Bounded Rationality as an Essential Ingredient of the Holdup Problem

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Abstract: We provide experimental evidence for the hypothesis that bounded rationality is an important element of the theory of the firm. We implement a simplified version of a mechanism that was designed in order to perfectly solve the holdup problem under conditions of perfect rationality (Maskin 2002). We test whether this mechanism either is able to perfectly solve our experimental holdup problem or may at least improve economic performance. We show that neither is the case: the implementation of the mechanism worsens economic performance. We reconstruct the main features of participants' behavior by applying the logit agent quantal response equilibrium (McKelvey and Palfrey 1998) as an equilibrium concept that takes players' potential mistakes into account.

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1 Introduction

Bounded rationality is an important element of the theory of the firm and the theory of institutions in general. The objective of this paper is to provide experimental evidence to confirm the first of these statements. In our experiment we implement a simplified version of a mechanism that was designed in order to perfectly solve the holdup problem (Maskin and Tirole 1999, Maskin and Moore 1999 and Maskin 2002). We test whether this mechanism is either able to perfectly solve our experimental holdup problem or at least improve economic performance. We show that neither is the case: the implementation of the mechanism worsens economic performance.

The theory of the firm has a long tradition. In the 1970s several contributions identified the holdup problem as one core element of the theory of the firm (Williamson 1975, 1985, Klein, Crawford and Alchian 1978 and Alchian 1984). This strand of literature is known as transaction cost economics. The corresponding empirical research has provided an impressive amount of confirmation of the basic hypotheses (cf. Lafontaine and Slade 2007 and Shelanski and Klein 1995). Unfortunately, transaction cost economics largely remained a verbal approach so that the description of the interdependencies between the central variables remained rather vague. This changed substantially with the publication of the seminal paper by Grossman and Hart (1986) introducing the property rights model. Like transaction cost economics, the property rights approach places the holdup problem at the center of the game theoretic analysis. In the years that followed an impressive amount of game theoretical variations and refinements emerged so that the former property rights model evolved to a much broader theory of incomplete contracts. Hart and Moore (1990) and Hart (1995) are basically extensions of Grossman and Hart (1986). Rosenkranz and Schmitz (2003), Schmitz and Sliwka (2001) and Schmitz (2006) provide variations of the property rights model. In addition, a parallel strand of research aimed at solving the holdup problem by contractual solutions emerged. Some of the most important of these papers are Hart and Moore (1988) and Edlin and Reichelstein (1996). Che and Hausch (1999) show that the proposed solutions to the holdup problem are based on the assumption of "selfish investments" and that in case of "cooperative investments" no contractual solution exists if players cannot commit not to renegotiate.

Yet Maskin and Tirole (1999), Maskin and Moore and Maskin (2002) show that there exists a mechanism that is able to solve the holdup problem perfectly, even in the case of cooperative investments. As a consequence, this mechanism questions the theoretical foundations of the theory of incomplete contracts in general: there exists no holdup problem anymore because first-best can always be achieved as long as all players have perfect foresight. Although Maskin (2002) emphasizes that the heuristic value of the contributions to the theory of incomplete contracts remains unchanged, the interest in incomplete contract theory decreased and some of its main contributors proposed other aspects than the incompleteness of contracts to be central to the contracting problem; e.g.

Hart and Moore (2008, 2009) introduce a semi-behavioral theory of contracts and as of ownership.[2]

Parallel to the development of the theory of the firm, the role of bounded rationality changed as well. In the beginning (Williamson 1975, 1985) bounded rationality took a central position in the theory of the firm; later, however, it more or less disappeared from the scene. As early as in 1990 Oliver Hart claimed that bounded rationality is not a crucial ingredient in the theory of institutions (Hart 1990, 696) and many economists followed his assessment by restricting their analysis to standard game theoretic equilibrium concepts. Yet it is Eric Maskin himself (2002, 732) who supposes that the rather complicated mechanism he introduced may exceedingly rely on agents' abilities to foresee future payoffs.

We follow Maskin's supposition by implementing a special and much simplified version of his mechanism in our laboratory experiment. We organized the experiment in such a way that the participants did not need to calculate parameters that make the mechanism workable. At each stage of the game, all they had to do was to choose between two alternative actions with one sequence of actions being the subgame perfect Nash equilibrium path through the game tree. Therefore, we believe that we have given Maskin's mechanism an ideal environment to work. Yet if the participants in our experiment do not exhibit equilibrium play in the majority of cases, we regard this as evidence in favor of the bounded rationality hypothesis.

There exists some literature on experimental tests of the holdup model: Hackett (1993, 1994), Olcina (2000), Königstein (2001), Sonnemans et al. (2001), Sloof et al. (2004, 2006, 2007) Bruttel and Eisenkopf (2009), Hoppe and Schmitz (2011) and Erlei and Siemer (2012). Most of these contributions, by and large, confirm the existence of an underinvestment problem and analyze different further aspects of the holdup problem. Yet none of these papers refers to Maskin's mechanism. To the best of our knowledge, this paper is the first attempt to test this mechanism experimentally.

Our paper is organized as follows. In section 2 we describe the structure of the experimental game, its equilibrium and the experimental procedures. In section 3 we present behavioral predictions. The main results of our experiment are given in section 4. Since the experimental behavior substantially deviates from equilibrium play, we try to reconstruct participants' behavior by applying the logit agent quantal response equilibrium to our experimental games in section 5. Finally we present some conclusions and some perspectives for future research.

[2] The experimental evidence regarding this reference point approach is mixed (cf. Fehr, Hart and Zehnder (2009, 2011) and Erlei and Reinhold (2011)).

2 Experimental design

2.1 Experimental game

Motivated by the question whether the Maskin mechanism can solve the holdup problem, this paper compares its effectiveness with the performance of a much simpler but inefficient alternative: vertical integration. To answer this research question we implemented two treatments, the Maskin mechanism treatment (MM treatment) and the vertical integration treatment (VI treatment).

The holdup problem considered in this paper consists of the trade relationship between a buyer and the seller. Both parties can simultaneously conduct cooperative specific investments. If the seller decides to invest, he has to bear a cost of s = 30 and increases the buyer's valuation of the product from v = 50 to v = 100. Accordingly, the overall surplus increases by 20 monetary units ("tokens"). The costs of investment for the buyer amount to b = 15 tokens. By investing the buyer decreases the seller's production costs from c = 30 to c = 10 so that the overall surplus increases by 5 tokens. We assume that it is impossible to write a complete contingent contract before carrying out the investments and that investment decisions are unverifiable to third parties. As a consequence, we have an ordinary holdup problem.

