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PUBLIC-PRIVATE PARTNERSHIPS VERSUS TRADITIONAL PROCUREMENT: AN EXPERIMENTAL INVESTIGATION

Eva I Hoppe, David J Kusterer and Patrick W Schmitz

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Eva I Hoppe, University of Cologne
David J Kusterer, University of Cologne, Cologne Graduate School in Management, Economics and Social Science
Patrick W Schmitz, University of Cologne and CEPR

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Centre for Economic Policy Research
77 Bastwick Street, London EC1V 3PZ, UK
Tel: (44 20) 7183 8801, Fax: (44 20) 7183 8820
Email: cepr@cepr.org, Website: www.cepr.org

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ABSTRACT

Public-private partnerships versus traditional procurement: An experimental investigation

A government agency wants an infrastructure-based public service to be provided. Our experimental study compares two different modes of provision. In a public-private partnership, the two tasks of building the infrastructure and operating it are delegated to one private contractor (a consortium), while under traditional procurement, these tasks are delegated to separate contractors. We find support for the theoretical prediction that, compared to traditional procurement, a public-private partnership provides stronger incentives to make cost-reducing investments (which may increase or decrease service quality). In two additional treatments, we study governance structures which explicitly take subcontracting within private consortia into account.

JEL Classification: D86, H11 and L33
Keywords: experiment, incomplete contracts, procurement and public-private partnerships

Eva I Hoppe
University of Cologne
Albertus-Magnus-Platz
50923 Köln
GERMANY

Email: eva.hoppe@uni-koeln.de

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David J Kusterer
University of Cologne
Albertus-Magnus-Platz
50923 Köln
GERMANY

Email: david.kusterer@uni-koeln.de

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Patrick W Schmitz
University of Cologne
Albertus-Magnus-Platz
50923 Köln
GERMANY

Email: patrick.schmitz@uni-koeln.de

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1 Introduction

Over the last two decades, governments in a growing number of countries initiated public-private partnerships to let the private sector take over the responsibility for building an infrastructure and subsequently operating it to provide public goods or services. In industrialized countries as well as in emerging economies, public-private partnerships have been set up for large-scale projects in various sectors such as public transportation, health care, and education.[1]

A key characteristic of public-private partnerships is that the two tasks of building a facility and subsequently operating it are bundled and delegated to a single private contractor, while under traditional procurement, separate contractors are in charge of these two tasks.[2] An argument often put forward in favor of public-private partnerships is that when the same private contractor is responsible for construction as well as operation of a public facility, then he will be inclined to invest more during the construction phase in order to reduce the costs incurred in the subsequent operating stage.[3]

Hart (2003) demonstrates that the incomplete contracting approach offers a very useful framework to theoretically investigate the pros and cons of public-private partnerships compared to traditional procurement. In his model, there are two stages. In the first stage, a public infrastructure is built, while in the second stage, the infrastructure is operated to provide a public service. In the first stage, the builder can make investments that reduce the operating costs in the second stage. In line with the above-mentioned argument, Hart (2003) finds that given a public-private partnership, the private contractor has strong incentives to make investments, since they reduce the operating costs that he will have to incur in the operating stage. In contrast, under traditional procurement, the builder has no incentives to invest in cutting the operating costs, since another private party will have to bear these costs.

Whether a public-private partnership or traditional procurement is prefer-

[1] See Grimsey and Lewis (2004), Yescombe (2007), OECD (2008), and Asian Development Bank (2008). According to Henckel and McKibbin (2010, p. 5), public-private partnerships "have increased sevenfold in developing countries from 1990-92 to 2006-08 and sixfold in Europe during the same period."

[2] See e.g. Grimsey and Lewis (2004, pp. 129, 222). See also Iossa et al. (2007, p. 17), who argue that the "bundling of project phases into a single contract is the main characteristic of PPP contracts."

[3] See Yescombe (2007, p. 21). Moreover, Grimsey and Lewis (2004, p. 92) argue that a public-private partnership provides the private contractor with incentives "to plan beyond the bounds of the construction phase and incorporate features that will facilitate operations."

able depends on the effects that the cost-reducing investments have on the service quality. In particular, Hart (2003) assumes that two different kinds of investments can be made. Investment i not only reduces the operating costs, but it also increases the service quality. In contrast, while investment e also reduces the operating costs, it does so at the expense of a reduced service quality. Hence, investment i is socially desirable, while investment e might be socially undesirable if the negative side effect on the service quality is sufficiently strong.

In line with Hart (2003), we consider a situation in which in a first-best world (i.e., if the investments were contractible), a high level of investment i, but a low level of investment e would be chosen. In a second-best world (i.e., if the investments are non-contractible), we are then confronted with the following trade-off. In a public-private partnership, high levels of both kinds of investments are induced. Hence, there is overinvestment with regard to e, while the first-best level of investment i is chosen. In contrast, under traditional procurement, there are no incentives to make high investments. Thus, there is underinvestment regarding i, while the first-best level of investment e is chosen.

It is an important research question to investigate whether the trade-off identified by Hart (2003) is of empirical relevance. As a first step in that direction, we have conducted a large-scale public procurement experiment in the laboratory.

Specifically, we conducted two main treatments, a public-private partnership (PPP) treatment and a traditional procurement (TP) treatment. We have implemented a parameter constellation where encouraging the desirable investment i is more important than preventing the undesirable investment e, so that according to the theoretical analysis, a public-private partnership is preferable to traditional procurement. The experimental data largely corroborates the theoretical analysis. In the PPP treatment, subjects chose the high levels of both kinds of investments significantly more often than in the TP treatment. As a consequence, also the total surplus generated in the PPP treatment was significantly larger than the total surplus in the TP treatment.

However, modelling the private contractor in a public-private partnership as a single decision maker might be seen as an analytical shortcut. In practice, different skills are needed in the building and operating stages. Thus, it is important to take a closer look at different subcontracting arrangements. For this reason, we have conducted two further treatments. In one treatment (Sub I), the builder is the main contractor and subcontracts with an opera-

tor. As has already been pointed out by Hart (2003), in theory this setting induces the same investment behavior as the simple PPP setting (since the main contractor must reimburse the subcontractor for his operating costs, the main contractor internalizes these costs). In another treatment (Sub II), the operator is the main contractor and subcontracts with a builder. In theory, this setting leads to the same investment behavior as traditional procurement (since the subcontractor disregards the operating costs, he has no incentives to invest). Also in the subcontracting treatments, it turns out that the observed behavior in the laboratory is mostly in line with the theoretical predictions.

In recent years, the theoretical literature on public-private partnerships has grown steadily. Building on Hart (2003), several contributions have investigated the implications of bundling the building and operating stages in public procurement projects.[4] Bennett and Iossa (2006a,b) and Chen and Chiu (2010) explore how different ownership structures interact with the choice between a public-private partnership and traditional procurement.[5] Martimort and Pouyet (2008) analyze a model that includes both traditional agency problems and property rights and they find that the most relevant question is not who owns the assets, but instead whether the tasks are bundled or not. Iossa and Martimort (2008, 2009) discuss extensions and applications of this framework. Also focusing on the externalities between the tasks of building and operating a public project, Li and Yu (2010) investigate whether these tasks should be auctioned off separately or bundled. Valéro (2010) studies which effect the strength of the institutional framework (i.e., the government's commitment power) may have on the bundling decision. Hoppe and Schmitz (2010b) study how the decision to bundle the building and operating stages affects the incentives to gather information about future costs of adapting the service provision to changing circumstances.

[4] While most papers in this literature consider incomplete contracts, Bentz, Grout, and Halonen (2004) study related questions in a complete contracting framework. On the pros and cons of bundling sequential tasks when complete contracts can be written, see also Schmitz (2005).

[5] Hart, Shleifer, and Vishny (1997) have developed the leading model to study the effects of public and private ownership on investment incentives, building on the property rights approach based on incomplete contracting (Grossman and Hart, 1986; Hart and Moore, 1990; Hart, 1995). See also Hoppe and Schmitz (2010a), who extend their framework by considering a richer set of contractual arrangements. Moreover, Besely and Ghatak (2001), Francesconi and Muthoo (2006), and Halonen-Akatwijuka and Pafilis (2009) build on the property rights approach to analyze whether non-governmental organizations should own public goods.

While public-private partnerships have received growing attention in the theoretical literature, so far empirical research is scarce.[6] In particular, to the best of our knowledge, our study is the first experimental contribution that compares the performance of public-private partnerships and traditional procurement in the laboratory.[7]

The remainder of the paper is organized as follows. In Section 2, public-private partnerships and traditional procurement are compared, while in Section 3, different ways of subcontracting are considered. Each of these two sections consists of subsections in which we describe the theoretical framework, present the experimental design, derive predictions, and report the results. Concluding remarks follow in Section 4.

2 Public-private partnerships vs. traditional procurement

2.1 Theoretical framework

In this section, to motivate our experimental study, we present the theoretical framework based on Hart (2003) as a starting point. We consider a government agency who wants a certain public good or service to be provided. For this purpose, two tasks have to be performed: a suitable infrastructure has to be built and subsequently, it has to be operated. We study two different modes of provision. In case of a *public-private partnership*, the two tasks are bundled; i.e., the government agency contracts with a single party (a consortium) to build the infrastructure and to subsequently operate it. In contrast, under *traditional procurement* the two tasks are separated; i.e., the government agency contracts with one party to build the infrastructure and with another party to operate it.

We assume that only incomplete contracts can be written. In particular, the party in charge of building the infrastructure can make two kinds of observable

[6] For empirical studies on public-private partnerships, see Chong et al. (2006a,b) and Porcher (2010) on water distribution, de Brux and Desrieux (2010) on the car park sector, and Blanc-Brude and Jensen (2010) on school contracts.

[7] However, there are some laboratory experiments on procurement contracting that focus on quite different aspects. Cox et al. (1996) examine fixed-price and cost-sharing contracts in frameworks with moral hazard and adverse selection. Güth et al. (2006) study the efficiency and profitability of different procurement auctions. Bigoni et al. (2009) investigate the effects of explicit incentives framed as either bonuses or penalties in procurement contracts.

but non-contractible investments, $i \in \{i_l, i_h\}$ and $e \in \{e_l, e_h\}$, that affect the characteristics of the infrastructure and thus the nature of the service to be provided ($0 \leq i_l < i_h$ and $0 \leq e_l < e_h$). The investments are measured by their costs; i.e., the total investment costs equal $i + e$. The government agency's benefit is given by

$$B(i, e) = B_0 + \beta(i) - b(e),$$

while the operating costs are given by

$$C(i, e) = C_0 - \gamma(i) - c(e),$$

where $B(i, e) > C(i, e) \geq 0$ and $\beta(i)$, $b(e)$, $\gamma(i)$, $c(e)$ are non-negative and increasing. Thus, the quality-enhancing investment i increases the government agency's benefit from service provision and at the same time it reduces the operating costs. In contrast, while investment e also reduces the operating costs, it does so at the expense of a reduced service quality.

In a first-best world, i.e. if the investments were contractible, the government agency would implement the investment levels that maximize the total surplus

$$\begin{aligned} & B(i, e) - C(i, e) - i - e \\ = \; & B_0 + \beta(i) - b(e) - C_0 + \gamma(i) + c(e) - i - e. \end{aligned}$$

In the first-best benchmark solution, the high investment level would be chosen whenever the additional gains generated outweigh the additional investment costs. In particular, $i^{FB} = i_h$ whenever $\beta(i_h) + \gamma(i_h) - [\beta(i_l) + \gamma(i_l)] \geq i_h - i_l$. Similarly, $e^{FB} = e_h$ whenever $c(e_h) - b(e_h) - [c(e_l) - b(e_l)] \geq e_h - e_l$. In accordance with Hart (2003), we assume that only in case of the quality-improving investment i it is socially desirable to choose the high investment level. Specifically, we make the following assumption.

Assumption 1. (i) $\gamma(i_h) - \gamma(i_l) \geq i_h - i_l$.

(ii) $c(e_h) - c(e_l) - [b(e_h) - b(e_l)] < e_h - e_l < c(e_h) - c(e_l)$.

Assumption 1(i) says that the additional reduction of the operating costs alone already outweighs the additional investment costs when the high investment level i_h instead of the low investment level i_l is chosen. Since moreover this investment increases the benefit, it is clearly first-best to choose $i = i_h$. Assumption 1(ii) says that while the reduction of the operating costs does outweigh the additional investment costs of choosing e_h instead of e_l, the negative

side effect on the service quality is so strong that from a social perspective it is optimal to choose $e = e_l$. As a consequence, the total surplus in the first-best solution is $B(i_h, e_l) - C(i_h, e_l) - i_h - e_l$.

We now return to the second-best world in which the investments are non-contractible. Note that since we assume throughout that the investment levels are observable, the party in charge of operating the facility knows its operating costs regardless of the governance structure.

