The Proper Scope of Government Reconsidered: Asymmetric Information and Incentive Contracts

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June 2023

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Abstract.
We revisit the contract-theoretic literature on privatization initiated by Hart et al. (1997). This literature has two major shortcomings. First, it is focused on ex-ante investment incentives, whereas ex-post inefficiencies which are ubiquitous in the real world cannot be explained. Second, ownership does not matter when incentive contracts can be written. Both shortcomings are due to the fact that this literature has studied the case of symmetric information only. We explore how asymmetric information leads to different kinds of ex-post inefficiencies depending on the ownership structure. Moreover, we show that under asymmetric information ownership matters even when incentive contracts are feasible.

Keywords: incomplete contracts; privatization; control rights; asymmetric information; investment incentives

JEL Classification: D86; D23; D82; H11; L33

This is the working paper version of the following article:
Schmitz, P.W. (2023). The Proper Scope of Government Reconsidered: Asymmetric Information and Incentive Contracts. *European Economic Review*, Vol. 157, 104511.

1 Introduction

What should determine the boundaries between the government and the private sector? This is one of the central questions in economics. Consider services that the public is going to pay for, e.g. education, health care, or the operation of prisons. Should the government own schools, hospitals, and prisons, such that government employees provide the services in-house? Or should the provision of the services be contracted out to private suppliers?

By now, Hart et al. (1997) is widely regarded as the leading contract-theoretic framework capable of explaining the differences between public and private ownership.[1] They have argued that the fundamental difference between private and public ownership is the allocation of residual control rights. If some future decisions are not contractible ex-ante, then the outcome of ex-post negotiations over these decisions will depend on who has the right to decide in case no agreement is reached. The division of the surplus that will be attained in the ex-post negotiations is important, because it has an impact on the incentives to make non-contractible investments ex-ante. However, as has been pointed out by Hart (2021), this framework has two major shortcomings. First, it is solely focused on ex-ante investment incentives and thus it cannot explain ex-post inefficiencies, even though they seem to be ubiquitous in the real world. Second, in the model ownership rights are the only way to provide investment incentives, whereas in practice investment incentives are often provided by contracts. If incentive contracts were allowed in Hart et al.'s (1997) model, ownership would not matter at all, which would be hard to square with the fact that the pros and cons of privatization are such a hotly debated topic. In the present paper, we argue that both shortcomings are due to the fact that Hart et al. (1997)

[1] Cf. Nobel Prize Committe (2016). See also Stanford APARC (2021), a documentary video on Hart et al.'s (1997) influential role in research, teaching, and policy. The video was produced by Karen Eggleston in celebration of the 25th birthday of Hart et al. (1997). In the video, renowned scholars such as Jonathan Levin, David Martimort, and Elisabetta Iossa reflect on the paper's impact, and they also provide some interesting anecdotes. For instance, David Martimort mentions that Hart et al. (1997) is the article on the reading list of his contract theory course that his students choose most often when they have to write a term paper. Oliver Hart has responded to some questions that were raised in the video in his keynote address for the Stanford Asia Health Policy Program's colloquium series on public and private roles. Hart (2021) is the transcript of the keynote address.

and the subsequent literature have studied the case of symmetric information only. Once we allow for asymmetric information, ex-post inefficiencies gain center stage and ownership matters even when incentive contracts are feasible.

Our basic model closely follows Hart et al.'s (1997) framework. The government wants a certain good or service to be provided. The government's payoff is given by the benefit created by the service minus the payment to the service provider. The provider (referred to as the "manager") is either a government employee or a private supplier, depending on whether there is public or private ownership of the non-human assets required to provide the service. In any case, the manager's payoff is given by the payment from the government minus the manager's provision costs. The manager can make non-contractible investments to come up with innovations to decrease the provision costs. Yet, implementing a cost-reducing innovation may also reduce the government's benefit. When an innovation was made, the government and the manager bargain over its implementation. If no agreement is reached, the ownership structure determines who has the right to decide about the implementation. Under symmetric information, there are no ex-post inefficiencies. In the absence of incentive contracts, private ownership leads to overinvestment compared to the first-best benchmark, while public ownership leads to underinvestment. If incentive contracts can be written, the first-best outcome is achieved regardless of the ownership structure.

The central contributions of the present paper are concerned with the case in which only the manager learns the size of the cost reduction. In this case, ex-post inefficiencies occur. Specifically, it turns out that under private ownership some cost-reducing innovations are implemented even when the adverse effect on the benefit outweighs the cost reduction. In contrast, under public ownership some innovations are not implemented even when the adverse effect on the benefit would be smaller than the cost reduction. In the absence of incentive contracts, the fact that the manager gets an information rent implies that under private ownership the overinvestment problem is further aggravated, while under public ownership the underinvestment problem is mitigated. Together with the fact that there are ex-post inefficiencies it thus follows that asymmetric information is welfare-reducing in the case of private ownership, whereas the welfare effects under public ownership depend on the manager's bargaining power. If incentive contracts can be written, then the fact that there are ex-post inefficiencies due to asymmetric information implies that the parties agree on contracts inducing underinvestments compared to the first-best benchmark under both ownership structures. The ex-post inefficiencies and hence the underinvestment problem will be more severe under private ownership than under public ownership whenever the adverse side effects of cost-reducing innovations are sufficiently strong.

As an illustration, in the context of prisons, one possibility to reduce costs is to hire less qualified guards, which may have the adverse effect of leading to more escapes and more contraband drug use by inmates (Camp and Gaes, 2002). As has been pointed out by Hart (2021, p. 3), in Hart et al.'s (1997) original framework negotiations under symmetric information would ensure that inefficiently low skilled guards will never be hired, regardless of the ownership structure. In contrast, in our model the presence of asymmetric information about the size of the cost reduction implies that low-skilled guards will actually be hired in privatized prisons, which is in line with the empirical observations reported by Camp and Gaes (2002). Moreover, as has been reported by Genders (2002) and Brown (2018), in practice incentives to reduce the costs of prison services can be provided by contracts based on performance measures. While such contracts would render ownership meaningless in Hart et al.'s (1997) original framework, we show that in the presence of asymmetric information public and private ownership still lead to markedly different outcomes. For instance, private ownership may be optimal in the case of halfway houses and youth correctional facilities, while public ownership may be preferable in the case of maximum security prisons, because in the latter case the adverse effects of cost reductions may be more severe (e.g., there may be more violence by prisoners).[2]

Related literature. The model developed by Hart et al. (1997) has been extended by numerous authors.[3] For example, Eggleston (2008) studies soft budget constraints,

[2] While prisons are the lead example in Hart et al.'s (1997) paper, analogous points can be made in other contexts such as health care (cf. Eggleston et al., 2008) or education (cf. Neal, 2002). Also in these contexts ex-post inefficiencies are pervasive in the real world and performance-based contracts can be used to provide incentives.

[3] Cf. the literature survey by Walker (2016), who also discusses important papers on privatization that predate Hart et al. (1997) such as Laffont and Tirole (1991) and Schmidt (1996a,b).