The Maskin mechanism treatment

The game we have designed for our economic experiment is a simplified version of the mechanism described in Maskin (2002). The main idea behind this mechanism is to solve the holdup problem with cooperative investments. In the following we are going to describe our version of the mechanism and its working mechanism according to conventional game theory. It is important to note that the working of the mechanism depends upon the assumptions of perfect rationality and strictly selfish preferences, of course.

The basic structure of the MM consists of two players, the seller and the buyer, and four stages of play:

Table 1: Structure of the Maskin mechanism game

Stage	Actions
Stage 1:	Simultaneous investment decisions by the buyer and the seller
Stage 2:	The buyer reports his value and the seller reports his cost (simultaneously)
Stage 3:	a) The seller decides whether to challenge the buyers report b) Only if the seller decides not to challenge, the buyer gets the opportunity to challenge the sellers report
Stage 4:	If any party has challenged the other party's report, then the challenged party has to decide whether to trade according to a prespecified price

At stage 1 both players have to make their investment decision as described above. Since the buyer's investment costs b are below the induced reduction of the seller's production costs c and the seller's investment costs are below the induced increase of the buyer's product value, both investments are efficient from a social point of view.

At stage 2 both players send messages to each other. In his message the buyer reports his value of the product $\hat{v} \in \{50,100\}$. The buyer may not report the true valuation of the product so that $v \neq \hat{v}$. Likewise, in his message the seller reports his costs $\hat{c} \in \{10,30\}$. Again, the seller does not need to report his true costs so that possibly $c \neq \hat{c}$. By sending their messages both players unavoidably make an indirect claim about each other's investment decision because the buyer's product value can only be 100 if the seller has invested and the seller's production costs will be 10 if and only if the buyer has invested.

At stage 3 the seller has the opportunity to challenge the buyer's report, i.e. he may claim that the buyer's message is not true. If he does this, the buyer immediately has to pay a fine of 60 tokens to the seller. Only if the seller does not challenge the buyers report, the buyer gets the opportunity to challenge the seller's report. Again, if the buyer makes a challenge, the seller has to pay a fine of 60 tokens to the buyer.

If both players decide not to challenge the other party's report, the price of the product being traded between the seller and the buyer is determined to $p = \hat{v} + \hat{c} - 45$. Thus, the profits are given by

$\pi_S = 100 + p - c - s = 100 + \hat{v} + (\hat{c} - c) - s - 45$ for the seller and

$\pi_B = 100 + v - p - b = 100 + (v - \hat{v}) - \hat{c} - b + 45$ for the buyer.[3]

Stage 4 will only be reached if any player has challenged the other player's report. In this case the challenged player has to decide whether he wants to trade at a prespecified price. This trading decision serves to reveal the true amount of either the buyer's product value or the sellers cost.

If the seller has challenged the buyer's message, the buyer may trade at a price of $50 < p = 60 < 100$ or he may not trade at all. If $v = 100$, the buyer can earn 40 tokens by choosing to trade. If the player is perfectly rational and has purely selfish preferences, he would decide not to forgo this amount of money. Yet if $v = 50$, trading will cause a loss of 10 tokens so that a rational and selfish buyer will choose not to trade. If one assumes that players are indeed rational and selfish, the decision whether to trade reveals the true value of the product. In this sense we define the "revealed buyer's value" (v_{rev}) to be.

$$v_{rev} = \begin{cases} 100 & \text{if the buyer trades} \\ 50 & \text{if the buyer does not trade} \end{cases}.$$

If the buyer's revealed value is the same as his reported value, then the buyer's message is regarded as being true and the seller's challenge of the buyer's message is regarded as inappropriate so that the seller has to pay a fine of 120 tokens. Yet this fine is not paid to the buyer but to a third person (in our experiment: to the experimental investigator by

[3] Note that we paid an extra amount of 100 to both players in each period because we wanted to avoid participants making losses.

reducing the seller's profits). If, in contrast, the buyer's revealed value is not the same as his reported value, then the challenge is regarded as appropriate and the seller does not have to pay any fine at all.

If the buyer has challenged the seller's message, the seller has to make a trading decision. He can sell the product at a price of $10 < p = 20 < 30$ or he can abstain from trading. If the true costs are 10, then a perfectly rational and selfish seller would decide to trade. In contrast, if the true costs are 30, the seller will prefer not to trade. Again, if we assume that all players are rational and selfish, the trading decision can be regarded as a revelation of the seller's true costs. Accordingly, we define the "revealed costs" c_{rev} as

$$c_{rev} = \begin{cases} 10 & \text{if the seller trades} \\ 30 & \text{if he does not trade} \end{cases}.$$

Again, if the seller's revealed costs are the same as his reported costs, then the seller's message is regarded as being true and the buyer's challenge is regarded as inappropriate so that the buyer has to pay a fine of 120 tokens (to experimental investigator). If, in contrast, the seller's revealed costs are not the same as his reported costs, the challenge is regarded as appropriate and the buyer does not have to pay any fine at all.

The equilibrium of the Maskin mechanism game

In order to understand the nature of this mechanism, we describe the subgame perfect Nash equilibrium beginning with the last stage and assuming that all players are perfectly rational and purely selfish.

We have already shown that rational and selfish buyers will trade if and only if the products value is 100. In behaving like this the buyer reveals the true product value. In exactly the same way sellers reveal their true costs. As a consequence, the challenging party will have to pay a fine of 120 if the challenged party's message was true. Since this fine is larger than the amount of money the challenged party has to pay to the challenging player (60 tokens), the decision to challenge induces a severe loss when the other party has sent a true message. If, in contrast, the challenged party reveals that he has sent a false message before, then the challenger is rewarded for his decision to challenge. Because of this, buyers and sellers will challenge each other's transaction partner in stage 3 if and only if the message was false.

At stage 2 both players anticipate that false messages will be challenged and that true messages will not be challenged. Because the challenged party has to pay a comparatively large fine, it does not pay off to send a false message. Accordingly, both players will send true messages.