Consider first a *public-private partnership* (bundling). We assume that there is a competitive supply of private consortia that could build the infrastructure and subsequently operate it. They submit offers to the government agency who then decides with whom to contract. The consortium that is awarded the contract will choose the investment levels i and e that maximize its payoff $P_0 - C(i, e) - i - e = P_0 - C_0 + \gamma(i) + c(e) - i - e$, where P_0 is the price that the government agency pays to the consortium. Since by assumption $\gamma(i_h) - \gamma(i_l) \geq i_h - i_l$ and $c(e_h) - c(e_l) \geq e_h - e_l$, the consortium will invest $i^{PPP} = i_h$ and $e^{PPP} = e_h$. Hence, anticipating their investment behavior in case of being awarded the contract, in a competitive market the consortia submit offers equal to their total costs $C(i_h, e_h)+i_h+e_h$. This means, the government agency will make the payment $P_0 = C(i_h, e_h) + i_h + e_h$ to the consortium that is awarded the contract and the government agency's payoff is $B(i_h, e_h) - C(i_h, e_h) - i_h - e_h$.

Now consider *traditional procurement* (unbundling). In this case the government agency initially contracts with one private party to build the infrastructure and subsequently, it contracts with another private party that will operate it. If there is a competitive supply of operators, they will make offers in which they demand to be reimbursed for their operating costs, given the investment levels that were chosen. Hence, the government pays $P_1 = C(i, e)$ to the chosen operator. The builder who is awarded the construction contract chooses the investment levels i and e to maximize his payoff $P_0 - i - e$, where P_0 is the payment from the government agency to the builder. Hence, he will choose $i^{TP} = i_l$ and $e^{TP} = e_l$. Anticipating this, the builders will submit offers equal to $i_l + e_l$. The government agency's payoff is thus $B(i_l, e_l) - C(i_l, e_l) - i_l - e_l$.

Proposition 1 summarizes the main insights of the theoretical analysis.

Proposition 1 *The investment levels given a public-private partnership and given traditional procurement can be ranked as follows.*

$i^{TP} = i_l < i^{PPP} = i^{FB} = i_h$.

$e^{TP} = e^{FB} = e_l < e^{PPP} = e_h$.

Intuitively, the trade-off between the two governance structures is as follows. In case of a public-private partnership, in the building stage the consortium anticipates that it will have to bear the operating costs in the subsequent stage. Hence, the consortium not only chooses the high investment level of i, which is socially desirable, but it also chooses the high investment level of the quality-reducing investment e, which is socially undesirable. This is because the consortium is interested in cutting the operating costs, while it does not internalize the negative impact that the investment e has on the government agency's benefit.

In contrast, under traditional procurement, the builder who is in charge of the investments internalizes neither the operating costs nor the government agency's benefit, as he gets a fixed payment P_0 independent of the investment levels that he chooses. As a consequence, by choosing $i^{TP} = i_l$, he underinvests in the socially desirable investment, while he chooses the first-best level $e^{TP} = e_l$ of the quality-reducing investment.

While the government agency's payoff is always below the first-best level, which one of the two governance structures is optimal depends on the relative impacts of the non-contractible investments.

2.2 Experimental design

In each treatment of our experiment, a government agency wants a public infrastructure to be built and subsequently to be managed. The party in charge of building can decide how much it wants to invest during the construction stage. Specifically, the building party makes the investment decisions $i \in \{i_l, i_h\}$ and $e \in \{e_l, e_h\}$, where $i_l = e_l = 0$ and $i_h = e_h = 4$. The investments influence the operating costs and the government agency's benefit. Depending on the investment decisions, the operating costs are $C(i, e) = C_0 - \gamma(i) - c(e)$ and the government agency's benefit is $B(i, e) = B_0 + \beta(i) - b(e)$, where $C_0 = 24$, $B_0 = 48$, $\beta(i) = \gamma(i) = 3i$, and $b(e) = c(e) = 3e$. Table 1 summarizes the operating costs and the government agency's benefit.

$C(i,e)$	$e=0$	$e=4$
$i=0$	24	12
$i=4$	12	0

$B(i,e)$	$e=0$	$e=4$
$i=0$	48	36
$i=4$	60	48

Table 1. The operating costs and the government agency's benefit depending on the investment levels.

Hence, taking into account the investment costs $i+e$, the first-best outcome is achieved if $i = i^{FB} = 4$ and $e = e^{FB} = 0$ are chosen, so that the first-best total surplus is 44.

We now describe the two main treatments of our experiment. Figure 1 summarizes the sequences of events in the two treatments.

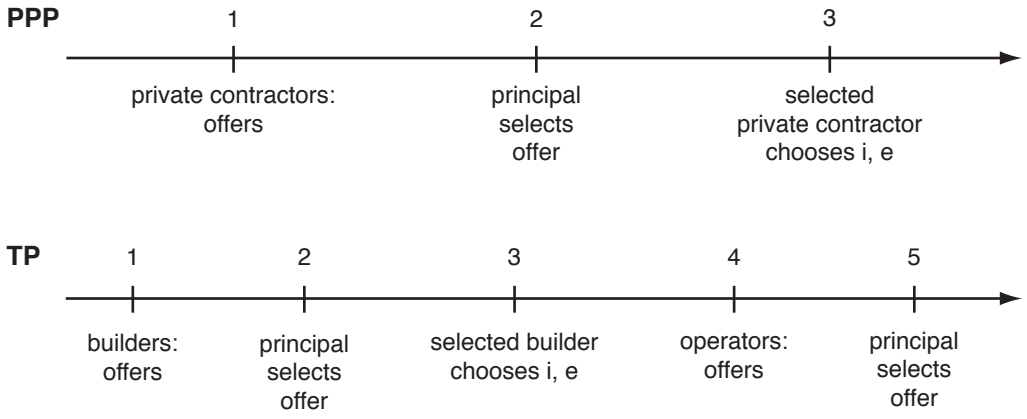

Figure 1. The sequences of events in the PPP treatment and the TP treatment.

Public-private partnership (PPP) treatment. In this treatment, always four subjects interact within a group. One subject is in the role of a principal (representing the government agency) and each of the three other subjects is in the role of a private contractor (each one representing a consortium). There are three stages. In the first stage, each of the private contractors submits an offer at which he is willing to build the infrastructure and to operate it.[8] In the second stage the principal learns the submitted offers and he selects one of the private contractors. The two contractors who are not selected make zero profits. In the third stage, the selected contractor chooses investment levels i and e. Depending on the investment decisions, the principal's payoff is $B(i,e) - P_0$ and the selected contractor's payoff is $P_0 - C(i,e) - i - e$, where P_0 is the price offer made by the selected contractor.

Traditional procurement (TP) treatment. In this treatment, always seven subjects play within a group. One subject is in the role of a principal (representing

[8]Throughout, offers had to be integers and the upper bounds for the offers were chosen large enough such that for any combination of investment decisions the parties could have shared the net surplus equally. For instance, in the PPP treatment, the private contractors could make offers in the range from 0 to 38.

the government agency), three subjects are in the role of builders, and the other three subjects are in the role of operators. There are five stages. In the first stage, each builder submits an offer to build the infrastructure. In the second stage the principal learns the submitted offers and he selects one of the builders. The two builders who are not selected make zero profits. In the third stage, the selected builder makes the investments i and e. His payoff is $P_0 - i - e$, where P_0 is the price offer he made in the first stage. In stage 4, the three operators learn the selected builder's investment decisions and thus they know the operating costs. Then each operator submits an offer at which he is willing to operate the infrastructure. In stage 5, the principal learns the selected builder's investment decisions and the operators' submitted offers. He then selects an operator. The other operators make zero profits. The principal's payoff is $B(i, e) - P_0 - P_1$, where P_1 is the selected operator's price offer. The selected operator's payoff is $P_1 - C(i, e)$.

Subjects, payments, and procedures. In total, 176 subjects participated in these two main treatments. Moreover, 224 subjects participated in two additional treatments which will be described in Section 3. All 400 subjects were students of the University of Cologne from a wide variety of fields of study. The computerized experiment was programmed and conducted with z-Tree (Fischbacher, 2007), and subjects were recruited using ORSEE (Greiner, 2004).

For the PPP treatment, we conducted two sessions with 32 subjects per session. In each session, there were 8 groups consisting of 4 players (one principal and three contractors). For the TP treatment, we conducted four session with 28 subjects per session. In each session, there were 4 groups consisting of 7 players (one principal, three builders, three operators).[9] In every treatment, the sessions consisted of 20 rounds. Each subject kept its role and stayed in the same group over all rounds, so that we have 16 independent observations per treatment. All interactions were anonymous; i.e., no subject knew the identities of the other group members. At the beginning of each session, written instructions were handed out to the participants. No subject was allowed to participate in more than one session.

[9] In the two subcontracting treatments described in Section 3, we also conducted four sessions with 28 subjects per session. In each session, there were 4 groups consisting of 7 players (one principal, three builders, three operators), so that we also have 16 groups per subcontracting treatment.

We made use of an experimental currency unit (ECU). To prevent the occurrence of losses, each subject was given an initial endowment of 75 ECU.[10] After each round, a subject's payoff was added to his account. The final balance was paid out to them in cash (1 ECU = 0.07 Euro). A session lasted between 70 and 90 minutes. Subjects were paid on average 13.19 Euro.

2.3 Predictions

Under standard contract-theoretic assumptions (in particular, if it is commonly known that all players are rational and have self-interested preferences), the predictions are as follows.

In the PPP treatment, the selected private contractor will minimize his total costs $C(i,e)+i+e$ by choosing the high levels of both investments, $i=4$ and $e=4$, so that his total costs are 8. Since in a subgame-perfect equilibrium, the principal will choose a contractor making the smallest price offer, at least two contractors will make the price offer 8. This implies that the principal obtains the total surplus, which then is 40.[11]

In the TP treatment, since the principal will choose the operator offering the smallest price, at least two operators will make price offers equal to the operating costs $C(i,e)$. The selected builder will maximize his payoff P_0-i-e by choosing the low investments $i=0$ and $e=0$. Anticipating that the principal will choose a builder making the smallest price offer, at least two builders will offer the price 0. Hence, the principal obtains the total surplus, which now is 24 only.[12]

Since the games we are interested in consist of several stages and involve several players, we wanted the subjects to have a chance to learn how to play the games, so that we implemented a repeated game design. However, a potential drawback of this design could be the well-known fact that in repeated games, subjects often manage to establish cooperation. Hence, we are par-

[10] If in any round a subject's balance became negative, we would have excluded the whole group from our data analysis. Yet, no subject ever had a negative balance.

[11] More precisely, note that since 1 ECU is the smallest monetary unit, the price paid to a contractor may also be 9. If the other two contractors make this offer, the best response is to also offer 9. In this case, the selected contractor's payoff is 1 and the principal's payoff is 39.

[12] Note again that due to the smallest monetary unit, there are further equilibria that differ slightly from the standard equilibrium prediction. E.g., all operators may offer 25 and all builders may offer 1, so that the selected contractors each make a profit of 1 and the principal's payoff is 22.

ticularly interested in the final round, which corresponds most closely to the one-shot interaction modelled in the theoretical framework that motivated our study.

Numerous experimental studies have shown that subjects' behavior in the laboratory often violates perfect rationality and pure self-interest.[13] On the other hand, previous work has shown that competitive forces, which are central ingredients of our setting, can be quite strong also in laboratory settings.[14] Thus, our main research question is whether the contract-theoretic reasoning as outlined above can be useful to organize the experimental data. Guided by the theoretical analysis, we make the following qualitative predictions.

Prediction 1. *In the PPP treatment, the high levels of both investments will be chosen more often than in the TP treatment.*

If Prediction 1 is corroborated by the data, then this offers support for the fundamental trade-off identified by Hart's (2003) analysis. More specifically, given the parameters that we have chosen for the experiment, the total surplus is larger if both kinds of investments (i.e., desirable and undesirable) are made than if no investments are made. The theoretical analysis thus suggests that the principal will be better off given a public-private partnership (since due to competition he will be able to extract the total surplus). The following prediction hypothesizes that this finding is also reflected in the data, which is a somewhat more ambitious test of the relevance of the theory.

Prediction 2. *The principals' payoffs will be larger in the PPP treatment than in the TP treatment.*

2.4 Results

In this section, we describe and analyze the results of our two main treatments. Table 1 shows the key findings summarized over all rounds and for the last round.

Let us first consider the investment behavior. Recall that in the PPP treatment, the private contractor builds the infrastructure and subsequently operates it, so that the profit-maximizing decision is to make both investments. In contrast, in the TP treatment the builder who takes the investment decisions

[13] For surveys, see e.g. Camerer (2003) or Fehr and Schmidt (2006).

[14] Specifically, we decided to model competition using three players, since Dufwenberg and Gneezy (2000) showed that price competition works quite well in experimental markets with three sellers.

is not in charge of operation, so that according to standard theory, he will not invest at all.

	all rounds		final round	
	PPP	TP	PPP	TP
no investments	0.3%	49.1%	0.0%	93.8%
only investment i	4.7%	48.4%	6.3%	6.3%
only investment e	0.9%	1.9%	0.0%	0.0%
both investments	94.1%	0.6%	93.8%	6.3%
investment i	98.8%	49.1%	100.0%	6.3%
investment e	95.0%	2.5%	93.8%	0.0%
principals' payoff	34.86	24.88	37.00	16.63
selected contractors' payoff	5.09		3.25	
selected builders' payoff		6.97		8.13
selected operators' payoff		1.86		0.50
total surplus	39.95	33.71	40.25	25.25

Table 1. The first four rows summarize the relative frequencies of the investment decisions in which no investment, only one investment, or both investments were chosen. The following two rows show the relative frequencies of all cases in which investment i and investment e, respectively, were chosen. The final rows show the parties' average payoffs and the average total surplus.

