DISCUSSION PAPER SERIES

No. 5747

OPTIMAL SELLING STRATEGIES WHEN BUYERS MAY HAVE HARD INFORMATION

Patrick W. Schmitz

INDUSTRIAL ORGANIZATION

Centre for Economic Policy Research

www.cepr.org

Available online at: **www.cepr.org/pubs/dps/DP5747.asp**

ISSN 0265-8003

OPTIMAL SELLING STRATEGIES WHEN BUYERS MAY HAVE HARD INFORMATION

Patrick W. Schmitz, University of Bonn and CEPR

Discussion Paper No. 5747
July 2006

Centre for Economic Policy Research
90–98 Goswell Rd, London EC1V 7RR, UK
Tel: (44 20) 7878 2900, Fax: (44 20) 7878 2999
Email: cepr@cepr.org, Website: www.cepr.org

CEPR Discussion Paper No. 5747

July 2006

ABSTRACT

Optimal Selling Strategies When Buyers May Have Hard Information*

Consider a revenue-maximizing seller who can sell an object to one of n potential buyers. Each buyer either has hard information about his valuation (i.e., evidence that cannot be forged) or is ignorant. The optimal mechanism is characterized. It turns out that more ignorance can increase the expected total surplus. Even when the buyers are ex ante symmetric, the object may be sold to a buyer who does not have the largest willingness-to-pay. Nevertheless, an additional buyer increases the expected total surplus in the symmetric case, whereas more competition can be harmful if there are ex ante asymmetries.

JEL Classification: D42 and D82
Keywords: hard information and mechanism design

Patrick W. Schmitz
Wirtschaftspolitische Abteilung
Universität Bonn
Adenauerallee 24-42
D-53113 Bonn
GERMANY
Tel: (49 228) 737937
Fax: (49 228) 739221
Email: patrick.schmitz@uni-bonn.de

* I would like to thank Anke Kessler, Andreas Roider, Stephanie Rosenkranz, and Urs Schweizer for helpful discussions.

Submitted 16 June 2006

1 Introduction

Starting with Myerson's (1981) seminal article, an extensive literature has considered the optimal design of selling mechanisms when buyers have private information.[1] In most papers in this literature it has been assumed that the buyers have soft information; i.e., a buyer i who has privately learned that his willingness-to-pay for the object to be sold is v_i can always claim that his valuation is $\hat{v}_i \neq v_i$. However, the assumption that it is impossible (or prohibitively costly) to disclose one's private information in a verifiable way is restrictive. Indeed, it is conceivable that agents can provide evidence with regard to signals that they have privately observed. The present paper therefore analyzes the case of hard (or certifiable) information; i.e., situations in which privately informed parties have the ability to credibly disclose their valuations.[2]

Obviously, if every potential buyer were known to have hard information about his valuation, it would be optimal for the seller to make information disclosure a prerequisite for trade and the first-best solution would always be achieved. Yet, it will be assumed here that buyers are not informed with certainty. A buyer may be ignorant; i.e., he may have received no valuable signal with regard to his valuation.[3] While hard information means that

[1] See e.g. Bulow and Roberts (1989) or Fudenberg and Tirole (1991, ch. 7) for accessible expositions of some prominent results of this literature.

[2] Hard information is a standard assumption in the literature on strategic information sharing, see e.g. Grossman (1981), Milgrom and Roberts (1986), Okuno-Fujiwara, Postlewaite, and Suzumura (1990), Bhattacharya, Glazer, and Sappington (1992), or d'Aspremont, Bhattacharya, and Gérard-Varet (2000). The focus of this literature is quite different from Myerson's (1981) goal; i.e., to characterize profit-maximizing (selling or procurement) mechanisms.

[3] The implications of ignorance in agency problems have also been studied in Lewis and Sappington (1993) and Kessler (1998). They consider models with soft information;

buyer i cannot forge evidence (i.e., claim to have a valuation v_i if he has not received such a signal), he can always say that he is ignorant, even if he has received a valuable signal.

As an illustration, assume that there is only one buyer, whose valuation v_1 is uniformly distributed on the unit interval. With probability π_1, the buyer receives a signal indicating that his valuation is v_1. With probability $1 - \pi_1$, the buyer remains ignorant. What selling mechanism should the seller (who has zero costs) choose? One possibility is to always require disclosure. If the buyer discloses v_1, he gets the object for the price v_1, otherwise no trade occurs. In this case, the seller's expected profit is $\pi_1/2$. Another possibility is to offer the object for the price $1/2$, so that even an ignorant buyer would buy the object. Moreover, if the buyer proves that his valuation is $v_1 < 1/2$, he gets the object for the price v_1. In this case, the seller's expected profit is $\pi_1 (E[v_1|v_1 < 1/2]/2 + 1/4) + (1-\pi_1)/2 = 3\pi_1/8 + (1-\pi_1)/2$. The latter possibility is hence more profitable if $\pi_1 < 4/5$. Note that in this case an informed buyer can enjoy an information rent, even though his valuation is provable.

