When Less Information is Good for Efficiency: Private Information in Bilateral Trade and in Markets

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Abstract

We consider a simple bilateral trading game between a seller and a buyer who have private valuations for an indivisible good. The seller makes a price offer which the buyer can either accept or reject. If the seller can observe the valuation of the buyer (if information is symmetric), then the trading outcome is trivially efficient. If the seller can not observe the valuation (if information is asymmetric), then the outcome must be inefficient, as is known from the Myerson-Satterthwaite Impossibility Theorem. We embed this bilateral trading game between a single buyer and a single seller into a matching market with a continuum of traders. We show that in this market the relation between information and efficiency is reversed. In particular, if information is symmetric, trading in the market is, in fact, inefficient.

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1 Introduction

Asymmetric information makes bilateral trade inefficient, as is known from the Myerson-Satterthwaite impossibility theorem. With symmetric information, however, bilateral trade is efficient. Embedding a bilateral trading game into a larger market, we show that this connection between efficiency and information is reversed: with symmetric information, the market outcome is bounded away from the efficient one, even when trading frictions are small. In the same model, trading with asymmetric information becomes efficient once frictions vanish, as shown in Lauermann (2007).

To model a decentralized market, we use a steady state, dynamic matching and bargaining game with an exogeneous inflow, building on Gale (1987). He considers bilateral trade between one buyer and one seller and embeds it into a larger dynamic market game as follows: There is a continuum of buyers and sellers who are matched into pairs at the beginning of each period. Within each pair, they bargain over the terms of trade. The pairs are connected by allowing an unsuccessful trader to be matched with another partner in a new pair in the next period. However, there is a friction that makes waiting for the next period costly, so the integration of the market is not perfect. Here, we follow McAfee (1993), and in particular Satterthwaite and Shneyerov (2005) and assume that this friction is an exogeneous probability $\delta \in (0,1)$ that a trader cannot enter the next period and will exit (die).

The equilibrium outcome of versions of the dynamic matching and bargaining game have been shown to be efficient if frictions are small and any of the following three *market clearing forces* is present: if bargaining power is symmetric between buyers and sellers (e.g., Gale (1987)); if there is a chance that one buyer receives prices from several competing sellers (Satterthwaite and Shneyerov (2005));[1] or if information is asymmetric (Lauermann 2007). Formally, with δ converging to one, equilibrium outcomes of these models become efficient. Here we show the opposite: If sellers have all the bargaining power, if bargaining takes place only in pairs, and if information is symmetric, then the outcome can never become efficient, not even for small frictions when δ converges to zero.

The intuition for the negative result is the following: If sellers can observe their buyers' willingness to pay and if sellers have all the bargaining power, then sellers will

[1] Satterthwaite and Shneyerov (2005) assume that there is an exogeneous exit rate, as we do here. In their later 2007 paper, they assume that there is no exogeneous exit, see the discussion in Section 3.1.

be able to perfectly price discriminate among buyers. This allows sellers to make strictly positive profits - even in the limit for small δ. Thus, sellers are not willing to trade with those buyers whose valuations are just above the cost of the sellers. Therefore, marginal buyers who should trade in the efficient allocation do not find a trading partner, and the allocation is inefficient.

The first step of the intuition is well-known from the Diamond paradox (Diamond (1971) as discussed in the next section). But note that price discrimination by itself does not create inefficiencies.[2] Inefficiencies arise only because the bilateral bargaining problem is part of a market and sellers can wait and make profits on future buyers. Therefore, inefficiencies become larger when the market is more integrated, i.e., when δ is small. When sellers can wait at lower cost, i.e., when the exit rate is small, the inefficiencies are strongest. On the other hand, trading is efficient when the exit rate is close to one and bargaining is essentially bilateral.

Our result suggests that in a market with a very skewed distribution of market power, the ability of the stronger side to price discriminate is harmful. Therefore, our results emphasize the economic importance of private information, i.e., "consumer privacy" (Varian (1996)). This paper is also related to the literature on embedding problems of "contract design" into (matching) markets (e.g., Inderst (2001, 2004) or Felli and Roberts (2002)). As in their models, a property of exchange between a small set of agents in isolation is fundamentally altered when considered as part of the equilibrium of a market.

