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ABSTRACT

The Costs and Benefits of Additional Information in Agency Models with Endogenous Information Structures

We study the effect of additional private information in an agency model with an endogenous information structure. If more private information becomes available to the agent, this may hurt the agent, benefit the principal, and affect the total surplus ambiguously.

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1 Introduction

Agency models with precontractual private information play a central role in modern contract theory.[1] While in the vast majority of models the information structure is exogenously given, more recently a relatively small literature has emerged in which the agent is not privately informed from the outset, but has the ability to acquire private information; i.e., the information structure is endogenous.

We consider two scenarios, in which costly information gathering at the contracting stage is a pure rent seeking activity, because it is commonly known that the ex post efficient trade decision does not depend on the state of nature.

In the first scenario, if the agent does not acquire information before the contract is signed, he will not learn the state of nature before trade can take place. In the second scenario, if the agent has not gathered information before signing the contract, he costlessly learns the state of nature before trade can take place. In other words, in the second scenario information gathering is not only a rent-seeking activity in the above-mentioned sense, but it is also only "strategic" according to the classification of Crémer, Khalil, and Rochet (1998a).

We show that there are circumstances under which the agent's expected rent is *smaller* in scenario II than in scenario I; i.e., the agent is worse off when more information becomes available to him over time. In contrast, the principal's expected profit is always weakly larger in scenario II; i.e., she benefits from the fact that the agent costlessly becomes privately informed before trade takes place. If the costs of gathering information at the contracting stage are small, then scenario II leads to a weakly larger expected total surplus than scenario I. However, for intermediate values of information gathering costs, the expected total surplus is weakly larger in scenario I, while the first best is achieved in both scenarios if the information gathering costs are sufficiently large.

In accordance with Crémer and Khalil (1992), strategic information gather-

[1] See the seminal works of Myerson (1981) and Maskin and Riley (1984). See also Laffont and Martimort (2002) and Bolton and Dewatripont (2005) for comprehensive textbooks.

ing is always deterred in scenario II. However, we find that a principal may well induce costly information acquisition in scenario I, even though this is a pure rent seeking activity in the above-mentioned sense.[2]

2 The model

Consider a principal who wants an agent to produce the quantity $x \in [0, 1]$ of a specific good. Both parties are risk-neutral. If the agent produces the quantity x for the principal, then the principal obtains a return xR and the agent incurs a disutility of production xc. At the outset, while both parties know that the distribution of $c \in \{c_l, c_h\}$ is given by $p = prob\{c = c_l\}$, no one knows the realization of c.

At date 0, nature selects the agent's disutility of production c. At date 1, the principal offers a contract to the agent. At date 2, the agent decides whether ($\lambda = 1$) or not ($\lambda = 0$) he wants to incur information gathering costs γ to learn the realization of his disutility of production. At date 3, the agent decides whether to reject the contract (in which case the principal's and agent's payoffs are 0 and $-\lambda\gamma$, respectively) or whether to accept it. In the latter case, at date 4, production takes place and the principal pays the agent the contractually specified transfer payment t. Then the principal's payoff is $xR - t$ and the agent's payoff is $t - xc - \lambda\gamma$.

We assume throughout that $c_l < c_h < R$. Hence, it is commonly known that $x = 1$ is the first-best trade level, regardless of the state of nature. In other words, costly information gathering has no productive function and is a rent-seeking activity only.

We will compare two scenarios. In scenario I, if the agent does not gather

[2] Costly information acquisition at the contracting stage is also induced in Crémer, Khalil, and Rochet (1998a), where information gathering is productive (i.e., the ex post efficient trade level depends on the state of nature and the agent does not learn the state before trade can take place). Strategic information gathering occurs with positive probability in Crémer, Khalil, and Rochet (1998b), where however it takes place before the contract is offered. See also Schmitz (2006), who studies information gathering in an incomplete contracting framework.

information at date 2, then he will learn the realization of his disutility c only after production has taken place (i.e., when the final payoffs are realized). In scenario II, the agent will costlessly learn the realization of his disutility c at date 3.5, before production takes place.[3] Thus, in scenario II, costly information gathering at date 2 is not only a rent-seeking activity in the above-mentioned sense, but it is also "strategic" in the sense of Crémer, Khalil, and Rochet (1998a).

3 Scenario I

In scenario I, costly information acquisition at date 2 is the agent's only possibility to learn his type before production takes place.