It will turn out that actually the seller cannot do better than just described. In Section 2, the seller's optimal mechanism is derived for the case of $n \geq 1$ buyers and arbitrary distribution functions. In Section 3, several interesting implications of the optimal mechanism are explored. It is demonstrated that more ignorance may either decrease or increase the expected total surplus.[4] The analysis will be carried out in the private in-

i.e., in these papers an uninformed agent can claim to know his valuation.

[4]It is well known that more information can be harmful if commitment not to use the information is ruled out, see e.g. Riordan (1990), Dewatripont and Maskin (1995), Crémer (1995), or Schmidt (1996). In contrast, I consider a complete contracting framework without any commitment problems.

dependent values framework of Myerson (1981). In contrast to his model, we will see that an object may be sold to a buyer who does not have the highest willingness-to-pay, even if the buyers are ex ante symmetric. Nevertheless, adding a buyer will always increase the expected total surplus in the case of ex ante symmetric buyers, whereas more competition can be welfare reducing if there are ex ante asymmetries.[5]

Before proceeding to the analysis, it should be noted that in practice there are many situations in which potential acquirers may have hard information. For example, when selling a piece of land or radio frequencies, the government may ask the potential buyers to disclose their business plans. When a firm sells a license, it can ask the potential buyers to disclose the specific purpose for which they will use the license. Moreover, the model can easily be rewritten in order to analyze a procurement problem, where a buyer designs a mechanism when there are n potential sellers who may have hard information about their costs. Clearly, when the government awards a contract to a firm, it can ask for blueprints and detailed cost calculations, that may be based on experience gained by the firm in past projects.

Finally, it should be noted that the model can also be re-interpreted in the spirit of the recent behavioral economics literature, that incorporates psychological assumptions on human behavior into standard economic analysis and studies their consequences.[6] In reality, it may well be the case that agents experience significant emotional discomfort when they ac-

[5]Compte and Jehiel (2002) have recently shown a related result for second-price auctions where bidders have interdependent valuations. In contrast, I consider optimal mechanisms and stay within the standard private values framework.

[6]In a recent survey article, Rabin (2002) has called this new movement "second-wave behavioral economics," because it goes beyond simply pointing out problems with standard economic assumptions.

tively lie and support their false statements with forged evidence, while withholding information and just claiming to be ignorant might cause less moral scruples.[7] More research along these lines seems to be desirable, as is further discussed in the concluding remarks in Section 4.

2 The model

A seller has one unit of an indivisible object. There are n potential buyers. All parties are risk-neutral. At date 1, the seller designs a mechanism. At date 2, each buyer decides whether to participate. Finally, at date 3 the object is assigned to a party and payments are made according to the mechanism. If buyer i gets the object with probability $q_i \in [0, 1]$ and makes a payment t_i, then his date-3 payoff is given by $v_i q_i - t_i$. Buyer i's valuation $v_i \geq 0$ is drawn by nature at date 0 according to the distribution function F_i, where $v_i \leq \bar{v}_i$. It is assumed that the valuations are independently distributed. For expositional simplicity, let the seller's costs be zero.[8]

At date 0, each buyer privately observes a signal s_i. With probability $\pi_i \in [0, 1)$, buyer i learns his valuation ($s_i = v_i$), whereas with probability $1 - \pi_i$, the buyer learns nothing ($s_i = \phi$).[9] Whether or not buyer i remains ignorant is independent of the valuations and the other buyers' signals. The buyer can prove that his valuation is v_i if and only if $s_i = v_i$. Thus, in

[7] Related papers that study different agency and mechanism design problems when agents are more honest than is assumed in standard economic theory include Alger and Ma (2003), Alger and Renault (2004, 2005), Chen (2000), Deneckere and Severinov (2003), Severinov and Deneckere (2004), and Matsushima (2002).

[8] It is straightforward to adapt the model to the case where the seller incurs nonzero costs when the object is sold.

[9] Lewis and Sappington (1993) have introduced the possibility of ignorance in a similar way into their (single-agent) adverse selection model with soft information.

contrast to the case of soft information, it is not possible to manipulate the signal and claim that the valuation is $\hat{v}_i$ with $\hat{v}_i \neq s_i$. However, the buyer can always hide any evidence about his valuation; i.e., he can claim that he has learned nothing.

What is the class of contracts that the seller takes into consideration when she designs the selling mechanism at date 1? It is shown in the appendix that the revelation principle holds in the present context, so that the seller can restrict attention to mechanisms where each buyer has an incentive to truthfully reveal his signal.[10] When buyer i reports s_i, let $q_i(s) \in [0,1]$ denote the probability that buyer i gets the object and let $t_i(s)$ denote the transfer payment that buyer i must make to the seller, where $s = (s_1, ..., s_n)$. Let $Q_i(s_i) = E_{-i}[q_i(s)]$ denote the probability with which buyer i expects to get the object given his report s_i, and let $T_i(s_i) = E_{-i}[t_i(s)]$ denote the payment that buyer i expects to make given his report.[11]

The seller maximizes her expected profit $E[\Sigma_i t_i(s)] = E[\Sigma_i T_i(s_i)]$ subject to the incentive compatibility constraints

$$v_i Q_i(v_i) - T_i(v_i) \geq v_i Q_i(\phi) - T_i(\phi) \quad \forall i, \forall v_i,$$

[10]On the revelation principle in the case of soft information, see e.g. Myerson (1982). Green and Laffont (1986) have explored in a single-agent framework when the revelation principle holds in settings with partially verifiable information, where some messages can only be sent by certain types. In their wording, the present model is (the n-agents version of) a "no-evidence game."