2 Model and Analysis

2.1 The Model

There is a continuum of buyers and sellers. Sellers are endowed with one unit of an indivisible good, and their costs of trading are $c = 0$. Buyers want to buy one unit of the good, and their valuation for the good is $v \in [0, 1]$. Buyers and sellers interact in a repeated market over infinitely many periods, with time running from minus to plus infinity. At the beginning of each period, there is a pool of buyers and sellers. All traders from this pool are matched into pairs consisting of one seller and one buyer. Within each pair, the seller observes the type of the buyer and then announces a price p. The

[2] In Diamond's orginal paper, the inefficiency of the equilibrium outcome stems from the assumption that sellers use linear prices while buyers have elastic demand.

buyer announces whether he accepts or rejects the offer. If he accepts, the seller receives a payoff p, while the buyer receives $v - p$; if he rejects, both traders receive nothing. Subsequently, those agents who have already traded leave the market together with a share δ of those who have not. After that, new players enter the market. The inflow of buyers and the inflow of sellers has mass one each. The distribution of valuations among entering buyers is given by the c.d.f. $G(\cdot)$. With the inflow of new traders, the period ends, and the next period starts according to the same rules. Finally, we describe the pool by M, and $\Phi^B(\cdot)$: M denotes the mass of buyers in the pool at the beginning of each period. This mass is equal to the mass of sellers. The c.d.f. $\Phi^B(\cdot)$ describes the distribution of buyers' types v in the pool. This distribution Φ^B is, of course, endogeneous and depends on how agents trade. The distribution of types in the inflow, $G(\cdot)$, on the other hand, is exogeneous.

The mass of entering buyers with valuations above some given v, $(1 - G(v)) \in [0, 1]$ can be interpreted as "demand," and we assume that it is strictly decreasing, i.e., its density $g(\cdot)$ is strictly positive. "Supply," i.e., the mass of entering sellers, is equal to one. Let p^w be the Walrasian price at which demand is equal to supply, i.e.,

$$1 - G(p^w) = 1,$$

and this price is clearly $p^w = 0$. In a more complicated model, sellers could be heterogeneous as well, and in this case p^w would be interior (see Section 3.3).

We restrict attention to equilibria in which sellers use symmetric and stationary pricing strategies $P(\cdot,\cdot)$, where $P(p', v)$ is the probability of offering a price $p \leq p'$ to a buyer of type v, i.e., $P(\cdot, v)$ is a c.d.f.. The payoff to a seller who uses a pricing strategy $P(\cdot,\cdot)$ can be derived as follows. Let us denote by $D(P(\cdot,\cdot))$ the probability of trading in any given period,[3] and let $q^S(P(\cdot,\cdot))$ be the probability that a seller is able to trade at some time during his lifetime. Given $D(P(\cdot,\cdot))$, we can derive $q^S(P(\cdot,\cdot))$ recursively from

$$q^S(P(\cdot,\cdot)) = D(P(\cdot,\cdot)) + (1 - D(P(\cdot,\cdot)))(1-\delta) q^S(P(\cdot,\cdot)),$$

as

$$q^S(P(\cdot,\cdot)) \equiv \frac{D(P(\cdot,\cdot))}{1 - (1-\delta) D(P(\cdot,\cdot))}.$$

Since there is no discounting, the seller does not care about when he conducts a trade

[3]Buyers accept p iff p is below their reservation price $r(v)$ as defined below. Given r, $D(P(\cdot,\cdot)) = \int_0^1 P(r(\tau),\tau)\, d\Phi^B(\tau)$.