Suppose first that the principal decides not to induce information acquisition, so production will be independent of the state of nature and the principal offers the agent a contract $[x_0, t_0]$. The principal will maximize her profit $x_0 R - t_0$ subject to the constraints $x_0 \in [0, 1]$,

$$\begin{aligned} t_0 - x_0 E[c] &\geq 0, && \text{(PC)} \\ t_0 - x_0 E[c] &\geq p \max\{t_0 - x_0 c_l, 0\} \\ &\quad +(1-p) \max\{t_0 - x_0 c_h, 0\} - \gamma, && \text{(NIG)} \end{aligned}$$

where the (PC) constraint says that the (uninformed) agent will accept the contract and the (NIG) constraint ensures that the agent prefers not to gather information.

Lemma 1 *Suppose the principal wants to deter information gathering. Then she sets $x_0 = 1$. Moreover, she sets $t_0 = c_h - \frac{\gamma}{1-p}$ if $\gamma \leq p(E[c] - c_l)$ and $t_0 = E[c]$ otherwise.*

Proof. First observe that $\max\{t_0 - x_0 c_h, 0\} = 0$, because if t_0 was strictly larger than $x_0 c_h$, the principal could increase her profit by reducing t_0 without violating

[3] Hence, if he already gathered information at date 2, then he does not learn anything new at date 3.5.

any constraints. Due to (PC), the (NIG) constraint can thus be rewritten as $t_0 - x_0 E[c] \geq p(t_0 - x_0 c_l) - \gamma$. It is easy to see that $x_0 = 1$.[4] If only the (PC) constraint is binding, so that $t_0 = E[c]$, then the (NIG) constraint is satisfied if $\gamma \geq p(E[c] - c_l)$. If only the (NIG) constraint is binding, such that $t_0 = c_h - \frac{\gamma}{1-p}$, then the (PC) constraint is satisfied if $\gamma \leq p(E[c] - c_l)$. ■

If information acquisition were costless ($\gamma = 0$), the principal would have to offer $t_0 = c_h$ if she wants to ensure that the agent has no incentive to gather information (so that the uninformed agent gets an expected rent $c_h - E[c] > 0$). The larger is γ, the smaller is the offer that the principal has to make in order to deter information gathering. However, the offer cannot fall below $E[c]$, because otherwise an uninformed agent would reject it.

Next, suppose that the principal wants the agent to gather information. According to the revelation principle, we can confine our attention to direct revelation mechanisms $[x_l, t_l; x_h, t_h]$; i.e., if the agent reports to have disutility c_i, $i \in \{l, h\}$, then the trade level is x_i and the transfer payment is t_i. The principal maximizes her expected profit $p[x_l R - t_l] + (1-p)[x_h R - t_h]$ subject to $x_i \in [0, 1]$,

$$t_l - x_l c_l \geq t_h - x_h c_l, \qquad (\text{IC}_l)$$

$$t_h - x_h c_h \geq t_l - x_l c_h, \qquad (\text{IC}_h)$$

$$t_l - x_l c_l \geq 0, \qquad (\text{PC}_l)$$

$$t_h - x_h c_h \geq 0, \qquad (\text{PC}_h)$$

$$p[t_l - x_l c_l] + (1-p)[t_h - x_h c_h] - \gamma \geq t_l - x_l E[c], \qquad (\text{IG}_l)$$

$$p[t_l - x_l c_l] + (1-p)[t_h - x_h c_h] - \gamma \geq t_h - x_h E[c], \qquad (\text{IG}_h)$$

where the (IC) constraints ensure truthful reporting, the (PC) constraints ensure that the contract is accepted, and the (IG) constraints say that the agent has an incentive to gather information.

Lemma 2 *Suppose the principal wants to induce information gathering. Con-*

[4] Consider a contract $[x_0, t_0]$, where $x_0 < 1$. This contract cannot be optimal. In order to see this, consider the alternative contract $\tilde{x}_0 = 1$, $\tilde{t}_0 = t_0 + (1 - x_0)c_h$. The alternative contract leads to a larger profit for the principal without violating the constraints.

sider the case $\gamma \leq p(E[c]-c_l)$. *If* $R-c_h < p(R-c_l)$, *then* $x_l = 1$, $x_h = 0$, $t_l = c_l + \frac{\gamma}{p}$, $t_h = 0$. *If* $R - c_h \geq p(R-c_l)$, *then* $x_l = 1$, $x_h = 1 - \frac{\gamma}{p(E[c]-c_l)}$, $t_l = c_h - \frac{\gamma}{1-p}$, $t_h = c_h x_h$. *In the case* $\gamma > p(E[c]-c_l)$, *it is impossible to induce information gathering.*

