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Abstract

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JEL Classification: D23, D86, D82, C78, L33, H41

Keywords: Incomplete Contracts, Control Rights, Public Goods, private information, Investment incentives

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I have benefitted from valuable discussions with Daniel Müller, Stephanie Rosenkranz, and Urs Schweizer on the topic of this paper.

Optimal Ownership of Public Goods under Asymmetric Information

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1 Introduction

One of the most fundamental questions in public economics is who should be the owner of public projects. For example, should the government or a non-governmental organization (NGO) be in charge of running a school? Should government agencies at the federal or at the local level be the owners of facilities that are required to provide local public goods?

The optimal allocation of ownership rights is a central theme of the incomplete contracting approach developed by Grossman and Hart (1986) and Hart and Moore (1990).[1] In this literature, parties can make non-contractible investments and subsequently bargain over the division of the investments' returns. Physical assets are necessary to realize the returns. Ownership of the assets determines the parties' disagreement payoffs in the ex post negotiations. A central conclusion of the incomplete contracting approach is that when one party has a superior investment technology in an otherwise symmetric setting, then this party should be the owner.

While most applications of the incomplete contracting approach deal with the boundaries of private firms, a few studies have also investigated who should own the physical assets needed to provide public goods. By now, the leading application of the incomplete contracting theory to the choice between public and private ownership is Hart et al. (1997). Their model captures situations in which private for-profit entities may invest in tasks such as running a prison, so the investing party does not directly care about the public good to be provided.[2]

In contrast, Besley and Ghatak (2001) study a model in which two parties can make non-contractible investments and subsequently bargain over the provision of a public good that both parties may care about. Their lead example is the

[1] See also Hart (1995) for a textbook exposition. The incomplete contracting approach is widely regarded as one of the most important advances in microeconomic theory in the past three decades (cf. Aghion et al., 2016).

[2] Hence, Hart et al. (1997) is close to a private-good setup. For more recent work in this vein, see e.g. King and Pitchford (2008), Hoppe and Schmitz (2010), De Brux and Desrieux (2014), and Hamada (2017). See also Walker (2016) for a literature survey.

relationship between a government and an educational NGO, that may both care about the quality of a school. The main conclusion of their analysis is that the party who values the public good most should be the owner, regardless of the investment technology. This result is in contrast to the fundamental insight of the incomplete contracting approach according to which the investment technology is an important determinant of the optimal ownership structure.

In the present contribution, we show that Besley and Ghatak's (2001) central result crucially relies on their assumption that the parties are symmetrically informed. Specifically, we consider a version of their setup in which the parties privately learn the valuations after the investments have been made, so that negotiations about the provision of the public good take place under asymmetric information. It turns out that in this case the investment technology plays an important role in determining the optimal ownership structure, which is in contrast to the main conclusion of Besley and Ghatak (2001), but in line with the insights of the original property rights theory developed by Oliver Hart and his coauthors. In particular, we show that if party A has a better investment technology than party B, then ownership by party A can be optimal even when party A has a smaller expected valuation of the public good than party B.

Our findings are important, because in practice there are many situations in which two parties invest in a public good that they both care about. For instance, NGOs are often involved in various public projects in less developed countries (e.g., building agricultural extension system to serve farmers, or developing monitoring and screening technologies for microlending programs).[3] Moreover, as has been emphasized by Besley and Ghatak (2001, p. 1366), the "notion of joint provision of public goods by concerned parties is of much wider interest than government-NGO relations". For example, the two parties in the model could be different units of the government (local versus federal), or partners collaborating on projects in the fields of scientific research or art. In each of these instances, it is seems to be

[3]See e.g. Aldashev and Navarra (2018) and Roy and Chowdhury (2009). Note also that NGOs may have too much control in the context of refugee crises, when they highly value the well-being of illegal immigrants, but the government has significantly better investment technologies.

realistic that the parties are not perfectly informed about each other's valuation of the public good.[4]

