Holdups, Quality Choice, and the Achilles' Heel in Government Contracting

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Abstract

We investigate a long-term trade relationship in an incomplete contracts framework, and compare the equilibrium outcomes in public procurement (welfare-maximizing buyer) and private procurement (profit-maximizing buyer). There exist multiple trading opportunities which differ in benefits and production costs, but are indistinguishable for the court. Moreover, the seller can make relationship-specific investments to decrease the expected production costs of a high-quality projeczt, the 'innovation'. Given a contract-specific environment under which the optimal long-term arrangement is an at-will contract, a first-best result can always be attained in private procurement. In contrast, we show that public procurement may lead to suboptimal investments of the supplier. The government's weak ex-post individual rationality constraint turns out to be its Achilles' Heel: equilibrium trade prices differ in public and private procurement, although ex-post efficient trade is realized in both regimes. Accordingly, and in contrast to the literature, the superiority of private contracting does not hinge upon a trade off between allocative and productive efficiency. The article argues for a splitting-up of government institutions, investigates option contracting, and shows that efficiency is restored if the court can distinguish between both project versions.

1 Introduction

Inefficiencies in government behavior are a real-world phenomenon. The recent privatization waves in most industrialized countries, for example, are pursued mainly as a reaction to mismanagement of the public sector. As long as governments are assumed to maximize social welfare, however, economic theory has difficulties to find convincing explanations for the superiority of private as compared to public economic performance. This is not surprising, since, under welfare considerations, a welfare maximizer should always perform at least as well as a profit-maximizing agent. The present paper shows that this argument may be incorrect.

We analyze an incomplete-contract procurement model in a variant of the canonical Hart-Moore (1988) framework. A principal (which is either a profit-maximizing private buyer or a welfare-maximizing public buyer) enters a long-term trade relationship with a private supplier who must engage in relationship-specific investments, which increase the expected net benefit from an innovative project whose realization is uncertain at the beginning. The major problem the principal faces is to design a contract which induces optimal investments.

The main difference to the Hart-Moore setup concerns the introduction of a quality-choice problem. In line with some recent articles on the holdup problem, we assume that the good to be traded ex post is not only undescribable ex ante, but there exist additional trading opportunities. More precisely, we assume that there exists a lower-quality standard project which may be realized instead of a more expensive real innovation. Since ex ante the parties cannot describe the different projects sufficiently clearly to enable a court to tell them apart, an initial contract can not discriminate between both projects, but can only be contingent upon trade of any of the goods. This feature is realistic in large procurement relationships, first of all in the weapons-acquisition process. Not only the characteristics of a new airfighter can only roughly be specified prior to the development stage, but the private supplier may be able to foist on the government an old design as a real innovation. Therefore, arguments about product quality are notorious in weapons procurement. In many cases, the government complains that the delivered good does not meet particular quality requirements. Judicial decisions are ambiguous in this respect, which indicates that initial contracts were not, and could not be, comprehensively written. Moreover, the ex-post realization of large weapons systems is highly uncertain at the date when the project is started, say for budget reasons, changes of the political situation, or because the project's production costs increase excessively due to further progress in R&D. If such circumstances make the completion of an innovative military system inefficient ex post, it may be substituted by a cheaper, less sophisticated or less innovative, alternative design.

In our framework, the existence of this 'standard design' and its possible efficiency of realization are necessary conditions for inefficiencies in government procurement. While in private procurement efficient investments can always be induced under the optimal long-term contract, a welfare-maximizing principal may attain only suboptimal outcomes.

We are not the first to show relative inefficiency of public behavior: public choice theory investigates this issue extensively. This literature starts from behavioral assumptions on bureaucrats who do not maximize welfare, but instead pursue a private agenda which is modelled, for example, as maximizing the number of subordinates or output provided by the bureau. In a principal-agent model, Shapiro-Willig (1990) show that a privatized firm may outperform a public enterprise if the regulator's objective function includes particular private goals. In such setups, government activities go hand in hand with allocative and productive inefficiencies.

Even under the assumption of a welfare-maximizing government, however, a couple of contributions arrive at a relative inefficiency of public economic activities. In a privatization context, Schmidt (1996) demonstrates that privatization may outperform public governance. In his model, privatization erects an informational barrier between the welfare-maximizing government and the owner-manager. While only very incomplete contracts are feasible before the manager exerts cost-reducing effort, complete contracts on output become feasible at a subsequent stage. Hence, since the private owner-manager is privately informed on his type when the complete contract is written, he obtains an informational rent at the production stage, while output is distorted under the optimal adverse-selection contract. If the enterprise remains public, the government is symmetrically informed ex post and can enforce the ex-post optimal solution. However, since the public manager anticipates his exploitation, he will not exert any effort at a prestage. The private owner-manager's investment incentives, on the other hand, are positive due to the informational rent. This gives rise to the following tradeoff: while privatization induces ex-post inefficient decisions but increases positive effort, exactly the opposite happens in public enterprises.

In a less rigorous way, Schmidt's argument carries over to a situation without informational asymmetries. One may simply argue that privatization increases the manager's effort since he fears the profit maximizer's hard budget constraint, that is, his commitment to close the firm if it goes bankrupt. A welfare maximizer, in contrast, may decide to operate the firm even if profits are negative, since his value of output includes more than just profit. This issue has been emphasized in a slightly different context by Tirole (1994) who argues for a splitting-up of government institutions. While a welfare-maximizing minister should be in charge of the enterprise at an ex-ante stage to choose among promising projects, ex-post renegotiations with the agent (e.g., the public firm's manager) should be executed by a minister with a tougher budget constraint, e.g., the minister of finance.

All these approaches, however, suffer from the requirement that a welfare-maximizing head of government does not intervene in the private owner's or finance minister's ex-post discretion. Hence, the government has to *commit ex ante to accept suboptimal allocations ex post*. In the privatization example above, the government would have an interest to let the private owner refrain from a shut-down of the enterprise in exchange for a side-payment. If this intervention is anticipated by the agent, privatization or splitting-up of government becomes useless.[1] In contrast, our paper demonstrates that an ex-ante commitment to ex-post inefficient behavior is not a necessary prerequisite to motivate the relative inefficiency of public contracting: independently of the principal's objective function, ex-post efficiency is obtained although private and public principal differ in their renegotiation habits. The government's softer renegotiation behavior turns out to be its Achilles' heel in the presence of a quality-choice problem.

As stated above, our framework is in line with some recent contributions which extend the standard incomplete-contracts procurement framework with self-interested parties by introducing different project versions. Aghion-Tirole (1994, 1995), Hart (1995), Lülfesmann (1995) and Segal (1995) suppose that these versions are not distinguishable for the court. As in our setup, the parties' specific investments increase the expected net surplus from trade of one of the goods, in our context of the 'innovation'. While most of these articles find that one-sided efficient investments may still be attained,[2] they also demonstrate that underinvestment cannot be avoided if both-sided investments are relevant.[3] These findings reconfirm the outcome of Hart-Moore (1988) who demonstrated the existence of the holdup problem in a one-good world if both parties have to invest in specific assets. In the main part of our paper, we stick to their assumption that the

[1] Olsen-Torsvik (1993) investigate a dynamic adverse-selection framework where the agent produces output in two periods, and obtain a possible suboptimality of public procurement. They assume that, at the beginning of the first period, only short-term contracts are feasible, so that a ratchet effect arises. Since a public principal maximizes welfare, he optimally offers a contract at the beginning of the second period which may make it harder (compared to a profit-maximizing principal) to elicit the private agent's information at the first stage. Hence, their result is also driven by the private principal's commitment to an ex-post inefficient outcome.

[2] The optimal long-term contract in these settings is surprisingly simple: while Aghion-Tirole (1994, 1995) find that a contract on property rights is second-best optimal, Segal (1995) even arrives at cases where any long-term contract is useless.

[3] The only exception is Lülfesmann (1995). Under the assumption of the Hart-Moore renegotiation game, he finds that efficient investments may be attained for certain specifications of the parameters of the model.

court can only observe if trade is realized, but cannot observe individual responsibility for a no-trade outcome: under this assumption, Hart-Moore demonstrated that the optimal contract is a simple at-will contract, which allows both parties to step back from trade if they want to.

The above mentioned restatements of Hart-More's underinvestment result in multi-good setups are interesting since several articles showed that a particular change of Hart-Moore's verification assumptions make the first best achievable if only one good is present.[4] Nöldeke-Schmidt (1995) proved that the first best can be achieved by the employment of option contracts where one party can unilaterally insist on trade. Option contracts become feasible if the court can not only monitor the accomplishment of trade, but it can verify if the seller delivered the project. This modification makes it possible to let payments be contingent on the seller's delivery decision, and to solve the holdup problem by option contracting.[5] The present paper compares the efficiency implications of at-will and option contracts in our multi-quality setup, and finds a reversal of their efficiency implications.

Finally, our paper extends the Hart-Moore (1988) renegotiation game to the case of multiple trade opportunities.[6] Clearly, after the state of the world has been materialized, it may be in the mutual interest of buyer and seller to verify the characteristics of the projects before the court. It is very plausible to assume that they can bring up enough pieces of evidence to enable the court to learn the precise difference between the projects. Thus, we allow the parties to verify the projects' attributes after the characteristics of the goods have become known, and show that this ex-post verification is necessary to enable efficient trade of the innovation.

The paper is organized as follows. In section 2 we present the model: the sequence of events, the specific setup and a first-best benchmark. Section 3 introduces the renegotiation and verification game. We then solve the model for the case of nonverifiable differences between the projects (Section 4) and provide a comparison of public and private procurement. Section 5 examines several extensions: a split-up of government institutions, option contracts, and the case of verifiable differences between the projects. A conclusion follows.

[4]In a variable-quantity setting, Chung (1991) and Aghion-Dewatripont-Rey (1994) showed that a first-best result can be attained by 'specific-performance' contracts, that is, if the trade of a prespecified quantity can be enforced by the court in the case of disagreement between the parties.