In both treatments, the subjects' last-round investment behavior is remarkably close to the standard contract-theoretic predictions. In the PPP treatment, 15 of the 16 selected builders chose the high levels of both kinds of investment (while one selected builder chose the high level of the quality-improving investment only). In contrast, in the TP treatment, 15 of the 16 selected builders chose the low levels of both investments (while one selected builder chose the high level of the quality-improving investment only).

Let us now take all 20 rounds into consideration. For each round, Figure 2 illustrates the relative frequencies with which the high levels of the quality-improving investment i and the quality-reducing investment e were chosen. For each investment i and e, we have 320 investment decisions per treatment. In the PPP treatment, the investment behavior was very close to the theoretical prediction over all 20 rounds. Altogether, the high level of the desirable investment i was chosen in 98.8% of the 320 cases, while the high level of the

undesirable investment e was chosen in 95%. In the TP treatment, the high level of the desirable investment i was chosen in 49.1% and the high level of the undesirable investment e was chosen in 2.5% of all cases. The investment behavior regarding e is again very close to the standard prediction. Even though in rounds 1 to 19, the high level of the quality-improving investment i is chosen more often than predicted, we do find strong evidence in support of Prediction 1. Not only in the last round, but also taking averages per group over all 20 rounds, the subjects' behavior with regard to both kinds of investments differs significantly between the treatments.[15]

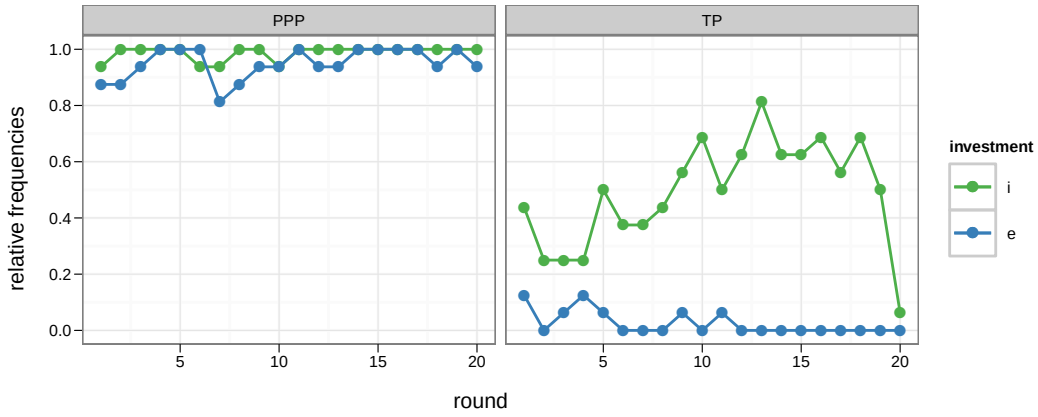

Figure 2. The relative frequencies with which the high levels of the investments i and e were chosen.

For each round, Figure 3 shows the average total surplus resulting from the described investment behavior. In the PPP treatment, the average surplus is larger than in the TP treatment in every round except round 13 (where the surplus is the same in both treatments).[16] Hence, as predicted, the public-private partnership was the welfare-maximizing governance structure, even

[15] Between treatments and for each investment, we compare the distributions of average investment levels. An average investment level refers to one single group and describes the relative frequency of high investment levels over all rounds within this group. The p-values of two-sided Mann-Whitney U tests with regard to the investments e and i are both smaller than 0.001. Moreover, we have also compared the individual investment decisions between treatments in each single round. According to χ^2 tests, the p-values regarding investment e are smaller than 0.001 in every round, while with regard to investment i, they are smaller than 0.02 in 18 rounds (in rounds 10 and 13, we still have $p < 0.08$).

[16] Over all rounds, the surplus differs significantly between the two treatments. Comparing the distributions of the average surplus per group over all rounds, the p-value is 0.002 according to a two-sided Mann-Whitney U test.

though in rounds 1 to 19, the total surplus in the TP treatment was noticeably larger than predicted (due to the fact that in almost half of the cases, the first-best investment decisions were taken). In the final round, the surplus in both treatments is very close to the respective theoretical prediction.

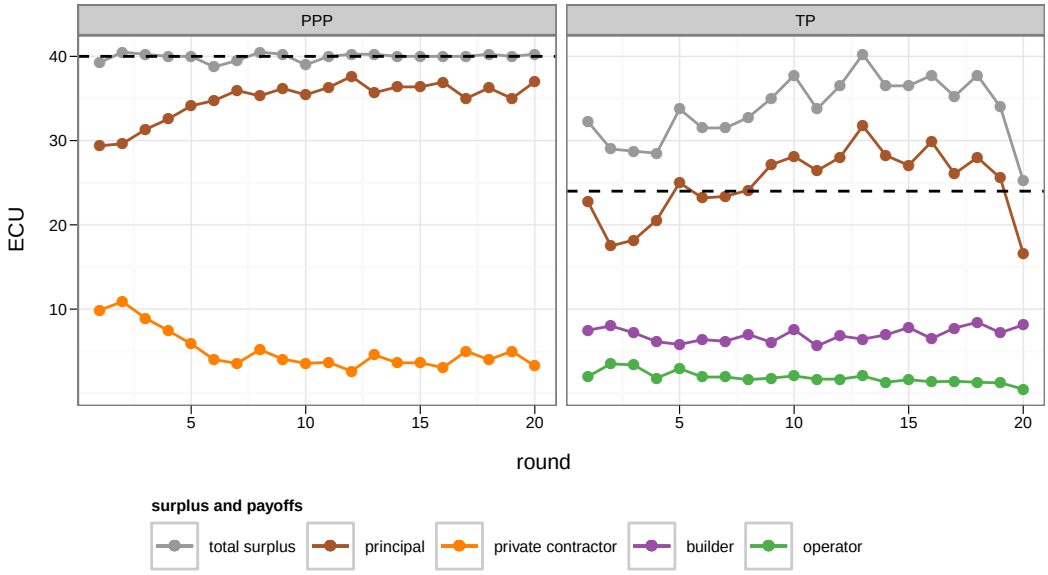

Figure 3. The average total surplus and the average payoffs of the principals, the selected private contractors (in PPP), and the selected builders and operators (in TP). The dashed lines represent the theoretically predicted total surplus levels (40 in PPP and 24 in TP).

In the PPP treatment, the total surplus is the sum of the principal's and the selected private contractor's payoffs. In the TP treatment, the total surplus is the sum of the principal's, the selected builder's, and the selected operator's payoffs. In both treatments, the principals obtain by far the largest share of the total surplus. Hence, competition seemed to work quite well. As a consequence, we find strong support for Prediction 2. Over all rounds, the principals' average payoff in the PPP treatment was 34.86, while it was only 24.88 in the TP treatment. Taking averages per group over all 20 rounds, the difference between the distributions of the principals' payoffs is highly significant.[17]

[17] The p-value of a two-sided Mann-Whitney U test is smaller than 0.001. Comparing the individual profits in each round, the p-values are smaller than 0.04 in 18 of the 20 rounds ($p = 0.213$ in round 1 and $p = 0.125$ in round 13).

Let us now take a closer look at how the different parties' payoffs developed over time. In the PPP treatment, the private contractors' average profits decreased over the early rounds, while they were small and quite stable in the later rounds. In the TP treatment, the builders' average profits were small and almost constant, while the operators' profits were even smaller.

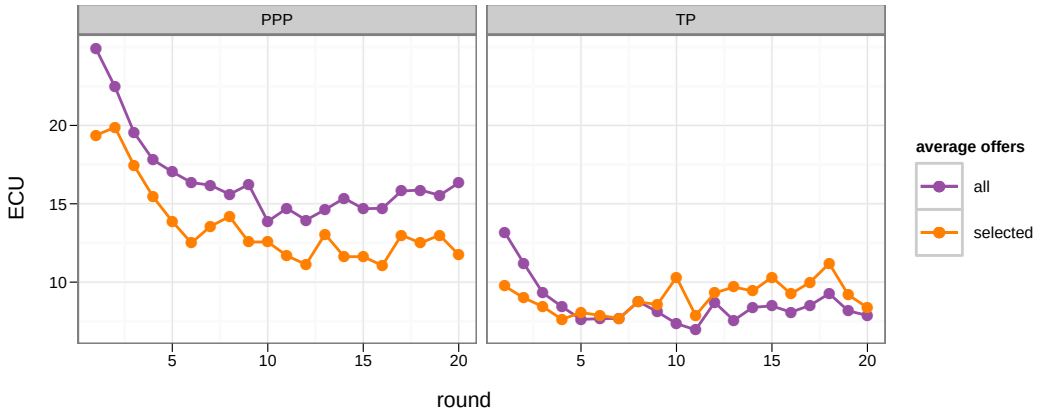

Figure 4. The average offers made by all private contractors (in PPP) and by all builders (in TP) as well as the average offers selected by the principals.

In the PPP treatment, the principals' payoffs increased over the early rounds, while in the TP treatment the principals' payoffs exhibited an increasing trend from the second to the 13th round. The reasons for these growing payoffs differ between the treatments. In the PPP treatment, increases of principals' payoffs cannot be driven by changing investment behavior (since the average investment levels and thus the total surplus were almost constant over all rounds). Instead, the principals' increasing payoffs resulted from the fact that on average, during the first rounds, payments from the principals to the private contractors decreased. This fact is illustrated in the left panel of Figure 4, which shows the averages per round of all private contractors' offers and of the selected offers. Note that in every round, the average selected offer is smaller than the average of all offers that were made. In the TP treatment, the principals' growing payoffs are also due to decreasing payments to the builders in the first few rounds (see the right panel of Figure 4), while they are mainly driven by increasing investment levels of the quality-enhancing investment i in later rounds (see Figure 2).

We will now explore the behavior within the individual groups in greater detail. For each of the 16 groups in the PPP treatment, Figure 5 shows all

three private contractors' offers, as illustrated by the three colored curves. In each round, the offer actually selected by the principal is indicated by a symbol, whose shape reflects the selected contractor's investment decisions.

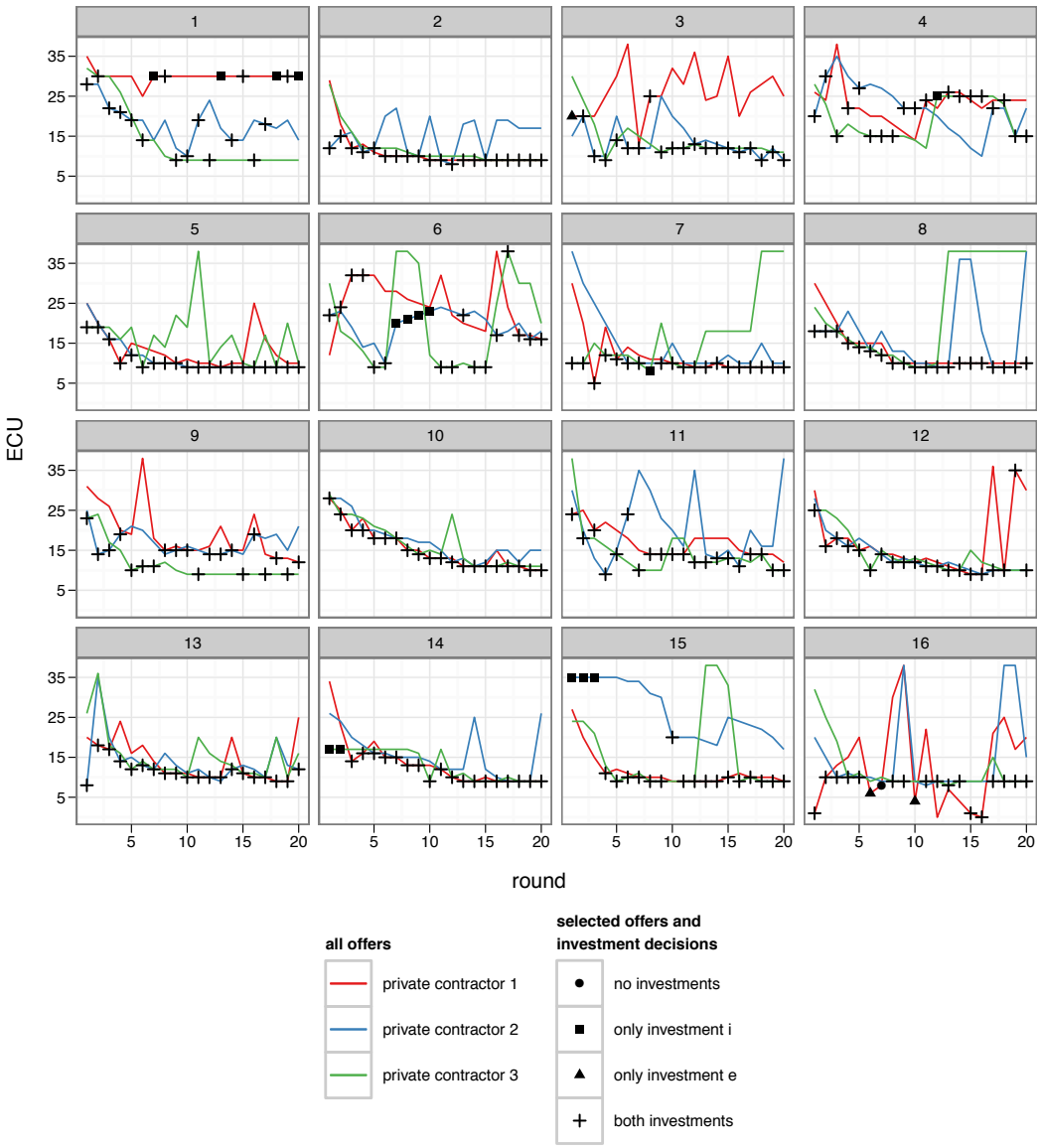

Figure 5. The offers made by the three contractors, the principal's choices, and the selected contractors' investment decisions for each of the 16 groups in the PPP treatment.