Related literature. With regard to optimal ownership structures in private-good settings, following the seminal work of Grossman and Hart (1986) and Hart and Moore (1990), most papers in the incomplete contracting literature are focused on symmetric information. Hence, in line with the Coase Theorem negotiations always lead to an ex post efficient agreement after the non-contractible investments are sunk.[5] Yet, the fact that in practice we often observe ex post inefficiencies has been emphasized by several authors such as Holmström and Roberts (1998) and Williamson (2000, 2002). In Schmitz (2006), an otherwise standard version of the Grossman-Hart-Moore property rights model has been studied where the ex post negotiations take place under asymmetric information, such that ex post inefficiencies may occur.[6] More recently, further studies such as Goltsman (2011), Goldlücke and Schmitz (2014), and Su (2017a) have also explored different aspects of hold-up problems under asymmetric information in private-good contexts.

With regard to optimal ownership structures in public-good settings, to the best of my knowledge all papers building on Besley and Ghatak (2001) so far have assumed that there is symmetric information. Specifically, Francesconi and Muthoo (2011) consider a model in which the default payoffs are linear combinations of the public-good and the private-good cases. Halonen-Akatwijuka (2012) studies a variant of Besley and Ghatak (2001) in which a party's investment may have a stronger impact on the disagreement payoffs when the other party

[4]Indeed, the presence of asymmetric information is actually a standard assumption in the complete contracting (i.e., mechanism design) literature on public good provision; see e.g. Arrow (1979), d'Aspremont and Gérard-Varet (1979), Crémer and Riordan (1985), Mailath and Postlewaite (1990), Norman (2004), Ledyard and Palfrey (2007), and Goldlücke and Schmitz (2018).

[5]See the recent review article by Medema (2020) for an extensive discussion of the literature on the Coase Theorem (cf. Coase, 1960).

[6]See also Mori (2017, 2020) for alternative explanations of ex post inefficiencies in the theory of the firm due to haggling and ex post adaptations.

is the owner. Halonen-Akatwijuka and Pafilis (2014) have added location choice. Schmitz (2015) and Müller and Schmitz (2017) have studied optimal ownership of public goods when there are bargaining frictions in negotiations that take place under symmetric information. Building on Halonen's (2002) important reputation model that was developed in a private-good setting, Halonen-Akatwijuka and Pafilis (2020) have recently studied ownership of public goods in a repeated game.

Finally, the role of asymmetric information has also been studied in the context of public-private partnerships by Hoppe and Schmitz (2013) and Buso (2019). Yet, following Hart (2003) these papers do not explore optimal ownership structures; instead, they are focused on the question whether or not different tasks should be bundled in a partnership.[7]

Organization of the paper. The remainder of the paper is organized as follows. In Section 2, we introduce the basic model and discuss the first-best benchmark solution. In Section 3, we study the case of symmetric information and show that our simple model replicates the main insight of Besley and Ghatak (2001), according to which the investment technology does not matter in a public-good context. In Section 4, we introduce asymmetric information and point out that now the investment technology matters, vindicating the original insights of Grossman and Hart (1986) and Hart and Moore (1990) also in a public-good setting. Concluding remarks follow in Section 5.

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[7] Hart (2003, p. C71) points out that he ignores ownership issues and that he takes bundling to be the key property of a public-private partnership. With regard to the contract-theoretic literature on public-private partnerships, cf. also the recent work by Iossa and Martimort (2015a), Martimort and Straub (2016), Buso et al. (2017), and Henckel and McKibbin (2017). See also Li et al. (2015), who study the bundling of tasks in procurement auctions where the firms have private information about their costs. Schmitz (2012) explores investment incentives in a public-good setting with private information, though without studying ownership issues.

2 The Model

2.1 The basic setting

Consider two risk-neutral parties, A and B, who can undertake human-capital investments in order to provide a public good.[8] At some initial date 0, an ownership structure $o \in \{A, B\}$ is chosen. At date 1, party A invests $a \geq 0$ and party B invests $b \geq 0$. The investments are observable but non-contractible. Let party A's investment costs be given by $\frac{1}{2}c_A a^2$, while party B's investment costs are given by $\frac{1}{2}c_B b^2$, where $c_A > 0$ and $c_B > 0$.

