Price-setting power vs. private information: An experimental evaluation of their impact on holdup

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Price-setting power versus private information: An experimental evaluation of their impact on holdup.*

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Abstract

This paper investigates the extent of the holdup problem in a buyer-seller relationship in which the seller has private information about his alternative opportunities. Theory predicts that, compared to a situation in which outside options are publicly observed, the seller obtains an informational rent whereas the buyer bears an informational loss. As a result the seller is predicted to invest more while the buyer is expected to invest less. In contrast to these predictions, private information has no impact on the investment levels observed in the experiment. But, actual investments do increase with the price-setting power of the investor. These experimental findings are roughly consistent with a model in which agents are inequality-averse. Overall the results question some recent theoretical suggestions that private information rents might substitute for price-setting power in mitigating holdup.

1 Introduction

When a party makes a relationship-specific investment, this investment is at risk because the other party may force a renegotiation of the deal. Anticipating that she may be unable to reap the full return, the investor will invest less than the efficient level. This is the well-known holdup underinvestment problem. This problem is considered to be of central importance in a wide variety of economic contexts (cf. Klein et al. 1978, Williamson 1985). For example, it serves as the cornerstone of the property rights theory of the firm; see Hart (1995) for an overview.

Most existing theoretical work analyses the holdup problem under the assumption of symmetric information. This carries over to the experimental

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studies in the field. In reality, however, the contracting parties usually possess some private information, and this may have important implications for holdup. Malcomson (1999, p. 2333) for instance notes that:

> "...in some cases at least, a firm will not know the value of the employee's outside option $w(s)$, if only because it does not know how much the employee enjoys this job relative to others. Similarly, an employee may not know the value of the firm's outside option $\pi(I, s)$. Little is known about hold-up and renegotiation under these circumstances."

Intuitively the impact of private information on holdup seems rather clear. Private information yields the informed party an informational rent, while the uninformed party bears an informational loss. This boosts the investment incentives of the informed party and weakens those of the uninformed party. Some theoretical contributions indeed indicate that holdup is less severe when the investor is better informed. Gul (2001), for example, shows that the holdup problem disappears when the investor is privately informed about the actual investment made (and only the non-investor makes frequently repeated offers).[1] In his model the creation of private information rents induces efficient investment incentives. The exploratory analysis in Malcomson (1997) suggests that similar results are to be expected when the investor has private information about its outside options (rather than about the investment made). This paper studies such a situation in more detail. In particular, we consider a simple model in which a seller may have private information about his outside options. We first show that theoretically the private information rent he so obtains typically boosts his investment incentives. The downside is that the buyer, who now has an informational disadvantage, then has less incentives to invest.

Standard theory thus predicts that investment incentives under private information are quite different from those under public information. Moreover, it also indicates that private information itself can serve as an effective instrument in alleviating holdup. One objective of Gul (2001, p. 344), for example, is:

> "...to emphasize the role of allocation of information as a tool in dealing with the hold-up problem. Audits, disclosure rules or privacy rights could be used to optimize the allocation of rents and guarantee the desired level of investment. Controlling the flow of information may prove to be a worthy alternative to controlling bargaining power in designing optimal organizations."

[1] See also Konrad (2001), Lau (2002) and Tirole (1986, Proposition 3) for settings in which the specific investment itself is private information.

Rogerson (1992), Lau (2002) and Gonzalez (2004) similarly suggest that private information rents might substitute for bargaining power in mitigating holdup. Our theoretical analysis yields the same result for a situation with private information about outside options. The main contribution of this paper, however, is that it addresses the empirical validity of this prediction by means of a controlled laboratory experiment. In particular, the experiment studies the impact of both private information about outside options and price-setting power on investment behavior.

Only a few other experiments on holdup under asymmetric information have been conducted. Inspired by the theoretical predictions of Gul (2001), Sloof et al. (2002) compare two treatments. In the control treatment the non-investor dictates the division of a surplus which is created by an *observable* investment. Here no investment is predicted. In another – *unobservable* investment – treatment only the investor knows the actual investment made, and thus the size of the surplus that can be divided. Here investment is predicted to occur with positive probability. The main conclusion the authors obtain is that subjects do invest more when the investment is private information (as standard theory predicts), but that they only do so when fairness and reciprocity considerations provide only weak incentives to invest (i.e. when investment costs are high).

Ellingsen and Johannesson (2005) consider a setting in which the investor makes an ultimatum offer about how to divide the (observable) surplus created by her investment. In one treatment the investor is privately informed about the costs of investment, in two other treatments these costs are publicly observed (and are either low or high). Standard predictions are exactly the same in the three treatments; the investor invests efficiently and obtains the complete surplus. But, when inferiority-averse preferences are accounted for, these predictions change. In particular, under private information non-investors may fear being exploited and therefore turn down offers that are profitable (and also fair). This in turn may induce high-cost investors to refrain from investing. Nevertheless, in their experiments Ellingsen and Johannesson find little evidence that investment incentives are seriously affected by private information about investment costs. In line with standard theory investment rates do not differ significantly across treatments.

The essential difference between the current experiment and these previous ones is that we consider a situation in which parties may have private information about their outside options, rather than about the investment made. As illustrated by the quote from Malcomson in the second paragraph, this seems a particularly relevant situation to consider. Another important difference is that we also consider the impact of variations in bargaining (price-setting) power on investment incentives.

This paper proceeds as follows. In the next section we present a very simple model of a buyer-seller relationship in which (only) the seller may have private information about his outside options. Assuming selfish preferences, this section subsequently derives the equilibrium predictions regarding the impact of price-setting power and private information on investment incentives. Section 3 provides the details of the experimental design and formulates the hypotheses that are put to the test. Results are discussed in Section 4. In Section 5 we informally explore whether subjects' tastes for fairness, i.e. inequality averse preferences as introduced by Fehr and Schmidt (1999), can explain the observed differences between standard theory and experimental results. The final section summarizes our main findings.

2 Theory

2.1 A simple holdup model with private information

For ease of exposition we describe the game that we consider in terms of the specific parameterization used in the experiment. A much more general specification is discussed in the working-paper version, see Sloof (2006).