Most principals selected the lowest offer right from the beginning,[18] which created competition between the private contractors, so that in most groups we observe decreasing offers over the early rounds (cf. also the left panel of Figure

[18] Over all rounds, the lowest offer was chosen in more than 80% of the cases.

4). As already pointed out, the vast majority of private contractors chose the high levels of both investments, which becomes apparent from inspection of Figure 5. Indeed, in most cases making both investments was the only way for the contractors to avoid losses. Recall that the private contractors' total costs were 8 if they made both investments, while their total costs were 16 if they made the first-best investment decisions (by choosing investment i only). 75% of the selected offers were smaller than 16, so that in these cases making the first-best investment decisions would have led to a loss for the contractors. As a matter of fact, competition was so strong that most contractors could make only very small profits even if they chose the high levels of both investments.[19]

For each of the 16 groups in the TP treatment, Figure 6 shows all builders' offers, the offers selected by the principal, and the selected builders' investment decisions. Figure 6 is particularly helpful to better understand the builders' investment behavior. Recall that in the TP treatment, the average level of the quality-improving investment i increases during the first rounds, remains relatively high in the following rounds, and then falls steeply close to zero in the last round (see also Figure 2). Why do builders in rounds 1 to 19 often choose first-best investment levels, although in a given round, this reduces their monetary payoff? Actually, the strategic situation resembles a gift-exchange game (Akerlof, 1982). In gift-exchange experiments, it is often observed that principals pay relatively generous wages and agents tend to reciprocate principals' behavior by exerting high effort, which they would not do according to standard theory.[20] In our TP treatment, principals could select relatively large offers, thereby paying the builder a generous fixed wage. Builders could then reward principals for doing so by making first-best investment decisions. Indeed, in some groups we observe behavior which is in line with the gift-exchange argument. In these groups, principals persistently preferred not to select the lowest offer. As a matter of fact, in later rounds, average selected offers were larger than the average of all offers (see also the right panel of Figure 4). Moreover, selected builders often reciprocated relatively large payments by choosing first-best investments.[21] However, the builders' reciprocal behavior

[19] In the last five rounds, 65% of the selected offers were smaller than or equal to 10.

[20] See e.g. Fehr, Kirchsteiger, and Riedl (1993) and Fehr and Falk (1999).

[21] Specifically, the first-best investment decisions were taken in 48.4% of all cases, while no investments were made in 49.1%. If the principal did not select the builder making the smallest offer (which happened in 63.4% of the cases), then the first-best decisions were taken in 66% of these instances, while in only 31.5% of these instances no investments were made. Note also that our experimental design was such that on the principals' screens the

was motivated by strategic considerations, since in the final round all builders but one decided not to invest at all.

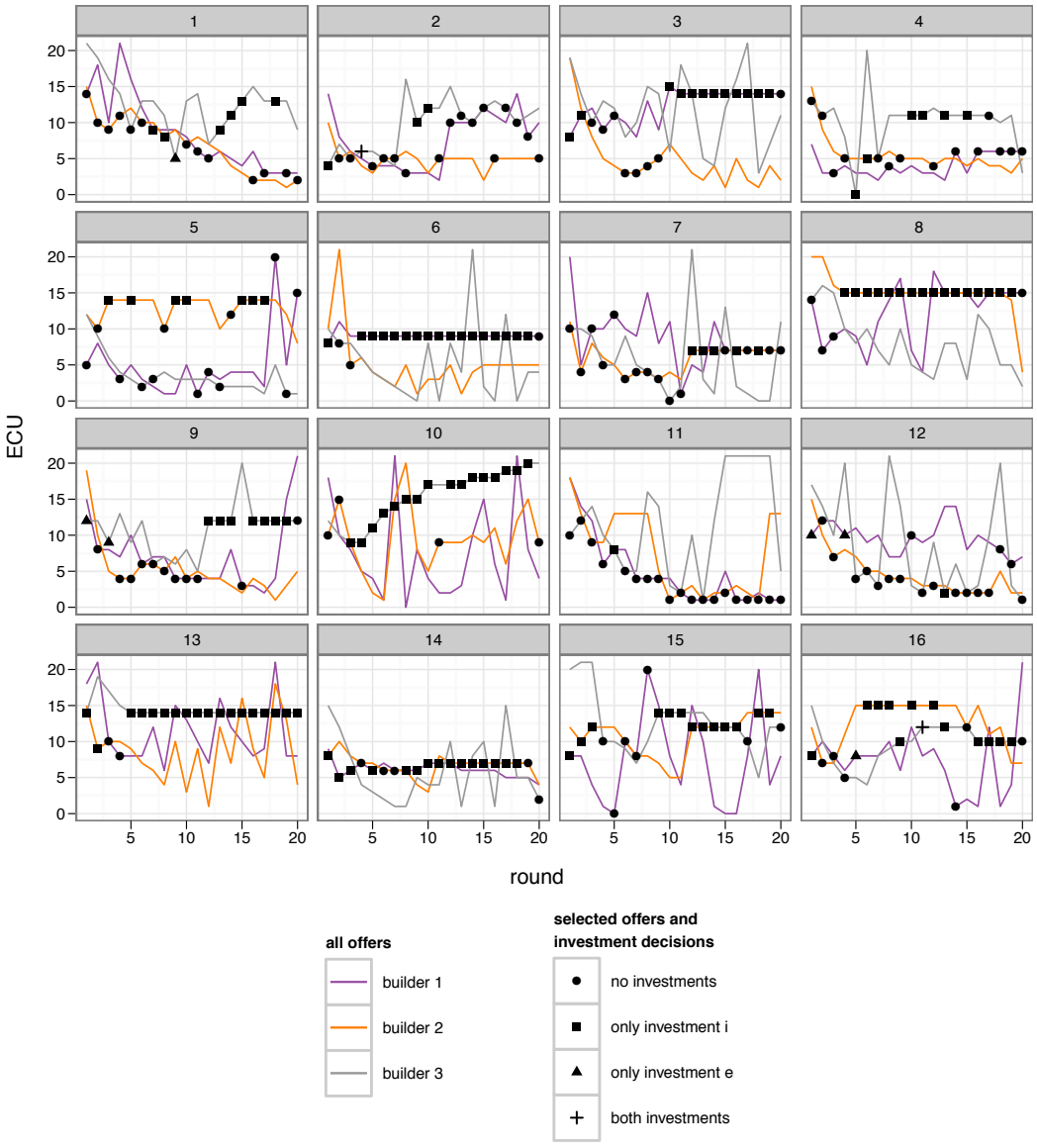

Figure 6. The offers made by the three builders, the principal's choices, and the selected builders' investment decisions for each of the 16 groups in the TP treatment.

Figure 7 illustrates all operators' offers and the offers selected by the principals. Note that the operating costs are determined by the builders' previous

offers were displayed in a random order, so that they did not know which offer was made by which builder. However, it seems that, by making similar offers over several rounds, in some groups builders managed to establish a reputation for choosing first-best investments when their offers are accepted.

investment decisions which are again indicated by the different shapes of the symbols. Recall that if no high investment levels were chosen, the operating costs were 24, if only one of the two investment levels was high, the operating costs were 12, while they were 0 otherwise. Most of the operators' offers were only slightly above their respective operating costs and, over all rounds, principals selected the lowest operating offers in 93.1% of the cases. This indicates that competition for being awarded the operating contract worked very well.

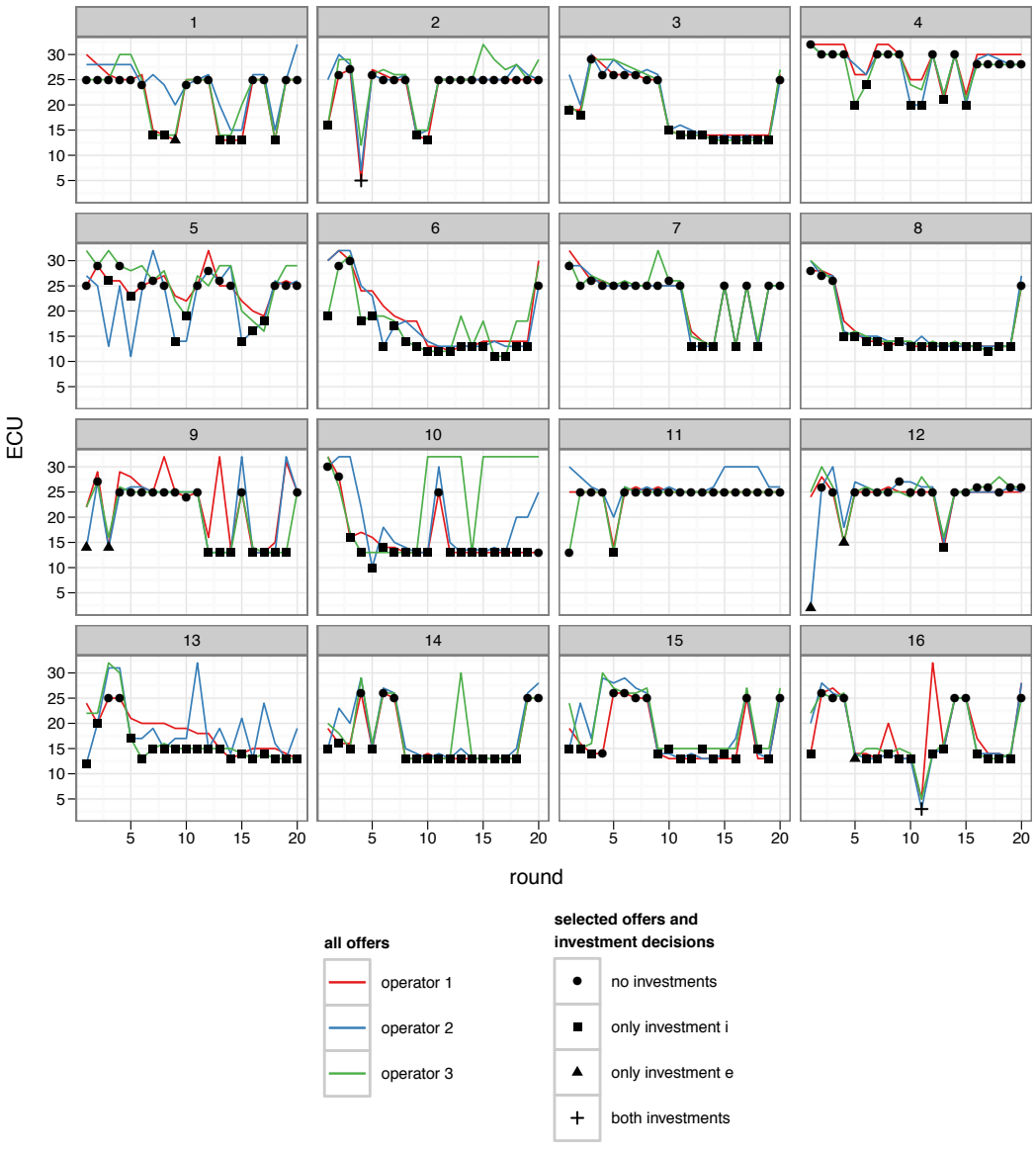

Figure 7. The offers made by the three operators and the principal's choices, given the selected builders' investment decisions for each of the 16 groups in the TP treatment.

3 Subcontracting

So far, we have assumed that in case of a public-private partnership, the government agency contracts with a single private contractor (representing a consortium), who is then responsible for both, infrastructure construction and operation. However, in practice different skills are required for the two different tasks, so that subcontracting is characteristic for a consortium. Hence, we have conducted two further treatments that capture the two ways of subcontracting that are possible in our public-private partnership setting. Either the government agency selects a builder as main contractor, who then subcontracts with an operator, or it selects an operator as main contractor, who then subcontracts with a builder.