[5]In an extension of their model, Nöldeke-Schmidt (1995) allow for different projects. In this case, their first-best result only holds under a very restrictive assumption; see below.

[6]The contributions with multi-good setup cited above usually do not specify a noncooperative renegotiation game, but simply assume that renegotiation leads to ex-post efficiency via Nash-bargaining.

2 The Model

2.1 Setup and Stages

There are two actors, a procurement agency and a private seller. The private seller has been determined by means of some bidding process or, alternatively, has been directly chosen by the government since he is the only potential seller. The procurement game refers to the trade of one unit of an indivisible good, frequently called the 'project'. This project can take two different forms: first, there is a standard good 1 placed at the disposal of the parties. Second, a new version of the good, called good 2, is developed after the start of the relationship. The final trade concerns at most one of the goods. For convenience, 'no trade' will be denoted as 'trade' of good 0.

We assume that both agency and private contractor are risk neutral, and consider a game with perfect and complete information. The time structure of the game is illustrated by Figure 1.

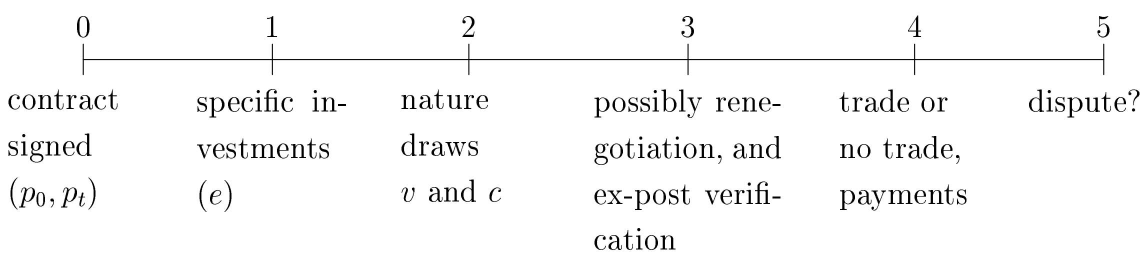

Figure 1

At *date 0* firm and government write an initial contract. Although we suppose perfect information of the agents, it is assumed that a third party - the court - can only observe
(1) if there has been trade or not, and
(2) whether the corresponding payments have been made.

The above verifiability assumptions, which prevent complete contracting, are made in Hart-Moore (1988): first, an outsider like the court can hardly verify the costs and benefits of the projects, and the same holds for the relationship-specific actions of the seller. Second, since the court cannot observe the responsibility for a no-trade outcome, individual breach penalties (as in option contracts) are not feasible. Hence, only at-will contracts can be written at the beginning of the relationship, so that final trade is a voluntary decision of both agents.

In our two-good setting, the assumptions additionally imply that the court can only observe if there is trade of *any* good or not unless ex-post verification takes place at date 3. The innovative design is not yet invented when the initial contract is written and, therefore, the characteristics of the improved project cannot sufficiently be prespecified. Moreover, the verifiable physical characteristics of the standard project are a subset of the innovation's attributes, so that the court cannot tell apart the two projects. Denoting quantities by x_i, $i \in \{0, 1, 2\}$, the courts information partition is

$$\mathcal{I} = \{(x_0), (x_1, x_2)\}. \tag{1}$$

Given the Hart-Moore verifiability assumptions, the only ex-ante enforceable contracts consist of a tuple (p_0, p_t) with p_t as the price to be paid if any project is realized at date 4.

After signing the contract, at *date 1* the supplier can engage in relationship-specific investments e at convex costs $\psi(e)$. These firm investments stochastically reduce the expected production costs c_2 of the innovation.

At *date 2*, nature determines the state of the world $s = (v_1, c_1, v_2, c_2) \in \mathcal{S}$, where v_i, c_i indicate project i's gross value and production costs, respectively. The elements of s are drawn from independent distributions. Let us denote a good with positive net surplus, $v_i - c_i(1 + \lambda) > 0$, a *valuable* project, where $\lambda \geq 0$ is the shadow price of public funds. Since the innovative project fits better to the government's demand, it is natural to assume that its gross benefit v_2 is always higher than v_1. Moreover, it is straightforward that the innovative project has higher production costs than the standard project. Finally, higher value and higher costs combine so as to make trade of the innovation efficient whenever it is valuable. More formally, these assumptions can be summarized as follows:

ASSUMPTION 1: (1) $v_2 > v_1 > 0$,
(2) $c_2 > c_1 > 0$,
(3) $v_2 - c_2(1 + \lambda) > 0 \quad \Longrightarrow v_2 - c_2(1 + \lambda) > v_1 - c_1(1 + \lambda)$.

Hence, after the draw of nature the agents face one of the four situations A to D:
A: both basic and innovative good are valuable; trade of the innovative good is efficient since its net value is higher;
B: only the innovative good is valuable whence its trade is efficient;
C: only the basic good is valuable and, therefore, should be traded;
D: no good is valuable; no trade is the efficient solution.

The distinction between these four cases is the driving force of our analysis. The gist of this analysis can very clearly be shown by means of an example. A more general setting based on Assumption 1 would in no way modify the economic message, but require unneccessary mathematical complication.[7] The example, which we shall use in the following, is

[7]Actually, all results of this paper remain valid under Assumption 1. While parts (1) and (2) are

described in table 1.

Standard Project (x_1)	Innovative Project (x_2)
• benefits $v_1 \in \{\underline{v}_1, \overline{v}_1\}$, with $q = \text{prob}\{v_1 = \overline{v}_1\}$.	• benefits $v_2 \in \{\underline{v}_2, \overline{v}_2\}$, with $\mu = \text{prob}\{v_2 = \overline{v}_2\}$.
• costs $c_1 \equiv c$.	• costs $c_2 \in \{\underline{c}_2, \overline{c}_2\}$, $\underline{c}_2 = c + \underline{F}$, $\overline{c}_2 = c + \overline{F}$, with $\rho(e) = \text{prob}\{F = \underline{F}\}$, $\rho'(e) > 0$, $\rho''(e) = 0$.

$$\min\{\overline{v}_2 - \overline{c}_2(1+\lambda), \underline{v}_2 - \underline{c}_2(1+\lambda)\} > \overline{v}_1 - c(1+\lambda) > 0 > \max\{\underline{v}_2 - \overline{c}_2(1+\lambda), \underline{v}_1 - c_1(1+\lambda)\}.$$

Table 1

The assumptions of Table 1 make sure that any of the relevant cases A to D can occur. In particular, the relations in the last line of the table guarantee that the realization of the innovative project is efficient in every state of the world unless low benefits and high production costs of this project appear simultaneously. In the latter case, the innovation is non-valuable and the standard good should be produced if it is valuable ($v_1 = \overline{v}_1$).

Given one of the situations A to D, at *date 3* the parties can enter renegotiations on prices and verify the projects' characteristics. Verification means that the projects' physical attributes are specified, which enables the court to distinguish between both goods and hence shift its information partition from $\mathcal{I}$ to $\mathcal{I}^*$, where $\mathcal{I}^*$ is defined as

$$\mathcal{I}^* = \{(x_0), (x_1), (x_2)\}. \tag{2}$$

To assume ex-post verifiability is quite natural in our setting: after the state of the world has become clear, there exist blue prints of both versions of the project which can be handed over to the court. Ex-post verification makes sense only if the initial contractual terms are revised. Hence, we assume that any of the prices agreed upon at the beginning

indispensable since they imply that buyer and seller prefer different project versions, part (3) is not essential as long as the presence of a standard good reduces first-best investments.

can be changed by mutual agreement at date 3. Furthermore, if verification is part of the parties' strategies, the parties can add one more trade price to the initial price tuple.

Finally, at *date 4*, at most one of the goods is traded if both firm and government voluntarily agree. The corresponding payments - initially contracted or renegotiated - are made and the game ends unless there are disputes on delivery or payments.

If such a dispute occurs at *date 5*, the court applies a particular decision rule to enforce either the old or a revised contract.

As already mentioned in the introduction to this paper, in section 5 we shall analyze several extensions of our basic setting:

(i) first, we shall relax the assumption that a single procurement agency is responsible for the whole relationship with the seller. We propose a split-up between a department of defense which is in charge of the project until the start of the renegotiation phase, and a budget department which is made responsible for executing possible renegotiations of the trade price;

(ii) second, we shall allow the court to observe who is responsible if there is no trade, and replace at-will contracting by option contracting. This is of particular interest, since the debate on Hart-Moore's 1988 impossibility result concentrated on their restrictive verifiability assumptions. In the original Hart-Moore setting, option contracts could be shown to be superior to at-will contracts (Nöldeke-Schmidt, 1995). As we shall see, this does not hold in our setting where at-will contracts are superior;

(iii) third, we will examine the case where at the contract date the court is able to distinguish between the two goods, that is, has an information partition $\mathcal{I}^*$, whence the ex-ante incomplete contract consists of a triple (p_0, p_1, p_2) designated for the corresponding states of the information partition the court faces ex post.

2.2 Objectives and First-Best Benchmark

The government has a welfare objective. It maximizes the sum of consumer surplus and the supplier's profit, but is subject to costs of raising public funds whose shadow price is $\lambda \geq 0$ (see, for example, Laffont-Tirole 1986, 1993).[8] Hence, the government's objective

[8] For a discussion of the theoretically correct consideration of shadow costs of public funds in welfare functions see Hylland and Zeckhauser (1979), Christiansen (1981) and Kaplow (1995).

function can be written as

$$U^G = \Sigma_{i=0}^2 \{x_i(v_i - p_i(1+\lambda)) + [x_i(p_i - c_i) - \psi(e)]\} \quad (3)$$
$$= \Sigma_{i=0}^2 x_i[v_i - c_i - \lambda p_i] - \psi(e),$$

where $p_i,\ i = 0, 1, 2$ denotes the final trade (or no-trade) price and x_i indicates the realized allocations. All x_i are zero-one variables, however, only one of them actually takes the value of unity. (No trade, trade of good 1, and trade of good 2 are mutually exclusive.)