Proof. Observe first that the (PC$_l$) constraint is redundant, as it is implied by (IC$_l$) and (PC$_h$). We ignore the (IC$_h$) constraint (which will turn out to be satisfied by the solution). Note that the (PC$_h$) constraint must be binding (otherwise, we could decrease t_h and t_l by the same small amount), hence $t_h = x_h c_h$. Thus, the reduced problem is to maximize $p[x_l R - t_l] + (1-p)x_h[R-c_h]$ subject to $x_i \in [0,1]$,

$$t_l - x_l c_l \geq x_h(c_h - c_l), \qquad \text{(IC}_l\text{)}$$

$$(1-p)(x_l c_h - t_l) \geq \gamma, \qquad \text{(IG}_l\text{)}$$

$$t_l - x_l c_l \geq x_h(c_h - c_l) + \frac{\gamma}{p}. \qquad \text{(IG}_h\text{)}$$

Obviously, (IC$_l$) is redundant, as it is implied by (IG$_h$). It is easy to see that $x_l = 1$.[5] Hence, the principal's problem is to maximize $p[R-t_l]+(1-p)x_h[R-c_h]$ subject to $x_h \in [0,1]$,

$$t_l \leq c_h - \frac{\gamma}{1-p}, \qquad \text{(IG}_l\text{)}$$

$$t_l \geq x_h(c_h - c_l) + c_l + \frac{\gamma}{p}. \qquad \text{(IG}_h\text{)}$$

Note that information gathering can be induced only if $\gamma \leq p(E[c]-c_l)(1-x_h)$. Hence, if $\gamma > p(E[c]-c_l)$, then it is impossible to induce information gathering. Consider the case $\gamma \leq p(E[c]-c_l)$. Observe that (IG$_h$) will always be binding, because otherwise the principal would reduce t_l. The principal thus maximizes $x_h[R-c_h-p(R-c_l)]+p(R-c_l)-\gamma$ subject to $0 \leq x_h \leq 1-\frac{\gamma}{p(E[c]-c_l)}$. Hence, she sets $x_h = 0$ if $R-c_h < p(R-c_l)$ and $x_h = 1-\frac{\gamma}{p(E[c]-c_l)}$ otherwise. ■

[5] Consider a contract where $x_l < 1$. This contract cannot be optimal, since it could be replaced by a contract where $\tilde{x}_l = 1$ and $\tilde{t}_l = t_l + (1-x_l)c_l$, which would lead to a larger profit without violating any constraints.

Consider the case $R - c_h < p(R - c_l)$. In a standard adverse selection model in which the agent is privately informed at the outset (or if $\gamma = 0$), the principal would offer a contract such that trade would occur at price c_l in the good state of nature only (so that the agent gets no rent). If the principal wants to induce costly information acquisition, she has to increase the price in order to compensate the agent for his information gathering costs.

Next, consider the case $R - c_h \geq p(R - c_l)$. In a standard adverse selection model, trade would occur at price c_h regardless of the state of nature (so that the agent's expected rent is $c_h - E[c]$). If the principal wants to induce costly information gathering, $x_l = x_h = 1$ can no longer be the solution, because then the agent would prefer to stay uninformed and claim to be of the type that obtains the larger transfer payment. Hence, the principal must induce a downward distortion in the bad state of nature.

Lemma 1 and Lemma 2 imply the following result.

Proposition 1 *If $\gamma \leq \frac{1-p}{2-p}[p(R - c_l) - R + c_h]$, then the principal induces information gathering by offering the contract $x_l = 1$, $x_h = 0$, $t_l = c_l + \frac{\gamma}{p}$, $t_h = 0$. Otherwise, the principal does not induce information gathering. In this case, she sets $x_0 = 1$. Moreover, she sets $t_0 = c_h - \frac{\gamma}{1-p}$ if $\gamma \leq p(E[c] - c_l)$ and $t_0 = E[c]$ if $\gamma > p(E[c] - c_l)$.*