Anticipating that both players will send true messages ($v = \hat{v}$ and $c = \hat{c}$) and that no player will challenge the other player's message, players' profit functions can be rewritten as follows:

$$\pi_S = 100 + v(s) - s - 45 \quad \text{and}$$

$$\pi_B = 100 + 45 - c(b) - b.$$

Since $v(30) - 30 = 70 > 50 = v(0) - 0$, the sellers prefer to invest. In the same way buyers prefer to invest because $-c(15) - b = -25 > -30 = -c(0) - b$. Consequently, in equilibrium both players will invest, both will send true messages, neither player will challenge the other party's message and total surplus is maximized. The equilibrium profits are $\pi_S^* = 125$ and $\pi_B^* = 120$.

The vertical integration treatment

In our second treatment we conducted an experimental game with a much simpler structure but an inefficient equilibrium. This treatment is very close in spirit to the first approaches of property rights theory (Grossman and Hart 1986; Hart and Moore 1990) and to transaction cost economics (Williamson 1985).

The game consists of only two stages. In stage I both players simultaneously make a takeover bid $p_B, p_S \in [0, 0.1, 0.2, \ldots, 99.9, 100\}$ for the other player's firm. The subject making the higher offer buys the other person's firm for a price equal to his own bid. In case both players make the same bid the winner of this auction is determined randomly.

At stage 2 the owner of the firm decides whether or not to invest. The subject having sold his firm in stage 1 has no opportunity to act in stage 2. The investments by both players have exactly the same consequences as in the MM treatment, i.e. the seller's investment *s* = 30 increases the product value from $v = 50$ to $v = 100$ and the buyer's investment b = 15 decreases production costs from *c* = 30 to *c* = 10. Remember that buyers can carry out only investment *b* and that sellers can conduct only investment *s*. The player's profit functions are given by

$$\pi_S = \begin{cases} 100 + v(s) - 30 - s - p_{takeover} & \text{in case of seller ownership} \\ 100 + p_{takeover} & \text{in case of buyer ownership} \end{cases}$$

$$\pi_B = \begin{cases} 100 + 50 - c(b) - b - p_{takeover} & \text{in case of buyer ownership} \\ 100 + p_{takeover} & \text{in case of seller ownership} \end{cases}.$$

In equilibrium both types of players will invest if they own the firm because the increase in value (decrease in production cost) is larger than the corresponding investment costs. Due to the fact that the seller's investment increases total surplus by more (20) than the buyer's investment increases surplus (5), seller integration is more efficient than buyer integration. This has an impact on equilibrium behavior at stage 1: Since the seller values the firm more than the buyer, his equilibrium bid is higher than the buyer's equilibrium bid. It shows, however, that the auction game in stage 1 has multiple equilibria which are characterized by $12.5 \leq p_B \leq 19.9$ and $p_S = p_B + 0.1$. The correspondent equilibrium profits are given by $\pi_S = 140 - p_S$ and $\pi_B = 100 + p_S$. Because only one player has the opportunity to invest, total equilibrium profits in the VI treatment are lower than those in the MM treatment. This means that vertical integration is only a second-best solution to the holdup problem in our experimental setting. However, in contrast to the mechanism in the MM treatment, vertical integration is a simple solution which may work better if subjects are only boundedly rational.

2.2 Experimental procedures

In each treatment, 40 subjects participated in two sessions. The participants were graduated and undergraduate students of Clausthal University of Technology from a wide variety of programs inclusive Business Administration. In total, 80 subjects participated in two treatments. The computerized experiment was programmed and conducted with zTree 3.2.12 (MM-Treatment) and zTree 3.3.11 (VI-Treatment) (Fischbacher 2007). In both treatments, the roles of the participants were fixed in a perfect stranger design. Half of the participants were assigned as buyers and the others as sellers. No subject was allowed to participate in more than one session. The exchange rate in both treatments was 1 € for 65 tokens. All interactions in the lab were anonymous.

In the MM treatment, a session took between 80 and 85 minutes. Next to the experiment, this time included the reading-time for the written instructions, the answering of the questionnaire and two practice periods. The announced time was 120 minutes. Subjects earned on average 17.28 € in 10 periods of play, including the showup fee of 3 €.

In the VI-Treatment, a session took between 45 and 50 minutes, again inclusive of reading-time, the answering of the questionnaire and two practice periods. The announced time was 120 minutes. Subjects earned on average 20.74 € in altogether 10 played rounds, including the showup fee of 3 €.

To ensure non-negative payoffs, in addition to the profits made in experiment, all participants get 100 tokens at the beginning of every period. Overall this accords to an average monetary payment of 15.63€.

3 Behavioral Predictions

Since it is our objective to test the workability of Maskin’s mechanism, our behavioral predictions are derived from the theoretical equilibrium.

Mechanism Design (MM). At the fourth stage the buyers or the sellers make the trading decision, if they were challenged before. Corresponding to equilibrium, participants will trade (, i.e. accept the price of 60 or 20), if and only if the real value of buyers in seller challenge is $v = 100$ or the real cost of sellers in buyer challenge is $c = 10$. Thus trading decisions are predicted to be the result of the investment decisions at stage 1. Table 1 displays the dependency of values and cost respective to the investment decision.

Table 1: Cost and values by varying investment

	investment	Seller’s cost	Buyer‘s value
Seller’s investment	0	-	50
	30	-	100
Buyer‘ s investment	0	30	-
	15	10	-

Prediction 1. *The challenged players will trade if either* $c = 10$ *or* $v = 100$.

At the third stage participants have the opportunity to conduct a challenge. In equilibrium, challenges will only occur if the investments do not match with the messages. Otherwise the challenging party will end up with a net fine payment accounting to $60 - 2 \cdot 60 = -60$.

Prediction 2. *A challenge only occurs if* $c \neq \hat{c}$ *or* $v \neq \hat{v}$.

At stage 2 buyers and sellers simultaneously send their messages about their own costs or values, respectively. Due to the perfect anticipation of the behavior in later stages, players understand that sending a false signal induces a challenge by the other player. Because this leads to the payments of a large fine (60) which is higher than any potential profits due to lying, all players will send true messages in equilibrium.

Prediction 3. *Sellers will report their true costs,* $\hat{c} = c$, *and buyers will report their true values, i.e.* $\hat{v} = v$.