At date 2, after the investments are sunk, the parties' valuations of the public good are realized and provision of the public good becomes contractible. Specifically, party A learns the realization of the random variable $\Theta_A \in \{0, 1\}$, which indicates whether or not party A values the public good highly. Let $\theta_A = \Pr\{\Theta_A = 1\}$. Similarly, party B learns the realization of the independently distributed random variable $\Theta_B \in \{0, 1\}$, where $\theta_B = \Pr\{\Theta_B = 1\}$. Note that we can interpret θ_A and θ_B as the expected valuations of party A and party B, respectively. The parties can now negotiate about the provision of the public good. Specifically, we suppose that with probability 1/2, party A can make a take-it-or-leave-it offer to party B, and otherwise party B can make a take-it-or-leave-it offer to party A.[9]

If the negotiations are successful and the parties agree to collaborate, the quantity of the public good that they can provide given the investment levels is $a + b$. If the parties do not reach an agreement at date 2, the quantity of the public good depends on who owns the physical assets that are necessary to

[8] In Besley and Ghatak's (2001) lead example, party A is the government and party B is an NGO (so A-ownership is public and B-ownership is private). However, party A and party B could also be two different government agencies (e.g., at the local and at the federal level). See also Section IV.2 of Besley and Ghatak (2001) for discussions of several other potential applications, e.g. regarding family economics or scientific collaborations.

[9] This simple bargaining game has often been used in the related literature, see 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 regular Nash bargaining solution (cf. Muthoo, 1999).

provide the public good. If party A is the owner, the default quantity is only a, because without party B's collaboration party A cannot make use of party B's human capital.[10] Similarly, the default quantity is only b if party B is the owner. The parties' date-2 payoffs in case of agreement and in case of disagreement are summarized in Table 1. Note that when the parties collaborate, they can agree on a (positive or negative) transfer payment t.

	Payoff of party A	Payoff of party B
Collaboration	$(a+b)\Theta_A + t$	$(a+b)\Theta_B - t$
Default, $o = A$	$a\Theta_A$	$a\Theta_B$
Default, $o = B$	$b\Theta_A$	$b\Theta_B$

Table 1. The parties' date-2 payoffs.

In order to keep the paper short, we focus on the most interesting case by making the following assumption.

Assumption 1. Suppose that $\theta_A \in (\frac{1}{2}, 1)$ and $\theta_B \in (\frac{1}{2}, 1)$.

Hence, in what follows we consider the case in which the probability that both parties value the public good highly is sufficiently large.

Note that the outcome of the negotiations at date 2 will depend on the ownership structure. At date 1, each party chooses the investment level that maximizes the party's expected payoff, anticipating the outcome of the date-2 negotiations. At date 0, the parties jointly agree on the ownership structure that maximizes the expected total surplus.[11]

[10] Note that the investments can be interpreted as acquisition of knowledge and project-specific skills that are not transferable to others in the absence of the investor.

[11] Note that at date 0 the parties are still symmetrically informed and there are no wealth constraints, so in line with the Coase Theorem the parties will always agree on the optimal ownership structure. The parties can divide the expected total surplus using suitable lump-sum payments.

2.2 The first-best benchmark

Before starting the analysis, we briefly describe the first-best benchmark solution that would be chosen by an omniscient and benevolent dictator. At date 2, the two parties' total surplus is maximized when the parties collaborate, so the quantity of the public good is $a+b$. At date 1, the parties' expected total surplus is given by

$$S(a,b) = (a+b)(\theta_A + \theta_B) - \frac{1}{2}c_A a^2 - \frac{1}{2}c_B b^2.$$

The first-best investment levels are thus given by

$$\begin{aligned} a^{FB} &= \frac{1}{c_A}(\theta_A + \theta_B), \\ b^{FB} &= \frac{1}{c_B}(\theta_A + \theta_B). \end{aligned}$$