Hoppe and Schmitz (2010a) explore two-sided investments and partial privatization, and De Brux and Desrieux (2014) consider divisible public projects. However, as has been pointed out by Hart (2021), so far the effects of asymmetric information have not yet been studied in this literature.

Hart et al.'s (1997) privatization theory is related to the incomplete contracting literature on vertical and lateral integration of firms initiated by Grossman and Hart (1986) and Hart and Moore (1990). Some authors such as Holmström and Roberts (1998), Holmström (1999), and Williamson (2000, 2002) have criticized that also in this literature ex-post inefficiencies have been largely neglected, even though they seem to play an important role in practice.[4] While a few papers such as Schmitz (2006, 2008) and Su (2017a) have studied asymmetric information in the context of integration decisions of private firms, the underlying effects are different from those in the present paper. For instance, in these models investments do not have adverse side effects, so there is no scope for overinvestments.[5] Moreover, Bajari and Tadelis (2001) also allow for both contractual incompleteness and asymmetric information. While we employ the same ex-post bargaining game, the model by Bajari and Tadelis (2001) is quite different from the present paper, since they do not study ownership arrangements but focus on the comparison of cost-plus and fixed-price contracts instead. Furthermore, it should be noted that there are also several papers in the industrial organization literature that have studied the impact of mergers on innovation incentives (cf. Federico et al., 2017, 2018; Jullien and Lefouili, 2018) and the role of private information in merger reviews (cf. Loertscher and Marx, 2019, 2021).[6] In contrast to Hart et al. (1997) and the present work, these papers do not study the pros and cons of privatization.

Finally, building on Hart et al. (1997) a vibrant literature on public-private partnerships was initiated by Hart (2003) and Bennett and Iossa (2006a,b); see e.g. Iossa

[4] This fact has also been acknowledged by Hart and Moore (2008, p. 2) and Moore (2016, p. 12).

[5] Cf. Hart (2003) for a discussion of the differences between Hart et al.'s (1997) setup and property rights models focused on private firms. See also Goldlücke and Schmitz (2014), Vasconcelos (2014), and Choi and Triantis (2021), who analyze models with relationship-specific investments and asymmetric information without focusing on ownership rights.

[6] See also Ausubel et al. (2002) for a review of the literature dealing with incomplete information bargaining and partnerships. Segal and Whinston (2013) provide a comprehensive survey of the literature on property rights.

and Martimort (2012, 2015a), Greco (2015), Martimort and Straub (2016), Hoppe and Schmitz (2021), and Buso and Greco (2023). While most contributions to this literature assume symmetric information, Hoppe and Schmitz (2013) and Buso (2019) have studied the implications of asymmetric information. However, the literature on public-private partnerships is focused on the pros and cons of bundling the sequential tasks of building and operating an infrastructure, while ownership rights play only a minor role.[7]

Organization of the paper. The remainder of the paper is organized as follows. In Section 2, the basic model is introduced and the first-best benchmark solution is derived. In Section 3, the case of symmetric information is analyzed. Our main results are reported in Section 4, where the implications of asymmetric information are studied. Concluding remarks follow in Section 5. Some technical details have been relegated to the Appendix.

2 The Model

2.1 The basic setting

Suppose the government wants a good or service to be provided. At some initial date 0, the government (G) and a manager (M) write a contract that specifies a basic version of the good and a payment P_0 from G to M. Both parties are risk-neutral and there are no binding wealth constraints. When M provides the basic good, M incurs costs C_0, while G's benefit is given by B_0, where $B_0 > C_0 \geq 1$. The parties can specify an ownership structure $o \in \{M, G\}$, which determines who is in control of the essential assets needed to provide the good. Under private ownership ($o = M$), only M has the right to modify the assets in order to implement innovations that may reduce the provision costs. Under public ownership ($o = G$), it is G who controls the essential assets, so modifications of the assets in order to implement cost-reducing innovations require G's consent. Since the parties are symmetrically informed at date 0, they always agree on the ownership structure that maximizes the expected

[7] See Hart (2003, p. C71) and Iossa and Martimort (2015a, p. 23).

total surplus, which they can divide according to their date-0 bargaining powers by choosing a suitable lump-sum payment P_0.

At date 1, M makes a non-contractible investment $e \in [0,1]$ in the development of a cost-reducing innovation. The probability that M will come up with an innovation is given by e. The investment costs are $\psi(e)$. Suppose that the investment costs are increasing and convex; specifically, $\psi(0) = \psi'(0) = 0$, $\psi'(e) > 0$, $\psi''(e) > 0$ for $e > 0$, and $\psi'(1) \geq 1$.

If an innovation was made, then at date 2 the parties can negotiate about whether or not to implement it. If the innovation is implemented (which requires a modification of the essential assets), M's costs of providing the adapted good are $C_0 - c$ only, where $c \in [0,1]$. Yet, implementing the cost-reducing innovation has the undesirable side effect of also reducing the good's quality, such that G's benefit is only $B_0 - b$, where $b \in [0,1]$.[8] The good's quality and thus the benefit reduction b are publicly observable. Yet, M may have private information about the size of the cost reduction. Specifically, suppose that c is the realization of a continuously distributed random variable, where the commonly known cumulative distribution function is denoted by $F(c)$. Suppose that $F(c)$ satisfies the usual monotonicity conditions that $F(c)/f(c)$ is increasing and $[1 - F(c)]/f(c)$ is decreasing, where $f(c)$ is the density function.[9] We will compare the case in which at date 2 only M learns the realization of c (asymmetric information) to the case in which both parties learn the realization of c (symmetric information).

In order to model the date-2 negotiations, suppose that with probability $\pi \in (0,1)$ it is M who can make a take-it-or-leave-it offer to G, while otherwise G can make a take-it-or-leave-it offer to M.[10] An offer specifies whether the innovation is

[8] Observe that in contrast to Hart et al. (1997), we allow b to be larger than c, so it can be ex-post inefficient to implement the innovation. Note that in addition to cost-reducing innovations, Hart et al. (1997) also consider investments in quality-enhancing innovations. Yet, the trade-off between public and private ownership in their model is solely driven by the cost innovations, while the quality innovations can strengthen the case for private ownership only. To streamline the exposition, we thus focus on cost-reducing innovations.

[9] These hazard rate assumptions are standard in the related literature, see e.g. Lewis and Sappington (1989) and Maggi and Rodriguez-Clare (1995). The conditions are implied by log-concavity of the density function and they are satisfied by many common distribution functions including the uniform distribution (cf. Bagnoli and Bergstrom, 2005).

[10] This simple bargaining game has often been used in the incomplete contracting literature, see

implemented and a transfer payment. When the offer is rejected, the owner is free to decide whether or not the innovation is implemented and no further payments apart from P_0 are made.