[11]Throughout, the expectations operator $E[\cdot]$ refers to all random variables in $[\cdot]$, whereas $E_{-i}[q_i(s)] = E_{-i}[q_i(s_i, s_{-i})]$ only refers to the random variables $s_{-i} = (s_1, ..., s_{i-1}, s_{i+1}, ..., s_n)$. For example, if $n = 2$, then (due to the independence assumption) $Q_1(s_1) = \pi_2 E_2[q_1(s_1, v_2)] + (1 - \pi_2) q_1(s_1, \phi)$, where $E_2[q_1(s_1, v_2)] = \int_0^{\bar{v}_2} q_1(s_1, v_2) dF_2(v_2)$.

the individual rationality constraints

$$v_i Q_i(v_i) - T_i(v_i) \geq 0 \quad \forall i, \forall v_i,$$

$$E[v_i]Q_i(\phi) - T_i(\phi) \geq 0 \quad \forall i,$$

and the feasibility constraints

$$\sum_i q_i(s) \in [0,1] \quad \forall s.$$

The incentive compatibility constraints ensure that a buyer who has learned his valuation does not hide his signal, while the individual rationality constraints ensure that informed buyers as well as ignorant buyers will participate.

Note first that the individual rationality constraint of an ignorant buyer must be binding, $T_i(\phi) = E[v_i]Q_i(\phi)$. If this were not the case, the seller could increase $t_i(\phi, s_{-i})$ without violating the other constraints. Next, observe that either the incentive compatibility constraint or the individual rationality constraint of an informed buyer must be binding, $T_i(v_i) = v_i Q_i(v_i) - \max\{v_i - E[v_i], 0\}Q_i(\phi)$.

Hence, the seller's expected profit can be rewritten as

$$\begin{aligned}
& \sum_i E[T_i(s_i)] = \sum_i \left(\pi_i E\left[T_i(v_i)\right] + (1-\pi_i)T_i(\phi)\right) \\
= \; & \sum_i \left(\pi_i E\left[v_i Q_i(v_i) - \max\{v_i - E[v_i], 0\}Q_i(\phi)\right] + (1-\pi_i)E[v_i]Q_i(\phi)\right) \\
= \; & \sum_i \left(\pi_i E\left[v_i E_{-i}[q_i(v_i, s_{-i})] - \max\{v_i - E[v_i], 0\}E_{-i}\left[q_i(\phi, s_{-i})\right]\right]\right. \\
& \left. +(1-\pi_i)E[v_i]E_{-i}\left[q_i(\phi, s_{-i})\right]\right) \\
= \; & \sum_i E\left[\pi_i v_i q_i(v_i, s_{-i}) - \pi_i E[\max\{v_i - E[v_i], 0\}]q_i(\phi, s_{-i})\right. \\
& \left. +(1-\pi_i)E[v_i]q_i(\phi, s_{-i})\right] \\
= \; & E\left[\sum_i \left(\pi_i v_i q_i(v_i, s_{-i}) + (1-\pi_i)\tilde{v}_i q_i(\phi, s_{-i})\right)\right],
\end{aligned}$$

where

$$\tilde{v}_i = E[v_i] - \frac{\pi_i}{1-\pi_i} E\left[\max\{v_i - E[v_i], 0\}\right]$$

might be called buyer i's "virtual expected valuation," in analogy to the usual "virtual valuations" in the case of soft information.

The seller's problem is thus to choose $q_i(s) \in [0,1]$ in order to maximize her expected profit[12]

$$E\left[\sum_i q_i(s)\left(v_i \mathbb{I}_{s_i \neq \phi} + \tilde{v}_i \mathbb{I}_{s_i = \phi}\right)\right]$$

subject to the feasibility constraint $\sum_i q_i(s) \in [0,1]$ for all s. Pointwise maximization leads to the following result.

Proposition 1 *It is optimal for the seller to offer the mechanism*

$$q_i(s) = \begin{cases} \frac{1}{\#\{k|s_k = v_i\}} & \text{if } s_i \neq \phi, v_i = \max_{\{j|s_j \neq \phi\}} v_j \geq \max_{\{j|s_j = \phi\}} \tilde{v}_j, \\ \frac{1}{\#\{k|s_k = \phi, \tilde{v}_k = \tilde{v}_i\}} & \text{if } s_i = \phi, \tilde{v}_i \geq 0, \tilde{v}_i = \max_{\{j|s_j = \phi\}} \tilde{v}_j > \max_{\{j|s_j \neq \phi\}} v_j, \\ 0 & \text{otherwise,} \end{cases}$$

$$t_i(s) = \begin{cases} v_i q_i(s) - \max\{v_i - E[v_i], 0\} q_i(\phi, s_{-i}) & \text{if } s_i \neq \phi, \\ E[v_i] q_i(s) & \text{if } s_i = \phi. \end{cases}$$

In words, if buyer i is informed, he will get the object only if his valuation v_i is the largest valuation of all informed buyers and only if no ignorant buyer has a larger virtual expected valuation. If there is more than one such buyer, the seller is indifferent with regard to the tie-breaking rule; for concreteness it is assumed here that each buyer will then get the object with equal probability. If buyer i is ignorant, he will get the object only if his virtual expected valuation is the largest among all ignorant buyers and only if it is larger than the valuations of all informed buyers. Moreover, he

[12] The indicator function $\mathbb{I}_C$ is equal to 1 if the condition C is satisfied and equal to 0 otherwise.

will only get the object if his virtual expected valuation is positive. It is again assumed that any ties are broken randomly with equal probabilities.