3 Symmetric information

Suppose for a moment that at date 2 both parties learn the realizations of the valuations Θ_A and Θ_B. Under symmetric information, an agreement will always be achieved. Consider A-ownership ($o = A$). If party A can make a take-it-or-leave-it offer to party B, then it offers to collaborate when party B pays $b\Theta_B$. Party B accepts, since by doing so it just gets its default payoff $a\Theta_B$.[12] If party B can make the offer, then party B asks party A to make the payment $b\Theta_A$. Party A accepts, as it gets its default payoff. Hence, at date 1 the expected payoffs are[13]

$$\begin{aligned} u_A^A(a,b) &= \frac{1}{2}\left[(a+b)\theta_A + b\theta_B\right] + \frac{1}{2}a\theta_A - \frac{1}{2}c_A a^2, \\ u_B^A(a,b) &= \frac{1}{2}a\theta_B + \frac{1}{2}\left[(a+b)\theta_B + b\theta_A\right] - \frac{1}{2}c_B b^2. \end{aligned}$$

Thus, the investment levels are given by

$$\begin{aligned} a^A &= \frac{1}{c_A}\theta_A, \\ b^A &= \frac{1}{c_B}\frac{\theta_A + \theta_B}{2}. \end{aligned}$$

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

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

Now consider B-ownership ($o = B$). By analogy, at date 1 the expected payoffs are

$$\begin{aligned} u_A^B(a,b) &= \frac{1}{2}\left[(a+b)\theta_A + a\theta_B\right] + \frac{1}{2}b\theta_A - \frac{1}{2}c_A a^2, \\ u_B^B(a,b) &= \frac{1}{2}b\theta_B + \frac{1}{2}\left[(a+b)\theta_B + a\theta_A\right] - \frac{1}{2}c_B b^2. \end{aligned}$$

As a consequence, the investment levels are

$$\begin{aligned} a^B &= \frac{1}{c_A}\frac{\theta_A + \theta_B}{2}, \\ b^B &= \frac{1}{c_B}\theta_B. \end{aligned}$$

Observe that $a^A \geq a^B$ as well as $b^A \geq b^B$ hold if and only if $\theta_A \geq \theta_B$. Hence, both parties invest more when the party with the larger expected valuation is the owner. Since the investments are always smaller than the first-best benchmarks, concavity of the total surplus $S(a,b)$ implies that ownership by the party with the larger expected valuation must be optimal.

Proposition 1 *Suppose that there is symmetric information.*

(i) If $\theta_A > \theta_B$, then $a^B < a^A < a^{FB}$ and $b^B < b^A < b^{FB}$. Hence, $S(a^A, b^A) > S(a^B, b^B)$, so A-ownership is optimal.

(ii) If $\theta_B > \theta_A$, then $a^A < a^B < a^{FB}$ and $b^A < b^B < b^{FB}$. Hence, $S(a^B, b^B) > S(a^A, b^A)$, so B-ownership is optimal.

Note that the optimal ownership structure does not depend on the investment technology; i.e., it does not matter whether c_A is smaller or larger than c_B. Proposition 1 thus replicates the main conclusions of Besley and Ghatak (2001) in our setup.[14]

[14] The central conclusion of Besley and Ghatak (2001) is that the optimal ownership structure is independent of the investment technology. In contrast, the conclusion that the party with the larger expected valuation should be owner is just due to Besley and Ghatak's (2001) assumption that both parties have the same bargaining power (cf. Schmitz, 2013). To see this here, suppose that party A can make a take-it-or-leave-it offer with probability $\pi \in [0,1]$, while party B can make the offer otherwise. It is straightforward to verify that both parties invest more under A-ownership (and thus party A should be owner) if and only if $(1-\pi)\theta_A > \pi\theta_B$. The important

4 Asymmetric information

Now suppose that at date 2 only party A learns the realization of Θ_A, and only party B learns the realization of Θ_B, so the negotiations take place under asymmetric information.

Consider A-ownership ($o = A$). Suppose first party A can make the take-it-or-leave-it offer. If $\Theta_A = 1$, party A will ask party B to pay b, which party B will accept whenever $\Theta_B = 1$, so party A's expected date-2 payoff is $\theta_B(a + b + b) + (1 - \theta_B)a = a + 2b\theta_B$. Note that party A could alternatively offer to collaborate without getting a payment from party B. Yet, party A's expected payoff at date 2 would then be $a + b$ only, which is smaller than $a + 2b\theta_B$ since $\theta_B > 1/2$. Moreover, if $\Theta_A = 0$, party A will also ask party B to pay b, so party A's expected date-2 payoff is $b\theta_B$. Note that regardless of the realization of Θ_A, party B's date-2 payoff is $a\Theta_B$ when party A can make the offer.