At the first stage sellers and buyers simultaneously decide whether to invest. Realizing that costs and values will be reported correctly and that there will be no challenges, the price formula ($p = \hat{v} + \hat{c} - 45 = p + c - 45$) ensures that investing is profitable for both players.

Prediction 4. *Sellers and Buyer will invest, i.e.* $s = 30$ *and* $b = 15$ *.*

Vertical Integration (VI). In the VI-treatment investment decisions take place at the second stage. At this particular point of time the two firms have already merged. Then the owner's payoff is no longer dependent on the other player's behavior so that his investment decision is not influenced by strategic reasoning, anymore. Consequently, the firm owner will make an efficient investment decision:

Prediction 5a. *In the VI treatment the owner of the firm will invest efficiently, i.e.* $b = 15$ *or* $= 30$ *.*

At stage 1 buyers and sellers compete for ownership. The participants offer a takeover bid for each other's firm. The agent with the larger offer "wins" the auction, pays his offer to the other player and becomes the sole owner of the integrated firm. Because the seller's investment is more productive, his valuation of the firm exceeds the buyer's value of the integrated firm. Consequently, the seller will outbid the buyer. Due to the existence of multiple equilibria, we get:

Prediction 5b. *The auction will lead to seller integration. Equilibrium takeover bids will be* $12.5 \leq p_B \leq 19.9$ *and* $p_S = p_B + 0.1$.

The Mechanism is designed to accomplish efficient behavior solving the holdup problem. In our experiment, vertical integration can solve the holdup problem only partially because only one of the parties can conduct an investment.

Prediction 6. *Profits in MM-treatment will be larger than profits in VI-treatment, so that* $\pi_S^{MD} + \pi_B^{MD} > \pi_S^{VI} + \pi_B^{VI}$.

4 Results

In this section we present the experimental results of both treatments.

Result 1. *Prediction 1 is rejected: in a significant number of cases buyers trade although their product value is only 50, or sellers trade although their production costs are 30.*

Table 2 shows the trading decisions at stage 4. In more than one third of the observations, buyers deviate from the predicted equilibrium behavior. In case of the sellers, it is exactly one third of the observations that deviate from the predicted behavior. As a consequence, in early stages of the game, players cannot rely on subsequent equilibrium behavior.[4]

Table 2: Trade decisions at stage 4

	MM	
	Buyer challenges	Seller challenges
Equilibrium behavior	35	44
Disequilibrium behavior	22	22
Percentage of equilibrium decisions	61.4 %	66.67%

Result 2. *Prediction 2 is rejected: there is a non-negligible number of observations showing players challenging the other party although the message was true or players not challenging the other player although the message was false.*

According to our equilibrium prediction, players challenge the other subject's message only if the message is false. Table 3 shows that the experimental behavior deviates from equilibrium predictions quite often. Buyers do not make equilibrium decisions in about 40 percent, sellers in 33.5 percent of the cases.[5]

[4] In a logit regression we tried to identify variables, which might explain the experimental behavior at stage 4. It turned out, however, that none of our explaining variables (prior behavior within the same period and some other variables) was significant at common levels.

[5] We conducted a logit regression that shows a significant impact of one's own investment and the truthfulness of the other player's message on the rationality of sellers' decision to challenge. Yet this result does not hold for buyers' decisions whether to challenge.

Table 3: Decisions to challenge at stage 3

	MM	
	Buyers' decisions to challenge	Sellers' decisions to challenge
Equilibrium choices	79	133
Disequilibrium choices	55	67
Percentage of equilibrium choices	58.69 %	66.5%

Result 3. *Prediction 3 is rejected: on average, one out of three messages is false.*

Table 4 shows that in more than 30 percent of the cases the buyers have sent false messages about their product value. In nearly 35% of the cases sellers do not report their true costs.[6]

Table 4: Quantities of messages in accordance with investment decision

	MM	
	Buyers' messages	Sellers' messages
True	137	131
False	63	69
Percentage of true messages	68.5 %	65.5%

Result 4. *Prediction 4 is rejected: in 43.5 percent of the observations players did not invest.*

According to equilibrium predictions the mechanism is able to solve the holdup problem perfectly so that buyers (b = 15) and sellers (s = 30) will always invest. Yet table 5 shows that this is far from being true. Buyers did not invest in 35 percent of the cases and, even worse, sellers did not invest in 52 percent of the cases. Consequently, the mechanism provides no behaviorally workable first best solution to the holdup problem.

[6] In logit regressions, we found that the investment of the other party has a significant impact on the truthfulness of messages.

Table 5: Quantities of investment decisions MM

	MM	
	Buyers	Sellers
Efficient investment (s = 30 or b = 15)	130	96
No investment (s = 0 or b = 0)	70	104
percentage of efficient investments	65.0 %	48.0 %

After having presented all results of participants' behavior in the MM treatment it remains to be shown whether theory works better in the VI treatment. Let us begin the description of behavior at stage 2 of the treatment, the investment decision.

Result 5a. *Prediction 5a is rejected: in 15 percent of the cases of the VI treatment players did not invest.*

According to equilibrium predictions both players will always invest once they own the firm. Table 6 shows that this is not true since there is a non-negligible number of cases in which there is no investment by the owner of the firm. The percentage on non-investing buyers and sellers is close to 15 percent which is far less than in the MM treatment but still too much to claim that firm owners always invest.

Table 6: Quantities of investment decisions in VI-treatment

	VI	
	Buyers	Sellers
Efficient investment (s = 30 or b = 15)	85	85
No investment (s = 0 or b = 0)	16	14
percentage merit of true investment	84.16 %	85.86 %

Result 5b. *Prediction 5b is rejected: at stage 1, buyers win the auction in the majority of cases. In addition takeover bids are well above the predicted level (*$12.5 \leq p_i \leq 20$*).*

According to equilibrium predictions sellers will always win the auction at stage 1 because their investment is more productive than the buyers' investments. Table 7 shows that in 101 out of 200 cases buyers win the auction and become the firm owners. In contrast to the MM treatment, we find some learning in the VI treatment. In the final three periods of play sellers win the takeover auction in about 62 percent of the cases. Yet even in these periods there are clearly too many buyer integrations to confirm the hypothesis that sellers will always become the firm owners.