2.2 The first-best benchmark

As a benchmark, let us characterize the decisions that maximize the expected total surplus. At date 2, if an innovation was made, it is ex-post efficient to implement the innovation whenever the cost reduction outweighs the quality reduction, i.e. whenever $c \geq b$ holds. Given the ex-post efficient implementation decision, the expected total surplus is

$$S(e) = B_0 - C_0 + e \int_b^1 (c - b) dF(c) - \psi(e).$$

At date 1, the efficient investment level is given by $e^{FB} = \arg\max_e S(e)$. Thus, the first-order condition reads

$$\psi'(e^{FB}) = \int_b^1 (c - b) dF(c) \tag{1}$$

and the expected total surplus in the first-best solution is $S(e^{FB})$.

Note that in a first-best world, ownership rights do not matter. In the remainder of the paper, following Hart et al. (1997), we consider an incomplete contracting world in which the investment level is non-contractible and the parties can bargain over the implementation of an innovation only after it has been made.[11] In this case ownership rights can matter, because they may have an impact on the outcome of the ex-post negotiations and hence on the investment incentives.

e.g. Hart and Moore (1999, p. 135), Bajari and Tadelis (2001), and Schmitz (2006). Observe that if the parties are symmetrically informed, this game leads to the same expected payoffs as the generalized Nash bargaining solution, where π is M's date-2 bargaining power (cf. Muthoo, 1999). Many authors such as Hart et al. (1997) have focused their attention on the case $\pi = 1/2$, where both parties have the same bargaining power.

[11] Note that in line with the standard incomplete contracting approach we assume that the ex-post bargaining game is exogenously given; i.e., the parties cannot ex-ante design the negotiation game that will be played ex-post (as in Aghion et al., 1994). See Tirole (1999) and Aghion et al. (2016, part 10) for discussions of the methodological foundations of the incomplete contracting approach.

3 Symmetric information

3.1 No incentive contracts

Suppose that when an innovation was made, then at date 2 both parties learn the realization of c. In line with Hart et al. (1997), ex-post efficiency will always be achieved, so the optimal ownership structure depends solely on M's incentives to invest.

Consider private ownership ($o = M$). If no agreement were reached, M would always implement the innovation, because doing so reduces M's date-2 costs. Hence, there is no scope for renegotiation when $c \geq b$, since in this case it is indeed ex-post efficient to implement the innovation. Now consider the case $c < b$, where it would be ex-post inefficient to implement the innovation. Suppose M can make a take-it-or-leave-it offer to G, which happens with probability π. Then M offers to refrain from implementing the innovation provided that G pays b to M, and thus G is just willing to accept the offer.[12] Next, suppose G can make the offer. Then G asks M not to implement the innovation and offers the payment c as a compensation, which M is just willing to accept. Therefore, at date 1 the expected payoffs are[13]

$$\begin{aligned} U_M^M(e) &= P_0 - C_0 + e\left[\int_0^b [\pi b + (1-\pi)c]\, dF(c) + \int_b^1 c dF(c)\right] - \psi(e), \\ U_G^M(e) &= B_0 - P_0 - e\left[\int_0^b [\pi b + (1-\pi)c]\, dF(c) + \int_b^1 b dF(c)\right]. \end{aligned}$$

At date 1, M chooses the investment level $e^M = \arg\max_e U_M^M(e)$. Hence,

$$\psi'(e^M) = \int_0^b [\pi b + (1-\pi)c]\, dF(c) + \int_b^1 c dF(c) \tag{2}$$

and the expected total surplus under private ownership is $S(e^M)$.

Observe that if a cost innovation had no side effect on quality ($b = 0$), such that implementation of the innovation would always be ex-post efficient, then M would

[12] We make the standard assumption that when a party is indifferent between accepting and rejecting an offer, it accepts the offer.

[13] Throughout, the superscripts M and G refer to the ownership structure $o \in \{M, G\}$.

choose the first-best investment level ($e^M = e^{FB}$). Otherwise, there is overinvestment compared to the first-best benchmark ($e^M > e^{FB}$), because M does not internalize the quality-reducing side effect of the cost innovation. Note that the investment level e^M is increasing in M's bargaining power π.

Next, consider public ownership ($o = G$). If no agreement were reached, G would never allow M to implement the cost-reducing innovation, because doing so would reduce the quality of the good. As a consequence, there is no scope for renegotiation when $c < b$, since in this case it is ex-post efficient not to implement the innovation. Now consider the case $c \geq b$. If M can make the offer, M proposes to compensate G with a payment b for implementation of the innovation, which G accepts. If G can make the offer, G asks for a payment c from M for allowing M to implement the innovation, which M accepts. Hence, at date 1 the expected payoffs are

$$\begin{aligned} U_M^G(e) &= P_0 - C_0 + e\left[\int_b^1 \pi(c-b)dF(c)\right] - \psi(e), \\ U_G^G(e) &= B_0 - P_0 + e\left[\int_b^1 (1-\pi)(c-b)dF(c)\right]. \end{aligned}$$

At date 1 it is optimal for M to invest $e^G = \arg\max_e U_M^G(e)$, so

$$\psi'(e^G) = \pi \int_b^1 (c-b)dF(c) \tag{3}$$

and the expected total surplus under public ownership is $S(e^G)$.

Observe that if the side effect of a cost innovation were so large that it should never be implemented ($b = 1$), then M would not invest ($e^G = e^{FB} = 0$). Otherwise, there is underinvestment compared to the first-best benchmark ($e^G < e^{FB}$), because M gets only a fraction of the renegotiation surplus. Notice that the investment level e^G is increasing in M's bargaining power π.

Taken together, the following results must hold, where part (iii) is implied by continuity.

Proposition 1 *Suppose that incentive contracts cannot be written and there is symmetric information.*

(i) Ex-post efficiency is always achieved.

(ii) Compared to the first-best benchmark, there is overinvestment under private ownership and underinvestment under public ownership, $e^G \leq e^{FB} \leq e^M$.

(iii) Private ownership is optimal (i.e., $S(e^M) > S(e^G)$ holds) when the adverse effect b is sufficiently small, while public ownership is optimal (i.e., $S(e^G) > S(e^M)$ holds) when b is sufficiently large.

Proposition 1 replicates in our setup the main trade-off that underlies the central insights reported by Hart et al. (1997). In particular, if the quality-reducing side effect b of a cost innovation becomes sufficiently small, then private ownership is optimal, because the overinvestment problem under private ownership vanishes, while under public ownership there is underinvestment. If b becomes sufficiently large, then public ownership is optimal, because the underinvestment problem under public ownership vanishes, while there is overinvestment under private ownership.

3.2 Incentive contracts

So far, following Hart et al. (1997) we have assumed that at date 0 the parties can agree on an ownership structure $o \in \{M, G\}$ and a lump-sum payment P_0 only. Suppose now that in addition also incentive contracts are feasible; i.e., at date 0 the parties can specify a payment w that is made from G to M if and only if a cost-reducing innovation was made, so the expected payment is $P_0 + ew$. Note that incentive contracts can be based on a verifiable signal indicating whether or not an innovation was made, while the size of the cost reduction remains non-contractible and the parties can negotiate about whether or not to implement the innovation only after it has been made. Hence, we are still in an incomplete contracting world.