Proof. If $\gamma > p(E[c] - c_l)$, it is impossible to induce information gathering. Consider $\gamma \leq p(E[c] - c_l)$. When the principal induces information gathering, her expected profit is $p(R - c_l) - \gamma$ if $R - c_h < p(R - c_l)$ and it is $(R - c_h)(1 - \frac{\gamma}{p(c_h - c_l)}) + \frac{p}{1-p}\gamma$ if $R - c_h \geq p(R - c_l)$. When she does not induce information gathering, her expected profit is $R - c_h + \frac{\gamma}{1-p}$. The proposition follows immediately. ■

Consider the case $R - c_h < p(R - c_l)$. In a standard adverse selection problem, the trade level would depend on the state of nature ($x_l = 1$, $x_h = 0$); i.e., the parties make use of the agent's private information. Accordingly, in our setting where private information does not exist at the outset but has to be acquired at some cost, the principal will induce the agent to gather information if the costs γ of doing so are sufficiently small.

Next, consider the case $R - c_h \geq p(R - c_l)$. In this case the principal does not induce costly information acquisition,[6] since even in a standard adverse selection setting where the information were freely available, the trade level would not depend on the state of nature ($x_l = x_h = 1$).

4 Scenario II

In scenario II, the agent costlessly learns his type at date 3.5. Due to Lemma 1 in Crémer and Khalil (1992), we can confine attention to contracts that avoid costly information gathering at date 2. Intuitively, a contract that induces information gathering can always be replaced by one that does not do so and that allows the agent to opt out after he has learned his type at date 3.5.

We consider again direct revelation mechanisms $[x_l, t_l; x_h, t_h]$. The principal chooses the contract that maximizes her expected profit $p[x_l R - t_l] + (1-p)[x_h R - t_h]$ subject to $x_i \in [0,1]$,

$$\begin{aligned} t_l - x_l c_l &\geq t_h - x_h c_l, && (\text{IC}_l) \\ t_h - x_h c_h &\geq t_l - x_l c_h, && (\text{IC}_h) \\ p[t_l - x_l c_l] + (1-p)[t_h - x_h c_h] &\geq 0, && (\text{PC}) \\ p[t_l - x_l c_l] + (1-p)[t_h - x_h c_h] &\geq p\max\{t_l - x_l c_l, 0\} + (1-p) \\ &\quad \cdot \max\{t_h - x_h c_h, 0\} - \gamma, && (\text{NIG}) \end{aligned}$$

where the (IC) constraints ensure that the agent truthfully reports his type at date 4, the (PC) constraint ensures that the (uninformed) agent accepts the contract at date 3, and the (NIG) constraint deters information gathering.

Proposition 2 *Consider the case $\gamma \leq p(E[c] - c_l)$. If $R - c_h \geq p(R - c_l)$, then $x_l = x_h = 1$, $t_l = t_h = c_h - \frac{\gamma}{1-p}$. If $R - c_h < p(R - c_l)$, then $x_l = 1$, $x_h = \frac{\gamma}{p(E[c]-c_l)}$, $t_l = c_l + \frac{\gamma}{p}$, $t_h = x_h c_h - \frac{\gamma}{1-p}$. Next, consider the case $\gamma > p(E[c] - c_l)$. Then $x_l = x_h = 1$, $t_l = t_h = E[c]$.*

[6] To see this formally, note that in the present case $\gamma \leq \frac{1-p}{2-p}[p(R - c_l) - R + c_h]$ cannot be satisfied.

Proof. It follows from (IC_l) and (PC), that $t_l - x_l c_l$ cannot be negative. Hence, the (NIG) constraint can be rewritten as $(1-p)[t_h - x_h c_h] \geq (1-p)\max\{t_h - x_h c_h, 0\} - \gamma$. Since $\gamma \geq 0$, the (NIG) constraint can thus be replaced by the constraint $\gamma \geq (1-p)[x_h c_h - t_h]$. We ignore ($IC_h$), which will be satisfied by the solution of the reduced problem. W.l.o.g., we can assume that (IC_l) is binding, so that $t_l = t_h - (x_h - x_l)c_l$.[7] Hence, the reduced problem is to maximize $x_l p[R - c_l] + x_h[pc_l + (1-p)R] - t_h$ subject to $x_i \in [0,1]$,