Two risk neutral parties, a female buyer and a male seller, may trade one unit of a particular good. The production costs of this unit are normalized to zero. The seller has an alternative trading opportunity denoted s, with s unknown at the start of the relationship. We assume that this outside option can take two values only, viz. a low value $s_l = 0$ and a high value $s_h = 4000$. The probability that the latter case applies equals $\Pr(s = s_h) \equiv p = \frac{1}{2}$. The expected value of s is denoted $E[s]$ (equal to 2000 here). The buyer does not have an outside option. Her valuation of the seller's good equals $R(I) = 4000 + 100 \cdot I$, with I reflecting the specific investment made by either the buyer or the seller. Investment costs are assumed to be quadratic: $C(I) = I^2$. The order of play in the holdup game is as follows:

1. *Investment stage.* Either the buyer or the seller chooses investment level I. Investment costs equal $C(I) = I^2$ and are borne by the investor;

2. *Information stage.* Nature draws the type of seller, i.e. the value of his outside option $s \in \{s_l, s_h\} = \{0, 4000\}$, with $\Pr(s = s_h) \equiv p = \frac{1}{2}$. The seller observes s, the buyer does so with probability $1 - q \in [0, 1]$;

3. *Offer stage.* One of the parties makes a take-it-or-leave-it price proposal to the other party. The identity of the proposer is drawn by nature. With probability $\pi_B \in [0, 1]$ the buyer makes a price offer, with probability $\pi_S = 1 - \pi_B$ the seller formulates a price demand;

4. *Trading stage.* The responder accepts or rejects the proposed price. In the first case trade takes place with the original buyer at the agreed price, in the second case the seller trades with an outside buyer at price s.

In fact various different situations are considered that differentiate along three dimensions. The first one concerns the identity of the investor. We consider both the case in which the buyer invests and the one in which the seller does so. The second dimension relates to the amount of information the buyer has about the seller's outside option. Like in Lau (2002), parameter $q \in [0, 1]$ measures the degree of information asymmetry between the two parties. The larger q, the less likely it becomes that also the buyer is informed on the seller's outside option. The third dimension is given by the price-setting power $\pi_B \in [0, 1]$ of the buyer. The larger π_B, the more (less) bargaining power the buyer (seller) has.

Due to our assumption that $s_h \leq R(I)$, trade between the buyer and the seller is always efficient. The efficient level of investment thus follows from maximizing net social surplus $R(I) - C(I)$. Given our linear-quadratic specification, we immediately obtain that $I_{eff} = 50$.

2.2 Equilibrium analysis

The question of interest is whether parties will make efficient investments and how this varies with their price-setting power and the level of information asymmetry. In this subsection we informally derive the (perfect Bayesian) equilibrium predictions, assuming that both buyer and seller are selfish.

In the final trading stage the buyer is willing to accept any price demand weakly below her valuation $R(I)$ whereas the seller is willing to accept any price offer weakly above his actual outside option s. Realizing this, the seller's equilibrium price demand just equals $R(I)$. Note that this demand will always yield him (weakly) more than his outside opportunity, because $s_h \leq R(I)$ by assumption. In case the buyer formulates a price proposal, her offer depends on whether she is informed on s or not. If she observes s, which happens with probability $1 - q$, she just matches the seller's actual outside option with her price offer.

However, in case the buyer is uninformed about s, she cannot simply match the seller's outside option. The relevant choice for her is then between a low price equal to s_l and a high price equal to s_h. The low price is accepted by the low seller type only whereas the high price is accepted by both types. Effectively, the buyer faces a tradeoff between a loss of profitable trades and a loss on actual trades realized. If she chooses the low price, the seller separates when his outside option turns out to be high, even though profitable trades do exist. Because a price equal to s_h would have been accepted by this type of seller, the expected loss to the buyer equals $p \cdot [R(I) - s_h] = 50 \cdot I$. A choice for the high price equal to s_h, however, brings about a loss on actual trades realized. This happens when the seller's outside option turns out to be low and a price equal to s_l would have been sufficient to secure trade. The expected value of this loss equals $(1 - p) \cdot [s_h - s_l] = 2000$. Clearly, in equilibrium the buyer chooses the price that minimizes her overall loss. The pricing strategy of an uniformed buyer thus equals:

$$\begin{aligned} P_B(I) &= s_l = 0 \quad \text{when} \quad I < 40 \\ &= s_h = 4000 \quad \text{when} \quad I \geq 40 \end{aligned} \tag{1}$$

Given all the above pricing strategies, investment incentives can be intuitively understood. First consider the case in which the buyer invests. Her expected payoffs from investment level I equal:

$$\begin{aligned} \Psi_B(I) &= \pi_B \cdot [R(I) - E[s]] \\ &\quad -\pi_B \cdot q \cdot \min\{p \cdot [R(I) - s_h], (1-p) \cdot [s_h - s_l]\} - C(I) \\ &= \pi_B \cdot [2000 + 100 \cdot I] - \pi_B \cdot q \cdot \min\{50 \cdot I, 2000\} - I^2 \end{aligned}$$

Only when the buyer formulates the price offer herself, she can capture some share of the trade surplus. This happens with probability π_B. The exact share she then obtains depends on whether she becomes informed on the seller's outside option s or not. In the former case she gets a share equal to $R(I) - E[s]$ in expectation. An uninformed buyer necessarily gets less. The second term in $\Psi_B(I)$ gives the reduction in the buyer's expected payoffs due to the outside option being private information to the seller. As explained above, the uninformed buyer faces a tradeoff between a loss on profitable trades and a loss on actual trades realized when setting her price. Her equilibrium pricing strategy minimizes the overall loss, explaining the min-component here. This is multiplied by the probability q that the buyer is uninformed. Irrespective of the division of the trade surplus, the buyer bears the costs of investment, yielding the third term.