Under private ownership, M's expected payoff now reads $U_M^M(e) + ew$. Observe that by specifying the incentive payment

$$w^M = -\int_0^b [\pi b + (1-\pi)c]\, dF(c) - \int_b^1 b dF(c)$$

the overinvestment problem can be overcome, because M now chooses the investment level e^{MI} characterized by

$$\psi'(e^{MI}) = \int_0^b [\pi b + (1-\pi)c]\, dF(c) + \int_b^1 c dF(c) + w^M = \psi'(e^{FB}).$$

Under public ownership, M's expected payoff now is $U_M^G(e) + ew$. By specifying the incentive payment

$$w^G = (1-\pi) \int_b^1 (c-b) dF(c)$$

the underinvestment problem can be overcome, as M now chooses the investment level e^{GI} given by

$$\psi'(e^{GI}) = \pi \int_b^1 (c-b) dF(c) + w^G = \psi'(e^{FB}).$$

Therefore, under both ownership structures M will choose the first-best investment level e^{FB}. Since under symmetric information the negotiations always lead to ex-post efficiency, the first-best solution is attained under both ownership structures.[14]

Proposition 2 *Suppose that incentive contracts are feasible and there is symmetric information. In this case, the first-best solution will be attained regardless of the ownership structure.*

As has been pointed out in the Introduction, the results that there are no ex-post inefficiencies and that ownership does not matter when incentive contracts can be written seem to be at odds with real-world observations. In the following section we show that both shortcomings of the model can be overcome when we allow for asymmetric information.

[14]Note that given risk-neutrality, this result would also hold if the incentive payment could be conditioned only on a signal correlated with the occurrence of an innovation, provided that there are no binding wealth constraints. For models with bounded payments, see e.g. Schmitz (2013), Martimort and Straub (2015), Hoppe and Schmitz (2021), and Buso and Greco (2023).

4 Asymmetric information

4.1 No incentive contracts

Suppose now that when an innovation was made, then at date 2 only M learns the realization of c. Thus, the date-2 negotiations take place under asymmetric information.

It seems to be a plausible assumption that M privately learns the extent by which implementation of the innovation can reduce M's costs, while the associated benefit reduction is publicly known.[15] For instance, the providers of prison services may be privately informed about the extent by which they can reduce their efforts when electronic surveillance systems are implemented, while an increase in the number of escapes can be publicly observed. Similarly, in the case of public transportation, the providers of transport services may have private information about the exact size of cost savings when there is some accounting leeway, while everyone can observe that trains and buses are congested and delayed.[16]

Consider private ownership ($o = M$), so when no agreement is reached M will implement the innovation. Suppose first M can make the take-it-or-leave-it offer. When $c \leq b$, then M offers to refrain from implementing the innovation provided that G pays b to M, and hence G is just willing to accept the offer. When $c > b$, no offer that is profitable for M would be accepted by G, so M implements the innovation. Next, suppose G can make the offer. In this case, G asks M not to

[15] Note that our information structure corresponds to the one studied by Klibanoff and Morduch (1995), who analyze more general bargaining procedures in a setting where a privately informed firm can cause externalities of a commonly known size. However, their model is not focused on privatization and they study neither investments nor ownership arrangements. It should also be emphasized that in our model the information structure does not depend on whether there is public or private ownership (which is in contrast to Schmidt, 1996a,b, where ownership changes the information structure).

[16] While the opposite case where G has private information about b and where c is publicly known seems to be less plausible, the occurrence of ex-post inefficiencies would carry over to this case. Yet, ex-post inefficiencies would occur if M can make the offer, while they will occur if G can make the offer in our model. Note that it is known from Myerson and Satterthwaite (1983) that in the case of two-sided private information ex-post inefficiencies can be unavoidable regardless of the bargaining protocol. Recall that we are in an incomplete contracting world, so by assumption it is not possible at the ex-ante stage to design revelation mechanisms in the spirit of d'Aspremont and Gérard-Varet (1979) and Rogerson (1992).

implement the innovation and G offers a payment p to M as a compensation.[17] Clearly, M accepts the offer whenever $c \leq p$. Hence, it is optimal for G to offer $p^M = \arg\min_p (pF(p) + b[1 - F(p)])$. Observe that $p^M \in [0, b]$ and p^M is uniquely defined by the first-order condition[18]

$$\frac{F(p^M)}{f(p^M)} + p^M = b.$$

Thus, at date 1 the expected payoffs are

$$\begin{aligned}
\tilde{U}_M^M(e) &= P_0 - C_0 + e\left[\pi\left(bF(b) + \int_b^1 cdF(c)\right)\right. \\
&\quad \left. +(1-\pi)\left(p^M F(p^M) + \int_{p^M}^1 cdF(c)\right)\right] - \psi(e), \\
\tilde{U}_G^M(e) &= B_0 - P_0 - e\left[\pi b + (1-\pi)\left(p^M F(p^M) + b[1 - F(p^M)]\right)\right].
\end{aligned}$$

At date 1 it is optimal for M to choose the investment level $\tilde{e}^M = \arg\max_e \tilde{U}_M^M(e)$. Therefore,

$$\psi'(\tilde{e}^M) = \pi\left(bF(b) + \int_b^1 cdF(c)\right) + (1-\pi)\left(p^M F(p^M) + \int_{p^M}^1 cdF(c)\right) \tag{4}$$

and the expected total surplus under private ownership is

$$\tilde{S}^M(\tilde{e}^M) = B_0 - C_0 + \tilde{e}^M\left[\pi\int_b^1 (c-b)\, dF(c) + (1-\pi)\int_{p^M}^1 (c-b)\, dF(c)\right] - \psi\left(\tilde{e}^M\right).$$

Note that if a cost innovation had no side effect on quality ($b = 0$), then $p^M = 0$, M would choose the first-best investment level ($\tilde{e}^M = e^{FB}$), and there would be no scope for an ex-post inefficiency, so the first-best outcome would be achieved (i.e., $\tilde{S}^M(\tilde{e}^M) = S(e^{FB})$ would hold). Otherwise, there is overinvestment compared

[17] It should be noted that when at the ex-post stage G can make a take-it-or-leave-it offer, then G could make M reveal c using a direct revelation mechanism. Yet, it follows from standard Bayesian mechanism design (cf. Fudenberg and Tirole, 1991, chapter 7) that at the ex-post stage G's expected payoff cannot be larger than the one that G attains with the optimal posted-price contract studied here.

[18] Note that $F(p)/f(p)+p$ is a continuous function that increases monotonically from 0 to a value larger than 1 when p goes from 0 to 1. Hence, by a straightforward intermediate value argument there must exist a unique p that satisfies the first-order condition.

to the first-best benchmark ($\tilde{e}^M > e^{FB}$) and there may be an ex-post inefficiency. Specifically, when G can make the offer and $c \in (p^M, b)$, then the innovation is implemented by M even though doing so is ex-post inefficient.