Note that only the expected payments are determined by the conditions $T_i(\phi) = E[v_i]Q_i(\phi)$ and $T_i(v_i) = v_iQ_i(v_i) - \max\{v_i - E[v_i], 0\}Q_i(\phi)$, so that the seller has some leeway when she designs the actual payments $t_i(s)$. It is straightforward to check that $t_i(s)$ can be chosen as specified in the proposition.

3 Implications

Let us now take a closer look at some interesting implications of the optimal mechanism that has been characterized in the preceding section.

First observe that an ignorant buyer i is willing to pay $E[v_i]$, which is what he has to pay if he gets the object. Yet, an informed buyer i may get the object for a cheaper price than v_i, because the seller must give informed buyers an incentive to disclose their information. Thus, buyer i's expected rent is $R_i(\pi_i) = \pi_i E[\max\{v_i - E[v_i], 0\}]Q_i(\phi)$.

The sum of the seller's expected profit and the buyers' expected rents is the expected total surplus $E\left[\sum_i \left(\pi_i v_i q_i(v_i, s_{-i}) + (1-\pi_i)E[v_i]q_i(\phi, s_{-i})\right)\right] = E\left[\sum_i v_i q_i(s)\right]$, which measures social welfare in our simple framework with quasi-linear utilities.

3.1 More ignorance can be beneficial

Clearly, if all buyers were informed with probability one, the seller would always insist on disclosure, the good would be sold to the buyer with the largest valuation, and thus the seller would extract the first-best surplus. However, in general increasing the probability π_i with which buyer i is informed can have ambiguous consequences for the expected rents, profit, and surplus.

Corollary 1 *(a) Buyer i's expected rent is maximal for intermediate values of* π_i. *(b) In general, the seller's expected profit and the expected total surplus are non-monotonic in* π_i. *In particular, increasing* π_i *can* decrease *the expected total surplus (i.e., more ignorance can be beneficial).*

In order to see why part (a) must be true, note first that a buyer who is always uninformed gets no rent, $R_i(0) = 0$. Moreover, a buyer who is informed with a sufficiently large probability will also get no rent. Specifically, if $\pi_i > \tilde{\pi}_i$, where

$$\tilde{\pi}_i = \frac{E[v_i]}{E[v_i] + E\left[\max\{v_i - E[v_i], 0\}\right]},$$

then $\tilde{v}_i < 0$, so that $q_i(\phi, s_{-i}) = 0$ and hence $Q_i(\phi) = R_i(\pi_i) = 0$. If the probability that a buyer is informed is sufficiently large, the seller will not sell the object to the buyer if he claims to be ignorant. Thus, the buyer can only get the object if he pays his valuation; i.e., he enjoys no rent. As a consequence, a buyer's expected rent attains its maximum if π_i is neither too small nor too large, so that some ignorance is valuable for the buyer.[13]

With regard to part (b), we must consider the following trade-off. On the one hand, $\tilde{v}_i$ is decreasing in π_i. In order to give informed buyers an incentive to disclose their information, the probability that a buyer who claims to be ignorant gets the object is distorted downwards. This distortion is more severe when the probability that a buyer actually is ignorant is small. On the other hand, when the probability of ignorance is increased, it becomes less likely that the object can be allocated to the buyer with the

[13] See also Kessler (1998) for a related result in a single-agent, two-type model with soft information.

largest valuation. Hence, in general the expected profit and the expected total surplus are non-monotonic in π_i.[14]

As an illustration, Figure 1a shows the expected total surplus as a function of π_1 when there are two buyers, v_1 and v_2 are uniformly distributed on the unit interval, and $\pi_2 = 0.9$. Note that there is a discontinuity at $\pi_1 = \tilde{\pi}_1 = 0.8$, because if π_1 is larger than this threshold level, no trade occurs when both buyers are ignorant (the virtual expected valuations are negative). Figure 1b depicts buyer 1's expected rent (buyer 2's rent is always zero), while the seller's expected profit is displayed in Figure 1c.

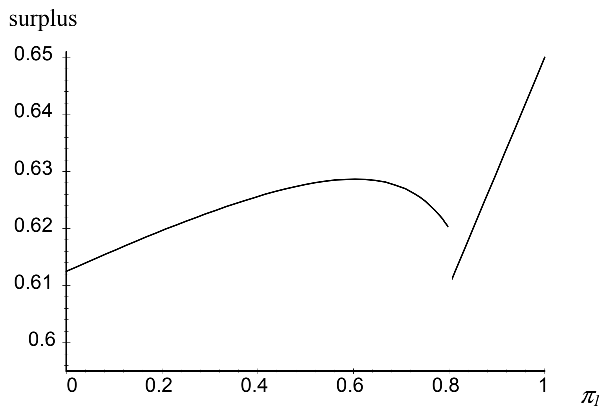

Figure 1a. The expected total surplus: More ignorance can be beneficial.