The profit-maximizing supplier bears the investment and the production costs (if trade is realized) and is compensated by a payment from the government. His utility function is

$$U^S = \Sigma_{i=0}^2 x_i(p_i - c_i) - \psi(e), \quad (4)$$

and his participation constraint requires U^S to be nonnegative at date 0.

For later reference, we calculate the first-best benchmark of this model.

Ex-post efficiency requires (a) trade to take place if and only if this increases welfare (i.e., a valuable project exists) and (b) that the project generating the higher net value is realized, i.e.

$$x_1^* = 1 \iff \max\{v_1 - c_1(1+\lambda), v_2 - c_2(1+\lambda), 0\} = v_1 - c_1(1+\lambda) \quad (5)$$
$$x_2^* = 1 \iff \max\{v_1 - c_1(1+\lambda), v_2 - c_2(1+\lambda), 0\} = v_2 - c_2(1+\lambda) \quad (6)$$
$$x_0^* = 0 \iff \max\{v_1 - c_1(1+\lambda), v_2 - c_2(1+\lambda), 0\} = 0. \quad (7)$$

Note that the specific investment of the firm is already sunk at the date of final trade and therefore does not influence the ex-post efficient trade decisions.

Ex-ante efficiency implies welfare-optimal specific investments e^*. Under the assumptions of table 1, the efficient investment level maximizes the concave program

$$max_e\, \mathcal{W} = \rho(e)\mu[\overline{v}_2 - \underline{c}_2(1+\lambda)] + \rho(e)(1-\mu)[\underline{v}_2 - \underline{c}_2(1+\lambda)] \quad (8)$$
$$+ (1-\rho(e))\mu[\overline{v}_2 - \overline{c}_2(1+\lambda)] + (1-\rho(e))(1-\mu)q[\overline{v}_1 - c(1+\lambda)] - \psi(e)(1+\lambda).$$

Since transfers are not welfare-neutral for any positive λ, the participation constraint of the private contractor is binding in this program.[9]

[9] Since the supplier's participation constraint is binding, the investment costs must (in expectation) be borne by the government. For this reason, the welfare function (8) must take into account the shadow price on investment costs $\psi(e)$.

The unique efficient investment level is implicitly given by the first-order condition

$$\mathcal{W}_e(e^*) = 0 \quad \Leftrightarrow \quad \rho_e(e^*)\left\{(1-\mu)\left[\frac{\underline{v}_2 - q\overline{v}_1}{1+\lambda} + qc\right] + \mu\overline{c_2} - \underline{c_2}\right\} - \psi_e(e^*) = 0. \qquad (9)$$

The efficient investments implicitly defined by (9) will be used as a benchmark to be compared with the actual choice of the supplier's investments in the equilibrium of the game. A *first-best result* is established if both ex-ante and ex-post efficiency are attained in a subgame-perfect equilibrium.

3 Renegotiation Game and Ex-post Verification

At date 3, after the state of the world has been realized, the parties can renegotiate the initial terms of contract. We extend Hart-Moore's (1988) renegotiation game[10] by allowing for ex-post verification of the differences between the two projects:

- *Date 3 – Revision Game and Ex-post Verification*
  Both parties may simultaneously submit written messages to each other. These messages can specify

  (1) a physical description of at least one of the projects' physical characteristics, V_i; $i \in \{1,2\}$, and

  (2) revised trade or no-trade prices, p_0, p_t, or $\{p_1, p_2\}$ in combination with the ex-post verification.

  If an offer verifies a good's attributes, a revised price offer can be contingent on this good. Messages are submitted to the other party before date 4. Their submission is non-observable for the court.

- *Date 4 – Trade Stage and Payments*
  At this date, both parties have to decide which (if any) good they want to trade. We assume the following sequential structure: the seller commits to the delivery of a good $i \in \{1,2\}$, or to no delivery at all. He will agree to trade if he anticipates acceptance of the government, and an equilibrium trade price p_i^e so that $p_i^e - c_i \geq p_0$. Having observed the seller's decision, the government may agree or refuse to trade

[10] We use Nöldeke-Schmidt's (1995) version of the Hart-Moore renegotiation game. In contrast to the original formulation where messages are submitted sequentially over a certain time interval, Nöldeke-Schmidt they assume that revision offers are sent simultaneously at a single date. This assumption simplifies the analysis without changing the equilibrium outcome; see their paper.

good i. If the government rejects, trade cannot take place. If $v_i - c_i - \lambda p_i^e \geq -\lambda p_0$, the government agrees. In this case, the seller produces and successfully delivers good i to the government. [11]

Moreover, at this date payments between the parties are realized.

- *Date 5 – Dispute Game*

  Each party can appeal to a court if it does not agree to the payments at date 4. At this dispute stage, each party may simultaneously reveal to the court messages it has received from the other party. The court rules as follows: the initial contract remains valid unless

  (1) exactly one of the parties presents a message (a new contract) referring to the trade outcome at date 4 as observed by the court (which can be no trade, trade, or trade of good i if the revealed message includes V_i);

  (2) both parties present messages which refer to the physical outcome of date 4 as observed by the court, and which are not in contradiction to each other.[12]

  If one (or both) of the parties presents a message which does not refer to the physical outcome of the trade stage as observed by the court, the court considers this message as non-existing.

4 Equilibrium Analysis

4.1 Renegotiation and Trade

We solve the model by backward induction. Hence, we start be analyzing the equilibria of the verification and renegotiation game (dates 3 – 5). Recall from the description of the game that at date 3 the agents alternatively face eight possible states of the world which are grouped into one of the four possible cases illustrated in table 2 below. In this table, $s_k, k = i, ...viii$ denote the possible states of the world which nature determines under the

[11] Alternatively, one could think of a sequential structure where the seller actually produces a good $i \in \{1, 2\}$. After a delivery of x_1 or x_2, the government decides to accept this project. If it does, physical trade is realized. Under this sequential structure, our results remain qualitatively unaffected. See footnote 19 below.

[12] If one party presents an offer which contains only a new trade price p_t, while the other presents an offer (p_i, V_i), these offers are not in contradiction after good i has been traded. If j has been traded, however, (1) is relevant and the court enforces p_t.

assumptions of table 1.

x_2 \ x_1	valuable	not valuable
valuable	A $x_2^* = 1$ $s_i = (\overline{v}_2, \underline{c}_2, \overline{v}_1)$ $s_{iii} = (\underline{v}_2, \underline{c}_2, \overline{v}_1)$ $s_v = (\overline{v}_2, \overline{c}_2, \overline{v}_1)$	B $x_2^* = 1$ $s_{ii} = (\overline{v}_2, \underline{c}_2, \underline{v}_1)$ $s_{iv} = (\underline{v}_2, \underline{c}_2, \underline{v}_1)$ $s_{vi} = (\overline{v}_2, \overline{c}_2, \underline{v}_1)$
not valuable	C $x_1^* = 1$ $s_{vii} = (\underline{v}_2, \overline{c}_2, \overline{v}_1)$	D $x_0^* = 1$ $s_{viii} = (\underline{v}_2, \overline{c}_2, \underline{v}_1)$

Table 2

Analyzing the verification and renegotiation game, we obtain the following result:

Proposition 1: *If* $\lambda < \overline{\lambda} \equiv (\overline{v}_1 - c)/\overline{c}_2$, *there exists a unique pareto-efficient subgame-perfect equilibrium of the renegotiation game, in which efficient trade is realized in every state of the world. In particular,*

(1) *Consider the state of the world where no trade is the ex-post efficient decision (Case D). In this case, there is no trade and* p_0 *is paid from the government to the private firm.*

(2) *Consider a state of the world where only one good* $i \in \{1, 2\}$ *is valuable and therefore should be traded (Cases B and C). In each of these states,* i *is traded at the initial trade price as long as* $(v_i - c_i)/\lambda \geq p_t - p_0 \geq c_i$, *i.e. both parties prefer trade to no trade. If only party* j, $j \in \{G, S\}$, *agrees to trade of* i *at* p_t, *renegotiation induces an equilibrium trade price which makes the other party* k, $k \neq j$ *just indifferent between trade and no-trade.*

(3) *Consider a state of the world where both goods are valuable, but trade of* x_2 *is ex-post efficient (Case A). In these states of the world, the following results hold:*

(a) *If $p_t - p_0$ is so low that the seller prefers no trade to trade of both x_1 and x_2, efficient trade of the innovation is induced via renegotiation and ex-post verification. The renegotiated trade price makes the seller indifferent between trade of x_2 and no trade;*

(b) *If a medium price difference $p_t - p_0$ induces both parties to prefer trade of x_1 to no trade, then renegotiation and ex-post verification guarantee efficient trade of the innovation. The realized trade price makes the supplier indifferent between trade of x_1 and x_2;*

(c) *If $p_t - p_0$ is so high that the government prefers no trade to trade of both x_1 and x_2, there is efficient trade of x_2. The equilibrium trade price after renegotiation makes the government indifferent between trade of x_2 and no trade.*

Proof: see appendix; Corollary 1 establishes the equilibrium prices.