Term $\pi_B \cdot q \cdot \min\{50 \cdot I, 2000\}$ can be defined as the buyer's *informational loss*. Because this loss is weakly increasing in I, its presence in general *weakens* investment incentives. By maximizing the buyer's expected payoffs $\Psi_B(I)$ her equilibrium investment level can be obtained:

$$\begin{aligned} I_B^*(\pi_B, q) &= (50 - 25 \cdot q) \cdot \pi_B \quad \text{when } \pi_B \cdot (100 - 25 \cdot q) < 80 \\ &= 50 \cdot \pi_B \quad \text{when} \quad \pi_B \cdot (100 - 25 \cdot q) > 80 \end{aligned} \tag{2}$$

The intuition follows from the uninformed buyer's pricing strategy given in (1). If the buyer offers a low price when she is uninformed, an investment equal to $(50 - 25 \cdot q) \cdot \pi_B$ is optimal for her. This investment level takes into account that the return on investment is lost whenever the uninformed buyer faces a high type of seller. If the uninformed buyer offers the high price equal to s_h instead, the corresponding optimal investment is $50 \cdot \pi_B$. Which of these two investment levels yields the buyer the most then follows from a simple payoff comparison.[2] The resulting equilibrium investment level

[2] The dividing inequality in expression (2) can be rewritten as: $50 \cdot \pi_B - 40 < [>] 40 - (50 - 25 \cdot q) \cdot \pi_B$. Therefore, of the two investment levels the one that is furthest away from the cutoff level of 40 is preferred.

$I_B^*(\pi_B, q)$ is increasing in the buyer's price-setting power π_B and weakly decreasing in the level of information asymmetry q.

When the seller makes the investment his expected payoffs are given by:

$$\begin{aligned}\Psi_S(I) &= E[s] + \pi_S \cdot (R(I) - E[s]) \\ &\quad + (1 - \pi_S) \cdot q \cdot \left[p \cdot (s_h - s_l) \cdot 1_{\{I \geq 40\}}\right] - C(I) \\ &= 2000 + \pi_S \cdot (2000 + 100 \cdot I) + (1 - \pi_S) \cdot q \cdot \left[2000 \cdot 1_{\{I \geq 40\}}\right] - I^2\end{aligned}$$

In this expression $1_{\{I \geq 40\}}$ denotes the indicator function, equal to one when $I \geq 40$ and zero otherwise. To understand $\Psi_S(I)$, note that the seller can always secure his outside option value, thus $E[s]$ in expectation. In case the seller sets the price himself, he is residual claimant of the remaining surplus, explaining the second term. The third term represents the *informational rent* the seller obtains. The seller explicitly benefits from his informational advantage only when the uninformed buyer offers a high price equal to s_h while the seller's actual outside option is low. Now, the uninformed buyer offers the high price if $I \geq 40$ and the expected gain to the seller then equals $p \cdot (s_h - s_l)$. This yields the third term in $\Psi_S(I)$.

The seller's informational rent is increasing in I. Private information thus in general *strengthens* his investment incentives. His equilibrium investment level follows from maximizing expected payoffs $\Psi_S(I)$ and equals:

$$\begin{aligned}I_S^*(\pi_S, q) &= 50 \cdot \pi_S \quad \text{when } (1 - \pi_S) \cdot q \cdot 2000 < (40 - 50 \cdot \pi_S)^2 \\ &= \max\{50 \cdot \pi_S, 40\} \quad \text{when } (1 - \pi_S) \cdot q \cdot 2000 > (40 - 50 \cdot \pi_S)^2\end{aligned} \tag{3}$$

Intuitively this expression can be understood as follows. Ignoring the informational rent, the optimal investment for the seller equals $50 \cdot \pi_S$. In case this is below 40, the seller may be tempted to increase his investment to 40 in order to get the informational rent equal to $(1 - \pi_S) \cdot q \cdot 2000$. The net costs of doing so are $(50 \cdot \pi_S - 40)^2$. Only when the benefits exceed the costs, the seller actually increases his investment. Overall, we obtain that the seller's equilibrium investment increases with both his price setting power π_S and the level of information asymmetry q. Theory thus predicts that private information may substitute for price-setting power in providing investment incentives.

Summing up, in all situations the equilibrium investment level is weakly below the efficient one. The extent of underinvestment depends on the investor's price-setting power and his/her informational (dis)advantage. In general it holds that price-setting power boosts investment incentives. However, a higher level of information asymmetry (i.e. higher q) weakens the buyer's incentives to invest. The intuition here is that when the buyer is uninformed, she bears an informational loss whenever she can make a price offer. This informational disadvantage leads to smaller possibilities for rent extraction. As a result the buyer has less incentives to invest when it becomes more likely that she is uninformed. For the seller the effect is in the opposite direction. He obtains better possibilities for rent extraction and thus an informational rent. This in turn gives him stronger incentives to invest. Theoretically private information rents thus provide an alternative instrument to boost investment incentives.

3 Experimental design and hypotheses

3.1 Treatments and hypotheses

Our main interest lies in how actual investment levels vary with the degree of information asymmetry q and the buyer's price-setting power π_B. In order to keep the experimental setup as simple as possible, we focus on the polar cases of these two treatment parameters. With respect to the information asymmetry we consider the *common information* case in which both agents become informed in stage 2 ($q = 0$), and the *private information* situation in which only the seller becomes informed on his outside option ($q = 1$). In regard to price-setting power we look at both the seller-sets-price ($\pi_B = 0$) and the buyer-sets-price ($\pi_B = 1$) case. By restricting both q and π_B to $\{0, 1\}$, the only stochastic element for the subjects involves the value of the outside option s. A third parameter concerns the identity of the investor. We consider both the case in which the buyer invests and the situation in which the seller does so. Overall a $2 \times 2 \times 2$ design results. Table 1 summarizes the various treatments considered. For ease of future reference they are labeled after the identity of the investor (B or S) and the type of information (C or P). The third dimension is accounted for through parameter $\pi_B \in \{0, 1\}$.

In the experiment investment choices are restricted to integer values between 0 and 80. The predicted investment levels follow from expressions (2) and (3) above and are reported in Table 1 as well. They lead to the following two comparative statics hypotheses:

H1 (a) When the seller sets the price ($\pi_B = 0$), investments are independent of the information condition. (b) In the buyer-sets-price case ($\pi_B = 1$), the buyer invests less and the seller invests more under private information ($q = 1$).

H2 For a given information structure, the buyer's investment is increasing is π_B and the seller's investment is decreasing in π_B.