but only about whether he is able to trade before he must exit.[4] Denote by $E[p|P(\cdot,\cdot)]$ the expected price conditional on being able to trade.[5] Then expected profits $\Pi(\cdot)$ are

$$\Pi(P(\cdot,\cdot)) = q^S(P(\cdot,\cdot))\, E[p|P(\cdot,\cdot)] \ .$$

To derive the optimal search strategy of a buyer, observe that he is essentially sampling without recall from a known and constant distribution of prices. For this problem, it is well known that the optimal solution can be described by a threshold, a reservation price r, such that a price p is accepted if and only if $p \leq r$ (see McMillan and Rothschild (1994)). The payoff to a buyer of type v with a reservation price r depends on the expected price offer, $E[p|p \leq r, v]$,[6] and the probability of trading some time during his lifetime, i.e., to receive an acceptable offer $p \leq r$ in any period, denoted by $q^B(r,v)$:

$$U^B(r,v) = q^B(r,v)\,(v - E[p|p \leq r, v]) \ .$$

Let $V(v) = \max_r U^B(r,v)$ be the maximized expected lifetime payoff. At the reservation price $r(v)$, buyers must be indifferent between acceptance and rejection, so $v - r(v) = (1-\delta)V(v)$. Rewriting yields

$$r(v) = v - (1-\delta)\,V(v)\,. \tag{1}$$

We will require the price offer $P(\cdot,v)$ to be optimal for every possible type v. For this, let $U^S(p,v|P(\cdot,\cdot))$ be the profit of a seller who offers a price p to a buyer of type v and continues according to the strategy $P(\cdot,\cdot)$, i.e.,

$$U^S(p,v|P(\cdot,\cdot)) = \begin{cases} p & \text{if } p \leq r(v) \\ (1-\delta)\,\Pi(P(\cdot,\cdot)) & \text{if } p > r(v)\,. \end{cases}$$

Formally, we require that every price in the support of $P(\cdot,v)$ be optimal:

$$p \in \arg\max U^S(p,v|P(\cdot,\cdot)) \ \text{ for all } v \text{ and } p \in \operatorname{supp} P(\cdot,v)\,. \tag{2}$$

The market is in a steady state if the inflow is equal to the outflow. The inflow of buyers with valuations below v is $G(v)$, while the outflow consists of all buyers who

[4] Including a discount rate would not change results.
[5] Let $E[p|P(\cdot,\cdot)] = 0$ if $q^S(P(\cdot,\cdot)) = 0$.
[6] Let $E[p|p \leq r, v] = r$ if $q^B(r,v) = 0$.

trade plus those buyers who die. Equality of in- and outflows holds if

$$G(v) = M \int_0^v \left[P(r(\tau), \tau) + \delta (1 - P(r(\tau), \tau)) \right] d\Phi^B(\tau), \tag{3}$$

and similarly for sellers:

$$1 = M \left[D(P(\cdot,\cdot)) + \delta (1 - D(P(\cdot,\cdot))) \right]. \tag{4}$$

We define a steady state equilibrium as a vector consisting of a pair of two strategies, $P(\cdot,\cdot)$ and $r(\cdot)$, the steady state distribution $\Phi^B(\cdot)$, and the mass M of traders, such that $P(\cdot,\cdot) \in \arg\max \Pi(\cdot)$, (2) holds, reservation prices satisfy (1), and the steady state conditions (3) and (4) hold.

2.2 Results

In order to characterize the set of equilibria with $\delta \to 0$, we will look at a strictly decreasing sequence of exit rates $\{\delta_k\}_{k=1}^{\infty}$ with $\lim_{k\to\infty} \delta_k = 0$. We will see that for each k at least one equilibrium exists, and we fix one equilibrium for each k, yielding a sequence $\left\{ \left(P_k(\cdot,\cdot), r_k(\cdot), \Phi_k^B(\cdot), M_k \right) \right\}_{k=0}^{\infty}$. Let $l_k(v)$ denote the lowest price offered to a type v, defined as $l_k(v) \equiv \inf\{p : P_k(p,v) > 0\}$.