$$p[t_h - x_h c_l] + (1-p)[t_h - x_h c_h] \;\geq\; 0, \qquad \text{(PC)}$$

$$\gamma \;\geq\; (1-p)[x_h c_h - t_h]. \qquad \text{(NIG)}$$

Obviously, the principal sets $x_l = 1$. If only (PC) is binding, such that $t_h = x_h E[c]$, then the principal's profit is $p(R - c_l) + x_h(1-p)(R - c_h)$, so that she will set $x_h = 1$. This is the solution if (NIG) is satisfied, which is the case when $\gamma > p(E[c] - c_l)$. Next, consider the case $\gamma \leq p(E[c] - c_l)$, so that (NIG) must be binding. Hence, $t_h = x_h c_h - \frac{\gamma}{1-p}$. The principal's problem is then to maximize $p[R - c_l] + x_h[R - c_h - p(R - c_l)] + \frac{\gamma}{1-p}$ subject to $x_h \in [0,1]$ and $x_h \geq \frac{\gamma}{p(E[c]-c_l)}$. Thus, if $R - c_h \geq p(R - c_l)$, then $x_h = 1$. If $R - c_h < p(R - c_l)$, the principal sets $x_h = \frac{\gamma}{p(E[c]-c_l)}$. ■

Consider the case $R - c_h < p(R - c_l)$, so that in a standard adverse selection problem where the agent knows his type at the outset (or if $\gamma = 0$), the principal would introduce a downward distortion of the trade level in the bad state of nature ($x_l = 1$, $x_h = 0$), leaving no rent to the agent. If γ is prohibitively large, the situation turns into a standard hidden information problem, where the principal can extract the first-best total surplus ($x_l = x_h = 1$). Accordingly, in our setting the quantity x_h that maximizes the principal's profit is increasing in γ and the agent obtains no rent.

Next, consider the case $R - c_h \geq p(R - c_l)$, so that in a standard adverse selection model, the trade level would not depend on the state of nature and

[7] To see this, consider a feasible contract where $t_l > t_h - (x_h - x_l)c_l$. This contract can be replaced by an alternative contract where $\tilde{t}_l = pt_l + (1-p)[t_h - (x_h - x_l)c_l]$ and $\tilde{t}_h = pt_l + (1-p)t_h + p(x_h - x_l)c_l$. This contract leads to the same expected profit for the principal and does not violate any side constraints.

the principal would pay c_h to the agent (who would thus enjoy a rent in the good state). If information gathering is costly, the principal will still implement $x_l = x_h = 1$, but the larger is γ, the more she can reduce the payment to the agent (as long as it does not fall below $E[c]$), since the agent would have to incur costs γ in order to be able to reject the offer in the bad state.

5 Comparison of the scenarios

Propositions 1 and 2 immediately imply the following result, which is illustrated in Figure 1.

Proposition 3 *(i) If $R - c_h < p(R - c_l)$ and $\frac{1-p}{2-p}[p(R - c_l) - R + c_h] < \gamma \leq p(E[c] - c_l)$, then scenario II (where the agent costlessly learns his type at date 3.5) leads to a decrease of the agent's expected rent, to an increase of the principal's expected profit, and to a smaller expected total surplus compared to scenario I.*

(ii) If $R - c_h < p(R - c_l)$ and $\gamma \leq \frac{1-p}{2-p}[p(R - c_l) - R + c_h]$, then scenario II leads to an increase of the principal's expected profit and to a larger expected total surplus compared to scenario I. The agent's expected rent is always zero.

(iii) Otherwise, scenarios I and II do not differ and lead to the first-best total surplus.

** Insert Figure 1 here. **

Consider the case $R - c_h < p(R - c_l)$. For sufficiently small information gathering costs ($\gamma \leq \underline{\gamma}$), in scenario I the principal induces the agent to gather information and implements $x_l = 1$, $x_h = 0$ as in a standard adverse selection problem. Yet, the larger is γ, the more the principal has to pay to the agent as a compensation for his information gathering expenses, and the smaller is the expected total surplus. For larger information gathering costs ($\gamma > \underline{\gamma}$), the principal deters information gathering in order to implement $x_l = x_h = 1$.

Hence, the first-best surplus is realized. When γ increases it becomes easier to deter information gathering and hence the principal can extract a larger fraction of the total surplus. For very large information gathering costs ($\gamma > \overline{\gamma}$), the principal can fully extract the first-best surplus.