3.2 Experimental procedures

In each session we kept the identity of the investor and the information structure fixed. A session thus either considered the BC-case, the SC-case, the BP-case or the SP-case (cf. Table 1). We ran two sessions for each of these four cases, such that we had eight sessions in total. All subjects within a session were confronted with both values of π_B. Overall 160 subjects

Table 1: Equilibrium investment levels

	Common information ($q = 0$)	Private information ($q = 1$)
Buyer invests	BC :	BP :
$\pi_B = 0$	0	0
$\pi_B = 1$	50	25
Seller invests	SC :	SP :
$\pi_B = 0$	50	50
$\pi_B = 1$	0	40

Remark: The efficient level of investment equals 50.

participated, with 20 participants per session. The subject pool consisted of the undergraduate student population of the University of Amsterdam. Most of them were students in economics. They earned on average 26.50 euros in less than two hours.

Each session contained 32 rounds. We employed a block structure of rounds to control for both learning and order effects. In particular, the 32 rounds were divided into four blocks of eight rounds. Within each block the identity of the price-setter was kept fixed. In one out of the two sessions per situation considered we used the 'upward'-order ($\pi_B = 0$, $\pi_B = 1$, $\pi_B = 0$, $\pi_B = 1$). In the other session we employed the opposite 'downward' order ($\pi_B = 1$, $\pi_B = 0$, $\pi_B = 1$, $\pi_B = 0$). By making within-session comparisons between the two blocks that considered the same value of π_B we could test for learning effects.[3] Using across-session comparisons between the two different orders we could also control for order effects. The start of every new block and the change of π_B were both verbally announced and shown on the computer screen.

Subject roles' varied over the rounds. Within each block of eight rounds each subject had the role of buyer exactly four times, and the role of seller also four times. The experiment used a stranger design. Subjects were anonymously paired and their matching varied over the rounds. Within each block subjects could meet each other only once. Subjects were explicitly informed about this. Moreover, within a session we divided the subjects into two separate groups of ten subjects. Matching of pairs only took place within these groups. We did this to generate two independent aggregate observations per session.

[3] In the BP-case buyers were informed on the seller's actual outside option at the end of each round (i.e. after stage 4). Learning possibilities are thus equal in all treatments.

To enhance comparability, the empirical distribution of the outside option s was exactly the same over the different groups and sessions. We used an empirical distribution that in the aggregate exactly matched the theoretical distribution, yet contained sufficient variation over the individual subjects. We also used a common endowment of $20,000$ points as show up fee. The conversion rate was 1 euro for 4000 points. All subjects thus started with a sufficient cash balance that enabled them to make investments in the first couple of rounds, without immediately running into a debt.

The experiment was computerized. Subjects started with on-screen instructions. Before the experiment started all subjects first had to answer a number of control questions correctly. Subjects also received a summary of the instructions on paper (see Sloof (2006) for a direct translation of this summary sheet). At the end of the experiment subjects filled out a short questionnaire and the earned experimental points were exchanged for money. Subjects were paid individually and discreetly.

4 Results

In presenting the results we pool the data from the sessions that differ only in the order of the π_B's. Although some order effects can be detected, these appear to be only minor. Further aggregations are not possible, as it appears that behavior evolves over time (see Sloof (2006) for details). Most findings are therefore reported separately for the first and second half of the experiment.

In the experiment the 32 rounds are divided into four blocks of 8 rounds. Within each block subjects have the role of investor four times. For each subject we calculate for each block his/her mean investment level based on 4 investment decisions. Statistical tests can then be based on a comparison of these *individual mean* investment levels. In addition we perform our tests on the group level data. As discussed in Section 3 we divided the 20 subjects within a session into two groups that were independently matched. We thus have per session two independent observations at the aggregate group level and we can compare the *group mean* investment levels (based on 40 investment decisions) across treatments. In the sequel we base our inferences on the results of both types of tests. If not stated otherwise, a significance level of 5% is employed.

The first result compares mean investment levels across information conditions (cf. Hypothesis H1).

Result 1. Irrespective of which party sets the price, mean investment levels are independent of the information condition.

Result 1 immediately follows from Table 2. This table reports the mean (of individual mean) investment levels by treatment and gives the test statistics

Table 2: Mean investments by treatment and tests for equality

	first: rounds 1-16			second: rounds 17-32		
	Common	Private	C vs. P	Common	Private	C vs. P
Buyer invests						
$\pi_B = 0$	30.48	29.0	0.6335	25.34	25.39	0.6157
	[0]	[0]	1.0000	[0]	[0]	1.0000
$\pi_B = 1$	45.21	42.78	0.4800	47.29	43.91	0.1502
	[50]	[25]	0.2000	[50]	[25]	0.2000
0 vs. 1	0.0000	0.0000		0.0000	0.0000	
Seller invests						
$\pi_B = 0$	38.38	40.04	0.3418	37.85	38.17	0.5268
	[50]	[50]	0.3429	[50]	[50]	0.8857
$\pi_B = 1$	30.31	29.09	0.5892	27.11	21.3	0.0526
	[0]	[40]	1.0000	[0]	[40]	0.3429
0 vs. 1	0.0002	0.0000		0.0000	0.0000	

Remark: Theoretical predictions within square brackets. The columns denoted 'C vs. P' report the p-values of Mann-Whitney ranksum tests. Per comparison made the upper (lower) p-value is based on individual (group) level data. The rows labeled '0 vs. 1' give the p-values of Wilcoxon signed-rank tests for matched pairs, based on individual level data.

for equality of these levels across treatments. It does so for the first and second half of the experiment separately. The columns 'C vs. P' report the p-values of comparing the common information case with the private information case by means of a two-sided ranksum test. Per comparison made the upper p-value refers to individual level data, the lower p-value to group level data. None of the comparisons yields significant differences at the 5% level. Only when $\pi_B = 1$ the individual level data provide some weak indication that the seller invests less under private information (here the p-value equals $p = 0.0526$ in the second half of the experiment). Yet this only applies when subjects have gained experience and does not hold at the aggregate group level. Moreover, from a theoretical perspective the difference is in the wrong direction.