Our main result is this: No buyer receives a price offer that is strictly below his valuation, i.e., $l_k(v) \geq v$ for all v. And for every k, the pricing strategy is characterized by a unique cutoff $\bar{v}_k$: The price offer is unacceptable for all buyers with a valuation below $\bar{v}_k$, i.e., the probability of offering a price at or below the valuation v, $P_k(v,v)$ is zero for all $v < \bar{v}_k$. For all other buyers the price offer is merely acceptable, i.e., $P_k(v,v) = 1$ for all $v > \bar{v}_k$. This cutoff type is decreasing in δ_k. Therefore, more buyers can trade when frictions are large and the equilibrium outcome is more efficient. Finally, $\bar{v}_k$ does not converge to the efficient level (zero) for vanishing frictions:

Proposition 1 *For every δ_k and in every equilibrium, $l_k(v) \geq v$ and $r_k(v) = v$. In addition, there is a unique cutoff $\bar{v}_k \in (0,1)$ such that*

$$P_k(v,v) = \begin{cases} 0 & \text{if } v < \bar{v}_k \\ 1 & \text{if } v > \bar{v}_k. \end{cases}$$

The cutoff $\bar{v}_k$ is decreasing in δ_k, and $\lim_{k\to\infty} \bar{v}_k \equiv \bar{v}_* > 0$.

The proposition is proven in the remainder of the section. The first statement, $l_k(v) \geq v$, follows from reasoning familiar from the Diamond paradox. Suppose there is some equilibrium with a pricing strategy $P(\cdot,\cdot)$ such that $l_k(v) < v$ for some v and δ_k. Because of the probability of dying while waiting, a buyer of type v is willing to pay a premium of $\delta_k(v - l_k)$ and so his reservation price r_k is above $l_k(v)$: $r_k = v - (1-\delta_k)V_k(v) > l_k$, from $V_k(v) \leq (v - l_k(v))$. So by definition of $l_k(v)$, there is some $p' \in suppP(\cdot,\cdot)$ such that $p' < r_k(v)$. However, offering a price p equal to the reservation price would strictly increase profits, i.e.,

$$U^S\left(p', v|P(\cdot,\cdot)\right) = p' < r_k(v) = U^S\left(r_k(v), v|P(\cdot,\cdot)\right),$$

and so $P(\cdot,\cdot)$ fails the optimality condition (2). Thus, $l_k(v) \geq v$. Noting that buyers reject all prices $p > v$, $l_k(v) \geq v$ implies that in every equilibrium sellers either offer an acceptable price $p = v$ or some unacceptable price. In both cases payoffs to the buyer are zero. Hence, $r_k(v) = v$.

The intuition for the remainder of the results is this: If sellers are able to price discriminate among buyers, they can offer a price equal to their valuation, $p(v) = v$. Given $p(v) = v$ for all v, the expected profit of sellers is strictly positive in every equilibrium, because the expected valuation of a buyer is strictly positive, $E[v] > 0$. For the outcome to become efficient, however, sellers must be willing to trade with *all* types $v \in (0,1]$. But if their expected continuation profits are strictly positive, no seller is willing to trade with a buyer with a valuation close to zero. Thus, the equilibrium outcome does not become efficient.

Suppose there is some equilibrium given δ_k (we will prove existence of such an equilibrium below) and let Π_k^* be the associated profit of sellers. Now, we want to derive the optimal offer to a buyer of type v': If this valuation is strictly above the continuation value of the seller, i.e., if $v' > (1-\delta_k)\Pi_k^*$, then the optimal offer is clearly a price $p = v'$; in this case, the seller makes more revenue from trading than from waiting further. If the valuation is below the continuation value, then any unacceptable price $p > v'$ is optimal. So there is a cut-off type $\bar{v}_k^*$ with $\bar{v}_k^* \equiv (1-\delta_k)\Pi_k^*$ such that every strategy in this equilibrium is characterized by $l_k(v) \geq v$ (from before) and

$$P_k^*(v,v) = \begin{cases} 0 & \text{if } v < \bar{v}_k^* \\ 1 & \text{if } v > \bar{v}_k^*. \end{cases} \tag{5}$$

Note that the exact unacceptable offer is not specified uniquely, and the optimal offer to the type $\bar{v}$ may or may not be acceptable.