To interpret this proposition, consider first cases B, C and D. In the corresponding states of the world, at most one of the goods is valuable. The proposition asserts that in these situations the results of Hart-Moore (1988) fully carry over to our two-goods setup. If no good is valuable, it is impossible that both parties will agree to trade at any price. Accordingly, they face a zero-sum game, and p_0 is paid without renegotiations. If only one of the goods is valuable, the other good will never be traded under at-will contracting. The voluntary-trade feature of at-will contracting ensures that the parties' default points in renegotiations are unaffected by the presence of this non-valuable project. In the spirit of Hart-Moore, renegotiations occur if trade is efficient, but one of the parties refuses this project's realization given initial prices. The whole renegotiation power accrues to the party which is willing to trade under the initial terms of contract.[13]

Now consider case A, where both goods are valuable, but trade of the innovation is efficient. This case is quite different from the one-good renegotiation game. In particular, suppose that under the initial prices both parties prefer trade of x_1 to no trade. Then the supplier will always deliver the standard good, since its production costs are lower. To prevent this ex-post inefficient outcome, the government will submit a revised contract offer including ex-post verification of x and a corresponding price offer p_2^G. This offer makes the seller just indifferent between trade of the innovation at the revised trade price, and

[13]This equilibrium outcome of the Hart-Moore renegotiation game is in sharp contrast to the more familiar Rubinstein game: there, the outcome of renegotiations is unaffected by the identity of the party which refused trade at the prespecified trade price; for an application of this bargaining game to an incomplete-contract model see McLeod-Malcomson (1993).

trade of the standard project. Accordingly, in contrast to the one-good setup, the seller's default point is shifted upward, namely to the net payoff he can accrue by delivering x_1.

The uniqueness result[14] of Proposition 1 rests upon the restriction to sufficiently small shadow costs of public funds ($\lambda < \overline{\lambda}$). This restriction ensures that - at the price difference $p_t - p_0$ where the government becomes unwilling to accept the standard good - the seller agrees to trade the innovation under initial prices even if production costs are high. Imagine a higher λ: then there are price differences $p_t - p_0$ under which, in some states of the world, the government is unwilling to trade the standard project, while at the same time the supplier credibly would reject trade of the innovation. Clearly, renegotiations will arise in such a situation, but now two different equilibria may occur: first, an efficient equilibrium in which x_2 is traded, and the whole renegotiation power rests with the government. Second, there exists an equilibrium in which the inefficient (but valuable) standard good is traded and the seller obtains the whole surplus from trade.

4.2 Investment Choice

We can now turn to the question whether ex-ante efficiency can be achieved, that is, whether there are prices agreed upon at date 0 which induce efficient specific investments of the seller.

For subsequent comparison, let us first briefly sketch the solution in case of private procurement, where the buyer maximizes profits.[15] In private procurement, the solution of the renegotiation/trade game differs from the exposition in the last subsection. The buyer's profit maximization changes the set of situations in which renegotiation actually occurs, but not his renegotiation behavior. Therefore, the spirit of proposition 1 carries over to private procurement: if one of the parties does not agree to trade the *efficient* good under the initial prices, the other party has the whole renegotiation power. Now, consider a price difference $p_t - p_0 > \overline{v}_2$. Since the private buyer's ex-post objective function is $U^B = v - p$, he will not accept any good under the initially contracted terms of trade. Accordingly, the seller has to submit a renegotiation offer to make trade possible, and the best he can do is to make the buyer indifferent between trade of the innovation and no trade. Therefore, his optimal offer specifies the innovation if trade of x_2 is efficient, and a new trade price is $p_i^S = p_0 + v_i$ if good $i \in \{1, 2\}$ is the ex-post efficient project. Since these

[14]Since the party without renegotiation power is forced down to its no-trade payoff, there exists an additional no-trade equilibrium in which this party submits an offer to prevent trade. This equilibrium outcome, however, is pareto-dominated and therefore neglected. See appendix.

[15]This is the focus of Lülfesmann (1995) who analyzes one- and both-sided investments for a profit-oriented buyer.

prices are realized in equilibrium, it is easy to see that the seller's investment incentives are optimal: up to the constant p_0 he obtains the whole surplus from trade, as well as the whole marginal benefit of his specific investments. Hence, we can state the following result which will serve as a benchmark for comparison with the equilibrium investments in public procurement:

Proposition 2 (Lülfesmann 1995): *In private procurement, if only one-sided investments are relevant, a first-best result is always attained in the unique undominated subgame-perfect equilibrium of the game.*

Let us now turn to public procurement. Consider an arbitrary ex-ante contract (p_0, p_t). Employing Proposition 1, let $p_j^{(k)}$ be the final trade price in state k given that good j is traded (for convenience, we will restrict ourselves to the undominated efficient equilibrium outcomes). Inserting this subgame-perfect continuation of the game, the firm's program at date 1 can be written as

$$\begin{aligned} \max_e \quad U^S &= \rho(e)\mu \left[q(p_2^{(i)} - \underline{c}_2) + (1-q)(p_2^{(ii)} - \underline{c}_2)\right] \\ &+ \rho(e)(1-\mu)\left[q(p_2^{(iii)} - \underline{c}_2) + (1-q)(p_2^{(iv)} - \underline{c}_2)\right] \\ &+ (1-\rho(e))\mu\left[q(p_2^{(v)} - \overline{c}_2) + (1-q)(p_2^{(vi)} - \overline{c}_2)\right] \\ &+ (1-\rho(e))(1-\mu)\left[q(p_1^{(vii)} - c) + (1-q)p_0\right] \\ &- \psi(e). \end{aligned} \tag{10}$$

The necessary and sufficient first-order condition of this program has a unique solution e^S, which is implicitly given by

$$\begin{aligned} U_e^S = 0 \iff \quad & \rho_e(e^S)\Big\{\mu\left[q(p_2^{(i)} - p_2^{(v)}) + (1-q)\,(p_2^{(ii)} - p_2^{(vi)})\right] \\ +\quad & (1-\mu)\left[q(p_2^{(iii)} - p_1^{(vii)}) + (1-q)\,(p_2^{(iv)} - p_0)\right] \\ +\quad & (1-\mu)cq - \underline{c_2} + \mu\overline{c_2}\Big\} \\ -\quad & \psi_e(e^S) = 0. \end{aligned} \tag{11}$$

Obviously, e^S is a function of the final prices which in turn depend on the initially contracted prices p_0 and p_t, as shown in Proposition 1. Comparing (11) with equation (9) which determines the welfare-optimal investments, one immediately arrives at the result that $e^S = e^*$ if and only if

$$\begin{aligned} A \ &\equiv\ \mu\left[q(p_2^{(i)} - p_2^{(v)}) + (1-q)\,(p_2^{(ii)} - p_2^{(vi)})\right] \\ &+\ (1-\mu)\left[q(p_2^{(iii)} - p_1^{(vii)}) + (1-q)\,(p_2^{(iv)} - p_0)\right] \\ &\overset{!}{=}\ (1-\mu)\,\frac{\underline{v}_2 - q\overline{v}_1}{1+\lambda} \equiv A^*. \end{aligned} \tag{12}$$

4.2.1 No Shadow Costs

Let us first investigate the special case $\lambda = 0$.[16] Analyzing (12) under this assumption, we can state the following proposition:

Proposition 3: *Let $\lambda = 0$. Under at-will contracting, the following results are obtained:*

(a) if the standard good is non-valuable with positive probability ($q < 1$), in the unique undominated subgame-perfect equilibrium the first best is achieved; the optimal contracted price difference is monotonically increasing in q;

(b) if the standard good is valuable in every state of the world ($q = 1$), there is no ex-ante contract which induces the firm to invest at all into relationship-specific assets.

Proof: see appendix.

The intuition for these results is as follows. If there are negligible shadow costs of public funds, the government accepts the delivery of the standard good at any price if it is valuable. Hence, if $q = 1$, the seller can always successfully trade x_1 at the initially contracted trade price, and has an interest to deliver the cheaper standard project even if trade of the innovation is efficient. Accordingly, in such states of the world, renegotiation is necessary to make efficient trade possible. Since the government agrees to both trade of x_1 and of x_2 under the initial prices, it has all renegotiation power in the Hart-Moore renegotiation game, and the seller's net payoff is $max\{p_0, p_t - c\}$ independent of nature's draw. Hence, his payoff is invariant with regard to the level of specific investments, so that the equilibrium investment level must be zero.

Note that $q = 1$ is very likely to occur in practice. Think of x_1 as a good which is produced by a reliable standard technology, whence $v_1 > c_1$ has been established for a long time. Then, it is clear that governments strictly prefer the ongoing realization of this standard project to a termination of trade.

In contrast, for any $q < 1$, there is a positive probability that the standard good is non-valuable and delivery of this commodity will not be accepted by the government. In this case, the incentives of the firm are a strictly and unboundedly increasing function of the initially contracted price difference $p_t - p_0$. By an appropriate choice of the initial contract

[16] We assume that in this case the government has a lexicographic preference ordering with respect to allocative efficiency and monetary payments to the firm. This is equivalent to the government's objective function (3) if $\lambda \to 0$.

efficient investment incentives can be guaranteed, because the firm fears the possibility of no trade in case of high production costs.[17]

It is important to recognize that the underinvestment result for $q = 1$ stands in sharp contrast to the previous formalizations of the holdup problem in the one-good world. In the standard framework, one-sided efficient investments can always be induced even if only the property rights can be specified in an initial contract (Grossman-Hart (1986)).[18]

A serious objection to the underinvestment result of Proposition 3(b) could be the fact that it strongly exploits the assumption of negligible shadow costs of public funds. Clearly, governments are often concerned with the level of expenditures which have to be spent for a project. The presence of positive shadow costs, however, guarantees the existence of ex-ante contracts under which the government - in the same way as a private buyer - can credibly commit *not* to accept the standard project even if it is valuable. This more realistic scenario is the focus of the next subsection.

4.2.2 Positive Shadow Costs

Does the negative result of Proposition 3(b) disappear if the government faces nonnegligible shadow costs of public funds? For a positive λ, the government's value of each dollar paid to the supplier is $-\lambda$. The government agrees to trade a valuable good i only if $v_i - c_i \geq \lambda(p_t - p_0)$. For this reason, it is obvious that it now can commit to reject valuable trade if the trade payment is too high. Since prices count in the government's objective function, the objectives of private and public buyer are more closely aligned. Hence, one should expect that - as in the case of a private buyer - an optimal adjustment of the prespecified payments can always induce optimal investments of the firm for any ex-ante probability that the standard good is valuable. However, this intuition may be misleading as is shown in the following theorem.