Next, consider public ownership ($o = G$), so when no agreement is reached G will not allow M to implement the innovation. Suppose M can make the offer. When $c \geq b$, then M proposes to compensate G with a payment b for implementation of the innovation, which G accepts. When $c < b$, no offer that G would accept is profitable for M. Next, suppose G can make the offer. Then G asks for a payment p from M for allowing M the implementation of the innovation, which M accepts whenever $c \geq p$. Thus, it is optimal for G to ask for $p^G = \arg\max_p (p-b)[1-F(p)]$. Observe that $p^G \in [b, 1]$ and it is uniquely defined by the first-order condition[19]

$$p^G - \frac{1-F(p^G)}{f(p^G)} = b.$$

Hence, at date 1 the expected payoffs are

$$\begin{aligned} \tilde{U}_M^G(e) &= P_0 - C_0 + e\left[\pi \int_b^1 (c-b)dF(c) + (1-\pi)\int_{p^G}^1 (c-p^G)dF(c)\right] - \psi(e), \\ \tilde{U}_G^G(e) &= B_0 - P_0 + e(1-\pi)(p^G - b)[1-F(p^G)]. \end{aligned}$$

At date 1, M invests $\tilde{e}^G = \arg\max_e \tilde{U}_M^G(e)$. Thus,

$$\psi'(\tilde{e}^G) = \pi \int_b^1 (c-b)dF(c) + (1-\pi)\int_{p^G}^1 (c-p^G)dF(c) \tag{5}$$

and the expected total surplus under public ownership is

$$\tilde{S}^G(\tilde{e}^G) = B_0 - C_0 + \tilde{e}^G\left[\pi \int_b^1 (c-b)dF(c) + (1-\pi)\int_{p^G}^1 (c-b)dF(c)\right] - \psi\left(\tilde{e}^G\right).$$

Note that if the side effect of a cost innovation were so large that it should never be implemented ($b = 1$), then $p^G = 1$ and M would not invest ($\tilde{e}^G = e^{FB} = 0$), so the first-best outcome would be attained. Otherwise, there is underinvestment compared

[19]To see this, note that $p - [1-F(p)]/f(p)$ is a continuous function that increases monotonically from a negative value to 1 when p goes from 0 to 1.

to the first-best benchmark ($\tilde{e}^G < e^{FB}$) and there may be an ex-post inefficiency. In particular, when G can make the offer and $c \in (b, p^G)$, then the innovation is not implemented even though it would be ex-post efficient to do so.

Our analysis implies the following results.

Proposition 3 *Suppose that incentive contracts cannot be written and there is asymmetric information.*

(i) Ex-post efficiency is not always achieved. Under private ownership the innovation may be implemented even when $c < b$, while under public ownership the innovation may not be implemented even though $c > b$.

(ii) The investment level $\tilde{e}^o$ under asymmetric information is larger than the investment level e^o under symmetric information and it is increasing in M's bargaining power π, for each $o \in \{M, G\}$. Compared to the first-best benchmark, there is overinvestment under private ownership and underinvestment under public ownership. Thus, $e^G \leq \tilde{e}^G \leq e^{FB} \leq e^M \leq \tilde{e}^M$.

(iii) Private ownership is optimal (i.e., $\tilde{S}^M(\tilde{e}^M) > \tilde{S}^G(\tilde{e}^G)$ holds) when the adverse effect b is sufficiently small, while public ownership is optimal (i.e., $\tilde{S}^G(\tilde{e}^G) > \tilde{S}^M(\tilde{e}^M)$ holds) when b is sufficiently large.

(iv) Given private ownership, the expected total surplus $\tilde{S}^M(\tilde{e}^M)$ under asymmetric information is smaller than the expected total surplus $S(e^M)$ under symmetric information.

(v) Given public ownership, the expected total surplus $\tilde{S}^G(\tilde{e}^G)$ under asymmetric information is larger (smaller) than the expected total surplus $S(e^G)$ under symmetric information when M's bargaining power π is sufficiently small (large).

Proof. See the Appendix.

As we have seen, under asymmetric information there may be ex-post inefficiencies (part i). Specifically, cost-reducing innovations are implemented too often under private ownership, while they are not implemented often enough under public ownership. Moreover, for any given ownership structure, the investment level under asymmetric information is larger than under symmetric information (part ii). Intuitively, the reason for this result is that M may now enjoy an information rent when the innovation is made, so M's incentives to invest are larger. As a consequence, the overinvestment problem under private ownership is aggravated, while the underinvestment problem under public ownership is mitigated. However, it is still the case that private ownership is optimal when the quality-reducing side effect of a cost innovation becomes sufficiently small, whereas public ownership is optimal when the side effect becomes sufficiently large (part iii).[20]

In the case of private ownership, the expected total surplus must be smaller under asymmetric information than under symmetric information (part iv). The reason is that under asymmetric information there can be an ex-post inefficiency and the overinvestment effect is even stronger than under symmetric information.

Now consider the case of public ownership. Under asymmetric information the underinvestment effect is weaker than under symmetric information, but under asymmetric information there can be an ex-post inefficiency. Hence, the overall effect of asymmetric information on the expected total surplus is ambiguous (part v). Note that the investment incentives are always increasing in M's bargaining power π and the first-best outcome would be achieved if π were equal to one. When we slightly reduce π below one, then there is only a second-order loss (due to the reduced investment level) under symmetric information, while there is a first-order loss (due to the ex-post inefficiency) under asymmetric information. Therefore, when π is sufficiently large, the expected total surplus is smaller under asymmetric information. In contrast, if π were equal to zero, there would be no investment under symmetric information, while (due to M's information rent) there would still be a positive investment under asymmetric information. As a consequence, when π is sufficiently small, then the expected total surplus is larger under asymmetric information.

[20] This result shows that a central finding of Hart et al. (1997) is remarkably robust to variations of the model. It should be emphasized that in general it is by no means to be taken for granted that incomplete contracting models are robust with regard to the introduction of asymmetric information. For instance, Besley and Ghatak (2001) have studied a model with symmetric information where the government and an NGO can invest in a public good that both parties care about. They have argued that the party with the larger valuation of the public good should be owner, regardless of the parties' investment technologies. Yet, Schmitz (2021) has shown that this result is not robust when asymmetric information is introduced.

4.2 Incentive contracts

Next, consider the case in which incentive contracts are feasible; i.e., at date 0 the parties can specify a payment w that G must make to M whenever a signal indicates that a cost-reducing innovation was made.[21] We still assume that the parties can bargain about the implementation of an innovation only after it has been made; i.e., we are still in an incomplete contracting world.