For the seller-sets-price ($\pi_B = 0$) cases Result 1 is in line with Hypothesis

1(a). Standard theory then predicts informational rents and losses to be absent, because his price-setting power already gives the seller the possibility to extract the complete surplus. For the buyer-sets-price ($\pi_B = 1$) cases Result 1 deviates from Hypothesis 1(b). Here informational rents/losses are predicted to affect investment incentives, but this is not what we observe. Investment levels remain constant when the seller's outside option becomes private information.

Our second result considers the impact of variations in price-setting power (cf. Hypothesis H2).

Result 2. Mean investment levels increase with the price-setting power of the investor.

In Table 2 the rows labeled '0 vs. 1' report the p-values of comparisons between the cases $\pi_B = 0$ and $\pi_B = 1$, based on individual level data. Because comparisons are on a within-subjects basis, we make use of a signed-rank test for matched pairs. For all situations considered differences are highly significant. In line with theoretical predictions, the investor invests more when s/he has price-setting power.[4] A similar conclusion is obtained from the group level data. With only four matched pairs per comparison, the smallest possible level of significance that a two-tailed signed-rank test can attain equals $p = 0.1250$. For each situation we then obtain a significant difference at this level between the $\pi_B = 0$ and $\pi_B = 1$ case.[5]

Together, Results 1 and 2 suggest that price-setting power is an effective instrument for boosting investment incentives whereas informational rents are not. To illustrate, take the SC-case with $\pi_B = 1$ as benchmark. Over all 32 rounds, sellers in that case choose an investment level of $28\frac{1}{2}$ on average. Giving the seller price-setting power ($\pi_B = 0$) increases his investment to around 38 on average. However, providing him with an informational advantage instead (SP-case with $\pi_B = 1$) does not affect investment levels. In the latter case the average investment equals 25. Standard theory predicts that both instruments would boost investment incentives. Our findings thus question the theoretical suggestion that private information rents might substitute for bargaining power in mitigating underinvestment.

Another observation that can be made from Table 2 is that in situations where no investment is predicted, holdup appears much less of a problem

[4] This conclusion is obtained by comparing $\pi_B = 0$ with $\pi_B = 1$, while keeping the identity of the investor (and the information condition) fixed. The same conclusion is obtained when comparing the Buyer invests case with the Seller invests case, while keeping π_B (and the information condition) fixed. All these comparisons yield significant differences, at both the individual and the group level. In particular, for $\pi_B = 0$ the seller invests significantly more than the buyer does. When $\pi_B = 1$ this is the other way around.

[5] Given the restrictions on the attainable significance level, these test results are not reported in Table 2. Because theory predicts significant differences between the $\pi_B = 0$ and the $\pi_B = 1$ case, one-sided tests may be considered appropriate here. The level of significance then equals $p = 0.0625$.

Table 3: Mean proposed relative prices by treatment and tests for equality

	first: rounds 1-16			second: rounds 17-32		
	Common	Private	C vs. P	Common	Private	C vs. P
Buyer invests						
$\pi_B = 0$	.728	.742	0.5867	.756	.801	0.0189
	[1]	[1]	0.6857	[1]	[1]	0.2000
$\pi_B = 1$	.378	.455	0.0001	.387	.465	0.0000
	[.242]	[.367]	0.0286	[.235]	[.367]	0.0286
0 vs. 1	0.0000	0.0000		0.0000	0.0000	
Seller invests						
$\pi_B = 0$	.733	.753	0.2366	.759	.776	0.3812
	[1]	[1]	0.1143	[1]	[1]	0.4857
$\pi_B = 1$	.483	.512	0.3240	.509	.510	0.7182
	[.302]	[.188]	0.4857	[.309]	[.069]	1.0000
0 vs. 1	0.0000	0.0000		0.0000	0.0000	

Remark: Predicted relative prices (based on actual investment levels chosen) within square brackets. The columns denoted 'C vs. P' report the p-values of Mann-Whitney ranksum tests. Per comparison made the upper (lower) p-value is based on individual (group) level data. The rows labeled '0 vs. 1' give the p-values of Wilcoxon signed-rank tests for matched pairs, based on individual level data.

than standard theory predicts it to be. This finding is line with earlier experimental studies that consider complete information settings. These studies indicate that a partial solution to holdup is provided by fairness and reciprocity considerations. Investment is typically seen as a kind act, which is therefore rewarded by the non-investor with a larger than predicted return.[6] Our results suggest that this informal fairness mechanism carries over to situations with private information about outside options. In Section 5 we return to this issue when we look at a particular fairness model, viz. inequality-aversion, in somewhat more detail.

Given Results 1 and 2, the question of interest becomes why price-setting

[6] See e.g. Berg et al. (1995), Ellingsen and Johannesson (2004a, 2004b), Gantner et al. (2001), Hackett (1993), Königstein (2000), Sloof et al. (2004) and Sonnemans et al. (2001).

power does appear to work as an effective instrument against holdup whereas informational rents do not. We next investigate whether actual pricing behavior can provide an explanation for this.

Result 3. Proposed and accepted relative prices $P/R(I)$ are significantly higher in the seller-sets-price case than in the buyer-sets-price case.

Within each block of 8 rounds every subject makes 4 price proposals, either in the role of seller or as a buyer. We first convert absolute prices P into relative prices $P/R(I)$. Because the different treatments induced different investment levels and thus different amounts of gross surplus $R(I)$, this normalization is needed to make prices comparable. Subsequently, we calculate for every treatment the *individual mean* relative price based on 4 relative prices and the *group mean* relative price based on 40 relative prices. We do so for proposed and accepted prices separately. Tables 3 and 4 report the overall means together with tests for equality across treatments. Result 3 follows from the reported p-values in the rows '0 vs. 1'.[7] In line with theoretical predictions, the seller obtains a better deal when he can make the price offer himself. Because a party can secure a larger (relative) gain when it has more price-setting power, it obtains a higher return on investment. This explains our earlier finding that investment levels increase with the price-setting power of the investor.

We next consider the impact of private information on pricing behavior.

Result 4. (a) When the seller sets the price, proposed and accepted relative prices are independent of the information condition. (b) In case the buyer sets the price, proposed and accepted relative prices (i) vary with the information condition when the buyer invests, but (ii) are independent of the information condition when the seller invests.