Table 7: Takeover bids and ownership structures

	VI	
	Buyers	Sellers
Mean takeover bid	28.60	25.24
Number of auction wins	101	99
Percentage of auction wins	50.5 %	49.5 %

This far we have shown that participants' behavior substantially deviates from equilibrium predictions. It remains to be shown, however, whether the use of the mechanism improves economic performance. In order to assess the efficiency of the participants' behavior we use two benchmarks. The first one is the first-best solution and provides the total profit of 245. The Maskin mechanism was originally designed to achieve this result. The second benchmark, the zero investment baseline, consists of both players' payoffs in the case that neither of them invests and neither of them challenges the other person. Here the sum of total profits equates 220. Basically this benchmark serves as the case in which there is no institutional arrangement in solving the holdup problem.

Result 6. *Prediction 6 is rejected: total profits in the VI treatment are significantly higher than in the MM treatment.*

Table 8 shows that the profits in the VI treatment are between the two benchmark cases in the last three periods. In the periods before, but even in the last three periods the buyers' bids are above equilibrium offer. Due to the occurrence of some non-investment by firm owners, total surplus is slightly below the equilibrium of the VI treatment's game. Vertical integration as an instrument to alleviate the holdup problem may best be regarded as an imperfect but workable solution.

In contrast to this, the Maskin mechanism turns out to be a complete failure in solving the holdup problem. Profits of both buyers and sellers are well below the zero investment benchmark. Thus, the implementation of the mechanism does not improve but impairs economic performance. Furthermore, the subgame perfect equilibrium path was realized in only 17 (out of 200) interactions.

Table 8: Mean Profits

	Buyer		Seller	
	total	last three periods	total	last three periods
MM treatment	94.33	102.42	91.38	89.50
VI treatment	107.55	115.79	123.08	117.04
First-best equilibrium	120		125	
Zero investment case (no institutional arrangement)	115		105	

Summarizing the results of our experiment, we can state that (1) the implementation of the Maskin mechanism leads to worse payoffs than ignoring the holdup problem in the first place and (2) that, without exception, all predictions according to equilibrium theory have to be rejected. As a consequence, the question arises whether there exists a better approach to explain subjects' behavior in our experiment. In the next section we try to show that the logit agent quantal response equilibrium (LAQRE) is able to reconstruct the basic features of the behavior and the economic performance in our experiment.

5 Logit agent quantal response equilibrium

The starting point of conducting our economic experiment was the presumption that Maskin's mechanism is much too complicated for being used in practice. Due to the successful use of logit quantal response equilibrium as an alternative to Nash equilibrium, it is currently widely accepted as a static benchmark (cf Camerer et al. 2004) so that its application needs no further justification.

In logit quantal response equilibria (LQRE) subjects do not optimize perfectly but choose each feasible strategy with a strictly positive probability. The probability pr_{ki} of subject k choosing a particular strategy a_i increases with its expected utility and is described by the following logit choice function:

$$pr_{ki} = \frac{e^{\frac{EU_{ki}}{\mu}}}{\sum_j e^{\frac{EU_{kj}}{\mu}}}.$$

Subject k's expected utility, in turn, depends on his expectations about the other players' probabilities of choosing their feasible strategies $\sigma_{\kappa\gamma}$: $EU_{ki} = f(\sigma_{11}, \sigma_{12}, \dots, \sigma_{\kappa\gamma}, \dots, \sigma_{nm})$ for all players and all their strategies. In addition to the logit choice rule LQRE demands a consistency requirement: $\sigma_{\kappa\gamma} = pr_{\kappa\gamma}$. This means that players' expectations about other players' behavior are correct (in a probabilistic sense).

The parameter μ in the logit choice function measures the players' degree of rationality. The smaller the parameter value, the higher is the degree of rationality assumed. If μ approaches zero, LQRE coincides with the perfect Nash equilibrium. If, in contrast, μ

approaches infinity, each feasible strategy is chosen with the same probability. The additional parameter provides an additional degree of freedom. Usually the parameter is estimated for each game separately by using maximum likelihood techniques.

The concept of logit agent quantal response equilibrium (LAQRE) extends LQRE by taking the dynamic structure of the game into account. This is achieved by using the agent normal form of the game and calculating its LQRE. In the following we are going to apply LAQRE to the experimental games in the two treatments. Our maximum likelihood estimations of the rationality parameter are $\mu = 39.06$ for the game played in the MM treatment and $\mu = 27.54$ for the VI treatment.

5.1. The LAQRE of the Maskin mechanism game

The LAQRE probabilities for the trading decision at stage 4 are given in table 9. It is evident that the LAQRE probabilities are much closer to the corresponding empirical values than the predictions of the subgame perfect Nash equilibrium (SPNE). This is particularly true for the buyers' decisions to trade within seller challenges.

Table 9: Probabilities of trading at stage 4

	Empirical percentages	LAQRE probabilities (%)	SPNE (%)
	Buyer challenges (i.e. sellers decide whether to trade)		
c = 10	76.3	**56.4**	100
c = 30	68.4	**43.6**	0
	Seller challenges (i.e. buyers decide whether to trade)		
v = 50	40.5	**43.6**	0
v = 100	75.9	**73.6**	100

In case of buyer challenges LAQRE still clearly outperforms SPNE but the distance between the LAQRE probabilities and the empirical values is also quite large. In case of c = 30 the distance is 24.8 percent, after all. It is important to understand that Maskin's mechanism critically depends on a behavior in accordance with SPNE at stage 4 because only this clear-cut equilibrium behavior can serve as a reliable revelation of true costs and the true values, respectively. Deviations from standard Nash equilibrium lead to modified incentives at earlier stages of the game and thereby destroy incentives to invest at stage 1.

At stage 3 the seller (and later maybe the buyer) has to decide whether to challenge the other player's message. Since Maskin's mechanism crucially depends on the identity of true costs and reported costs and on the identity of true values and reported values, we have to distinguish four constellations of true costs and values and four constellations of reported costs and values. In addition, we have to distinguish between buyers' (BC) and sellers' decisions to challenge (SC). Table 10 provides an overview over the empirical data, the LAQRE and the SPNE for all 32 constellations. The upper line in each cell provides the value of the SPNE, followed by the LAQRE and the empirical relative frequency. Empirical values in square brackets are based on a subsample of less than or exactly 5 cases.