Take any pricing strategy that has this structure, i.e., take any $P(\cdot,\cdot)$ such that $P(v,v)=1$ if $v>\bar{v}$ and $P(v,v)=0$ if $v<\bar{v}$, as in (5). Denote this strategy by a subscript $\bar{v}$, $P_{\bar{v}}(\cdot,\cdot)$. If sellers use this strategy, we can calculate expected profits and denote them by $\Pi_k(P_{\bar{v}}(\cdot,\cdot))$. A strategy $P_{\bar{v}}(\cdot,\cdot)$ is part of an equilibrium if and only if

$$\bar{v}=(1-\delta_k)\,\Pi_k(P_{\bar{v}}(\cdot,\cdot)). \tag{6}$$

To derive $\Pi_k(P_{\bar{v}}(\cdot,\cdot))$, we need the trading probability of a seller and we need the expected price he receives. For the former, note that all entering buyers with valuations above $\bar{v}$ will trade immediately; no other buyer can trade. Thus, the total mass of buyers who enter the market and who trade is $(1-G(\bar{v}))$. In a steady state, this mass of trading buyers must be exactly equal to the mass of trading sellers. Therefore, a mass $(1-G(\bar{v}))$ of all sellers in the inflow will trade, and hence

$$q_k^S(P_{\bar{v}}(\cdot,\cdot))=1-G(\bar{v}).$$

The expected price a seller receives conditional on trading, $E[p|P_{\bar{v}}(\cdot,\cdot)]$, is simply the expected valuation given $v\geq\bar{v}$. Note that buyers with such a valuation remain in the market only for one period; consequently, the distribution of their types is given by $G(\cdot)$. Thus:

$$E[p|P_{\bar{v}}(\cdot,\cdot)]=\frac{1}{1-G(\bar{v})}\int_{\bar{v}}^{1}vg(v)\,dv,$$

and profits are

$$\Pi_k(P_{\bar{v}}(\cdot,\cdot))=q_k^S(P_{\bar{v}}(\cdot,\cdot))\,E[p|P_{\bar{v}}(\cdot,\cdot)]=\int_{\bar{v}}^{1}vg(v)\,dv. \tag{7}$$

Using this observation and condition (6), we find that $P_{\bar{v}}(\cdot,\cdot)$ is an equilibrium pricing strategy if and only if $\bar{v}$ satisfies

$$\bar{v}=(1-\delta_k)\int_{\bar{v}}^{1}vg(v)\,dv. \tag{8}$$

A solution to this equation exists by the intermediate value theorem, since both sides are continuous, and, in addition, at $\bar{v}=0$ the right-hand-side is strictly above zero, while at $\bar{v}=1$ the right-hand-side is zero. Therefore, an equilibrium exists. Furthermore, the right-hand-side is strictly decreasing in $\bar{v}$, so the solution is unique. Denoting this value by $\bar{v}_k$ for any given δ_k, an inspection of (8) reveals that $\bar{v}_k$ must be decreasing in δ_k.

Finally, let $\bar{v}_*$ be the limit of $\bar{v}_k$ as δ_k becomes zero, $\bar{v}_* = \lim_{k\to\infty} \bar{v}_k$ with $\delta_k \to 0$. This limit exists by $\bar{v}_k$ being decreasing in δ_k. In the limit, (8) becomes

$$\bar{v}_* = \int_{\bar{v}_*}^{1} vg(v)\,dv,$$

and clearly $\bar{v}_* = 0$ is not a solution by $g(v) > 0$ for all v (from the assumption that "demand" $(1 - G(\cdot))$ is strictly decreasing). This implies $\bar{v}_* > 0$, completing the proof.