This finding follows from the p-values reported in the columns 'C vs. P' in Tables 3 and 4. Again, the upper p-value refers to individual level data, the lower p-value to group level data. For the seller-sets-price case ($\pi_B = 0$) we find no significant differences at the 5% level.[8] In case the buyer sets the price ($\pi_B = 1$), results depend on the identity of the investor. When the buyer made the investment all differences are significant. The buyer then proposes and pays a higher relative price under private information. In

[7] These p-values are based on individual level data. The same result is obtained by looking at the group level data. As before, the smallest possible significance level that can be attained then equals $p = 0.1250$ (two-sided). For each comparison we obtain a significant difference at this level between the $\pi_B = 0$ and $\pi_B = 1$ case.

[8] Only when the buyer invests we find a significant difference at the individual level between proposed relative prices in the second half of the experiment (cf. Table 3, first row). At the group level we then do not find significant differences though.

Table 4: Mean accepted relative prices by treatment and tests for equality

	first: rounds 1-16			second: rounds 17-32		
	Common	Private	C vs. P	Common	Private	C vs. P
Buyer invests						
$\pi_B = 0$	.707	.713	0.7508	.749	.781	0.0799
	[1]	[1]	1.0000	[1]	[1]	0.4857
$\pi_B = 1$	.384	.469	0.0001	.390	.483	0.0000
	[.233]	[.387]	0.0286	[.231]	[.386]	0.0286
0 vs. 1	0.0000	0.0000		0.0000	0.0000	
Seller invests						
$\pi_B = 0$	.718	.735	0.6168	.752	.761	0.5866
	[1]	[1]	0.6857	[1]	[1]	0.6857
$\pi_B = 1$	.497	.539	0.2315	.511	.555	0.0833
	[.251]	[.226]	0.3429	[.278]	[.083]	0.6857
0 vs. 1	0.0000	0.0000		0.0000	0.0000	

Remark: Predicted relative prices (based on actual investment levels chosen) within square brackets. The columns denoted 'C vs. P' report the p-values of Mann-Whitney ranksum tests. Per comparison made the upper (lower) p-value is based on individual (group) level data. The rows labeled '0 vs. 1' give the p-values of Wilcoxon signed-rank tests for matched pairs, based on individual level data.

case the seller made the investment, relative prices are independent of the information condition.

Result 4(a) is in line with theoretical predictions. It provides an explanation for our finding that investment levels do not vary with the information condition when the seller sets the price (as predicted). However, mean proposed and accepted prices are then around 75% of the gross surplus $R(I)$, while theory predicts a price equal to $P_S = R(I)$. In line with numerous ultimatum game experiments, our subjects thus typically arrive at a more equal division of the surplus. This implies that the buyer obtains some return on investment when $\pi_B = 0$ and that the seller is not full residual claimant. This in turn may explain why buyers invest more and sellers invest less than predicted (cf. Table 2).

When the buyer sets the price, private information is predicted to have an impact on observed prices. Specifically, the buyer's predicted offer equals $P_B = s$ in the common information case. Under private information her equilibrium price offer is governed by (1). Depending on the actual investments made, one thus either expects a lower relative price offer under private information (when typically $I < 40$), or a higher one (in case typically $I \geq 40$). Now, when the buyer invests she chooses $I \geq 40$ in most cases, explaining why relative prices are higher under private information (Result 4(bi)). The seller typically invests $I < 40$, so here one would expect lower relative prices under private information (cf. the predictions in brackets in Tables 3 and 4). Result 4(bii) indicates that this is not the case.

Result 4(b) is inconclusive about why private information does not affect investment incentives when the buyer sets the price. Our final experimental result therefore considers this situation in more detail.

Result 5. Consider the buyer-sets-price case ($\pi_B = 1$). (a) Under common information the buyer gives the seller a markup that decreases with his outside option s. (b) Under private information, in around $40 - 50\%$ of the observations with $I < 40$ the buyer offers a price of 4000 or more.[9]

Result 5 follows from the frequency distributions of proposed absolute prices in Figures 1 and 2.[10] Figure 1 considers the common information case, Figure 2 the one with private information. In both figures the left (right) hand panel corresponds to the situation in which the buyer (seller) makes the investment. Standard predictions imply that the dark bars should be at a price of $P_B = 0$ and the light grey bars at a price of $P_B = 4000$.

< Figures 1 and 2 >

[9] When the buyer invests this applies in 31 out of 63 observations (49%), in case the seller invests this holds for 91 out of 235 observations (39%).

[10] The same conclusions follow when we look at the frequency distributions of accepted prices and when we consider the first and the second half of the experiment separately.

With common information the buyer gives the seller a markup on his outside option. This is most evident in the buyer invests case, see the left hand panel of Figure 1. The average markup when $s = 0$ is around 2000 experimental points, while for $s = 4000$ it is around 500 points. The actual markup is thus substantially lower for higher values of s. This also applies when the seller makes the investment, although there somewhat more variation in the actual markups is observed. The finding of decreasing markups is consistent with a number of other experimental studies. Knez and Camerer (1995), Binmore et al. (2002) and Sloof (2005), for instance, include ultimatum game treatments with varying outside option values. They all observe that the higher the outside option of the responder is, the smaller the markup s/he receives in the actual bargaining.

Result 5(b) indicates that under private information the buyer is more easily persuaded to offer a high price than expected. In particular, when $I < 40$ standard theory predicts a price offer of $P_B = 0$. However, in a large fraction of the cases buyers offer a price of 4000 or more. This suggests that already a lower investment is sufficient to induce the buyer to offer a high price. This in turn may explain why informational losses/rents have less impact on investment incentives than standard theory predicts. In the next section we offer a behavioral explanation that can partially account for the observed deviations from standard predictions.

5 Inequality-aversion

The hypotheses formulated in Subsection 3.1 assume that agents solely care about their own monetary payoffs. A common motivation of many people, however, is that they dislike inequality. Our experimental findings also hint at this. In particular, buyers' actual price offers intend to divide the available surplus much more equally than standard theory predicts (cf. Result 5(a)). Two forces may be at work here. First, the seller may dislike being behind and therefore willing to reject 'unfair' prices. (Indeed, when responding to an offer some subjects reject large material payoffs.) In that case the buyer is forced to offer the seller a markup on his outside option, especially when this outside option is low. Second, when the buyer dislikes being ahead she will refrain from making very low price offers in the first place. In both cases prices are more equal and hence investment incentives are affected.