In order to quantitatively compare the predictive power of SPNE and LAQRE, we calculated the mean absolute distance (MAD) between the theoretical and empirical probabilities. Taking into account all 32 cells we get $MAD_{LAQRE} = 0.24$ and $MAD_{SPNE} = 0.41$. Ignoring the cells in which the number of empirical cases is less than or equal to five, we get $MAD_{LAQRE} = 0.09$ and $MAD_{SPNE} = 0.28$. Obviously, LAQRE outperforms SPNE. Greater deviations in a few cells notwithstanding, LAQRE can largely reconstruct subjects' challenging behavior in our experiment.

Table 10: The decision whether to challenge the other party's message

		c = 10; v = 100	c = 30; v = 100	c = 10; v = 50	c = 30; v = 50
SPNE SC LAQRE SC Data SC	$\hat{c} = 10; \hat{v} = 100$	0 0.2332 0.04	0 0.2582 [1]	1 0.3421 0.294	1 0.4097 0.667
SPNE BC LAQRE BC Data BC		0 0.5157 0.292	1 0.5481 –	0 0.6505 0.5833	1 0.714 [1]
SPNE SC LAQRE SC Data SC	$\hat{c} = 30; \hat{v} = 100$	0 0.1541 0.148	0 0.1726 0.158	1 0.2376 0.091	1 0.2937 0.375
SPNE BC LAQRE BC Data BC		1 0.7243 0.522	0 0.5779 0.5	1 0.8212 [0.4]	0 0.738 0.8
SPNE SC LAQRE SC Data SC	$\hat{c} = 10; \hat{v} = 50$	1 0.8232 0.714	1 0.842 [0.5]	0 0.5585 0.444	0 0.628 0.444
SPNE BC LAQRE BC Data BC		0 0.2284 [0.5]	1 0.2522 [1]	0 0.341 0.2	1 0.4097 0.4
SPNE SC LAQRE SC Data SC	$\hat{c} = 30; \hat{v} = 50$	1 0.7362 [1]	1 0.7616 0.917	0 0.4312 0.538	0 0.5029 0.188
SPNE BC LAQRE BC Data BC		1 0.4221 –	0 0.2757 [1]	1 0.5608 0.667	0 0.4392 0.154

Let us now turn to the contents of the messages. At this stage of the game we can distinguish four cases: costs and values can be either high or low. Table 11 shows of the probabilities of sending true messages according to SPNE, LAQRE and the empirical data. Once again, it shows that LAQRE fits the data much better than SPNE. Taking the mean absolute aviation over all eight cells as a measure of the goodness of fit, LAQRE (MAD = 0.1642) is clearly closer to the empirical data than SPNE (MAD = 0.3186). We find only one cell (c = 30; v = 100; $\hat{c} = 30$; $\hat{v} = 50$) in which SPNE is closer to the data.

Table 11: LAQRE at stage 2 (sending of messages)

		Probabilities of true messages ($\hat{c} = c$ or $\hat{v} = v$)			
		$c = 10$; $v = 100$	$c = 30$; $v = 100$	$c = 10$; $v = 50$	$c = 30$; $v = 50$
SPNE		1	1	1	1
LAQRE	$\hat{c}$	0.5812	0.5084	0.5740	0.4834
Data		0.5161	0.9118	0.6471	0.6667
SPNE		1	1	1	1
LAQRE	$\hat{v}$	0.7094	0.6781	0.4583	0.4552
Data		0.8387	0.5882	0.5882	0.6944

Table 12 shows the LAQRE's probabilities of investment and players' expected profits in comparison to SPNE and participants' behavior in our experiment. Again, LAQRE is much closer to the empirical data. Yet the difference between the relative frequency of buyers' investments and the investment probabilities according to LAQRE is still rather large. Most important, LAQRE can explain the surprisingly low value of mean profits in our experiment. LAQRE explains deviations from equilibrium behavior at all stages of the experimental game and thereby explains the occurrence of inefficient challenges and the inefficient payment of fines. As a consequence, expected profits in the LAQRE are well below 100. In other words: completely ignoring the holdup problem and thereby realizing the maximum of underinvestment induces larger profits (105/115) than using the Maskin mechanism.

Table 12: Investment probabilities and expected profits in the LAQRE

	Investment probabilities		
	Data	LAQRE	SPNE
Sellers	0.48	0.4043	1
Buyers	0.65	0.4503	1
	Expected profits		
	Data	LAQRE	SPNE
Sellers	91.38	84.84	125
Buyers	94.33	84.98	120

We have shown that the LAQRE provides a much better fit to the data than the SPNE. Of course, it is no surprise that the LAQRE as a generalization of SPNE that has an additional degree of freedom (parameter μ) gets a better fit for the entire game. Yet it is not self-evident that LAQRE outperforms SPNE at all stages of the game which is true for our MM treatment. Furthermore, the LAQRE not only provides a better fit but it also turns the normative evaluation of the Maskin mechanism on its head, and this is perfectly in accordance with the data of our experiment. The Maskin mechanism is simply too complicated to reliably work with ordinary people being only boundedly rational. Yet mechanism design does not take into account any limits of human rationality and thereby overestimates the efficiency of its solutions.

5.2 The LAQRE in the Vertical Integration game

Stage 2 of the VI treatment consists of a large trivial investment decision of the owner of the firm. He only needs to understand that his investment costs are smaller than the investment benefit so that it pays to invest. Table 13 shows that the subjects in the VI treatment have largely understood this. The average empirical investment probability is about 85 percent whereas LAQRE, assuming that $\mu = 27.54$, predicts substantially smaller investment probabilities. As a consequence, SPNE outperforms LAQRE at stage 2 of this treatment.

