alpha = 1$) is not feasible with F, then

$$E\left[b \mid F_X(X) \leq 1\right] = E\left[b\right] < E\left[s \mid F_X(X) = 1\right].$$

Since $s(\omega)$ is increasing in ω, then by (8),

$$E\left[b \mid G_Y(Y) \leq 1\right] = E\left[b\right] < E\left[s \mid F_X(X) = 1\right] < E\left[s \mid G_Y(Y) = 1\right].$$

So full trade is not feasible under G. *Q.E.D.*

The next result provides conditions under which the maximal amount of trade will decrease in response to greater information asymmetry. Let α_F denote the maximal amount of trade with information structure F.

Proposition 5 (information decreases trade). Suppose $G \succ_{MIO} F$. Trade is decreasing in information if

(i) $b(\omega) - s(\omega)$ is increasing in ω,

(ii) $G(\cdot \mid G_Y(Y) = \alpha) - F(\cdot \mid F_X(X) = \alpha) \succ_{FOSD} G(\cdot \mid G_Y(Y) \leq \alpha) - F(\cdot \mid F_X(X) \leq \alpha)$ for all $\alpha > \alpha_F$.[8]

Proof. Pick any $\alpha > \alpha_F$, and consider the possibility of α trade. When information improves, the buyer's valuation for the average good falls by

$$E\left[b \mid F_X(X) \leq \alpha\right] - E\left[b \mid G_Y(Y) \leq \alpha\right]. \tag{10}$$

By (i) (and using (MIO)), this is greater than the fall in the seller's valuation for the average good:

$$E\left[s \mid F_X(X) \leq \alpha\right] - E\left[s \mid G_Y(Y) \leq \alpha\right]. \tag{11}$$

[8] Of course, neither side of this inequality is a probability distribution. However, for two signed measures H_1, H_2, say that $H_1 \succ_{FOSD} H_2$ if and only if $H_1(\omega) \leq H_2(\omega)$ for all $\omega \in \Omega$.

In turn, (ii) implies that this exceeds the possible decrease in the seller's valuation for the marginal good:

$$E\left[s \mid F_X(X) = \alpha\right] - E\left[s \mid G_Y(Y) = \alpha\right]. \tag{12}$$

Since (10) $\geq$ (11) $\geq$ (12),

$$E\left[b \mid F_X(X) \leq \alpha\right] < E\left[s \mid F_X(X) = \alpha\right] \Longrightarrow E\left[b \mid G_Y(Y) \leq \alpha\right] < E\left[s \mid G_Y(Y) = \alpha\right].$$

So the fact that trade $\alpha > \alpha_F$ is infeasible under F means it is infeasible under G. *Q.E.D.*

Together with MIO, condition (i) implies that the decrease in the buyer's value for average quality will be larger than the decrease in the seller's value for average quality (the buyer is more sensitive to information). In turn, condition (ii) implies that the decrease in the seller's value for average quality will be greater than the possible decrease in her value for marginal quality. Taken together, this means that the intensified-buyer's-curse effect operating on the demand side must outweigh the potential selection effect on the supply side, and trade will fall with better information.

A corresponding set of conditions can be given under which trade increases with more information.

Proposition 6 (information increases trade). Suppose $G \succ_{MIO} F$. Trade is increasing in information if

(iii) $b(\omega) - s(\omega)$ is decreasing in ω,

(iv) $G(\cdot \mid G_Y(Y) \leq \alpha) - F(\cdot \mid F_X(X) \leq \alpha) \succ_{FOSD} G(\cdot \mid G_Y(Y) = \alpha) - F(\cdot \mid F_X(X) = \alpha)$

for $\alpha = \alpha_F$.

The proof and interpretation are analogous. Condition (iii) and MIO relate changes in the buyer's and seller's values for average quality, while condition (iv) relates changes in average versus marginal quality. Taken together, the conditions guarantee that the selection effect of sellers into the market will dominate the intensified buyer's curse.

Finally, recall the partition-information model of Section 3. A refinement of partition information is a special case of the MIO information ordering. However, its effect on trade depends entirely on where the information arrives. Information *in the market* does not change either the buyer's average valuation or the seller's marginal valuation at the initial level of trade. Information *on the market margin* again does not change the buyer's valuation, but it necessarily increases the seller's marginal valuation, so trade decreases. Finally, information *out of the market* has no effect at the initial level of trade, but at higher levels of trade it may permit a large selection effect that allows new trade to occur.