[14]Note that the seller's expected profit is increasing in π_i for $\pi_i \geq \tilde{\pi}_i$, because in this case an uninformed buyer i never gets the object anyway. Yet, the expected total surplus may still go down in this case, since the object might be allocated with a larger probability to an informed buyer i who does not have the highest willingness-to-pay and whose expected valuation is small (as will be explained below).

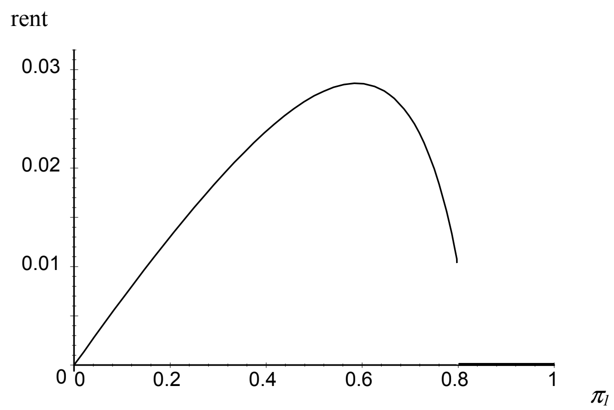

Figure 1b. Buyer 1's expected rent is maximal if there is some ignorance.

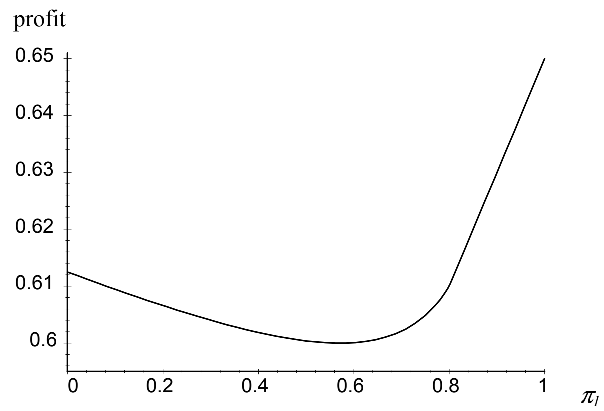

Figure 1c. The seller's expected profit is non-monotonic in π_1.

3.2 The wrong buyer may get the object

If there is more than one potential buyer, inefficiencies can occur for two reasons. First, the object might not be sold. In the present setting, this happens if all buyers are uninformed and $\pi_i > \tilde{\pi}_i$ for all i. Second, the object might be sold to a buyer who does not have the largest willingness-to-pay. It is interesting to analyze if the second kind of inefficiency can occur even if the buyers are identical from an ex ante point of view.

Corollary 2 *Even in the case of ex ante symmetry ($F_i = F$ and $\pi_i = \pi$ for all i), it may happen that the object is sold to a buyer who does* not *have the highest willingness-to-pay.*

This result is in stark contrast to Myerson's (1981) well-known soft-information model, where in the case of ex ante symmetry, inefficiencies only occur when the object is not sold. In his model, a good will be sold to a buyer who does not have the largest willingness-to-pay only if there are ex ante asymmetries (i.e., different distribution functions).[15]

In order to see why the corollary holds, consider states of the world in which buyer 1 is informed (his willingness-to-pay is v_1), while buyer 2 is ignorant (his willingness-to-pay is $E[v_2]$). If the signals were public information, the object would be sold to buyer 1 whenever $v_1 \geq E[v_2]$. However, in the case of private information, the object will be sold to buyer 1 whenever $v_1 \geq \tilde{v}_2$. Hence, if $\tilde{v}_2 < v_1 < E[v_2]$, the object is sold to a buyer who does not have the largest willingness-to-pay, which may happen even though the buyers are ex ante symmetric.

As an illustration, let there be two buyers whose valuations v_1 and v_2 are uniformly distributed on the unit interval. Let $\pi_1 = \pi_2 = \pi$. Figure 2 shows who gets the object if $s_1 = v_1$ and $s_2 = \phi$, so that buyer 2's willingness-to-pay is 1/2. As can be seen in the figure, buyer 1 gets the object even if $v_1 < 1/2$, as long as $v_1 \geq \tilde{v}_2$.

[15] Note that in soft-information auction models where buyers have interdependent valuations, the object also need not be allocated to the ex post efficient bidder (see Maskin, 1992; Jehiel and Moldovanu, 2001).