Theorem 1: *Assume $\overline{\lambda} > \lambda > 0$. If $\mu\overline{F} > \underline{F}$, there exists a nonempty interval of q-values, $[\hat{q}, \tilde{q}], \tilde{q} > \hat{q}$, where efficient investments in public procurement cannot be attained by any ex-ante contract. In this range, the second-best optimal contract induces either under- or overinvestment.*

Proof: see appendix.

[17] An increase in q diminishes the equilibrium probability of no trade, so that the 'incentive difference' $(p_t - p_0)^*$ must be an increasing function of q.

[18] For a welfare-maximizing buyer, in a one-good setting Bös-Lülfesmann (1996) arrive at a first-best result even in the general case of two-sided investments. This positive result *requires* the assumption of vanishing shadow costs of public funds.

The theorem asserts that, under some technical conditions, there exists a nonempty interval of q in which efficient investments are not feasible. Figure 2 below illustrates the seller's equilibrium investments depending on the initially contracted prices for $\tilde{q} > q > \hat{q}$.

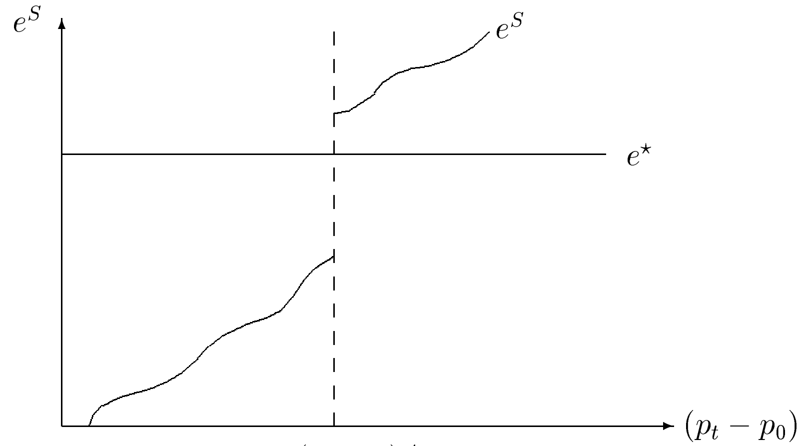

Figure 2

The figure demonstrates that the critical price difference is $b := (\overline{v}_1 - c)/\lambda$, where the government ceases to accept delivery of the standard good under the initial prices. At this price difference, there is a discontinuity in marginal and in absolute investment incentives. The reason is as follows:

(i) at low price differences $(p_t - p_0) \leq b$, the government is always willing to accept trade of the standard good at the initial prices. Hence, if trade of the innovation is efficient, the government must submit a renegotiation offer $p_2^G = (p_t + F, V_2)$ to make the seller indifferent between trade of both projects. As long as $q \leq \hat{q}$, efficient investments can be generated by an ex-ante contract with $(p_t - p_0)^* \leq b$; if $q > \hat{q}$, underinvestments are induced.

(ii) at high price differences $(p_t - p_0) > b$, the government is unwilling to trade the standard good at the initial prices. In that case, the innovative good is traded at the initial price p_t (instead of $p_t + F$ for $p_t - p_0 \leq b$). Since the firm now cannot recoup the higher production costs of the innovation via renegotiation, its investment incentives sharply rise at point b. For $q \geq \tilde{q}$, efficient investments can be attained by an ex-ante contract where $(p_t - p_0)^* > b$; for lower q, overinvestments are induced.

Summarizing, when $q \in [\hat{q}, \tilde{q}]$, the government is caught between Scylla and Charybdis, i.e. it has only the choice between underinvestment or overinvestment in specific assets.

Theorem 1 implies the following corollaries:

Corollary 2: *$lim_{\lambda \to 0}\ \hat{q} = lim_{\lambda \to 0}\ \tilde{q} = 1$. For $\lambda \to 0$, the interval $[\hat{q}, \tilde{q}]$ converges to the point $q = 1$, whence the result of Proposition 3 is replicated.*

Corollary 3: *Both $\tilde{q}$ and $\hat{q}$ are strictly larger than zero. If $q = 0$, or, alternatively, if the standard good does not exist, efficient investment can always be attained.*

Proof: see appendix.

The limit result of Corollary 2 is important, since it makes private and public procurement directly comparable. In a strict sense, efficiency requires different investment levels in private and public procurement, since the government has to take into account the shadow costs of public funds. For $\lambda \to 0$, however, this difference becomes negligible while the welfare loss resulting from the distortion of investments in public procurement is non-marginal.

Corollary 3 is in line with the previous literature on the holdup problem, especially Grossman-Hart (1986) and Hart-Moore (1988): as long as no (valuable) alternative trade opportunity exists, one-sided first-best investments can always be induced by a proper choice of ex-ante prices.

Let us summarize the results of this section.[19] Combining Propositions 2 and 3 and Theorem 1, we obtain the following Theorem 2 on the comparison of private and public procurement:

Theorem 2: *Assume that only the seller has to invest in relationship-specific assets. A first-best result can always be attained in private procurement. In contrast, in public procurement there potentially exists a nonempty interval $[\hat{q}, \tilde{q}]$ in which only a second-best optimal result can be attained. If $\lambda = 0$, no investment incentives can be given to the firm if the standard good is valuable in every state of the world. If $q = 0$, or if a standard good does not exist, a first-best result is always feasible even in public procurement.*

[19] Let us briefly sketch the outcome under a trade structure where the seller can produce (i.e., sink production costs) prior to the government's acceptance decision: for vanishing shadow costs, no investments can be induced for any $q \in [0, 1]$, since the government now accepts even a non-valuable standard good (the production costs are already sunk, and $v_1 > 0$). Hence, unless trade of x_1 is efficient, renegotiation is necessary to prevent an ex-post inefficient outcome. The reader will verify that the government holds the renegotiation power, so that the seller's payoff is independent of investments. For $\lambda > 0$, one can show that the results are qualitatively identical to those of Theorem 1.

The theorem establishes that private is preferable to public procurement due to the more efficient provision of relationship-specific investments. It contradicts the outcome of complete-contracting models, where welfare never decreases if a profit maximizing principal is replaced with a welfare-maximizer.[20] In contrast, some existing incomplete-contract models demonstrate the superiority of private contracting. This conclusion, however, rests on additional asymmetries between the two cases beyond the differing objectives of both principals. Shapiro-Willig (1990) and Schmidt (1996), for example, assume that privatization generates an informational barrier between the regulator and the firm.[21] This informational asymmetry after privatization prevents an ex-post efficient outcome and generates investment-enhancing quasi-rents of the agent. While the assumption on a correspondence between ownership rights and informational flows may be reasonable in practice, our result shows that a mere change in objectives suffices to motivate a welfare-dominance of private over public contracting.

5 Extensions

5.1 The Virtues of a Multiheaded Government

The result of the preceding section can be used as the basis of a policy recommendation in favor of a splitting-up of government authorities in the case of procurement issues. Recall Tirole (1994): the author deals with the regulation of a public enterprise, where the firm at a first stage can sink some nonmonetary investment in order to increase the benefits of subsequent production. If there is a monolithic welfare-maximizing government, the firm frequently will not invest even if this is efficient since it anticipates the government's soft budget constraint: after high production costs are realized, the government will forgive the poor performance for welfare reasons and realize the project. However, this changes if the regulatory duties are split up between, say, the spending minister and the finance minister. If at the second stage the public enterprise is governed by the finance minister who takes his decision on the basis of an observable monetary fraction of the total benefits, the budget constraint is hardened and higher investment incentives are given to the firm. As Tirole

[20]See, for example, De Fraja's (1993) privatization model. In his adverse-selection framework, a welfare-maximizing principal always demands higher production. Accordingly, the marginal benefit of inducing higher relationship-specific investment is increased compared to the case of a private principal. If the shadow costs of public funds converge to zero, even a first-best result can be attained by the well-known Loeb-Magat mechanism.

[21]Shapiro-Willig employ the further assumption that the public owner/regulator is malevolent, i.e. pursues a private agenda.

notes, his result rests on an important assumption: the benevolent prime minister must credibly commit not to intervene after high production costs are realized although such an intervention would be welfare-enhancing from an ex-post view.

In our case, the procurement process would have to be split between, for example, the department of defense (the 'spending ministry') which is in charge of the weapons procurement project until the start of the renegotiation phase, and a budget department (the 'finance ministry') which is responsible for possible renegotiations of the trade price. If the objectives of a private buyer are assigned to the budget department, the government can reproduce the first-best result of private contracting.[22] In contrast to Tirole's split-up of a regulatory decision, there is no need for an ex-ante commitment of the welfare-maximizing 'prime-minister' in our setting. This guarantees the independence of the budget department. Since an ex-post efficient result is always attained, there is no incentive for the prime minister ex post to interfere in the budget department's discretionary power.

5.2 Option Contracts

Under option contracts, the option holder can unilaterally insist on trade under the initial contract terms.[23] We will show that option contracts are strictly dominated by at-will contracting if the court ex-ante is unable to distinguish between different design features. This outcome is in contrast to Nöldeke-Schmidt (1995) who attain the opposite result in a setting without (essential) verifiability problems.[24]

Proposition 4: *The unique undominated SPE under option contracting is ex-post efficient. However, the supplier never provides relationship-specific investments.*

Proof: ex-post efficiency can be proved along the lines of Proposition 1; the proof for the no-investment result is sketched below.

The intuition for this result is equivalent to that of Proposition 3(b). Assume, for example, that the option contract assigns to the seller the right to supply some good at price p_t,

[22]Note that the merits of multiheaded government become even more obvious in a variable-quantity model: in general, a private buyer will order a different quantity than the government. Accordingly, the spending ministry should decide on the quantity to be produced.