Table 13: Investment probabilities in the VI treatment

	Data	LAQRE	SPNE
Sellers	0.8586	0.6740	1
Buyers	0.8416	0.5453	1

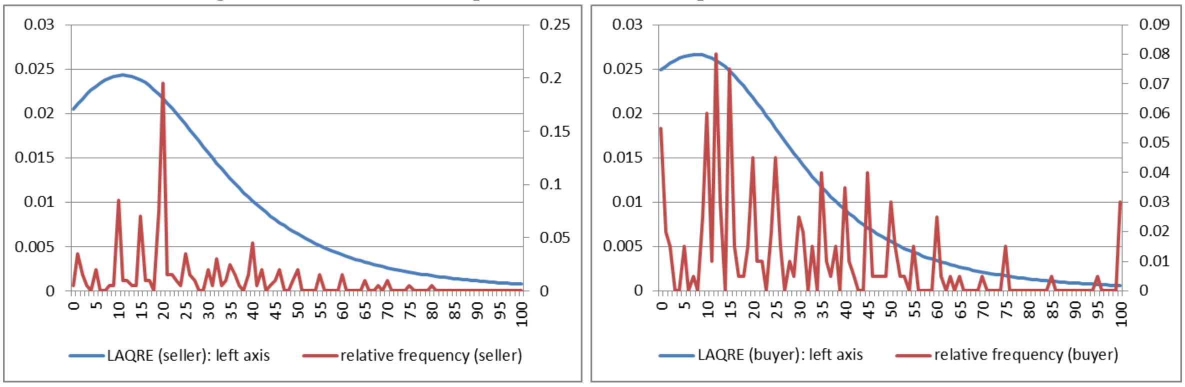
At stage 1 of the VI game the ownership of the firm is auctioned off. Table 14 shows that both buyers and sellers submitted substantially higher bids than predicted by SPNE. By and large, LAQRE covers players' overbidding quite well.

Table 14: Mean takeover bids

	Data	LAQRE	SPNE
Sellers	25.235	26.020	$p_{Seller} = p_{Buyer} + 0.1$
Buyers	28.598	23.864	$12.5 \leq p_{Buyer} \leq 19.9$

LAQRE not only approximates the means of takeover bids but also provides a rough estimate of the distribution of bids. Figure 1 shows the relative frequencies of takeover bids and the corresponding LAQRE probabilities. One can see that the shape of the distribution is similar. Yet LAQRE does not cover the preferred choice of prominent numbers as takeover bids. Obviously, multiples of five are overrepresented in the distribution of takeover bids. Furthermore, the peak of the LAQRE distribution lies left to the peak of takeover bids for buyers and sellers.

Figure 1: Relative bid frequencies and LAQRE probabilities of takeover bids



Sellers **Buyers**

To sum up, the LAQRE of the VI game can explain (a) why we find many cases of buyer integrations and (b) why takeover bids are well above the level predicted by SPNE. Yet it underestimates the efficiency of investment decisions at stage 2.

6 Conclusions

Some decades ago institutional economics started out as an approach emphasizing that bounded rationality should be at the core of the research program (Williamson 1975, 1985). Beginning with the seminal paper by Grossman and Hart (1986) the emphasis shifted to game theoretic models with perfectly rational players. Oliver Hart (1990, 696) claimed that “bounded rationality in the sense that agents have limited cognitive, computational or comprehension skills is not” a crucial ingredient of the theory of institutions. The research program called the “theory of incomplete contracts” emerged and evolved and many ingenious solutions to the holdup problem were introduced. Then the papers by Maskin and Tirole (1999), Maskin and Moore (1999) and Maskin (2002) raised doubts regarding the foundations of this program by introducing a mechanism ensuring efficient equilibria.

Maskin (2002) emphasizes that he does not believe that we should ignore the results of this strand of literature which seem to be valuable to him. Furthermore, he supposes that bounded rationality could be a potentially fruitful explanation of incompleteness. We agree with Maskin that the theory of incomplete contracts still has a large heuristic value. Furthermore, the results of our experiment strongly confirm Maskin’s second assessment (referring to bounded rationality) and they show that implementing the proposed mechanism may lead to disastrous economic consequences. Traditional game theoretic equilibrium analysis cannot account for our experimental data. Yet the application of LAQRE which takes players mistakes explicitly into account can reconstruct the important results of our experiment: LAQRE outperforms SPNE as a predictor of behavior at all stages of the MM treatment.

We regard our findings as evidence for the non-workability of institutional arrangements that are too complex. In our case the use of the complicated mechanism does not even improve performance but worsens it: participants' payoffs are even smaller than in an institutional setting which totally ignores the holdup problem! In contrast, the simple but inefficient solution of vertical integration leads to a significant improvement of economic performance.

As a first consequence, we submit that – in stark contrast to Hart (1990) – bounded rationality is a crucial ingredient of the theory of the firm and of the theory of institutions in general. In some respects Williamson (1985) provided a deeper and better understanding than the theory of incomplete contracts nowadays.

The second conclusion we want to draw is that solutions to incentive problems must be kept simple in order to be workable with human players. Our final conclusion is that most solutions to the different versions of the holdup problem should be reassessed in the light of our findings. By this we mean that the complexity of institutional arrangements needs to be taken into account and that it is difficult to imagine that first-best solutions exist at all. Some important steps have already been taken in this direction: in particular the contributions of Hoppe and Schmitz (2011), (2013a) and (2013b) provide valuable insights.

Although LAQRE clearly outperforms SPNE, there remains a large potential for further improvements in predicting and explaining subjects behavior in contract theoretic experiments. First, it seems promising to rely more heavily on learning models. Second, social preferences may be able to fill some of the gaps that remain in our analysis of this experiment. Finally, we may be able to deepen our understanding by using other tools than equilibrium analysis, e.g. agent-based models of organizations might serve as a useful complement to (behavioral and traditional) game theory. We are looking forward to moving in these directions.

References

Alchian, Armen A. (1984): Specificity, Specialization, and Coalitions, *Journal of Institutional and Theoretical Economics*, 140 (1), p. 34–49.

Bruttel, Lisa and Gerald Eisenkopf (2009): Incentive Compatible Contracts? *Research Paper Series Thurgau Institute of Economics and Department of Economics at the University of Konstanz,* 43, p. 1 – 31.

Camerer, Colin F. and George Loewenstein (2004): Advances in Behavioral Economics, *New York: Princeton University Press*, p. 3 – 51.

Che, Yeon-Koo and Donald B. Hausch (1999): Cooperative Investments and the Value of Contracting, *American Economic Review*, 89 (1), p. 125–147.

Edlin, Aaron S. and Stefan Reichelstein (1996): Holdups, Standard Breach Remedies, and Optimal Investment, *American Economic Review*, 86 (3), p. 478 – 501.

Erlei, Mathias and Christian Reinhold (2011): To Choose or Not to Choose: Contracts, Reference Points, Reciprocity, and Signaling, *Working Paper*, TU Clausthal.