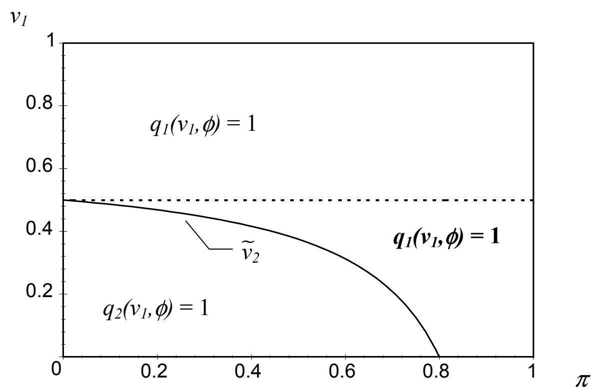

Figure 2. The wrong buyer may get the object despite symmetry.

3.3 Competition can be harmful

Intuitively, one might guess that more competition due to the presence of additional buyers should always increase the expected total surplus. It turns out that this intuition is correct only if the buyers are ex ante identical. Clearly, when there are more buyers, the seller's expected profit will always be (weakly) increased, because the seller could simply ignore the additional buyers. Yet, in the case of ex ante asymmetries, competition may reduce the expected rents more than it increases the seller's expected profit.

Corollary 3 *In the case of ex ante symmetry, the presence of an additional buyer can only increase the expected total surplus. In the case of ex ante asymmetries, the presence of an additional buyer with a sufficiently small expected valuation may* reduce *the expected total surplus.*

Consider first the case of ex ante identical buyers. If we add a buyer $n+1$, the following constellations may occur: (a) The original winner of the object was ignorant and buyer $n+1$ is ignorant. In this case, the surplus will remain the same. (b) The original winner as well as buyer $n+1$ are informed. In this case, the surplus will be weakly increased. (c) The original winner was informed, while buyer $n+1$ is ignorant. The new buyer will only get the object if $\tilde{v}_i$ (and hence $E[v_i]$) is larger than the valuation of the original winner, which means that the surplus cannot decrease. (d) The original winner was ignorant, while buyer $n+1$ is informed. The new buyer can only win if $v_{n+1} \geq \tilde{v}_i$. In this case, the new winner's expected valuation is $E[v_i|v_i \geq \tilde{v}_i]$, which cannot be smaller than $E[v_i]$, the original winner's expected valuation. (e) Finally, note that if originally no trade occurred, the addition of a buyer will weakly increase the surplus.

Now consider the case of ex ante asymmetries. The addition of a buyer may increase the surplus in all constellations. However, in constellation (d), it may happen that the surplus is smaller if buyer $n+1$ is present. In order to see this, let buyer 1 be the original winner who is ignorant. If the distribution functions are not identical, we may now have $E[v_{n+1}|v_{n+1} \geq \tilde{v}_1] < E[v_1]$. Hence, increasing the number of buyers may decrease the expected total surplus if the additional buyer has a sufficiently small expected valuation.

As an illustration, assume that there are two buyers. Let v_1 be uniformly distributed on $[1,2]$, while v_2 is uniformly distributed on $[0,1]$. Let $\pi_2 = 0.9$. In Figure 3a, the dashed line shows the expected total surplus when there is only buyer 1, while the solid line depicts the expected total surplus when both buyers are present. If π_1 is sufficiently small, the object will always be sold to buyer 1, so that there is no difference between the two scenarios. Yet, there is an intermediate range of π_1, such that the object would be sold to an ignorant buyer 1 if $n=1$, while it is sold to an informed buyer 2 (who always has a smaller valuation) if $n=2$. For sufficiently large π_1, the good will never be sold to an ignorant buyer 1, so that the addition of buyer 2 is welfare improving. Figure 3b shows that buyer 1's expected rent is reduced by the presence of buyer 2 (whose rent is always zero), while Figure 3c illustrates that the seller's expected profit is increased.

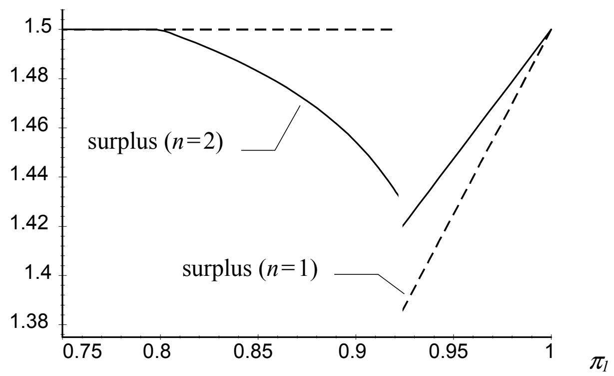

Figure 3a. The expected total surplus: Competition can be harmful.

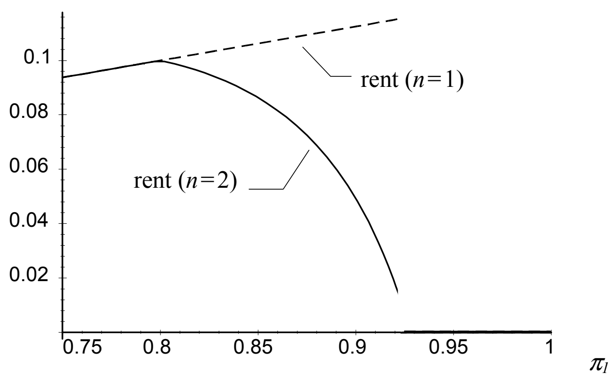

Figure 3b. Buyer 1's expected rent is reduced by competition.