3.1 Theoretical framework

Keeping the assumptions regarding the available technology unchanged (see Section 2.1), we now consider two variants of public-private partnerships in which either the task of building the public facility or the task of operating it is delegated to a subcontractor.

The builder as main contractor and the operator as subcontractor (Sub I). We assume that there is a competitive supply of builders as main contractors who could build the infrastructure and who would then subcontract operation. They submit offers to the government agency who chooses a main contractor. The main contractor who is awarded the contract will build the infrastructure and choose the investment levels i and e. Assuming that there is a competitive supply of operators, they will submit offers in which they demand to be reimbursed for their operating costs, given the investment levels. Thus, the main contractor pays $P_1 = C(i, e)$ to the chosen operator. The main contractor chooses the investment levels i and e that maximize his payoff $P_0 - P_1 - i - e = P_0 - C(i, e) - i - e$, where P_0 is the price that the government agency pays to the main contractor. Given Assumption 1, the main contractor thus chooses $i^I = i_h$ and $e^I = e_h$. Anticipating their investment behavior in case of being awarded the contract and the price they will have to pay to a subcontractor, the main contractors submit offers equal to their total costs $P_1 + i_h + e_h = C(i_h, e_h) + i_h + e_h$. Therefore, the payment from the government agency to the main contractor is given by $P_0 = C(i_h, e_h) + i_h + e_h$. The government agency's payoff is $B(i_h, e_h) - C(i_h, e_h) - i_h - e_h$.

The operator as main contractor and the builder as subcontractor (Sub II). In this case, the government agency initially contracts with a main contractor who will subcontract the construction of the infrastructure and who will then operate it. The payoff of the builder who will be chosen as the subcontractor is $P_1 - i - e$, where P_1 is the payment from the main contractor to the subcontractor. Hence, the selected builder will choose $i^{II} = i_l$ and $e^{II} = e_l$. Given competition, the builders will submit offers equal to their investment costs $i_l + e_l$. Anticipating that the low investment levels will be chosen, in a competitive market the main contractors will submit offers equal to their total costs $C(i_l, e_l) + P_1 = C(i_l, e_l) + i_l + e_l$. Hence, the government agency pays $P_0 = C(i_l, e_l) + i_l + e_l$ to the operator who is chosen as main contractor. The government agency's payoff is thus $B(i_l, e_l) - C(i_l, e_l) - i_l - e_l$.

Proposition 2 *The investment levels given subcontracting can be ranked as follows.*

$i^{II} = i_l < i^I = i^{FB} = i_h$.

$e^{II} = e^{FB} = e_l < e^I = e_h$.

Propositions 1 and 2 reveal that when operation is subcontracted, then the investment incentives are the same as in a public-private partnership without subcontracting, $i^I = i^{PPP}$, $e^I = e^{PPP}$. In contrast, when the facility construction is subcontracted, then the investment incentives are as in the case of traditional procurement, $i^{II} = i^{TP}$, $e^{II} = e^{TP}$. This is because when the builder is the main contractor, then he anticipates in the building stage that he will have to reimburse the subcontractor for his operating costs in the subsequent stage. Hence, just as in the case of a public-private partnership without subcontracting, the builder is interested in cutting the operating costs, while he does not internalize the investments' impact on the government agency's benefit, so that he chooses the high investment levels i_h and e_h. In contrast, when the operator is the main contractor, then the builder as subcontractor who is in charge of the investments obtains a fixed payment independent of the investment levels that he chooses. Hence, just as under traditional procurement, he neither internalizes the operating costs nor the government agency's benefit, so that he chooses the low investment levels i_l and e_l.

As a consequence, the government agency is indifferent between a public-private partnership without subcontracting and a public-private partnership in which operation is subcontracted. Similarly, it is indifferent between traditional procurement and a public-private partnership in which facility construction is subcontracted.

3.2 Experimental design

In our two subcontracting treatments, we consider the same parameter constellation as in the two main treatments (see Section 2.2). The sequences of events are illustrated in Figure 8.

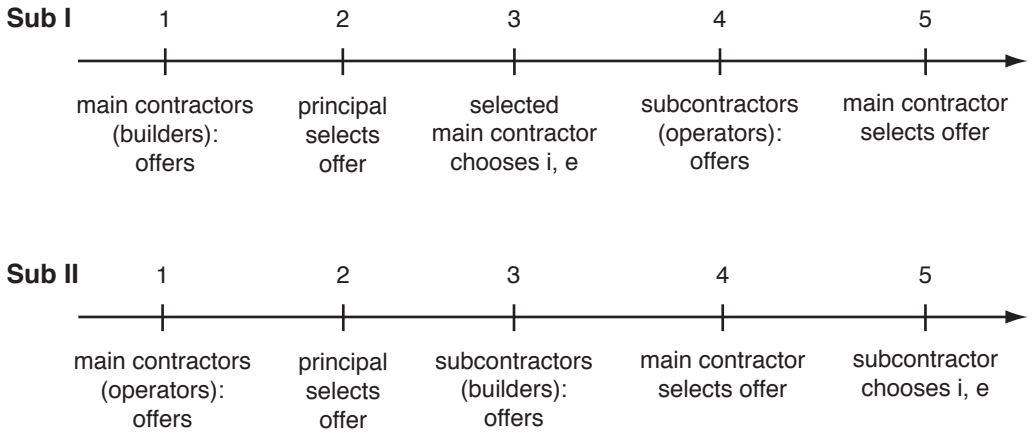

Figure 8. The sequences of events in the Sub I treatment and the Sub II treatment.

Treatment Sub I (the builder as main contractor and the operator as subcontractor). In this treatment, always seven subjects interact within a group. One subject is in the role of a principal (representing the government agency), three subjects are in the role of main contractors, and the other three subjects are in the role of subcontractors. There are five stages. In the first stage, each main contractor submits an offer to build the infrastructure and subcontract operation. In the second stage, the principal learns the submitted offers and he selects one main contractor. The two main contractors who are not selected make zero profits. In the third stage, the selected main contractor makes the investments i and e. In stage 4, the three subcontractors learn the investment decisions and thus they know the operating costs. Then each subcontractor makes an offer at which he is willing to operate the infrastructure. In stage 5, the main contractor learns the subcontractors' offers and he selects an operator. The other subcontractors make zero profits. The principal's payoff is $B(i,e) - P_0$, where P_0 is the selected main contractor's price offer. The selected main contractor's payoff is $P_0 - P_1 - i - e$, where P_1 is the selected subcontractor's price offer. The selected subcontractor's payoff is $P_1 - C(i,e)$.

Treatment Sub II (the operator as main contractor and the builder as subcontractor). Again, always seven subjects play within a group. One subject is in the role of a principal (representing the government agency), three subjects are in the role of main contractors, and the other three subjects are in the role of subcontractors. There are five stages. In the first stage, each main contractor submits an offer to operate the facility and to subcontract the facility construction. In the second stage, the principal learns the submitted offers and he selects a main contractor. The two main contractors who are not selected make zero profits. In the third stage, each subcontractor submits an offer at which he is willing to build the infrastructure. In stage 4, the main contractor learns the subcontractors' offers and he selects a builder. The other subcontractors make zero profits. In stage 5, the selected subcontractor makes the investment decisions i and e. The principal's payoff is $B(i,e) - P_0$, where P_0 is the selected main contractor's price offer. The selected main contractor's payoff is $P_0 - P_1 - C(i,e)$, where P_1 is the selected subcontractor's price offer. The selected subcontractor's payoff is $P_1 - i - e$.

3.3 Predictions

We now derive predictions for the subcontracting treatments under standard contract-theoretic assumptions. Consider first the Sub I treatment. Since in a subgame-perfect equilibrium the main contractor (builder) will choose a subcontractor (operator) making the smallest price offer, at least two subcontractors will submit offers equal to their operating costs $C(i,e)$. This implies that the selected main contractor will minimize his total costs $C(i,e) + i + e$ by choosing the high levels of both investments, $i = 4$ and $e = 4$. Anticipating that the principal will select a main contractor making the smallest price offer, at least two main contractors will offer the price 8. Thus, the principal obtains the total surplus, which then is 40.[22]

In the Sub II treatment, the selected subcontractor (builder) will maximize his payoff $P_1 - i - e$ by choosing the low investment levels $i = 0$ and $e = 0$. Anticipating that the main contractor (operator) will choose a subcontractor making the smallest offer, at least two subcontractors will offer the price 0. Knowing that the principal will choose the lowest offer and that their operating

[22]Note again that taking into account that 1 ECU is the smallest monetary unit, there are further equilibria. Yet, the principal's payoff is always between 38 and 40.

costs will be $C(0,0) = 24$, at least two main contractors submit offers equal to 24. The principal obtains the total surplus, which is 24.[23]

In analogy to the main treatments, we make the following qualitative predictions.

Prediction 3. *In the Sub I treatment, the high levels of both investments will be chosen more often than in the Sub II treatment.*

Prediction 4. *The principals' payoffs will be larger in the Sub I treatment than in the Sub II treatment.*

3.4 Results

Table 3 displays the key results of the subcontracting treatments summarized over all rounds and for the final round.

	all rounds		final round	
	Sub I	Sub II	Sub I	Sub II
no investments	3.4%	71.3%	0.0%	100.0%
only investment i	20.9%	14.4%	12.5%	0.0%
only investment e	10.6%	0.3%	12.5%	0.0%
both investments	65.0%	14.1%	75.0%	0.0%
investment i	85.9%	28.4%	87.5%	0.0%
investment e	75.6%	14.4%	87.5%	0.0%
principals' payoff	31.02	22.55	31.06	21.56
selected main contractors' payoff (builder)	4.98		6.06	
selected subcontractors' payoff (operator)	2.17		0.88	
selected main contractors' payoff (operator)		0.94		–2.63
selected subcontractors' payoff (builder)		5.62		5.06
total surplus	38.16	29.11	38.00	24.00

Table 3. The first four rows summarize the relative frequencies of the investment decisions in which no investment, only one investment, or both investments were chosen. The following two rows show the relative frequencies of all cases in which investment i and investment e, respectively, were chosen. The final rows show the parties' average payoffs and the average total surplus.

[23] Due to the smallest monetary unit, there are further equilibria; yet, the principal's payoff is always between 22 and 24.

The investment behavior is again of central interest. In the Sub I treatment, the subjects' last-round investment behavior is very close to the theoretical prediction. 12 of the 16 main contractors (builders) made both investments, while 4 main contractors made one of the two investments. Altogether, the high level of each investment was chosen in 14 out of 16 cases. In the Sub II treatment, the last-round investment levels are exactly as predicted; i.e., there were no investments at all.

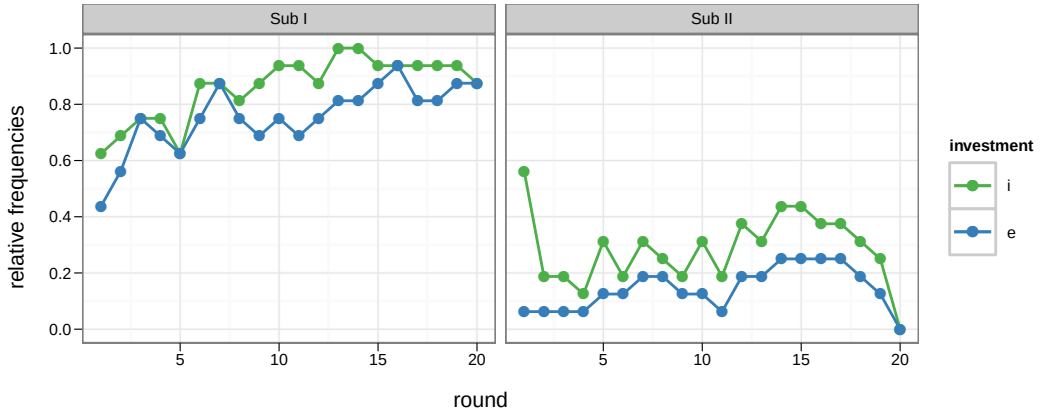

Figure 9. The relative frequencies with which the high levels of the investments i and e were chosen.