In this section we informally explore whether subjects' tastes for equality can explain the observed ineffectiveness of private information as investment incentive device. The focus is therefore on the situations in which the buyer sets the price ($\pi_B = 1$).[11] Following Fehr and Schmidt (1999) we assume

[11] A much more elaborate discussion containing a detailed analysis of all situations considered (i.e. including $\pi_B = 0$) can be found in Sloof (2006).

that players' preferences take the following form (for $i = B, S$):

$$U_i(m_i, m_j) = m_i - \alpha_i \cdot \max\{m_j - m_i, 0\} - \beta_i \cdot \max\{m_i - m_j, 0\}$$

Here m_i refers to the monetary payoff of player i and α_i and β_i to non-negative parameters (with $\beta_i \leq \alpha_i$ and $\beta_i < 1$). The second term in the utility function measures the utility loss from being behind (*inferiority-aversion*), the third term the loss from being ahead (*superiority-aversion*).

First consider the isolated impact of inferiority-aversion and let $\beta_i = 0$ for the time being. In case the seller's outside option is high he necessarily earns more (on the equilibrium path) than the buyer does and his inferiority-aversion plays no role. His acceptance threshold then equals $P_h = 4000$. But when his outside option is low an inferiority-averse seller who chose the investment himself accepts (a low) price offer P_B only if:

$$P_B - C(I) - \alpha_S \cdot (P_B - C(I) - [R(I) - P_B]) \geq -C(I) - \alpha_S \cdot C(I)$$

Here the l.h.s. (r.h.s.) gives the utility the seller obtains from accepting (rejecting) P. For the situation in which the buyer invests a similar inequality applies. The resulting lowest acceptable price for the seller equals:

$$P_l = \frac{\alpha_S \cdot \left[R(I) - C(I) \cdot 1_{\{B\ invests\}}\right]}{1 + 2\alpha_S} \tag{4}$$

with $1_{\{B\ invests\}}$ denoting the indicator function, equal to one in the buyer invests case and zero otherwise. In equilibrium the (inferiority-averse) buyer necessarily chooses between the low price P_l in (4) and the high price $P_h = 4000$. Compared to standard theory (cf. expression (1)) inferiority-aversion thus shifts the low price up from 0 to P_l, but leaves the high price unaffected. The relevant issue is then how this affects investment incentives.

With the low price equal to P_l the seller still does not invest under common information about s. This holds because P_l (offered after $s = 0$) just gives him a utility equal to $-C(I) \cdot (1 + \alpha_S)$ and also the high price (offered when $s = 4000$) does not give him any return on investment made. The buyer in the BC-case, however, invests efficiently (i.e. $I = 50$). This follows because with P_l and P_h her utility still increases with $R(I) - C(I)$. Shifting from the SC-case to the BC-case while holding $\pi_B = 1$ constant, is equivalent to increasing the investor's price setting power. The above discussion thus intuitively explains why inequality-aversion leaves the incentive effects of additional price-setting power largely unaffected.

In contrast, the investment incentive effects of private information are seriously muted. Because price P_l increases with α_S, it becomes less attractive the more inferiority-averse the seller is. The buyer is therefore more easily persuaded to attract also the high outside option type through offering the high price P_h. In the BP-case where the buyer makes the investment herself price P_h together with the corresponding investment $I = 50$ then becomes most attractive to her (for α_S large enough). In that case informational losses do not affect investment incentives at all, just as we observe in Result 1. Also informational rents affect the seller's investment incentives to a lesser extent than under standard theory. Because the price differential $P_h - P_l$ decreases with α_S and I, an investment well below 40 (but above $13\frac{1}{3}$) is already sufficient to induce the buyer to offer the high price P_h, in line with Result 5(b).

Inferiority-aversion predicts that informational rents should still boost investment incentives to some extent and thus cannot explain their complete ineffectiveness as we observe it. The main problem is that inferiority-aversion cannot explain the higher than minimum investments observed for the SC-case. As pointed out before, inferiority-aversion predicts $I = 0$, which contrasts sharply with the average investment of around 29 that we observe. A potential explanation here is that the buyer dislikes being ahead and therefore never offers a price as low as P_l depicted in (4). Consider such a superiority-averse buyer with $\beta_B > \frac{1}{2}$. She strictly prefers the 'equitable' price P_e that induces an equal split of the net surplus $R(I) - C(I)$.[12] Because this price may not be accepted when the seller's outside option is high, the buyer always chooses between prices $P_l = P_e$ and $P_h = 4000$ in equilibrium. The crucial element is that the new 'low' price $P_l = P_e$ (which may actually exceed P_h) *does* give the seller a return on investment.

In the SC-case a superiority-averse buyer always offers $P_l = P_e$ after $s = 0$ and also does so after $s = 4000$ if I is sufficiently high. This gives the seller incentives to invest efficiently. Under private information he actually invests *less*. The intuition is that the buyer cannot condition her price proposal on s and for already low investment levels she offers $P_h = 4000$. The seller then chooses the lowest investment needed to induce the buyer to do so, which is well below 50. Note that in this case informational rents work in the *opposite* direction of what standard theory predicts.[13]

So far we considered buyers and sellers of a given preference type. Clearly, in practice people differ. Some people are very much concerned about inequality whereas others just care about their own material well-being. With a mixture of types observed aggregate behavior will be averaged out over the various types. This may explain why we observe no impact at all of informational rents on average, being the net effect of having some inferiority-averse sellers (yielding a positive effect) and some superiority-averse buyers (yielding a negative impact) within the subject pool. This suggestion is very loose, however, because with heterogeneous agents it is also highly likely

[12] This equitable price equals $P_e = \frac{R(I)+C(I)\cdot(1-2\cdot 1_{\{B\ invests\}})}{2}$.