Next, suppose that party B can make the offer. By analogy, party B asks party A to pay b, which party A will accept whenever $\Theta_A = 1$, so party B's expected date-2 payoff is $\theta_A(a + b + b) + (1 - \theta_A)a = a + 2b\theta_A$ if $\Theta_B = 1$ and $b\theta_A$ if $\Theta_B = 0$. Party A's date-2 payoff is thus $a\Theta_A$ when party B can make the offer.

Taken together, at date 1 the parties' expected payoffs read

$$\begin{aligned}
\tilde{u}_A^A(a,b) &= \frac{1}{2}\left[(a + 2b\theta_B)\,\theta_A + b\theta_B(1-\theta_A)\right] + \frac{1}{2}a\theta_A - \frac{1}{2}c_A a^2, \\
\tilde{u}_B^A(a,b) &= \frac{1}{2}a\theta_B + \frac{1}{2}\left[(a + 2b\theta_A)\,\theta_B + b\theta_A(1-\theta_B)\right] - \frac{1}{2}c_B b^2.
\end{aligned}$$

Observe that the expected total surplus now is

$$\tilde{S}^A(a,b) = (\theta_A + \theta_B)\,a + \left(\frac{1}{2}\theta_A + \frac{1}{2}\theta_B + \theta_A\theta_B\right) b - \frac{1}{2}c_A a^2 - \frac{1}{2}c_B b^2.$$

Notice that $S(a,b) - \tilde{S}^A(a,b) = \frac{1}{2}(1-\theta_B)\theta_A b + \frac{1}{2}(1-\theta_A)\theta_B b > 0$. If party A can make the offer, there is an ex post inefficiency when party B rejects party A's demand to pay b (which happens when $\Theta_B = 0$) and party A is of type $\Theta_A = 1$.

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insight is that this condition does *not* depend on c_A and c_B. For simplicity, following Besley and Ghatak (2001) and many other contributions to the property rights literature (cf. Hart, 1995), we focus on the case of symmetric bargaining powers ($\pi = 1/2$).

In this case, the surplus is only a instead of $a+b$. Similarly, when party B can make the offer, there is an ex post inefficiency when $\Theta_A = 0$ and $\Theta_B = 1$.

At date 1, the parties invest

$$\begin{aligned}\tilde{a}^A &= \frac{1}{c_A}\theta_A, \\ \tilde{b}^A &= \frac{1}{c_B}\frac{1+\theta_B}{2}\theta_A.\end{aligned}$$

Now consider B-ownership ($o = B$). By analogy, the parties' expected payoffs at date 1 are

$$\begin{aligned}\tilde{u}_A^B(a,b) &= \frac{1}{2}\left[(b+2a\theta_B)\theta_A + a\theta_B(1-\theta_A)\right] + \frac{1}{2}b\theta_A - \frac{1}{2}c_A a^2, \\ \tilde{u}_B^B(a,b) &= \frac{1}{2}b\theta_B + \frac{1}{2}\left[(b+2a\theta_A)\theta_B + a\theta_A(1-\theta_B)\right] - \frac{1}{2}c_B b^2.\end{aligned}$$

The expected total surplus now reads

$$\tilde{S}^B(a,b) = (\theta_A + \theta_B)\, b + \left(\frac{1}{2}\theta_A + \frac{1}{2}\theta_B + \theta_A\theta_B\right) a - \frac{1}{2}c_A a^2 - \frac{1}{2}c_B b^2,$$

and at date 1 the parties invest

$$\begin{aligned}\tilde{a}^B &= \frac{1}{c_A}\frac{1+\theta_A}{2}\theta_B, \\ \tilde{b}^B &= \frac{1}{c_B}\theta_B.\end{aligned}$$

Recall that under symmetric information both parties invest more under A-ownership than under B-ownership whenever party A has a larger expected valuation than party B. This result no longer holds when date-2 bargaining takes place under asymmetric information. It is still true that both parties invest more (less) under A-ownership than under B-ownership when θ_A is sufficiently large (small) compared to θ_B. Yet, there are now situations in which party A invests more under A-ownership even though $\theta_A < \theta_B$, and there are situation in which party B invests more under B-ownership even though $\theta_B < \theta_A$. Intuitively, while the owner's investment will always be used, the non-owner's investment will be used only if the parties agree to collaborate. Since an agreement is not always reached under asymmetric information, this means that the non-owner's investment incentives are now smaller than in the case of symmetric information.