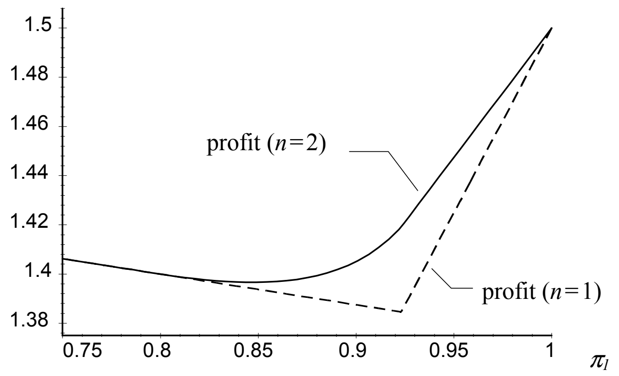

Figure 3c. The seller's expected profit is increased by competition.

4 Concluding remarks

I have characterized the revenue-maximizing selling mechanism when there are n potential buyers who may have hard information. The model turned out to be sufficiently rich in order to generate several interesting insights in the simplest possible framework. The simplicity of the model might make it a valuable building block in more applied work.[16] Furthermore, future research could extend the model, e.g. in order to investigate combinations of hard and soft information, costly certification,[17] and the effects of addi-

[16] One particularly promising application may build on Corollary 3. The fact that the presence of more competitors can reduce social welfare in the case of asymmetries might have important implications for competition policy. Trade liberalization (or EU enlargement) may not be welfare-enhancing if the involved countries are too heterogenous.

[17] In the literature on debt contracts and financial engineering, costly state verification models have been studied by Townsend (1979) and Gale and Hellwig (1985, 1989). This literature is focussed on questions that are quite different from the characterization of profit-maximizing selling or procurement mechanisms.

tional signals that may become available ex post.[18] While such extensions would complicate the model and might veil the clear intuition underlying the basic insights, the effects highlighted in this paper should still continue to be relevant.

Finally, it might also be an interesting avenue for future research to further explore the behavioral economics interpretation mentioned in the introduction. Experimental studies could try to quantify how the emotional costs that are incurred by agents who actively manipulate information and forge evidence differ from the discomfort that is experienced by agents who just withhold information. While the standard model considers one extreme case (the costs of lying are zero), the present paper provides another benchmark (forging evidence is prohibitively costly, while claiming to be uninformed is without costs). Clearly, more work is needed in order to bring the literature on optimal mechanism design closer to the behavior of real people.

[18] On the effects of verifiable ex post information in principal-agent models, see e.g. Riordan and Sappington (1988), Demougin and Garvie (1991), Laffont and Tirole (1993, ch. 12), and Kessler, Lülfesmann, and Schmitz (2005). See also Riley (1988), who studies ex post information in auctions.

Appendix

The revelation principle holds.

In a general mechanism, a buyer i of type s_i can choose a strategy $m_i(s_i)$, where $m_i(v_i) \in M_i \cup \{v_i\} \cup \{\phi\}$ and $m_i(\phi) \in M_i \cup \{\phi\}$. While M_i is an arbitrary set of messages that can be sent by everyone, only a buyer of type v_i can credibly disclose his type. Every buyer has the possibility to remain silent; i.e., to send the message ϕ.

Consider a general mechanism, where buyer i gets the object with probability $\bar{q}_i(m_1, ..., m_n)$ and pays $\bar{t}_i(m_1, ..., m_n)$ to the principal. In a Bayesian Nash equilibrium, we have

$$\begin{aligned} m_i^*(v_i) &\in \arg\max E_{-i}\left[v_i \bar{q}_i(m_i, m_{-i}^*(s_{-i})) - \bar{t}_i(m_i, m_{-i}^*(s_{-i}))\right], \\ m_i^*(\phi) &\in \arg\max E_{-i}\left[E[v_i]\bar{q}_i(m_i, m_{-i}^*(s_{-i})) - \bar{t}_i(m_i, m_{-i}^*(s_{-i}))\right]. \end{aligned}$$

The revelation principle says that this equilibrium outcome can also be obtained with a direct mechanism $[q_i(s_1, ..., s_n), t_i(s_1, ..., s_n)]$, where every buyer discloses his signal truthfully. In a direct mechanism, an ignorant buyer i can only say that $s_i = \phi$, while an informed buyer can either claim $s_i = v_i$ or $s_i = \phi$.

In order to see that the revelation principle holds, let $q_i(s_1, ..., s_n) = \bar{q}_i(m_1^*(s_1), ..., m_n^*(s_n))$ and $t_i(s_1, ..., s_n) = \bar{t}_i(m_1^*(s_1), ..., m_n^*(s_n))$. Hence, it remains to show that everyone telling the truth is a Bayesian Nash equilibrium. In the direct mechanism, an ignorant buyer cannot lie. An informed buyer also tells the truth, because

$$\begin{aligned} & E_{-i}\left[v_i q_i(v_i, s_{-i}) - t_i(v_i, s_{-i})\right] \\ = \; & E_{-i}\left[v_i \bar{q}_i(m_i^*(v_i), m_{-i}^*(s_{-i})) - \bar{t}_i(m_i^*(v_i), m_{-i}^*(s_{-i}))\right] \\ \geq \; & E_{-i}\left[v_i \bar{q}_i(m_i^*(\phi), m_{-i}^*(s_{-i})) - \bar{t}_i(m_i^*(\phi), m_{-i}^*(s_{-i}))\right] \\ = \; & E_{-i}\left[v_i q_i(\phi, s_{-i}) - t_i(\phi, s_{-i})\right]. \end{aligned}$$

References

Alger, I., Ma, C.A., 2003. Moral hazard, insurance, and some collusion. Journal of Economic Behavior and Organization 50, 225–247.