[13] Apart from affecting pricing behavior, superiority-aversion may have a *direct* impact on investment incentives as well. In Sloof (2006) it is shown that when the seller is superiority-averse, informational rents do not affect investment incentives at all.

that they are privately informed about their own tastes. This in turn makes the strategic situation much more complicated, because agents then may try to signal their preference type through the choices they make. In particular, the investment level itself may serve this signaling purpose, potentially boosting investment incentives (cf. von Siemens (2005)).

Overall, the informal discussion in this section suggests that the incentive effects of price-setting power are largely unaffected by inequality-aversion, while the incentive effects of informational losses and rents are seriously muted. Inequality-aversion thus seem to provide a reasonable explanation for our experimental findings that price-setting power is an effective instrument against holdup whereas informational rents are not.

6 Conclusion

The holdup underinvestment problem emerges in a wide variety of economic contexts. For instance, it provides the cornerstone of the property rights theory of the firm. Most existing studies analyze this problem assuming that the ex post bargaining takes place under symmetric information. But in reality contracting parties typically possess private information about the alternative trading opportunities they have, which may have important implications for holdup. In this paper we therefore study such a situation in more detail. We consider a buyer-seller relationship in which the seller may have private information about his outside options. It is shown that theoretically the presence of an informational rent typically strengthens the seller's investment incentives. At the same time, informational losses weaken the investment incentives of the buyer. The extent of the underinvestment problem is thus likely to be different under private information.

The main part of the paper is devoted to an experimental test of the theoretical predictions. A first treatment variable concerns whether the seller's outside option is private information to him, or whether it is commonly observed. The price-setting power of the two parties is used as a second treatment variable. Apart from that, we also vary the identity of the investor, i.e. either the buyer or the seller makes the specific investment. This design enables us to identify whether private information rents and price-setting power can be used as instruments for mitigating holdup.

We obtain two main findings with respect to the actual investments observed. First, investment levels increase with the price-setting power of the investor, just as standard theory predicts. Second, in contrast with standard predictions, we find no significant effect of both informational losses and rents on investment incentives. In the final part of the paper we informally explore whether subjects tastes' for equality can provide a reasonable explanation for these findings. Although our discussion of Fehr and Schmidt (1999)'s inequality-aversion model is far from rigorous and rather informal, it does yield some intuitive insights. First, because inferiority-averse sellers tend to reject low prices that are deemed ‘unfair’, the buyer is forced to offer the seller a markup that decreases with his outside option. It then becomes cheaper for the buyer to attract higher, and thus more, outside option types than standard theory predicts. The buyer’s own investment thus pays off with a larger probability, resulting in a lower impact of informational losses on investment incentives. For our setup with just two outside option types, a low level of inferiority-aversion is sufficient for private information to have no impact at all, just as we observe in the experiment. Inferiority-aversion also explains why informational rents have a much weaker investment incentive effect. Because already a lower investment induces the buyer to offer a high price, the seller has less incentives to invest. Still, informational rents should boost his investment incentives to some extent.

The presence of some superiority-averse buyers may explain the complete ineffectiveness of private information rents. Intuitively, when the buyer dislikes being ahead, she is willing to grant the seller a fair return on investment. So, even without price-setting power and no informational rents, he already invests a significant amount. With this informal (fairness) mechanism in place, the introduction of informational rents then has no additional impact on his investment incentives.

Inequality-aversion thus can roughly explain why private information leaves investment incentives unaffected. At the same time it also provides a rationale why changes in price-setting power do have an impact. Such changes would be immaterial only if (almost) all subjects are strongly superiority-averse. Because typically a large fraction of the subjects does not really care about being ahead, more price-setting power strengthens investment incentives, albeit to a smaller extent than standard theory predicts.

Taken together, our findings cast doubt on the suggestion made in Gul (2001, p. 344) that “...private information rents might substitute for bargaining power and ameliorate the hold-up problem...” We find that private information about outside options does not affect the extent of the underinvestment problem. Price-setting power does appear to be an effective instrument though.

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Figure 1. Price proposal of the buyer (π_B=1) under common information

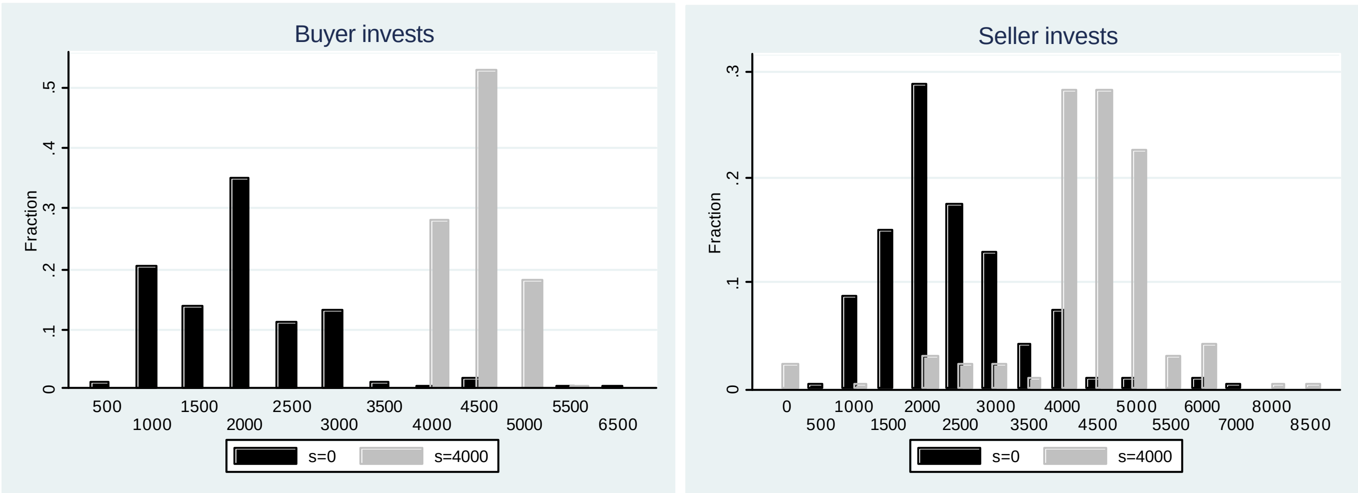

Figure 2. Price proposal of the buyer (π_B=1) under private information