3 Remarks and Conclusion

3.1 Infinitely Lived Agents

In some set-ups of dynamic matching and bargaining games, traders never die (i.e., $\delta = 0$). So agents can exit the market only through trade (e.g., Gale (1987) or Satterthwaite and Shneyerov (2007)). In these models, the frictions (search costs) stemming from the exit rate are replaced by frictions stemming from discounting. On the individual level, this replacement does not change the incentives of the traders. But the absence of an exit rate does change the composition of the pool. In particular, in a steady state of such a model, all traders who choose to enter must be able to trade at some point, for otherwise they would accumulate over time. To ensure the existence of a steady state, one therefore has to introduce an entry stage at which traders can decide whether they want to enter the market. Without going into the very subtle details of such models, we can already see that our line of reasoning does not apply here: Suppose we would like to support some inefficient equilibrium in which only buyers with valuations above some threshold $\bar{v} > 0$ trade. So, at most, buyers with such a valuation can enter the market, and the total mass of buyers who enter in every period is strictly below one, since by assumption $(1 - G(\bar{v})) < 1$ for all $\bar{v} > 0$. In a steady state, the mass of entering buyers must be equal to the mass of entering sellers. Hence, only a mass $(1 - G(\bar{v}))$ of sellers becomes active. This, however, requires that some sellers stay out, which they do only if their expected profits are zero. Of course, if sellers make zero expected profits, then they are willing to trade with all buyers, including those with a valuation close to zero. Therefore, our line of reasoning does not longer work with infinitely living agents. More generally, the proposed threshold $\bar{v} > 0$ is upset by the "free entry condition," which is implicitly included in the assumption of infinitely lived agents.

3.2 Asymmetric Information and Bargaining Power

As noted in the introduction, the equilibrium becomes efficient with $\delta \to 0$ if information is asymmetric, i.e., if sellers do not observe the valuation of buyers before they make an offer. Recall that the source of the inefficiency in our model is the possibility of sellers making strictly positive profits. This is true even if sellers are willing to trade with all buyers since the expected profit from price discrimination is $E[v|v \geq 0]$, which is strictly positive (see Equation 7). This is different with asymmetric information: If the sellers are willing to trade with all buyers, they must be offering a uniform price $p = 0$. This implies that their profits are zero, and that they would indeed be willing to trade with low valuation buyers. For this reason, asymmetric information is important for efficiency: If valuations are private information, (perfect) price discrimination becomes impossible. Therefore, profits when trading with all types above some threshold $\bar{v}$ are, at most, $\bar{v}$ itself. With symmetric information, profits when trading with all buyers having a valuation above some threshold $\bar{v}$ might be strictly larger than $\bar{v}$.

Similarly, perfect price discrimination becomes impossible if the bargaining power of sellers is reduced. This is the case if buyers themselves can make counter offers (as in Gale (1987)) or if several sellers are directly competing for a single buyer, as in Satterthwaite and Shneyerov (2005, 2007)). This explains why in Gale (1987) the outcome becomes efficient with vanishing frictions. It is an open question whether the equilibrium outcome converges to efficiency in the setup by Satterthwaite and Shneyerov (2005) if we assume that information is symmetric. However, in the much simpler setup by Burdett and Judd (1983), who also analyse competing offers, it is possible to show that prices do become competitive, despite the valuation of the buyer being known.

3.3 Heterogeneous Sellers

To simplify the analysis, however, we assume in our model that sellers are homogeneous with costs $c = 0$. If sellers are heterogeneous with costs distributed according to some smooth c.d.f. $G^S(\cdot)$, then trading is not efficient in the limit. First, there will be a "market-clearing" price p^w such that $G^S(p^w) = 1 - G(p^w)$, and in an efficient allocation, all buyers having $v \geq p^w$ must trade with sellers having $c \leq p^w$ - and no one else. Second, by the same reasoning as in our model, buyers will make zero payoffs and accept all prices below their valuation. Thus, sellers with costs above p^w can trade (although they should not) with all buyers who have a valuation above their own costs, i.e., with all $v \geq c > p^w$. Basically, price discrimination allows unproductive sellers to trade, which makes the outcome inefficient. This is yet another reason for inefficiencies arising from symmetric information, which is distinct from the one analyzed in our main model.

3.4 Conclusion

Our model highlights the counterintuitive role played by symmetric information in dynamic matching and bargaining games: If traders are well informed, then the market outcome might not be competitive even for small frictions. This result is despite the fact that with symmetric information bargaining between all traders is efficient. One can use our result, by way of contrast, to understand better existing models of decentralized markets in which the trading outcome becomes competitive.

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