Looking at the investment behavior over all rounds (which is illustrated in Figure 9), we again have 320 investment decisions for each investment i and e per treatment. The high level of the investment i was chosen in 85.9% of the 320 cases in the Sub I treatment, while the investment e was chosen in 75.6%. The respective relative frequencies for these investments in the Sub II treatment were only 28.4% and 14.4%. Similar to our findings for the main treatments, these results indicate that the theoretical analysis also provides empirically relevant insights about the investment incentives in the subcontracting treatments. In particular, Prediction 3 is corroborated by the data. Not only in the final round, but also taking averages per group over all rounds, the subjects' behavior with regard to both investments differs significantly between the two subcontracting treatments.[24]

[24]Between treatments and for each investment, we compare the distributions of within-group average investment frequencies. The p-values of two-sided Mann-Whitney U tests with regard to the investments e and i are both smaller than 0.001. We have also compared the individual investment levels between treatments in each single round. According to χ^2

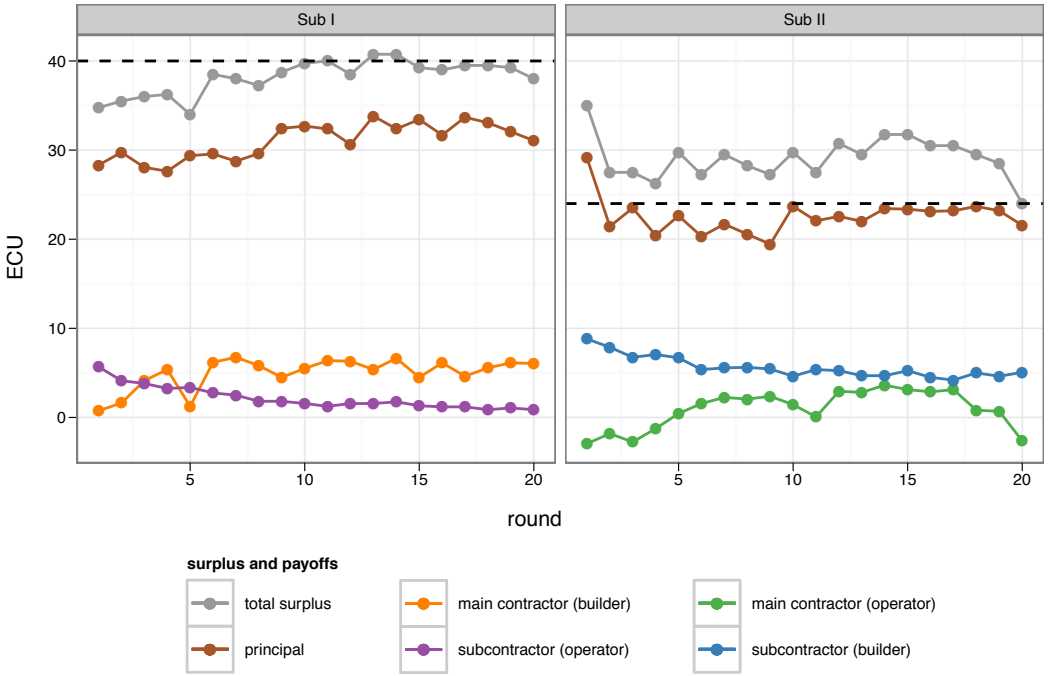

Figure 10. The average total surplus and the average payoffs of the principals and the selected (main and sub-)contractors. The dashed lines represent the theoretically predicted total surplus levels (40 in Sub I and 24 in Sub II).

For each round, Figure 10 shows the average total surplus as well as the average payoffs of the principals and the selected contractors. The average total surplus is larger in the Sub I treatment than in the Sub II treatment in every round except round 1.[25] In the final round, the total surplus is again very close to the theoretical prediction. The principals again managed to obtain by far the largest share of the total surplus. The average profits of the principals are larger in the Sub I treatment (31.02) than in the Sub II treatment (22.55). Taking averages per group over all 20 rounds, the difference between the distributions of the principals' payoffs is highly significant.[26] Thus, we find strong support for Prediction 4.

tests, the p-values regarding investment e are smaller than 0.004 in 19 rounds ($p = 0.014$ in round 1), while with regard to investment i, they are smaller than 0.005 in 18 rounds ($p = 0.719$ in round 1 and $p = 0.077$ in round 5).

[25] Comparing the distributions of the average surplus per group over all rounds between the two treatments, the p-value is smaller than 0.001 according to a two-sided Mann-Whitney U test.

[26] The p-value of a two-sided Mann-Whitney U test is smaller than 0.001. Comparing the individual payoffs in each round, the p-values are smaller than 0.01 in the last 15 rounds ($p < 0.08$ in rounds 2, 4, and 5, $p = 0.777$ in round 1, and $p = 0.272$ in round 3).

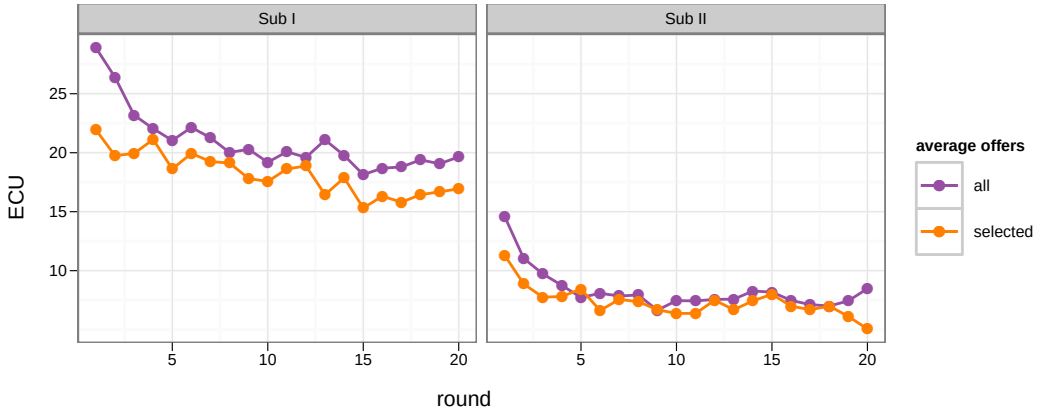

Figure 11. The average offers made by the builders (the main contractors in Sub I and the subcontractors in Sub II) and the average offers selected (by the principals in Sub I and by the main contractors in Sub II).

Let us now look at how behavior in the two subcontracting treatments changed over time. In analogy to Figures 5 to 7, Figures 12 to 15 show for each group in both treatments the offers that were made, the offers that were selected, and the investment decisions.

Consider the Sub I treatment. As can be seen in Figure 13, in the vast majority of cases (98.8%), the main contractors (builders) selected the subcontractor who made the smallest offer. Hence, fierce competition between subcontractors almost completely eroded their profits over time. While the principals sometimes tried to select a main contractor not making the smallest offer, the majority of main contractors did not reply by making the desirable investment i only (see Figure 12).[27] The payments from the principals to the main contractors decreased over time (see the left panel of Figure 11), so that main contractors decided more and more often to make both investments in order to minimize their total costs. In the Sub II treatment, the principals selected the main contractor (operator) making the smallest bid in 91.9% of the cases, which triggered strong competitive pressures (see Figure 14). The main contractors sometimes tried not to select the subcontractor making the

[27] Specifically, the first-best investment decisions were taken in 20.9% of all cases, while both investments were made in 65%. If the principal did not select the main contractor making the smallest offer (which happened in 33.8% of the cases), then the first-best decisions were taken in 37% of these instances, while the majority of main contractors (46.3%) still made both investments.

smallest offer (see Figure 15 and cf. the right panel of Figure 11). But if subcontractors reciprocated such offers, they often did so by making both investments (which is good for the main contractor, but not for the total surplus).[28]

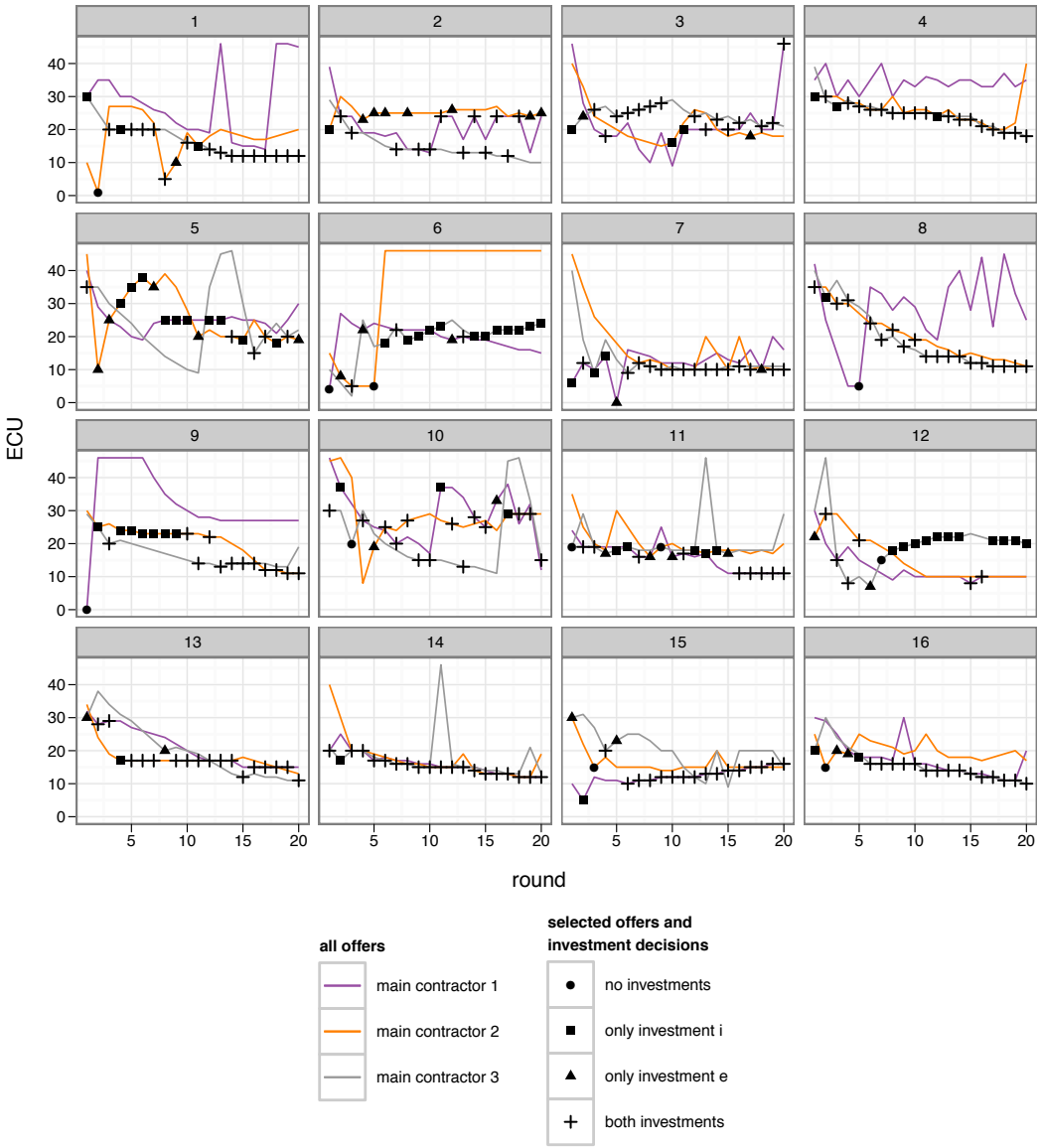

Figure 12. The offers made by the three main contractors (builders), the principal's choices, and the selected main contractors' investment decisions for each of the 16 groups in the Sub I treatment.

[28] The subcontractors' investment decisions were no investment in 71.3%, only investment i in 14.4%, only investment e in 0.3%, and both investments in 14.1% of all cases. If the main contractors did not select the subcontractor making the smallest offer (which happened in 63.1% of the cases), then the subcontractors' investment decisions were no investment in 39.8%, only investment i in 23.7%, only investment e in 0.9%, and both investments in 35.6% of these instances.