Erlei, Mathias and J. Philipp Siemer (2012): Endogenous Property Rights in a Hold-Up Experiment, *Metroeconomica*, p. 1 – 34.

Fehr, Ernst, Oliver D. Hart and Christian Zehnder (2009): Contracts, Reference Points, and Competition – Behavioral Effects of the Fundamental Transformation, *Journal of the European Economic Association*, 7 (2-3), p. 561–572.

Fehr, Ernst, Oliver D. Hart and Christian Zehnder (2011): Contracts as Reference Points – Experimental Evidence, *American Economic Review*, 101 (2), p. 493–525.

Fischbacher, Urs (2007): z-Tree: Zurich Toolbox for Ready-made Economic Experiments, *Experimental Economics*, 10 (2), p. 171–178.

Grossman, Sanford J. and Oliver D. Hart (1986): The Costs and Benefits of Ownership: A Theory of Vertical and Lateral Integration, *Journal of Political Economy*, 94 (4), p. 691–719.

Hackett, Steven C. (1993): Incomplete Contracting: A Laboratory Experimental Analysis, *Economic Inquiry*, 31 (2), p. 274–297.

Hackett, Steven C. (1994): Is Relational Exchange Possible in the Absence of Reputations and Repeated Contact?, *Journal of Law*, *Economics*, *and Organization*, 10 (2), p. 360 – 389.

Hart, Oliver D. (1990): Is "Bounded Rationality" an Important Element of a Theory of Institutions?, *Journal of Institutional and Theoretical Economics*, 146 (4), p. 596–602.

Hart, Oliver D. (1995): Firms, Contracts and Financial Structure. *Oxford: Oxford University Press*.

Hart, Oliver D. and John Moore (1988): Incomplete Contracts and Renegotiation, *Econometrica*, 56 (4), p. 755–785.

Hart, Oliver D. and John Moore (1990): Property Rights and the Nature of the Firm, *Journalof Political Economy*, 98 (6), p. 1119–1158.

Hart, Oliver D. and John Moore (2008): Contracts as Reference Points, *Quarterly Journal of Economics*, 123 (1), p. 1–48.

Hart, Oliver (2009): Hold-up, Asset Ownership, and Reference Points, *Quarterly Journal of Economics,* 124 (1), p. 267-300.

Hoppe, Eva I. and Patrick W. Schmitz (2011): Can Contracts Solve the Hold-up Problem? Experimental Evidence, *Games and Economic Behavior*, 73, p. 186–199.

Hoppe, Eva I. and Patrick W. Schmitz (2013a): Observability of Information Acquisition in Agency Models, *Economic Letters*, 119 (1), p. 104-107.

Hoppe, Eva I. and Patrick W. Schmitz (2013b): Public-Private Partnerships versus Traditional Procurement: Innovation Incentives and Information Gathering, *RAND Journal of Economics*, 44 (1), p. 56 – 74.

Klein, B., Robert G. Crawford and Armen A. Alchian (1978): Vertical Integration, Appropriable Rents, and the Competitive Contracting Process, *Journal of Law and Economics*, Vol. 21 (2), p. 297-326.

Güth, W., Manfred Königstein, Judit Kovacs and Eniko Zala-Mezo (2001): Fairness Within Firms: the Case of One Principal and Multiple Agents, *Schmalenbach Business Review*, 53, p. 82 – 101.

Lafontaine, Francine and Margaret E. Slade (2007): Vertical Integration and Firm Boundaries: The Evidence, *Journal of Economic Literature*, 45 (3), p. 629–685.

Maskin, Eric (2002): On Indescribable Contingencies and Incomplete Contracts, *European Economic Review*, 46 (4-5), p. 725–733.

Maskin, Eric and John Moore (1999): Implementation and Renegotiation, *Review of Economic Studies*, 66 (1), p. 39–56.

Maskin, Eric and Jean Tirole (1999): Unforeseen Contingencies and Incomplete Contracts, *Review of Economic Studies*, 66 (1), p. 83–114.

McKelvey, Richard D. and Thomas R. Palfrey (1998): Quantal Response Equilibria for Extensive Form Games, *Experimental Economics*, 1 (1), p. 9–41.

Olcina, Gonzalo, Enrique Fatas and Concepcion Penarrubia (2000): Inequity Aversion as an Efficient Equilibrium Selection Mechanism. An Experimental Analysis of the Hold Up Problem. *Working Paper 15/00, University of Valencia*.

Rosenkranz, Stephanie and Patrick W. Schmitz (2003): Optimal Allocation of Ownership Rights in Dynamic R&D Alliances, *Games and Economic Behavior*, 43 (1), p. 153–173.

Schmitz, Patrick W. (2006): Information Gathering, Transaction Costs, and the Property Rights Approach, *American Economic Review*, 96 (1), p. 422 – 434.

Schmitz, Patrick W. and Dirk Sliwka (2001): On Synergies and Vertical Integration, *InternationalJournal of Industrial Organization*, 19 (8), p. 1281–1295.

Shelanski, Howard A. and Peter G. Klein (1995): Empirical Research in Transaction Cost Economics: A Review and Assessment, *Journal of Law, Economics, and Organization*, 11 (2), p. 335–361.

Sloof, Randolph, Joep Sonnemans and Hessel Oosterbeek (2004): Specific investments, holdup, and the outside option principle, *European Economic Review*, 48(6), p. 1399-1410.

Sloof, Randolph, Joep Sonnemans and Hessel Oosterbeek (2006): Breach remedies, reliance and renegotiation, *International Review of Law and Economics*, 26(3), p. 263-296.

Sloof, Randolph, Joep Sonnemans and Hessel Oosterbeek (2007): Does Making Specific Investments Unobservable Boost Investment Incentives?, *Journal of Economics & Management Strategy*, 16(4), p. 911-942.

Sonnemans, Joep, Hessel Oosterbeek and Randolph Sloof (2001): On the Relation between Asset Ownership and Specific Investments, *Economic Journal,* 111, p. 791-820.

Williamson, Oliver E. (1975): Markets and Hierarchies: Analysis and Antitrust Implications, *New York: Free Press*.

Williamson, Oliver E. (1985): The Economic Institutions of Capitalism. Firms, Markets, RelationalContracting, *New York: The Free Press*.