In scenario II, the agent costlessly learns the state of nature at date 3.5. Hence, the trade level can now be state-dependent, $x_l = 1, x_h \in (0, 1)$, even though the principal always deters costly information gathering. If $\gamma \leq \underline{\gamma}$, so that $x_h = 0$ in scenario I, the principal can use the new possibility to set $x_h \in (0, 1)$ in order to increase the total surplus, whereas in the intermediate range $\underline{\gamma} < \gamma \leq \overline{\gamma}$ (where $x_h = 1$ in scenario I) the possibility to set $x_h \in (0, 1)$ enables the principal to extract the agent's rent, at the expense of ex post efficiency.

Next, consider the case $R - c_h \geq p(R - c_l)$. In this case, information gathering is always deterred and the first best is attained. Since it becomes less expensive for the principal to deter information acquisition for increasing information gathering costs, the principal's expected profit is increasing and the agent's expected rent is decreasing in γ, as long as the information gathering costs are not prohibitively high ($\gamma \leq \overline{\gamma}$).

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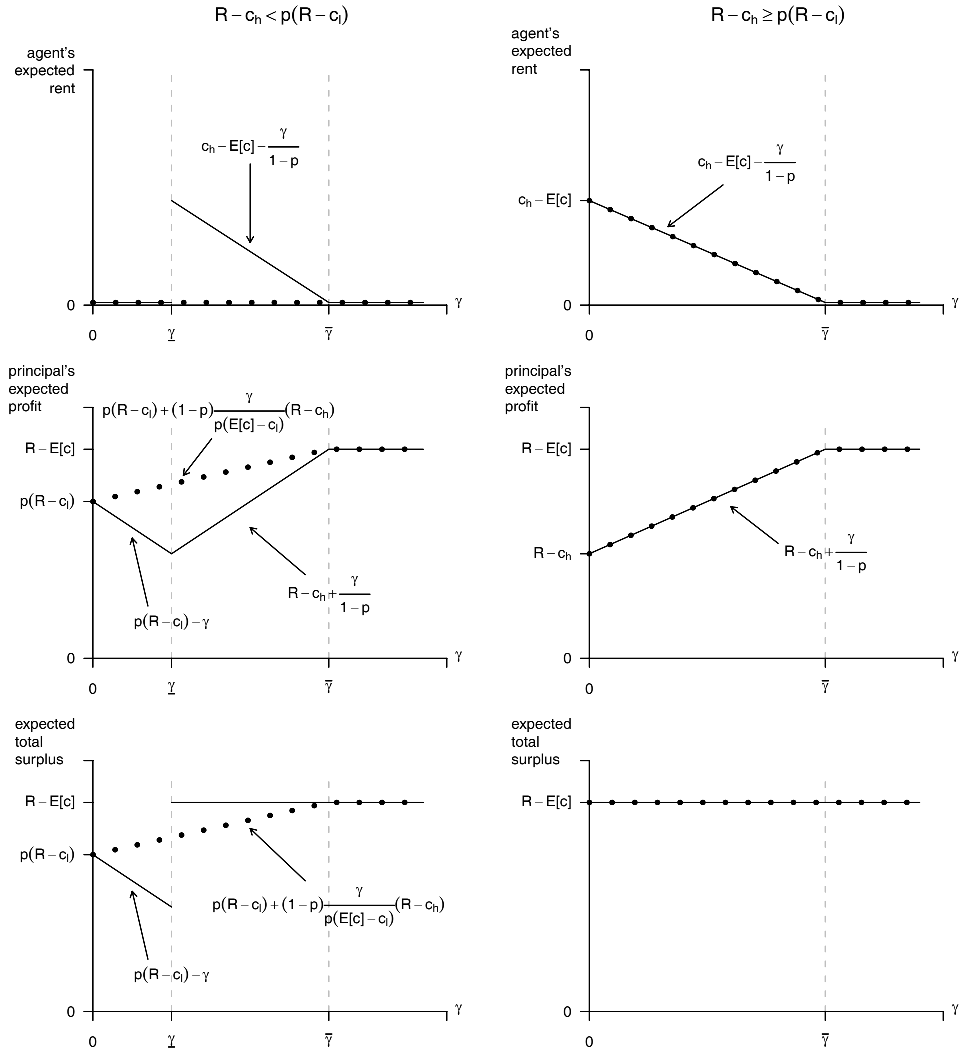

Figure 1. The parties' expected payoffs and the expected total surplus as functions of the information gathering costs γ, where $\underline{\gamma} = \frac{1-p}{2-p}[p(R - c_l) - R + c_h]$ and $\overline{\gamma} = p(E[c] - c_l)$. The solid curves correspond to scenario I, while the dotted curves depict scenario II.