[23]In order to make option contracts feasible, we must modify the verifiability assumptions of Hart-Moore (1988) from which we started in subsection 2.1 above: the court has not only to observe if there has been trade or not and whether the corresponding payments have been provided. He additionally has to observe if the seller delivered the good to the government.

[24]The main part of the paper is concerned with a one-ggod world. The authors assume that there exists at least one good which can verifiably be described ex ante, and whose value can sufficiently be influenced by specific investments. In our context, this assumption would imply verifiability of the innovation.

or not to supply and receive p_0. Assume $p_t - p_0 \geq c$. Unless renegotiation occurs, the seller will always deliver the standard good. Hence, if trade of the innovation, or no trade, is the ex-post efficient decision, the government will submit a renegotiation offer which makes the seller indifferent between trade of the standard good and his profit under the ex-post efficient allocation. As in the case of at-will contracts when $\lambda = 0$ and $q = 1$, the seller's net payoff is $p_t - c$ independent of the realized state. Clearly, for a low option price $p_t - c < p_0$, the seller will never exercise his option. Again, the government holds the renegotiation power, and the supplier's profits are independent of his investment level.

To summarize, under option contracting the seller's rent hinges only on the ex-ante contracted price difference $p_t - p_0$. Given this price difference, the firm achieves the same net payoff in all states of the world, which implies that it has no incentive to decrease the probability of the no-trade outcome by reducing the expected production costs of the innovation. The inefficiency result of Proposition 4 is attained even if the basic good is never produced in equilibrium, i.e. if $q = 0$. The mere possibility to deliver this good under option contracting is sufficient to destroy all investment incentives of the seller.[25]

5.3 Verifiable Project Designs

Finally, we will deviate from our previous assumptions on the information structure and assume that ex ante the parties can specify both projects sufficiently clearly, so that ex post the court is able to tell them apart. In this case, an enforceable (at-will or option) contract can be contingent on the three verifiable events 'no trade', 'trade of the standard good' and 'trade of the innovation' with prices (p_0, p_1, p_2). Accordingly, at date 0 the parties have one more instrument to achieve efficiency.

It is easy to demonstrate that this additional variable is sufficient to overcome the holdup problem. Imagine $p_1 < p_0 + c$ has been initially contracted. In this case, the seller will never deliver the standard project unless upward renegotiations occur. Notice the difference to an environment where the court cannot distinguish between the projects: while now by an appropriate choice of the price difference $p_2 - p_0$ the seller's investment incentives can be optimally adjusted[26] independent of q, this was not feasible if the goods cannot be specified in advance. The same argument holds if option contracts are employed. Under a seller's option and given $p_1 - p_0 < c$, the supplier will exercise his option to deliver

[25] It should be emphasized that in the absence of ex-post verifiability under option contracts the innovative good will never be traded under option contracts, whereas under at-will contracts trade of the innovation is an equilibrium outcome in states where the standard good's net value is negative.

[26] The optimal contract is characterized by $\overline{c}_2 > (p_2 - p_0)^* \geq \underline{c}_2$; see appendix.

the standard good under the initial terms of contract. Hence, his investment incentives are determined only by the choice of the second price difference $p_2 - p_0$, and they are strictly and unboundedly increasing in this variable.

The following proposition summarizes our discussion.

Proposition 5: *When the court ex ante can distinguish between the different types of projects, a first-best result is generated under both at-will and option contracting.*

Proof: see appendix.

While this efficiency result is not surprising, it is a necessary last step of our argument: whenever, in the main part of the paper, the government was unable to induce efficient investments, this did not hinge on the mere existence of additional trade opportunities, but on the parties' inability to specify projects in advance.

Note that, under the optimal contract, the seller receives a production rent if and only if the innovative project is actually realized ex-post. If a low net value of this project version makes it non-valuable, there may be trade of a standard version, but the supplier receives only his production costs - and hence incurs an overall loss from the trade relationship. This negative profit is necessary to induce him to invest efficiently: in the words of Rogerson (1989), a prize is paid only if inventory effort has come to a good end.

6 Conclusion

The article demonstrates a relative inefficiency of public as compared to private contracting. This main result is surprising since it has been derived under the assumption of a welfare-maximizing government, and does not utilize any ex-ante commitment of the government to accept an ex-post inefficient behavior.

We start from a standard incomplete-contracting procurement model à la Hart-Moore. However, in contrast to their approach as well as to most of the subsequent literature on organizational structures and the holdup problem, we introduce a quality-choice problem. Under two preconditions, suboptimal investments can arise in government contracting: first, the realization of a 'standard project' is efficient with positive probability; second, in the initial long-term contract the parties are not able to specify the differences between the standard good and a real invention.

In contrast, efficient investments can always be attained if the principal is a private buyer. Hence, the article sheds light on the mechanisms which may induce a superiority of private activities: a profit-maximizing principal can better commit himself to a tougher renegotiation behavior than a government even if the ex-post allocations are identical, which improves both the principal's bargaining position in renegotiations, and enables a continuous choice of the agent's (the seller's) equilibrium investments.

Interestingly, the welfare properties of at-will and option contracts are reversed if a quality-choice problem is brought into play. While at-will contracts can protect the government from accepting low quality, option contracts cannot prevent the seller from delivering 'lemons' to the government.

Finally, our results suggest that a split-up of government institutions may be welfare-enhancing. If the duties in the procurement process are divided between different branches of government, namely one minister who decides on the start of a project and the quantity to be ordered, and a second one who is in charge if renegotiations occur, the underinvestment problem can be resolved. Given this institutional structure, the equilibrium outcome is welfare-optimal ex post.

Appendix

Proof of Proposition 1:

The following corollary completely summarizes the trade prices in the unique undominated subgame-perfect equilibria of the renegotiation/trade stage:

Corollary 1: *Let $\lambda < (\overline{v}_1 - c_1)/\overline{c}_2$. Under at-will contracting, ex-post efficiency is attained as the unique undominated SPE of the Renegotiation/Trade game, if necessary by verification and renegotiation of ex-ante contracted prices. The corresponding unique equilibrium prices and allocations are as follows:*

(A) $v_2 - c_2(1+\lambda) > v_1 - c(1+\lambda) > 0 \Leftrightarrow x_2 = 1 = x_2^*$,

$$p_2^e = \begin{cases} max\{p_t + F, p_0 + c_2\} & if \quad p_t - p_0 \leq (\overline{v}_1 - c_1)/\lambda \\ min\{p_t, p_0 + (v_2 - c_2)/\lambda\} & if \quad p_t - p_0 > (\overline{v}_1 - c_1)/\lambda, \end{cases}$$

(B) $v_2 - c_2(1+\lambda) > 0 > v_1 - c_1(1+\lambda) \;\Leftrightarrow\; x_2 = 1 = x_2^*$

$$p_2^e = \begin{cases} max\{p_t, p_0 + c_2\} & if \quad p_t - p_0 \leq (v_2 - c_2)\lambda \\ p_0 + (v_2 - c_2)/\lambda & if \quad p_t - p_0 > (v_2 - c_2)/\lambda \end{cases}$$

(C) $v_1 - c_1(1+\lambda) > 0 > v_2 - c_2(1+\lambda) \;\Leftrightarrow\; x_1 = 1 = x_1^*$,

$$p_1^e = \begin{cases} max\{p_t, p_0 + c_1\} & if \quad p_t - p_0 \leq (\overline{v}_1 - c_1)/\lambda \\ p_0 + (\overline{v}_1 - c_1)/\lambda & if \quad p_t - p_0 > (\overline{v}_1 - c_1)/\lambda. \end{cases}$$

(D) $max\{v_2 - c_2(1+\lambda), v_1 - c_1(1+\lambda)\} < 0 \;\Leftrightarrow\; x_0 = 1 = x_0^*,\ p_0^e = p_0$,

where p_i^e is the equilibrium price if good i is traded.

The proof of Corollary 1 and Proposition 1 calculates equilibrium allocations and transfers in each possible state of the world given the initial terms of contract (p_0, p_t).

Case D: $x_0^* = 1$

Trade of a good i under at-will contracting requires an equilibrium trade price p_i^e which meets the condition $(v_i - c_i)/\lambda \geq p_i^e - p_0 \geq c_i$. Since $v_i < c_i(1+\lambda), i \in \{1,2\}$, this price does not exist. Hence, since the parties face a zero-sum game at date 3, $x_0 = x_0^* = 1$ is the unique equilibrium allocation, and p_0 is paid from the government to the seller.

Cases B, C: $x_i^* = 1$ and $v_j < c_j(1+\lambda), j \neq i$

First, note that the possibility of ex-post verification is irrelevant here: since the non-valuable good j can never be traded under at-will contracting, verification does not substantially enlarge the parties' strategy spaces. We begin by considering the case

$$\frac{v_i - c_i}{\lambda} \geq p_t - p_0 \geq c_i, \tag{13}$$

such that both parties prefer trade of i to no-trade under the initial terms of contract. Since each party can refrain from submitting any offer, and does not have to reveal received offers to the court, there is no room for renegotiation. Hence, the unique equilibrium allocation is $x_i = x_i^* = 1$, and x_i is traded at a price p_t. Now, assume initial prices where (13) does not hold. Then, exactly one of the parties is not willing to trade x_i, so that trade requires renegotiation. Assume that the party k which is unwilling to trade submits an offer proposing a revised trade price p_t^k, where $(v_i - c_i)/\lambda \geq p_t^k - p_0 \geq c_i$. Imagine trade of i at date 4. Then, the receiver of the message will never reveal p_t^k to the court, since $p_t > p_t^k$ for $k = S$, and $p_t < p_t^k$ for $k = G$. Since the proposer was not willing to trade x_i at price p_t, this result contradicts equilibrium trade at date 4. Therefore, a necessary condition for trade is a revision offer of the party which preferred trade to no trade under the initial prices. Consider an offer p_t^l of this party $l \neq k$ where $(v_i - c_i)/\lambda \geq p_t^l - p_0 \geq c_i$. Imagine trade at date 4. Then, receiver k can (and will) reveal l's offer to the court in case of dispute, and p_t^l is enforced. Since k (at least weakly) agrees to trade x_i to no-trade, in equilibrium trade is realized at date 4. Moreover, l will submit the most favorable offer, which makes k just indifferent between trade and no trade, i.e. $p_t^{*l} = p_0 + c_i$ if $l = G$, and $p_t^{*l} = p_0 + (v_i - c_i)/\lambda$ if $l = S$. Consider $l's$ optimal offer as specified above: given this offer, k cannot submit a counteroffer which increases his equilibrium payoff. To check this, one must recognize that l always has the option not to reveal p_t^k to the court, so that his minimum equilibrium payoff is determined by p_t^l. This proves the existence of an equilibrium where $x_i = x_i^* = 1$ at an equilibrium price $p_t^e = p_t^{*l}$.