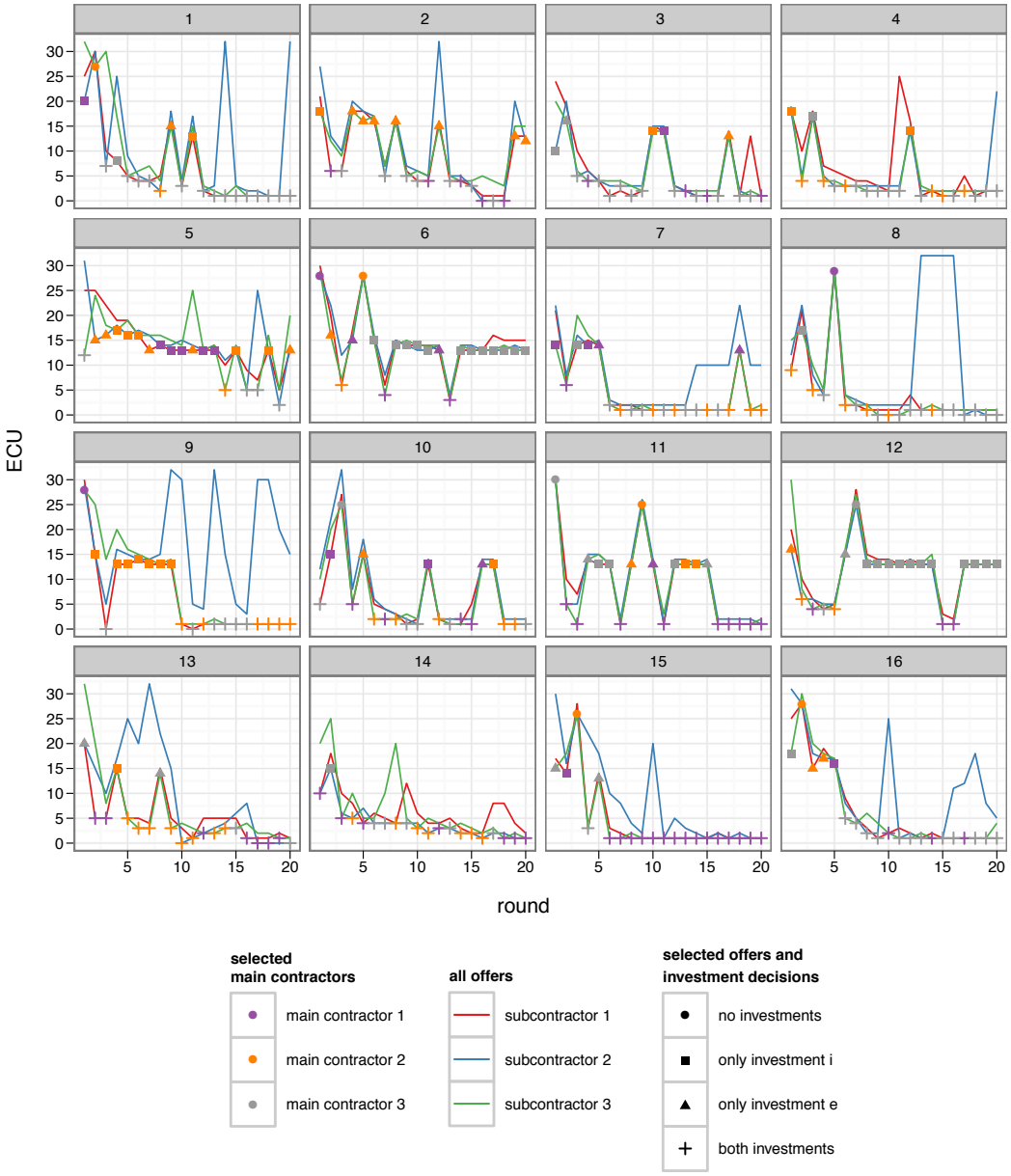

Figure 13. The offers made by the three subcontractors (operators) and the main contractors' choices for each of the 16 groups in the Sub I treatment. Note that the operating costs are determined by the investment decisions that were taken by the main contractors. The colors of the symbols identify which main contractor was selected by the principal (cf. Figure 12).

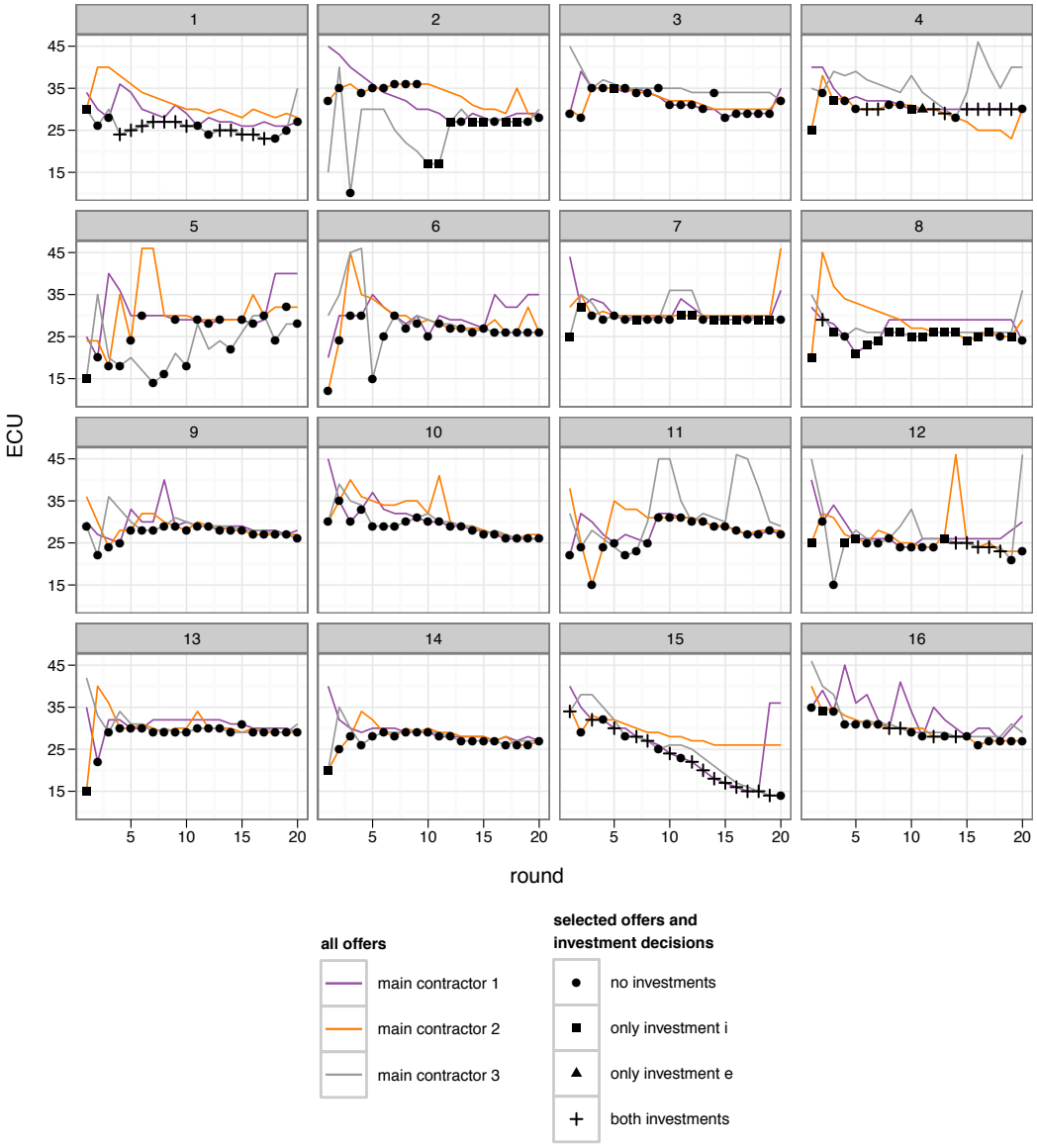

Figure 14. The offers made by the three main contractors (operators) and the principal's choices for each of the 16 groups in the Sub II treatment. Note that the shapes of the symbols refer to the investment decisions that will be taken by the selected subcontractors (cf. Figure 15).

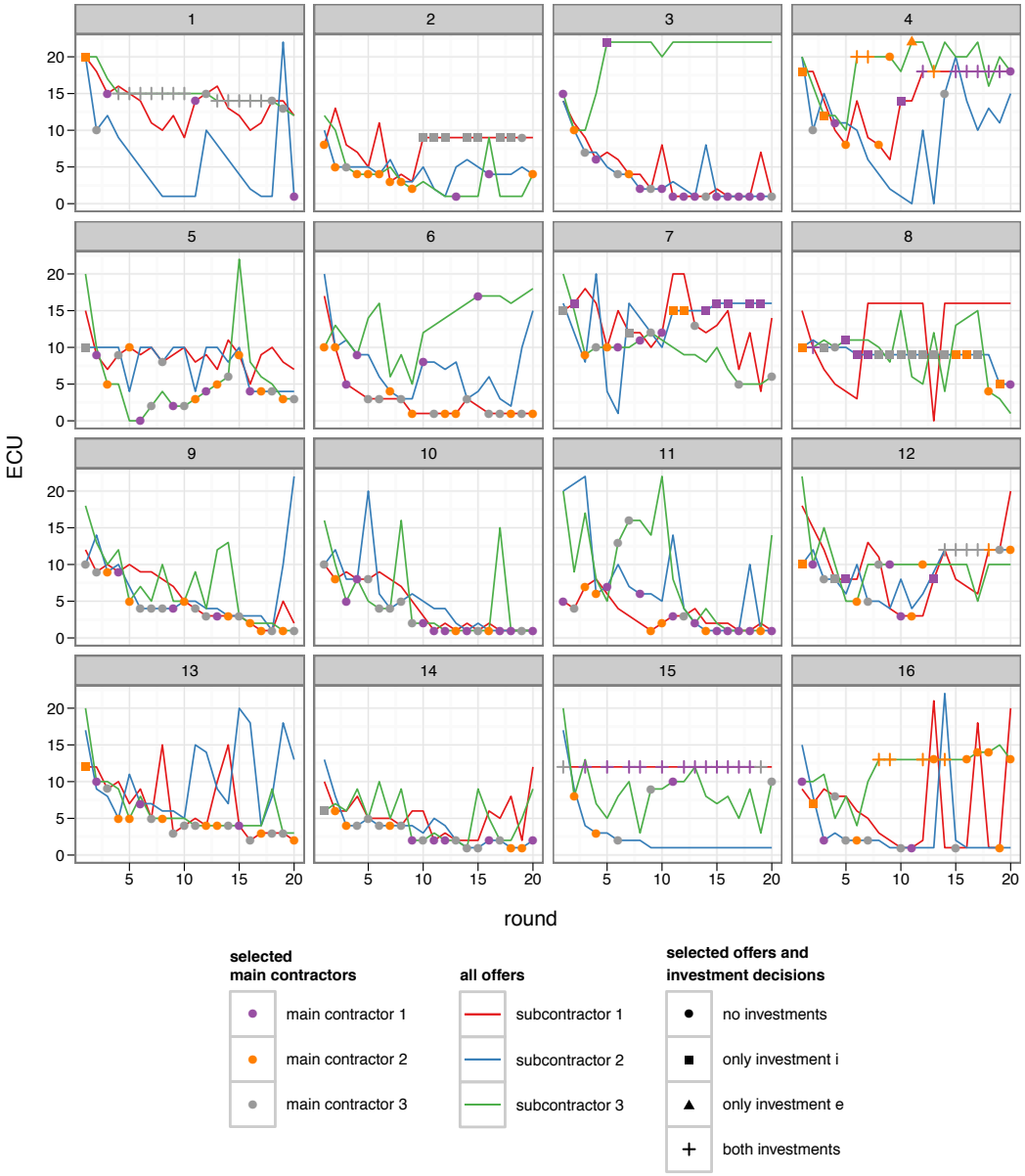

Figure 15. The offers made by the three subcontractors (builders) and the main contractors' choices for each of the 16 groups in the Sub II treatment. The colors of the symbols identify which main contractor was selected by the principal (cf. Figure 14).

4 Conclusion

Our two main treatments provide strong evidence for the fundamental trade-off identified by Hart (2003). A public-private partnership induces very strong incentives to invest in cost reductions, which is desirable if the investments are also quality-enhancing, but may well be undesirable if the investments have a negative side-effect on quality. In contrast, under traditional procurement incentives to invest are weak, both with regard to desirable as well as undesirable investments. In the experiment, we considered a parameter constellation where inducing the desirable investment was relatively more important, such that a public-private partnership would be preferable according to the theoretical analysis.

Indeed, in the experiment both kinds of investments were made much more often in the PPP treatment (in line with Prediction 1) and the principal was better off under this governance structure (in line with Prediction 2). While in the last round, almost all investment decisions were as theoretically predicted, the only noticeable deviation from the theoretical analysis was the fact that in the TP treatment, in a relevant number of cases the payments from the principals to the selected builders were relatively large, which was reciprocated by choosing high levels of the desirable investment i.[29]

In addition, we have considered two subcontracting treatments. The investment behavior and the principals' payoffs again differed between these two treatments as suggested by the theoretical analysis (supporting Predictions 3 and 4). According to the theoretical analysis, moreover there should be no differences between the PPP treatment and the Sub I treatment (where the builder is the main contractor), and similarly, there should be no differences between the TP treatment and the Sub II treatment (where the operator is the main contractor).

Figure 16 illustrates the average total surplus levels achieved in all four treatments. Note that in the final period, as predicted, neither PPP and Sub I nor TP and Sub II differ much from each other.

In the somewhat more complex Sub I treatment, in the early rounds the average surplus is smaller than in the PPP treatment. Yet, in practice there might be no real choice between PPP and Sub I, since modelling the consor-

[29] It would be interesting to also conduct experiments with parameter constellations in which traditional procurement would be optimal in theory. In the light of our results, we conjecture that given such a parameter constellation, traditional procurement would then turn out to be optimal also in the experiment.

tium as a single decision maker might best be seen as an analytical shortcut. Hence, Sub I may be considered to be the relevant alternative if (as in the parameter constellation that we have chosen in our experiment) a high level of the quality-reducing investment e is less harmful than underinvestment in i. Our experiment hence illustrates that frictions within the consortium might make a public-private partnership slightly less attractive than it appears when modelled as a monolithic entity. This result might encourage further theoretical studies of public-private partnerships to open the black box of contracting arrangements within the private consortia.