Alger, I., Renault, R., 2004. Screening ethics when honest agents keep their word. Discussion Paper.

Alger, I., Renault, R., 2005. Screening ethics when honest agents care about fairness. International Economic Review, forthcoming.

d'Aspremont, C., Bhattacharya, S., Gérard-Varet, L.-A., 2000. Bargaining and sharing innovative knowledge. Review of Economic Studies 67, 255–271.

Bhattacharya, S., Glazer, J., Sappington, D.E.M., 1992. Licensing and the sharing of knowledge in research joint ventures. Journal of Economic Theory 56, 43–69.

Bulow, J., Roberts, J., 1989. The simple economics of optimal auctions. Journal of Political Economy 97, 1060–1090.

Chen, Y., 2000. Promises, trust, and contracts. Journal of Law, Economics, and Organization 16, 209–232.

Compte, O., Jehiel, P., 2002. On the value of competition in procurement auctions. Econometrica 70, 343–355.

Crémer, J., 1995. Arm's length relationships. Quarterly Journal of Economics 110, 275–295.

Deneckere, R., Severinov, S., 2003. Mechanism design and communication costs. Discussion Paper.

Demougin, D., Garvie, D.A., 1991. Contractual design with correlated information under limited liability. Rand Journal of Economics 22, 477–489.

Dewatripont, M., Maskin, E., 1995. Contractual contingencies and renegotiation. Rand Journal of Economics 26, 704–719.

Fudenberg, D., Tirole, J., 1991. Game Theory. MIT Press, Cambridge, Massachusetts.

Gale, D., Hellwig, M., 1985. Incentive-compatible debt contracts: The one-period problem. Review of Economic Studies 52, 647–663.

Gale, D., Hellwig, M., 1989. Repudiation and renegotiation: The case of sovereign debt. International Economic Review 30, 3–31.

Green, J.R., Laffont, J.-J., 1986. Partially verifiable information and mechanism design. Review of Economic Studies 53, 447–456.

Grossman, S., 1981. The informational role of warranties and private disclosure about product quality. Journal of Law and Economics 24, 461–483.

Jehiel, P., Moldovanu, B., 2001. Efficient design with interdependent valuations. Econometrica 69, 1237–1259.

Kessler, A.S., 1998. The value of ignorance. Rand Journal of Economics 29, 339–354.

Kessler, A.S., Lülfesmann, C., Schmitz, P.W., 2005. Endogenous punishments in agency with verifiable ex post information. International Economic Review 46, 1207–1231.

Laffont J.-J., Tirole, J., 1993. A Theory of Incentives in Procurement and Regulation. MIT Press, Cambridge, Massachusetts.

Lewis, T.R., Sappington, D.E.M., 1993. Ignorance in agency problems. Journal of Economic Theory 61, 169–183.

Maskin, E., 1992, Auctions and privatizations. In: Siebert, H. (Ed.), Privatization. IWW, Kiel, pp. 115–136.

Matsushima, H., 2002. Honesty-proof implementation. Discussion Paper.

Milgrom, P., Roberts, J., 1986. Relying on the information of interested parties. Rand Journal of Economics 17, 18–32.

Myerson, R.B., 1981. Optimal auction design. Mathematics of Operations Research 6, 58–73.

Myerson, R.B., 1982. Optimal coordination mechanisms in generalized principal-agent problems. Journal of Mathematical Economics 10, 67–81.

Okuno-Fujiwara, M., Postlewaite, A., Suzumura, K., 1990. Strategic information revelation. Review of Economic Studies 57, 25–47.

Rabin, M., 2002. A perspective on psychology and economics. European Economic Review 46, 657–685.

Riley, J.G., 1988. Ex post information in auctions. Review of Economic Studies 55, 409–430.

Riordan, M.H., 1990. What is vertical integration? In: Aoki, M., Gustafsson, B., Williamson, O.E. (Eds.), The Firm as a Nexus of Treaties. Sage Publications, London.

Riordan, M.H., Sappington, D.E.M., 1988. Optimal contracts with public ex post information. Journal of Economic Theory 45, 189–199.

Schmidt, K.M., 1996. The costs and benefits of privatization: An incomplete contracts approach. Journal of Law, Economics, and Organization 12, 1–24.

Severinov, S., Deneckere, R., 2004. Screening when some agents are nonstrategic: Does a monopoly need to exclude?, Discussion Paper.

Townsend, R.M., 1979. Optimal contracts and competitive markets with costly state verification. Journal of Economic Theory 21, 265–293.