Example. I conclude with an example that illustrates MIO and particularly conditions (ii) and (iv). Suppose that quality is distributed with density h, and the signal X is uniform on [0, 1] and that they have a joint density parametrized by $\theta \geq 0$:

$$f(\omega, x; \theta) = h(\omega) + k(\omega) l(x; \theta),$$

where k is increasing in ω and satisfies $\int_\Omega k(\omega) d\omega = 0$, l is increasing in x and satisfies $\int_0^1 l(x;\theta) dx = 0$ for all θ, and $(1/\alpha) \int_0^\alpha l(x;\theta) dx$ is decreasing in θ for all α.

Note that when $l(x;\theta)$ is greater, probability mass shifts toward high quality. So conditioning on $X = x$ for high values of x leads to a high distribution of ω (FOSD holds), and conditioning on $X \leq x$ for high values of θ leads to low distribution of ω (the signal is more informative by MIO when θ is higher). Condition (ii) (respectively, (iv)) holds for a given α if

$$l(\alpha, \theta) - \frac{1}{\alpha} \int_0^\alpha l(x;\theta) dx \tag{13}$$

is increasing (respectively, decreasing) in θ. Here (13) captures the difference between conditioning on $X = \alpha$ (beliefs about marginal quality) and $X \leq \alpha$ (beliefs about average quality). Marginal quality is always higher ((13) is positive); the question is whether the difference becomes larger when information improves.

To take a simple case, let $l(x;\theta) = \theta(2x - 1)$. Then changes in quality induced by conditioning on higher signal realizations are proportionately magnified when information improves (θ increases). Condition (ii) is satisfied *for all* α, and so long as $b - s$ is increasing in quality, trade will steadily decrease as information improves.

Alternatively, suppose $l(x;\theta) = (2x)^{\theta+1} - 1$ for $x \in [0, 1/2]$, and $l(x;\theta) = 1 - (2 - 2x)^{\theta+1}$ for $x \in (1/2, 1]$. Now, an increase in θ deemphasizes changes in the signal at low signal values, and exaggerates these changes at high signal values. So for low values of α, an increase in θ will decrease (13) (condition (iv) holds), but for high values of α (13) will increase (condition (ii) holds). Supposing $b - s$ is constant in quality, whether trade will decrease or increase depends on the initial level of trade. If trade is initially low, an increase in information will increase trade. If trade is initially high, more information will decrease trade.

References

AKERLOF, G.A. "The Market for Lemons: Quality Uncertainty and the Market Mechanism." *Quarterly Journal of Economics*, Vol. 84 (1970), pp. 488–500.

ATHEY, S. AND LEVIN, J. "The Value of Information in Monotone Decision Problems." Working Paper no. 98–24, Department of Economics, MIT, 1998.

CROCKER, K.J. AND SNOW, A. "The Social Value of Hidden Information in Adverse Selection Economies." *Journal of Public Economics*, Vol. 48 (1992), pp. 317–347.

HIRSHLEIFER, J. "The Private and Social Value of Information and the Reward to Inventive Activity." *American Economic Review*, Vol. 61 (1971), pp. 561–574.

KESSLER, A.S. "Revisiting the Lemons Market." University of Bonn Discussion Paper Series A, no. 517, 1996.

———."The Value of Ignorance." *RAND Journal of Economics*, Vol. 29 (1998), pp. 339–354.

———. "Revisiting the Lemons Market." *International Economic Review,* Vol. 42 (2001), pp. 25–41.

LEHMANN, E.L. "Comparing Location Experiments." *Annals of Statistics*, Vol. 16 (1988), pp. 521–533.

LEWIS, T. AND SAPPINGTON, D.E.M. "Supplying Information to Facilitate Price Discrimination." *International Economic Review*, Vol. 35 (1994), pp. 309–327.

MAS-COLELL, A., WHINSTON, M.D., AND GREEN, J.R. *Microeconomic Theory*. New York: Oxford University Press, 1995.

MILGROM, P.R. "Good News and Bad News: Representation Theorems and Applications." *Bell Journal of Economics*, Vol. 12 (1981), pp. 380–391.

OTTAVIANI, M. AND PRAT, A. "The Value of Public Information in Monopoly." *Econometrica*, forthcoming.

PERSICO, N. "Information Acquisition in Auctions." *Econometrica*, Vol. 68 (2000), pp. 135–148.

SARATH, B. "Public Information Quality with Monopolistic Sellers." *Games and Economic Behavior*, Vol. 16 (1996), pp. 261–279.

SCHLEE, E.E. "The Value of Information in Efficient Risk-Sharing Arrangements." *American Economic Review*, Vol. 91 (2001), pp. 509-524..

WILSON, C. "The Nature of Equilibrium in Markets with Adverse Selection." *Bell Journal of Economics*, Vol. 11 (1980), pp. 108–130.