Proposition 2 *Suppose that there is asymmetric information at date 2.*

(i) $\tilde{a}^A > \tilde{a}^B$ *whenever* $\theta_A > \frac{\theta_B}{2-\theta_B}$.

(ii) $\tilde{b}^A > \tilde{b}^B$ *whenever* $\theta_A > \frac{2\theta_B}{1+\theta_B}$.

Note that A-ownership is better than B-ownership whenever

$$\Delta(\theta_A, \theta_B, c_A, c_B) := \tilde{S}^A(\tilde{a}^A, \tilde{b}^A) - \tilde{S}^B(\tilde{a}^B, \tilde{b}^B)$$

is positive.

First, suppose that both parties have the same investment technology, $c_A = c_B =: c$. It is straightforward to show that $\Delta(\theta_A, \theta_B, c, c) > 0$ whenever $\theta_A > \theta_B$ holds.[15] Hence, when no party has a technological advantage over the other party, then it is still true that the party with the larger expected valuation should be the owner.

Next, suppose that both parties have the same expected valuation, $\theta_A = \theta_B =: \theta$. It turns out that $\Delta(\theta, \theta, c_A, c_B) > 0$ whenever $c_A < c_B$ holds.[16] Hence, in this case the party with the lower investment costs should be the owner. Intuitively, the investment technology matters for the optimal ownership structure, because it depends on the ownership structure which investment will not be fully used due to ex post inefficiencies when bargaining takes place under asymmetric information. The owner's investment will always be used, so ceteris paribus the party with the smaller investment costs should be owner.

In general, the optimal ownership structure depends on the expected valuations as well as on the investment technologies.

Proposition 3 *Suppose that there is asymmetric information at date 2.*

(i) If both parties have the same investment costs, the party with the larger expected valuation should be owner.

(ii) If both parties have the same expected valuations, the party with the smaller investment costs should be owner.

[15] To see this, note that $\Delta(\theta_A, \theta_B, c, c)$ can be written as $\frac{1}{8c}(5\theta_A + 5\theta_B + 2\theta_A\theta_B)(\theta_A - \theta_B)$.

[16] In order to verify this claim, note that $\Delta(\theta, \theta, c_A, c_B)$ can be simplified to $\frac{3}{8}\frac{\theta^2}{c_A c_B}\left(3 - \theta^2 - 2\theta\right)(c_B - c_A)$.

(iii) If party A has a better investment technology than party B, then A-ownership can be optimal even when party A has a smaller expected valuation than party B, and vice versa.

Our main result is illustrated in Figure 1. In the figure, $\theta_A = 3/4$ and $c_A = 1$. Recall that under symmetric information, A-ownership is optimal whenever $\theta_B < \theta_A$ and B-ownership is optimal whenever $\theta_B > \theta_A$, regardless of c_B. In contrast, under asymmetric information, technology matters. If $c_B = c_A$, it is still the case that the party with the larger expected valuation should be the owner. Yet, if $c_B < c_A$, then B-ownership can be optimal even when $\theta_B < \theta_A$. Similarly, if $c_B > c_A$, then A-ownership can be optimal even when $\theta_B > \theta_A$.