Remark: Note that there exists a second, but pareto-dominated equilibrium where no-trade is realized: since party k is indifferent between trade and no-trade in the unique trade-equilibrium, he may submit an offer p_t^k which prevents trade, and gives k the same net payoff p_0 as in the trade equilibrium above.

Case A: $x_2^* = 1, v_1 - c_1(1+\lambda) > 0$

In these states of the world, both goods are valuable. The proof demonstrates that ex-post verification will be a necessary requirement to make efficient trade of the innovation possible. First, consider $(v_2 - c_2)/\lambda \geq p_t - p_0 \geq c_2$, so that both parties prefer trade of x_2 to no-trade. We must distinguish between two subcases:

(a) $(v_1 - c_1)/\lambda \geq p_t - p_0 \geq c_2$, i.e. the government even prefers trade of x_1 to no trade under the initial terms of contract. In this case, the seller can always successfully deliver the cheaper standard project,[27] and trade of x_2 requires a revision offer submitted by the government. The most favorable revision offer is $(p_2^{*G} = p_t + F, V_2)$, which makes S indifferent between trade of x_1 under the initial prices, and trade of x_2 at p_2^{*G}. Since S cannot attain a higher payoff, $x_2 = x_2^* = 1$

[27] One may think that G can prevent this option by submitting a revision offer $p_t^G > (v_1 - c_1)/\lambda$, and hence credibly commit not to accept delivery of x_1. S, however, can respond by an offer $(p_1^S < p_t, V_1)$. Given this strategy combination, both parties have a dominant strategy to reveal the received messages to the court after trade of x_1, and p_t is enforced since the court observes conflicting evidence.

in the unique (undominated) equilibrium, and the equilibrium price is p_2^{*G}.

(b) $p_t - p_0 > (v_1 - c_1)/\lambda > c_2$, i.e. G will not accept delivery of x_1. Again, the parties face a zero-sum game at date 3, and $x_2 = x_2^* = 1$ at the initial trade price p_t in the unique equilibrium of the game.

Second, consider $(v_2 - c_2)/\lambda > c_2 > p_t - p_0$. Two subcases have to be distinguished: (a) $p_t - p_0 \geq c_1$, i.e. S credibly rejects delivery of x_2, but prefers trade of x_1 to no-trade. In this case, the analysis is identical to the one above, i.e. the government offers $(p_2^{*G} = p_t + F, V_2)$ which is the equilibrium trade price in the unique (undominated) equilibrium of the game. (b) $p_t - p_0 < c_1$, i.e. S prefers no-trade even to the delivery of x_1. Here, it is easy to check that the government's best offer $(p_2^G = p_0 + c_2, V_2)$ is the equilibrium trade price in the unique (undominated) equilibrium.

Third, assume $(v_2 - c_2)/\lambda \geq p_t - p_0 > (v_1 - c_1)/\lambda$, so that G accepts delivery of x_2, but not x_1, under initial prices. By our assumption $\lambda < (\overline{v}_1 - c_1)/\overline{c}_2$, we know that $p_t - p_0 > \overline{c}_2$ in this case, so that S is always willing to deliver x_2 at p_t. Hence, the parties face a zero-sum game, and $x_2 = x_2^* = 1$ at the unique equilibrium price p_t.

Finally, assume $p_t - p_0 > (v_2 - c_2)/\lambda$, where the government is not willing to accept any good at price p_t. Hence, S will submit a revision offer $(p_2^{*S} = p_0 + (v_2 - c_2)/\lambda, V_2)$ which guarantees efficient trade and is the equilibrium price in the unique (undominated) equilibrium of the game. □

Proof of Proposition 3, Theorem 1, Corollary 2, Corollary 3: The proof constructs and examines the feasible ex-ante contracts.

(1) $p_t - p_0 < c_1$.
By corollary 1, if trade of good $i \in \{0, 1, 2\}$ is ex-post efficient, the equilibrium price is $p_i^e = p_0 + c_i$. Inserting these prices into (11) obviously yields zero incentives of the firm, since its net payoff is p_0 in all states of the world.

(2) $\underline{c}_2 > p_t - p_0 \geq c_1$.
Here, we have $p_2^{(i)} = p_2^{(iii)} = p_t + \underline{F}$, $p_2^{(ii)} = p_2^{(iv)} = p_0 + \underline{c}_2$, $p_2^{(v)} = p_t + \overline{F}$, $p_2^{(vi)} = p_0 + \overline{c}_2$ and $p_1^{(vii)} = p_t$. Inserting into (11), we obtain once again zero equilibrium investments: the supplier realizes a production rent $p_t - c_1$ with probability q, which is independent of the firm's investment decision.

(3) $\overline{c}_2 > p_t - p_0 \geq \underline{c}_2$.
At these prices, the firm's production rent depends on the innovation's production costs. Corollary 1 yields $p_2^{(i)} = p_2^{(iii)} = p_t + \underline{F}$, $p_2^{(ii)} = p_2^{(iv)} = p_t$, $p_2^{(v)} = p_t + \overline{F}$, $p_2^{(vi)} = p_0 + \overline{c}_2$ and $p_1^{(vii)} = p_t$. Inserting these prices into (12), we obtain the following condition for efficient investments:

$$A^* = \frac{\underline{v}_2 - q\overline{v}_1}{1 + \lambda}(1 - \mu) = (p_t - p_0)(1 - q) + q\underline{F} - \mu\overline{F} - (1 - q)\mu c_1 = A. \qquad (14)$$

Defining the function $S = A - A^*$ as the excess investment function of the firm, we have $\partial S/\partial(p_t - p_0) = (1-q) \geq 0$ and

$$\frac{\partial S}{\partial q} = \frac{\overline{v}_1}{1+\lambda}(1-\mu) + c_1\mu + \underline{F} - (p_t - p_0) < 0 \quad \text{iff} \quad p_t - p_0 > \frac{\overline{v}_1}{1+\lambda}(1-\mu) + c_1\mu + \underline{F} \quad (15)$$

If $q = 0$, the optimal $(p_t - p_0)^* = (1-\mu)\underline{v}_2 + \mu\overline{c}_2$ meets the condition above. Hence, since $\partial S/\partial q < 0$ and $\partial S/\partial(p_t - p_0) > 0$, $(p_t - p_0)^*$ must increase in q. At the upper bound of the interval (3) we are dealing with, $p_t - p_0 = \overline{c}_2$, and efficient investments are feasible for all q smaller than

$$q^*(S = 0, p_t - p_0 = \overline{c}_2) = \frac{(\overline{c}_2 - \underline{v}_2/(1+\lambda))(1-\mu)}{\overline{F} + c_1(1-\mu) - \overline{v}_1(1-\mu)/(1+\lambda) - \underline{F}} \quad (16)$$

where $0 < q^* < 1$ by assumptions made in table 1. We can conclude that the first-best investment level is feasible as long as $q \leq q^* < 1$.

(4) $(\overline{v}_1 - c_1)/\lambda \geq p_t - p_0 \geq \overline{c}_2$.
Corollary 1 implies $p_2^{(i)} = p_2^{(iii)} = p_t + \underline{F}$, $p_2^{(ii)} = p_2^{(iv)} = p_2^{(vi)} = p_t$, $p_2^{(v)} = p_t + \overline{F}$ and $p_1^{(vii)} = p_t$. Inserting these equilibrium prices, the efficiency condition (12) becomes

$$A^* = \frac{\underline{v}_2 - q\overline{v}_1}{1+\lambda}(1-\mu) = (p_t - p_0)(1-q)(1-\mu) + q\underline{F} - q\mu\overline{F} = A. \quad (17)$$

Again, defining $S = A - A^*$ as the excess investment function of the firm, one immediately obtains $\partial S/\partial(p_t - p_0) = (1-q)(1-\mu) \geq 0$ and

$$\frac{\partial S}{\partial q} = -(p_t - p_0 - \frac{\overline{v}_1}{1+\lambda})(1-\mu) + \underline{F} - \mu\overline{F} < 0 \quad (18)$$

by the assumptions made in table 1 (note that $\overline{v}_1/(1+\lambda) < \underline{v}_2/(1+\lambda) - \underline{F} < \overline{F} + c_1 - \underline{F}$). At the lower bound of this interval (4) we have $p_t - p_0 = \overline{c}_2$, and the excess investment function S is again zero for $q = q^*$. Since S is decreasing in q for any initial contract, and increasing in the price difference, we have to calculate the threshold level $\hat{q}$ generating $S(\hat{q}, p_t - p_0 = (\overline{v}_1 - c_1)/\lambda) = 0$ at the upper bound of the interval. After some algebraic manipulations, we obtain

$$\hat{q} = \frac{[(\overline{v}_1 - c_1)(1+\lambda) - \lambda\underline{v}_2](1-\mu)}{[(\overline{v}_1 - c_1)(1+\lambda) - \lambda\overline{v}_1](1-\mu) + [\mu\overline{F} - \underline{F}](1+\lambda)\lambda} \,. \quad (19)$$

Under the assumptions of table 1 and on λ, the nominator is positive. Hence, a sufficient condition for $1 > \hat{q} > 0$ is

$$\mu\overline{F} \geq \underline{F}. \quad (20)$$

This condition will become crucial in what follows. To summarize, efficient investment incentives can be induced for all $q \in [q^*, \hat{q}]$. For $\hat{q} < q \leq 1$, underinvestments are realized in the considered interval (4).