Under private ownership, M's expected payoff now reads $\tilde{U}_M^M(e) + ew$. Recall that there can be an ex-post inefficiency under asymmetric information. Thus, the parties will now agree on implementing the investment level that maximizes the expected total surplus $\tilde{S}^M(e)$, which they can divide according to their date-0 bargaining powers with a suitable lump-sum payment P_0. Hence, $\tilde{e}^{MI} = \arg\max_e \tilde{S}^M(e)$, so

$$\psi'(\tilde{e}^{MI}) = \pi \int_b^1 (c-b)\, dF(c) + (1-\pi) \int_{p^M}^1 (c-b)\, dF(c) \tag{6}$$

if the right-hand side of (6) is non-negative, and $\tilde{e}^{MI} = 0$ otherwise. Note that M's first-order condition reads

$$\psi'(e) = \pi \left(bF(b) + \int_b^1 cdF(c) \right) + (1-\pi) \left(p^M F(p^M) + \int_{p^M}^1 cdF(c) \right) + w. \tag{7}$$

Thus, the parties agree on the incentive payment $w = \tilde{w}^M$ with

$$\tilde{w}^M = (1-\pi)(b - p^M)F(p^M) - b$$

if the right-hand side of (6) is non-negative, and otherwise they specify w such that the right-hand side of (7) is zero.

Under public ownership, M's expected payoff now is $\tilde{U}_M^G(e) + ew$, so M's first-order condition reads

$$\psi'(e) = \pi \int_b^1 (c-b) dF(c) + (1-\pi) \int_{p^G}^1 (c - p^G) dF(c) + w.$$

[21] Recall that at date 0, the parties specify a contractual arrangement that maximizes their expected total surplus. Since the parties could agree on $w = 0$, given any ownership structure the expected total surplus must be (weakly) larger when incentive contracts are feasible.

The parties agree on implementing the investment level that maximizes the expected total surplus, $\tilde{e}^{GI} = \arg\max_e \tilde{S}^G(e)$, so

$$\psi'(\tilde{e}^{GI}) = \pi \int_b^1 (c-b)dF(c) + (1-\pi)\int_{p^G}^1 (c-b)dF(c). \tag{8}$$

Hence, the parties specify the incentive payment $w = \tilde{w}^G$, where

$$\tilde{w}^G = (1-\pi)[1-F(p^G)](p^G - b).$$

Observe that it is still the case that if a cost innovation had no side effect on quality ($b = 0$), then under private ownership $p^M = 0$, M would choose the first-best investment level ($\tilde{e}^{MI} = e^{FB}$), and the first-best outcome would be achieved (i.e., $\tilde{S}^M(\tilde{e}^{MI}) = S(e^{FB})$ would hold). Moreover, if the side effect of a cost innovation were so large that it should never be implemented ($b = 1$), then under public ownership $p^G = 1$ and M would not invest ($\tilde{e}^{GI} = e^{FB} = 0$), so the first-best outcome would be attained.

We can now state the following results.

Proposition 4 *Suppose that incentive contracts are feasible and there is asymmetric information.*

(i) Ex-post efficiency is not always achieved. Under private ownership the innovation may be implemented even when $c < b$, while under public ownership the innovation may not be implemented even though $c > b$.

(ii) There is underinvestment compared to the first-best benchmark under both ownership structures, $\tilde{e}^{MI} \leq e^{FB}$ and $\tilde{e}^{GI} \leq e^{FB}$. Moreover, $\tilde{e}^{MI} \geq \tilde{e}^{GI}$ when b is sufficiently small, while $\tilde{e}^{MI} \leq \tilde{e}^{GI}$ when b is sufficiently large.

(iii) Private ownership is optimal (i.e., $\tilde{S}^M(\tilde{e}^{MI}) \geq \tilde{S}^G(\tilde{e}^{GI})$ holds) when b is sufficiently small, while public ownership is optimal (i.e., $\tilde{S}^G(\tilde{e}^{GI}) \geq \tilde{S}^M(\tilde{e}^{MI})$ holds) when b is sufficiently large. The optimal ownership structure does not depend on M's bargaining power π.

Proof. See the Appendix.

Thus, while allowing for incentive contracts would make ownership meaningless in the case of symmetric information, the relevance of the cost innovation's side effect b for the optimal ownership structure is vindicated in the case of asymmetric information. Whether compared to the first-best benchmark the underinvestment problem will be stronger under public or under private ownership depends only on which ownership structure leads to the more severe ex-post inefficiency. As a consequence, the optimal ownership structure is now independent of the parties' date-2 bargaining powers.[22]

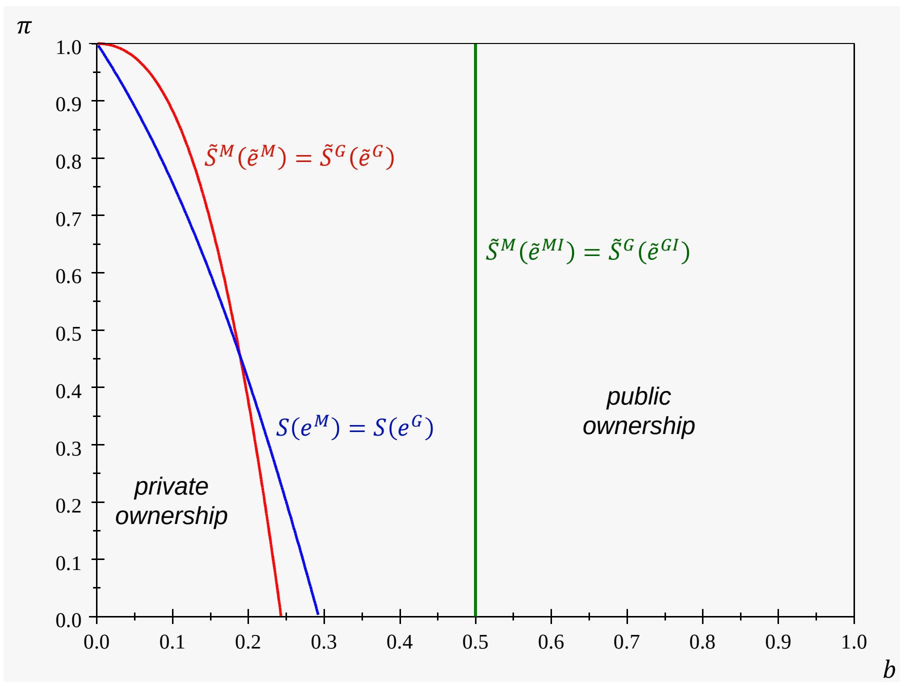

Figure 1. The optimal ownership structure.

Figure 1 illustrates the optimal choices between private and public ownership in the different scenarios that we have studied. The figure depicts the optimal ownership structure depending on the size of the adverse side effect b and on M's bargaining

[22]Recall that we follow the standard property rights approach (cf. Hart, 1995, p. 39) in assuming that the bargaining process is the same under both ownership structures. What differs between the ownership structures are the parties' bargaining positions, i.e., their disagreement payoffs.

power π in the case where $\psi(e) = \frac{1}{2}e^2$ and the cost reduction c is uniformly distributed.[23] In the benchmark model with symmetric information and no incentive contracts, private ownership is optimal (i.e., $S(e^M) > S(e^G)$ holds) to the left of the blue curve, while public ownership is optimal to the right of the blue curve. The red curve shows how the demarcation line changes when we introduce asymmetric information. In this case, for small values of π the range of b where private ownership is optimal becomes smaller, while the opposite holds for large values of π. Recall that ownership does not matter in the case of symmetric information when incentive contracts are feasible. If there is asymmetric information and incentive contracts can be written, then private ownership is optimal to the left of the green line, while public ownership is optimal to the right of the green line.