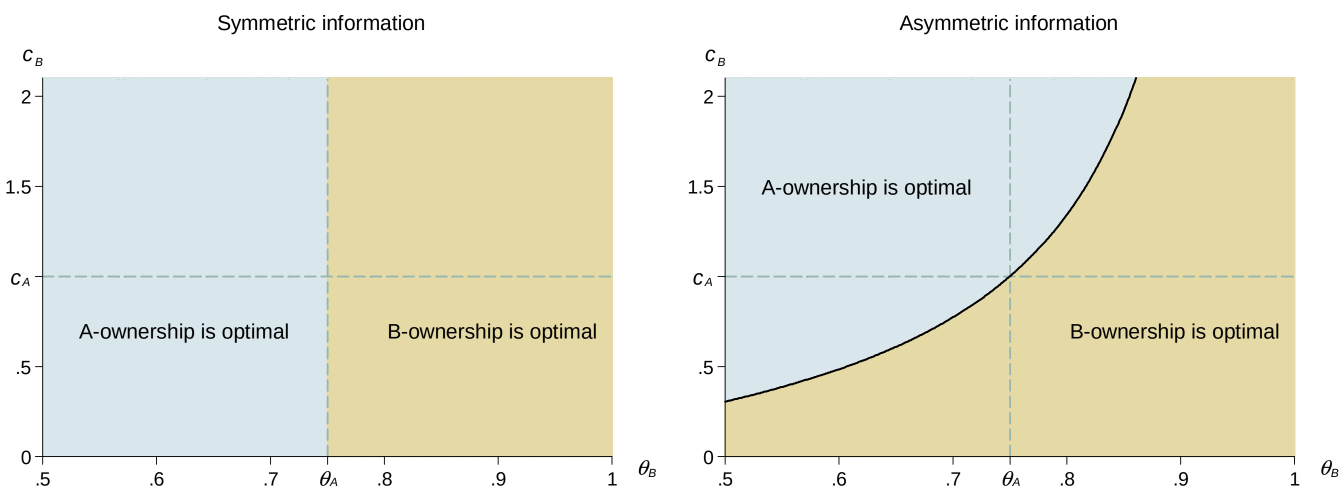

Figure 1. The optimal ownership structures. The solid curve in the case of asymmetric information depicts $\Delta(\theta_A, \theta_B, c_A, c_B) = 0$.

5 Conclusion

When parties can make non-contractible investments in the provision of a public good, Besley and Ghatak (2001) have argued that the party that values the public good most should have the relevant control rights, regardless of the investment technologies. Yet, we have shown that under the plausible assumption that parties may privately learn their valuations, the investment technologies matter. It may well be optimal to give ownership to the party with the smallest investment costs, even when another party has a larger expected valuation of the public good. Hence, the fundamental insights of the property rights approach that Grossman and Hart (1986) and Hart and Moore (1990) have derived in private-good contexts also hold in realistic settings with pure public goods.

It should be noted that in this short paper we have assumed that the information structure is exogenously given. In future research, it might be worthwhile to endogenize the information structure by allowing the parties to gather private information.[17] Moreover, following most contributions to the contract-theoretic literature on asymmetric information, we have assumed that the parties' information is "soft"; i.e., the parties are unable to provide any evidence (cf. Laffont and Martimort, 2002). It might be an interesting avenue for future research to explore the optimal ownership structure in public good problems when parties may have "hard" information that can be authenticated.[18] Finally, while we have considered sole ownership in the context of pure public goods, it might also be worthwhile to study the implications of asymmetric information in settings with impure public goods and various forms of joint ownership.[19]

[17] Starting with Crémer and Khalil (1992), several authors have studied information gathering in complete contracting models; see e.g. Lewis and Sappington (1997), Crémer et al. (1998), and the more recent work by Iossa and Martimort (2015b), Su (2017b), and Ye and Li (2018). Schmitz (2006) has studied the endogenous acquisition of private information in an incomplete contracting model, albeit in a private-good context.

[18] For contract-theoretic studies in which parties may have "hard" (i.e., certifiable) information, see e.g. Tirole (1986), Laffont and Martimort (1999), and Schmitz (2021).

[19] On impure public goods in the case of symmetric information, see Francesconi and Muthoo (2011). Rosenkranz and Schmitz (1999, 2003) have introduced different forms of joint ownership into the property rights approach under symmetric information when the owner's nonhuman assets may be excludable public goods. On joint ownership, cf. also Gattai and Natale (2017) for a recent literature survey.

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