(5) $(\overline{v}_1 - c_1)/\lambda < p_t - p_0 \leq \min\{(\overline{v}_2 - \overline{c}_2)/\lambda, (\underline{v}_2 - \underline{c}_2)/\lambda\}$.
Under these initial contracts, the subgame-perfect equilibrium prices are $p_2^i = p_2^{ii} = p_2^{iii} = p_2^{iv} = p_2^v = p_2^{vi} = p_2$ and $p_1^{vii} = (\overline{v}_1 - c_1)/\lambda$. After inserting these prices into (12), the efficiency condition becomes

$$A^* = \frac{\underline{v}_2 - q\overline{v}_1}{1+\lambda}(1-\mu) = (1-\mu)[(p_2 - p_0) - q\frac{\overline{v}_1 - c_1}{\lambda}] = A. \tag{21}$$

Examining this condition, we observe that the investment excess function is increasing in the price difference. Moreover,

$$\frac{\partial S}{\partial q} = (1-\mu)[-\frac{\overline{v}_1 - c_1}{\lambda} + \frac{\overline{v}_1}{1+\lambda}] < 0. \tag{22}$$

Hence, excess investment decreases in q for any ex-ante prices in this interval. Let us investigate the lower bound of the interval (4), and calculate $S(\tilde{q}, p_t - p_0 = (\overline{v}_1 - c_1)/\lambda) = 0$. Solving for the threshold level $\tilde{q}$, we arrive at

$$\tilde{q} = \frac{(\overline{v}_1 - c_1)(1+\lambda) - \lambda\underline{v}_2}{(\overline{v}_1 - c_1)(1+\lambda) - \lambda\overline{v}_1}, \tag{23}$$

where $1 > \tilde{q} > 0$ under the assumptions of table 1 and on λ. Accordingly, we obtain overinvestments for any ex-ante contract in the considered interval as long as $0 < q < \tilde{q} < 1$. Note that $\tilde{q} > \hat{q}$ if and only if (20) holds. Therefore, at the lower bound of the interval (4), the equilibrium investments jump upwards. Hence, for any $q \in [\tilde{q}, \hat{q}]$, efficient investment incentives cannot be induced by any ex-ante contracts from price intervals (1) to (5). Moreover, it is easy to see that $\tilde{q} \to 1, \hat{q} \to 1$ as $\lambda \to 0$, i.e. the overinvestment, resp. underinvestment, ranges converges to the point $q = 1$ for vanishing shadow costs.

(6) Finally, for the intervals starting with a price difference $p_t - p_0 > \min\{(\underline{v}_2 - \underline{c}_2), (\overline{v}_2 - \overline{c}_2)\}$, equilibrium investments are increasing in the ex-ante contracted price difference. Moreover, since incentives are continuous at the lower bounds of each of these intervals, we have proved that that efficient investments can only be obtained as long as $q \notin [\hat{q}, \tilde{q}]$, or if (20) is not valid.

To conclude, efficient investments are attainable unless $q \in [\hat{q}, \tilde{q}]$ and (20) jointly hold. If $\lambda = 0$, only intervals (1)-(4) can occur. Since equilibrium investments in these intervals are strictly increasing in $(p_t - p_0)$ as long as the standard good is non-valuable with positive probability ($q < 1$), ex-ante efficiency is always feasible. If $q = 1$, however, (17) shows that investment incentives are zero for any initial contract, which proves Proposition 3. Finally, note that $\min\{\hat{q}, \tilde{q}\} > 0$ as long as (20) is valid, which proves Corollary 2. □

Proof of Proposition 5: We have to show that there exist ex-ante contracted price triples (p_0, p_1, p_2) which support an ex-ante efficient outcome. Again, equation (12) provides a necessary and sufficient condition for ex-ante efficiency. Assume that the initial terms of contract specify $p_1 - p_0 < c_1$. Note that for these prices, the seller is unwilling to deliver the standard project, which holds under at will- as well as option contracting. Accordingly, if trade of the standard project is efficient, in equilibrium there is upward renegotiation of the final trade price which becomes $p_1^{(vii)} = p_0 + c_1$ (see corollary 1). Moreover, we have to check the following relevant subcase:

$\overline{c}_2 > p_2 - p_0 \geq \underline{c}_2$.

Here, there is upward renegotiation if trade of the innovation is efficient and $\overline{c}_2$ has been realized. Hence, under at-will contracting, $p_2^{(i)} = p_2^{(ii)} = p_2^{(iii)} = p_2^{(iv)} = p_2$, $p_2^{(v)} = p_2^{(vi)} = p_0 + \overline{c}_2$. Inserting these prices into (12) yields the following condition for efficient investments:

$$(p_2 - p_0)^* = \left(\frac{\underline{v}_2}{1+\lambda} - q(\frac{\overline{v}_1}{1+\lambda} - c)\right)(1-\mu) + \overline{c}_2\mu. \tag{24}$$

In order to prove that this solution is compatible with the considered price range, we must show that $\overline{c}_2 > (p_2 - p_0)^* \geq \underline{c}_2$ holds. Note that the right-hand side of (24) is a linear combination of two terms, where the second term is equivalent to the upper bound of the feasible range, $\overline{c}_2$. Hence, since the left term is obviously smaller than $\overline{c}_2$, it remains to show that $\underline{v}_2/(1+\lambda) - q(\overline{v}_1/(1+\lambda) - c_1) \geq \underline{c}_2$. Suppose $q = 1$ to obtain the smallest possible value of the right-hand side of (24): since $\underline{v}_2 - \overline{v}_1 > \underline{F}(1+\lambda)$ by the assumptions of table 1, this inequality holds for all q, which proves the validity of our solution $(p_2 - p_0)^*$. Therefore, we have demonstrated that efficient investments are attainable under at-will contracting. Under option contracting, the result is the same, since the seller will exert his option only in states where low production costs have been realized, i.e. if trade of the innovation is ex-post efficient. □

References

Aghion, P., Dewatripont, M. and P. Rey (1994), "Renegotiation Design with Unverifiable Information," *Econometrica*, 62: 257-282.

Aghion, P. and J. Tirole (1994), "The Management of Innovation," *Quarterly Journal of Economics*, 109: 1185-1209.

Aghion, P. and J. Tirole (1995), "Formal and Real Authority in Organizations," *mimeo*, University of Toulouse.

Bös, D. and C. Lülfesmann (1996), "The Hold-up Problem in Government Contracting," *Scandinavian Journal of Economics*, 98: 21-34.

Christiansen, V. (1981), "Evaluation of Public Projects Under Optimal Taxation," *Review of Economic Studies*, 48: 447-457.

Chung, T.-Y. (1991), "Incomplete Contracts, Specific Investments and Risk Sharing," *Review of Economic Studies*, 58: 1031-1042.

De Fraja, G. (1993), "Productive Efficiency in Public and Private Firms," *Journal of Public Economics*, 50: 15-30.

Grossman, G. and O. Hart (1986), "The Costs and Benefits of Ownership: A Theory of Vertical and Lateral Integration," *Journal of Political Economy*, 94: 691-719.

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

Hart, O. and J. Moore (1988), "Incomplete Contracts and Renegotiation," *Econometrica*, 56: 755-785.

Hylland, A. and R. Zeckhauser (1979), "Distributional Objectives Should Affect Taxes But Not Program Choice or Design," *Scandinavian Journal of Economics*, 81: 264-284.

Kaplow, L. (1995), "Public Goods and Pigouvian Taxes: the Irrelevance of Tax Distortions and Distributive Effects," *Discussion Paper, Harvard University.*

Laffont, J.-J. and J. Tirole (1986), "Using Cost Observations to Regulate Firms," *Journal of Political Economy*, 94: 614-641.

Laffont, J.-J. and J. Tirole (1993), *A Theory of Incentives in Procurement and Regulation*, Cambridge, Massachusetts: The MIT Press.

Lülfesmann, C. (1995), "Incomplete Contracts, (Un)Verifiable Design Changes, and Renegotiation," Discussion Paper A-482, University of Bonn.

McLeod, B. and J. Malcomson (1993), "Investments, Hold-up, and the Form of Market Contracts," *American Economic Review,* 83: 811-837.

Nöldeke, G. and K. Schmidt (1995), "Option Contracts and Renegotiation: a Solution to the Hold-Up Problem," *Rand Journal of Economics*, 26: 163-179.

Olsen, T.E. and G. Torsvik (1993), "The Ratchet Effect in Common Agency: Implications for Regulation and Privatization," *Journal of Law, Economics, and Organization.* 9: 136-158.

Rogerson, W.P. (1989), "Profit Regulation of Defense Contractors and Prizes for Innovation," *Journal of Political Economy,* 97: 1285-1305.

Schmidt, K. (1996), The Costs and Benefits of Privatization - An Incomplete Contracts Approach, *Journal of Law, Economics and Organization*, 12: 1-24.

Segal, I. (1995), "Complexity and Renegotiations: a Foundation for Incomplete Contracts," *mimeo*, Harvard University.

Shapiro, C. and R. Willig (1990), "Economic Rationales for the Scope of Privatization," in E.N. Suleiman, and J. Waterbury (eds), *The Political Economy of Public Sector Reform and Privatization,* Boulder, Colorado: Westview Press, 55-87.

Tirole, J. (1986), "Procurement and Renegotiation," *Journal of Political Economy,* 94: 235-259.

Tirole, J. (1994), "The Internal Organization of Government," *Oxford Economic Papers,* 46: 1-29.