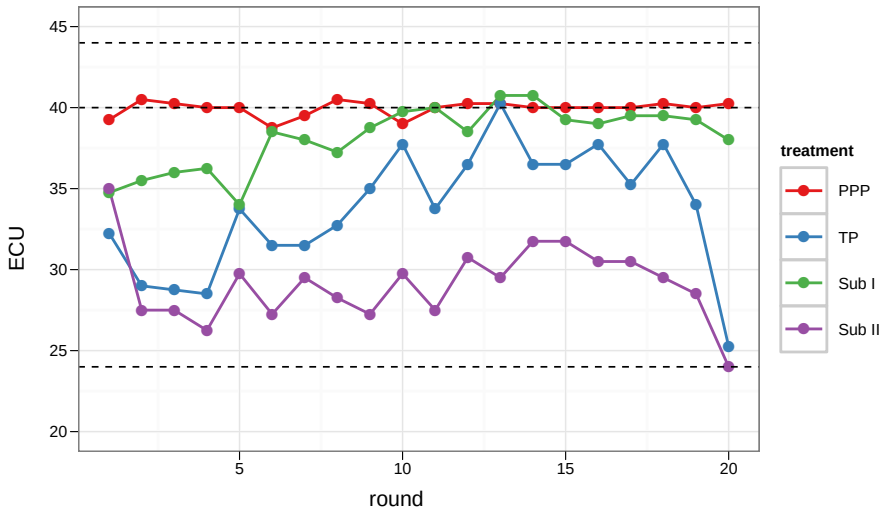

Figure 16. The average total surplus in the four treatments. Recall that the first-best surplus is 44. The theoretically predicted surplus is 40 in PPP and Sub I, while it is 24 in TP and Sub II.

Moreover, if it is more important to avoid overinvestment in e, our experiment leads to another important insight. If the parties involved are interested in establishing reputations by acting in reciprocal ways, then traditional procurement might be superior compared to a public-private arrangement with the operator as main contractor. The reason is that if the investing party reciprocates generous payments, then it tends to do so by taking the investment decisions that are best for the main contractor in the Sub II treatment, while it takes the first-best decisions in the TP treatment. This finding suggests that paying more attention to reputation and reciprocal behavior might be an interesting avenue for future theoretical research on the organization of public procurement.

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Supplementary material

The following instructions were handed out to the participants in the PPP treatment:

Experimental Instructions

This experiment deals with procurement projects in the public sector.

In this experiment always 4 subjects interact within a group. In each group there is a principal (representing the government) and three private contractors that could build and subsequently operate a public infrastructure (e.g., a school, a prison, or a hospital).

At the beginning of the experiment you are randomly assigned either to the role of a principal or to the role of a private contractor. You will keep your role and stay within the same group throughout the whole experiment.

The currency in the laboratory is called ECU (Experimental Currency Unit).
Your initial endowment is 75 ECU.
Throughout the whole experiment your current balance is displayed on your screen.

The experiment consists of 20 rounds.

In detail, the experiment proceeds as follows.

Each round consists of three stages:

Stage 1:
Each of the three private contractors offers the principal a price P at which he is willing to build and operate the public infrastructure.

Stage 2:
The principal selects one of the three anonymized price offers P.

The two private contractors whose price offers were not selected make zero profits in this round.

Stage 3:
The private contractor selected in stage 2 decides how much he wants to invest in building the public infrastructure. There are two kinds of investments: investment A und investment B, which cost him 4 ECU each.

The investments affect the principal's revenue and the private contractor's operating costs (see the tables on the following page).

Depending on the investment decisions, the total investment costs are:

	no investment B	investment B
no investment A	0 ECU	4 ECU
investment A	4 ECU	8 ECU

Depending on the investment decisions, the operating costs are:

	no investment B	investment B
no investment A	24 ECU	12 ECU
investment A	12 ECU	0 ECU

The selected private contractor's profit in this round equals his price offer P minus his operating and total investment costs:

	no investment B	investment B
no investment A	P – 24 ECU	P – 16 ECU
investment A	P – 16 ECU	P – 8 ECU

The principal's profit in this round equals his revenue minus the payment P to the selected private contractor:

	no investment B	investment B
no investment A	48 ECU – P	36 ECU – P
investment A	60 ECU – P	48 ECU – P

Your payoff:
After the last round your final balance will be paid out to you in cash (1 ECU = 0.07 Euro). In case that your final balance is negative you will receive no payoff.

Please note:
During the whole experiment communication is not allowed. If you have a question, please raise your hand out of the cabin. All decisions are anonymous; i.e., no participant ever learns the identity of a person who has made a particular decision. The payment is conducted anonymously, too; i.e., no participant learns what the payoff of another participant is.

The following instructions were handed out to the participants in the TP treatment:

Experimental Instructions

This experiment deals with procurement projects in the public sector.

In this experiment always 7 subjects interact within a group. In each group there is a principal (representing the government), three builders that could build a public infrastructure (e.g., a school, a prison, or a hospital), and three operators that could subsequently operate this infrastructure.

At the beginning of the experiment you are randomly assigned either to the role of a principal, to the role of a builder, or to the role of an operator. You will keep your role and stay within the same group throughout the whole experiment.

The currency in the laboratory is called ECU (Experimental Currency Unit).
Your initial endowment is 75 ECU.
Throughout the whole experiment your current balance is displayed on your screen.

The experiment consists of 20 rounds.

In detail, the experiment proceeds as follows.

Each round consists of five stages:

Stage 1:
Each of the three builders offers the principal a price P_0 at which he is willing to build the public infrastructure.

Stage 2:
The principal selects one of the three anonymized price offers P_0.

The two builders whose price offers were not selected make zero profits in this round.

Stage 3:
The builder selected in stage 2 decides how much he wants to invest in building the public infrastructure. There are two kinds of investments: investment A und investment B, which cost him 4 ECU each.

The investments affect the principal's revenue and the operator's operating costs (see the tables in stage 5).

Depending on his investment decisions, the selected builder's profit in this round is:

	no investment B	investment B
no investment A	P_0 – 0 ECU	P_0 – 4 ECU
investment A	P_0 – 4 ECU	P_0 – 8 ECU

Stage 4:
The three potential operators learn the builder's investment decisions and thus know the operating costs.

Each of the three operators offers the principal a price P_1, at which he is willing to operate the public infrastructure.

Stage 5:
The principal learns the builder's investment decisions and selects one of the operators' anonymized price offers P_1. Then the selected operator operates the public infrastructure. The two other operators make zero profits in this round.

The selected operator's profit in this round equals his price offer P_1 minus his operating costs:

	no investment B	investment B
no investment A	P_1 – 24 ECU	P_1 – 12 ECU
investment A	P_1 – 12 ECU	P_1 – 0 ECU

The principal's profit in this round equals his revenue minus the payment P_0 to the selected builder and minus the payment P_1 to the selected operator:

	no investment B	investment B
no investment A	48 ECU – P_0 – P_1	36 ECU – P_0 – P_1
investment A	60 ECU – P_0 – P_1	48 ECU – P_0 – P_1

Your payoff:
After the last round your final balance will be paid out to you in cash (1 ECU = 0.07 Euro). In case that your final balance is negative you will receive no payoff.

Please note:
During the whole experiment communication is not allowed. If you have a question, please raise your hand out of the cabin. All decisions are anonymous; i.e., no participant ever learns the identity of a person who has made a particular decision. The payment is conducted anonymously, too; i.e., no participant learns what the payoff of another participant is.

The following instructions were handed out to the participants in the Sub I treatment:

Experimental Instructions

This experiment deals with procurement projects in the public sector.

In this experiment always 7 subjects interact within a group. In each group there is a principal (representing the government), three main contractors that could provide a public infrastructure (e.g., a school, a prison, or a hospital), and three subcontractors that could operate this infrastructure.

At the beginning of the experiment you are randomly assigned either to the role of a principal, to the role of a main contractor, or to the role of a subcontractor. You will keep your role and stay within the same group throughout the whole experiment.

The currency in the laboratory is called ECU (Experimental Currency Unit).
Your initial endowment is 75 ECU.
Throughout the whole experiment your current balance is displayed on your screen.

The experiment consists of 20 rounds.

In detail, the experiment proceeds as follows.

Each round consists of five stages:

Stage 1:
Each of the three main contractors offers the principal a price P_0 at which he is willing to provide the public infrastructure (i.e., to build it and to pay a subcontractor for subsequently operating it).

Stage 2:
The principal selects one of the three anonymized price offers P_0.

The two main contractors whose price offers were not selected make zero profits in this round.

Stage 3:
The main contractor selected in stage 2 decides how much he wants to invest in building the public infrastructure. There are two kinds of investments: investment A und investment B, which cost him 4 ECU each.

The investments affect the principal's revenue and the subcontractor's operating costs.

The principal's profit in this round equals his revenue minus the payment P_0 to the main contractor:

	no investment B	investment B
no investment A	48 ECU – P_0	36 ECU – P_0
investment A	60 ECU – P_0	48 ECU – P_0

The main contractor has to select and pay a subcontractor for operating the infrastructure. Depending on the main contractor's investment decisions, the subcontractor's operating costs are:

	no investment B	investment B
no investment A	24 ECU	12 ECU
investment A	12 ECU	0 ECU

Stage 4:
The potential subcontractors learn the main contractor's investment decisions and thus know the operating costs.

Each of the three subcontractors offers the selected main contractor a price P_1 at which he is willing to operate the infrastructure.

Stage 5:
The main contractor selects one of the three anonymized price offers P_1 and the selected subcontractor will then operate the public infrastructure. The two other subcontractors make zero profits in this round.

The selected subcontractor's profit in this round equals his price offer P_1 minus the operating costs (which depend on the selected main contractor's investment decisions in stage 3):

	no investment B	investment B
no investment A	P_1 – 24 ECU	P_1 – 12 ECU
investment A	P_1 – 12 ECU	P_1 – 0 ECU

Depending on his investment decisions, the selected main contractor's profit in this round is:

	no investment B	investment B
no investment A	$P_0 – P_1$ – 0 ECU	$P_0 – P_1$ – 4 ECU
investment A	$P_0 – P_1$ – 4 ECU	$P_0 – P_1$ – 8 ECU

Your payoff:
After the last round your final balance will be paid out to you in cash (1 ECU = 0.07 Euro). In case that your final balance is negative you will receive no payoff.

Please note:
During the whole experiment communication is not allowed. If you have a question, please raise your hand out of the cabin. All decisions are anonymous; i.e., no participant ever learns the identity of a person who has made a particular decision. The payment is conducted anonymously, too; i.e., no participant learns what the payoff of another participant is.

The following instructions were handed out to the participants in the Sub II treatment:

Experimental Instructions

This experiment deals with procurement projects in the public sector.

In this experiment always 7 subjects interact within a group. In each group there is a principal (representing the government), three main contractors that could provide a public infrastructure (e.g., a school, a prison, or a hospital), and three subcontractors that could build this infrastructure.

At the beginning of the experiment you are randomly assigned either to the role of a principal, to the role of a main contractor, or to the role of a subcontractor. You will keep your role and stay within the same group throughout the whole experiment.

The currency in the laboratory is called ECU (Experimental Currency Unit).
Your initial endowment is 75 ECU.
Throughout the whole experiment your current balance is displayed on your screen.

The experiment consists of 20 rounds.

In detail, the experiment proceeds as follows.

Each round consists of five stages:

Stage 1:
Each of the three main contractors offers the principal a price P_0 at which he is willing to provide the public infrastructure (i.e., to pay a subcontractor for building the infrastructure and to subsequently operate it).

Stage 2:
The principal selects one of the three anonymized price offers P_0.

The two main contractors whose price offers were not selected make zero profits in this round.

Stage 3:
Each of the three subcontractors offers the selected main contractor a price P_1 at which he is willing to build the public infrastructure.

Stage 4:
The main contractor selects one of the three anonymized price offers P_1. The two other subcontractors make zero profits in this round.

Stage 5:
The selected subcontractor decides how much he wants to invest in building the public infrastructure. There are two kinds of investments: investment A und investment B, which cost him 4 ECU each.

Depending on his investment decisions, the selected subcontractor's profit in this round is:

	no investment B	investment B
no investment A	P_1 – 0 ECU	P_1 – 4 ECU
investment A	P_1 – 4 ECU	P_1 – 8 ECU

The investments affect the principal's revenue and the main contractor's operating costs.

The principal's profit in this round equals his revenue minus the payment P_0 to the main contractor:

	no investment B	investment B
no investment A	48 ECU – P_0	36 ECU – P_0
investment A	60 ECU – P_0	48 ECU – P_0

The main contractor's profit in this round equals his price offer P_0 minus the payment P_1 to the subcontractor and minus the operating costs (which depend on the selected subcontractor's investment decisions):

	no investment B	investment B
no investment A	P_0 – P_1 – 24 ECU	P_0 – P_1 – 12 ECU
investment A	P_0 – P_1 – 12 ECU	P_0 – P_1 – 0 ECU

Your payoff:
After the last round your final balance will be paid out to you in cash (1 ECU = 0.07 Euro). In case that your final balance is negative you will receive no payoff.

Please note:
During the whole experiment communication is not allowed. If you have a question, please raise your hand out of the cabin. All decisions are anonymous; i.e., no participant ever learns the identity of a person who has made a particular decision. The payment is conducted anonymously, too; i.e., no participant learns what the payoff of another participant is.