5 Concluding remarks

The costs and benefits of privatization are highly controversial.[24] Thus, sober considerations of their theoretical underpinnings are essential. Hart et al. (1997) and the subsequent literature have made important steps in this direction. Yet, so far this literature was focused on symmetric-information settings. Hence, ex-post inefficiencies could not be explained and the introduction of incentive contracts would have rendered the ownership structure meaningless. In the present paper we have shown that under the plausible assumption that there is asymmetric information we can account for ex-post inefficiencies and ownership still matters when incentive contracts can be written.

While the operation of prisons is their main example, Hart et al. (1997) have emphasized that their setup can also be applied in various other contexts such as garbage collection, weapons procurement, health care, and education. In many of these applications it is plausible that asymmetric information can play a role. For

[23] Thus, $F(c) = c$, so in this example $p^M = b/2$ and $p^G = (b+1)/2$.

[24] For example, the pros and cons of privatization have long been hotly debated in the context of health care, where they have recently become a pressing issue again in the COVID-19 pandemic (see e.g. Mertz, 2021). Controversies were also sparked by politicians who advocate to defund the police while enjoying private security (Matkin, 2021) and by the U.S. National School Boards Association that related parents criticizing public schools to domestic terrorism (McGurn, 2021).

instance, the introduction of new garbage trucks might reduce the effort that has to be exerted by workers. While the extent to which their effort costs are reduced cannot be publicly observed, quality reductions such as incompletely emptied garbage bins become commonly known. Since the negative side effects in this application appear to be relatively small compared to other contexts, in line with Hart et al. (1997) our model suggests that private ownership may be agreed upon, but it also shows that as a consequence ex-post inefficiencies such as filthy streets can become more likely. In the case of weapons procurement, cost-reducing innovations may have positive spillovers to other business activities of the producer that will not always show up in the accounting system, so the producer may have some private information. Moreover, in its "Guidance on Using Incentive and Other Contract Types" issued in March 2016, the U.S. Department of Defense points out that performance-based contracts may be used. Our analysis suggests that even though investment incentives can be steered by such contracts, private ownership may still lead to a more cost-effective weapons development than public ownership, given that there is asymmetric information.

It should be emphasized that while in our model the government can ensure a larger quality level under public ownership, this observation refers only to the quality of the public service as perceived by the government. In practice, citizens may well have different interests than government officials. For example, decision-makers in a state government might find it beneficial to divert funds from abortion clinics to other hospitals, whereas some citizens might consider such a measure to be a reduction of the quality of health care. Similarly, in the context of education, public bureaucrats might find it desirable to fund diversity, equity, and inclusion programs based on ideas associated with critical race theory, whereas parents might not want their children to be ideologically indoctrinated.[25] Therefore, from the citizens' perspective public ownership may lead to lower quality levels than private ownership, and the ownership structure that maximizes the expected total surplus of G and M may not be the one

[25] Public officials might also find it desirable to spend taxpayer money on programs where 'drag queens' interact with young schoolchildren, while parents might think that there are other ways to spend this money that would be more beneficial for the children (cf. Giatti, 2022). Moreover, following the 'defund the police' movement, several school districts in the U.S. have reduced or severed ties with police (see Riley, 2021). Parents who are concerned about school safety may disagree with the idea that such policies could be desirable.

that would be optimal from a welfare perspective. It has been suggested by Hart et al. (1997, p. 1132) that the political process may align the government's and society's interests.[26] Yet, often the quality of a specific public service might not be the dominant issue in an election.[27]

Our analysis suggests several further directions for prospective research. First, following Hart et al. (1997) we have focused our attention on the choice between public and private ownership. It could be an interesting avenue for future research to allow for hybrid forms of public-private ownership.[28] Moreover, notice that throughout we have assumed that the information structure is exogenously given. In future work, it might be worthwhile to endogenize the information structure.[29] Finally, instead of considering asymmetric information, one might explore alternative explanations for ex-post inefficiencies. In particular, Hart and Moore (2008) and Hart (2013) have suggested that contracts may serve as reference points, such that parties are aggrieved and shade on ex-post performance when they do not get what they feel entitled to.[30] It might be promising to investigate to what extent behavioral effects along these lines could also be relevant in the context of privatization.

[26] Indeed, commentators have argued that the issue of abortion has played an important role in the U.S. midterm elections in 2022 (see Kusisto and Calfas, 2022), while the fact that Glenn Youngkin was elected governor of Virginia in 2021 has been attributed to his focus on parents' rights in education (see Calvert and Corse, 2021; Barakat and Rankin, 2022).

[27] Moreover, majority voting does not take account of preference intensities, so in particular when participation costs in elections are low (e.g., due to mail-in ballots), the outcome may not be welfare-maximizing (cf. Chakravarty et al., 2018).

[28] Cf. Rosenkranz and Schmitz (1999, 2003), Hoppe and Schmitz (2010a), and Halonen-Akatwijuka and Pafilis (2020) for different forms of hybrid ownership structures, albeit in symmetric-information frameworks.

[29] For instance, information gathering could be modeled along the lines of Crémer and Khalil (1992), Hoppe and Schmitz (2010b), Iossa and Martimort (2015b), or Su (2017b).

[30] The behavioral approach can also contribute to the foundations of the incomplete contracting paradigm. Under full commitment, mechanisms such as the ones studied by d'Aspremont and Gérard-Varet (1979) can yield first-best results even when there is hidden information, though they seem to be rarely used in practice. However, Schmitz (2002) has shown that when hidden action and hidden information are combined, it can be impossible to achieve the first-best outcome even with general revelation mechanisms. Notably, the second-best solution of the asymmetric-information model in Schmitz (2002) is formally isomorphic to the no-aggrievement contract studied by Hart (2013) in his symmetric-information behavioral framework.

Appendix

Proof of Proposition 3.

Parts (i) and (iii) immediately follow from the analysis preceding Proposition 3.

With regard to part (ii), $\tilde{e}^M \geq e^M$ follows from convexity of $\psi(e)$ and the fact that the right-hand side of (4) is larger than the right-hand side of (2),

$$\pi \left(bF(b) + \int_b^1 cdF(c) \right) + (1-\pi) \left(p^M F(p^M) + \int_{p^M}^1 cdF(c) \right)$$
$$- \left(\int_0^b \left[\pi b + (1-\pi)c \right] dF(c) + \int_b^1 cdF(c) \right) = (1-\pi) \int_0^{p^M} \left(p^M - c \right) dF(c) \geq 0.$$

Moreover, $\tilde{e}^G \geq e^G$ follows immediately from inspection of (5) and (3). Furthermore, $\tilde{e}^G \leq e^{FB}$ holds because the right-hand side of (1) is larger than the right-hand side of (5),

$$\begin{aligned} & \int_b^1 (c-b)dF(c) - \left(\pi \int_b^1 (c-b)dF(c) + (1-\pi) \int_{p^G}^1 (c-p^G)dF(c) \right) \\ = \; & (1-\pi) \left(\int_b^1 (c-b)dF(c) - \int_{p^G}^1 (c-p^G)dF(c) \right) \geq 0, \end{aligned}$$

where $p^G \geq b$ has been used. The investment $\tilde{e}^M$ is increasing in M's bargaining power π, because implicit differentiation of (4) shows that

$$\begin{aligned} \frac{d\tilde{e}^M}{d\pi} &= \frac{1}{\psi''(\tilde{e}^M)} \left[bF(b) - p^M F(p^M) - \int_{p^M}^b cdF(c) \right] \\ &= \frac{1}{\psi''(\tilde{e}^M)} \left[\int_{p^M}^b F(c)dc \right] \geq 0, \end{aligned}$$

where integration by parts has been used. The investment $\tilde{e}^G$ is increasing in π, because implicit differentiation of (5) leads to

$$\frac{d\tilde{e}^G}{d\pi} = \frac{1}{\psi''(\tilde{e}^G)} \left[\int_b^1 (c-b)dF(c) - \int_{p^G}^1 (c-p^G)dF(c) \right] \geq 0.$$

With regard to part (iv), consider private ownership. In order to see that the expected total surplus $\tilde{S}^M(\tilde{e}^M)$ under asymmetric information is smaller than the expected total surplus $S(e^M)$ under symmetric information, observe that

$$\tilde{S}^M(e) - S(e) = e(1-\pi)\left(\int_{p^M}^{b} (c-b)\, dF(c)\right) \leq 0$$

for all e. In particular, $\tilde{S}^M(\tilde{e}^M) \leq S(\tilde{e}^M)$. Moreover, $S(\tilde{e}^M) \leq S(e^M)$ since $\tilde{e}^M \geq e^M \geq e^{FB}$ and $S(e)$ is concave in e. Therefore, $\tilde{S}^M(\tilde{e}^M) \leq S(e^M)$ must hold.

With regard to part (v), consider public ownership. Note that if M's bargaining power π were equal to one, then a marginal decrease of π would not reduce the expected total surplus in the case of symmetric information, while it would do so in the case of asymmetric information for all $b < 1$. Specifically,

$$\frac{dS(e^G)}{d\pi} = \left[\int_b^1 (c-b) dF(c) - \psi'\left(e^G\right)\right] \frac{de^G}{d\pi},$$

so at $\pi = 1$ we obtain

$$\left.\frac{dS(e^G)}{d\pi}\right|_{\pi=1} = 0 < \left.\frac{d\tilde{S}^G(\tilde{e}^G)}{d\pi}\right|_{\pi=1} = \tilde{e}^G \int_b^{p^G} (c-b) dF(c),$$

where (3) and (5) have been used. Hence, by continuity, if M's bargaining power $\pi < 1$ is sufficiently large, then $S(e^G)$ must be larger than $\tilde{S}^G(\tilde{e}^G)$. In contrast, if M's bargaining power π were equal to zero, then $e^G = 0$ and $\tilde{e}^G \in (0, \arg\max_e \tilde{S}^G(e))$ for all $b < 1$, so we obtain

$$\left.\tilde{S}^G(\tilde{e}^G)\right|_{\pi=0} = B_0 - C_0 + \tilde{e}^G \int_{p^G}^1 (c-b) dF(c) - \psi\left(\tilde{e}^G\right) > \left.S(e^G)\right|_{\pi=0} = B_0 - C_0.$$

It follows that if M's bargaining power $\pi > 0$ is sufficiently small, then $\tilde{S}^G(\tilde{e}^G)$ must be larger than $S(e^G)$.

Proof of Proposition 4.

Part (i) follows immediately from the analysis preceding Proposition 4.

With regard to part (ii), $\tilde{e}^{MI} \leq e^{FB}$ follows from the fact that the right-hand side of (1) is larger than the right-hand side of (6), as

$$\begin{aligned}
&\int_b^1 (c-b)dF(c) - \pi \int_b^1 (c-b)\, dF(c) - (1-\pi) \int_{p^M}^1 (c-b)\, dF(c) \\
= \;& (1-\pi) \int_{p^M}^b (b-c)\, dF(c) \geq 0.
\end{aligned}$$

Moreover, $\tilde{e}^{GI} \leq e^{FB}$ must hold because the right-hand side of (1) is larger than the right-hand side of (8),

$$\begin{aligned}
&\int_b^1 (c-b)dF(c) - \pi \int_b^1 (c-b)dF(c) - (1-\pi) \int_{p^G}^1 (c-b)dF(c) \\
= \;& (1-\pi) \int_b^{p^G} (c-b)\, dF(c) \geq 0.
\end{aligned}$$

Inspection of (6) and (8) reveals that $\tilde{e}^{MI} \geq \tilde{e}^{GI}$ holds whenever $\Delta(b) \geq 0$, where

$$\begin{aligned}
\Delta(b) &= \int_{p^M}^1 (c-b)\, dF(c) - \int_{p^G}^1 (c-b)dF(c) \\
&= \int_{p^M}^{p^G} (c-b)\, dF(c).
\end{aligned}$$

Observe that $\Delta(0) > 0$ and $\Delta(1) < 0$, so $\tilde{e}^{MI}$ must be larger (smaller) than $\tilde{e}^{GI}$ whenever b is sufficiently small (large).

With regard to part (iii), note that $\tilde{S}^M(e) \geq \tilde{S}^G(e)$ whenever $\Delta(b) \geq 0$ holds. Therefore, if $\Delta(b) \geq 0$ holds, then $\tilde{S}^G(\tilde{e}^{GI}) \leq \tilde{S}^M(\tilde{e}^{GI}) \leq \tilde{S}^M(\tilde{e}^{MI})$, where the latter inequality follows from $\tilde{e}^{MI} = \arg\max_e \tilde{S}^M(e)$. If $\Delta(b) \leq 0$ holds, then $\tilde{S}^M(\tilde{e}^{MI}) \leq \tilde{S}^G(\tilde{e}^{MI}) \leq \tilde{S}^G(\tilde{e}^{GI})$, where the latter inequality follows from $\tilde{e}^{GI} = \arg\max_e \tilde{S}^G(e)$. As a consequence, $\tilde{S}^M(\tilde{e}^{MI})$ is larger (smaller) than $\tilde{S}^G(\tilde{e}^{GI})$ whenever $\Delta(b)$ is positive (negative), which holds whenever b is sufficiently small (large). Moreover, whether $\Delta(b)$ is positive or negative is independent of π.

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