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# Control Allocation, Revenue Sharing, and Joint Ownership*

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## Abstract

This paper develops a two-period double moral hazard model with incomplete contracting to explore the implication of the possible adverse effects of unilateral control on the optimal allocation of control rights and revenue in a joint venture. We identify conditions under which joint ownership and control become optimal when unilateral control gives the controlling party opportunities to inefficiently extract private benefits at the expense of the joint revenue. Moreover, this adverse consequence of control may also lead to the separation of share ownership and control, i.e., it may be optimal for the minority owner to have the control rights.


JEL Classification: L22, D23, D82.

Keywords: Joint Ownership, Control Rights, Revenue Sharing, Incomplete Contract

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# 1. Introduction

The property rights theory of the firm of Grossman, Hart, and Moore (henceforth GHM) (Grossman and Hart, 1986; Hart and Moore, 1990; Hart, 1995) has made significant progress in our understanding of firm ownership. According to the theory, firm ownership gives the owner the residual control rights over the use of the firm's physical assets and acts as an incentive mechanism for relationship-specific investments in the absence of complete contracting. Specifically, asset ownership allows the owner to reap at least some of the benefits from her specific investments, which gives her incentives for making such investments. However, in the GHM framework, joint ownership of assets is never optimal as it prevents either of the owners from enjoying any of the benefits of specific investments without the other party's consent. More generally, as Rajan and Zingales (1998) observe, GHM have focused only on the positive incentive effects of ownership but overlooked its adverse consequences.

In this paper, we develop a two-period double moral hazard model with incomplete contracting to show that when an owner with full control rights of a joint venture can extract private benefits at the expense of joint revenue, unilateral control may distort investment incentives and joint control can be optimal.[1] Specifically, we consider a model in which two parties each make an unverifiable investment (effort) to a joint project in the first period; and some further action (e.g., an operating decision) involving the project is then taken in the second period. The revenue from the project is stochastically determined by the ex ante investments as well as the ex post action. The ex ante contract can specify how the revenue is to be shared.[2] This initial contract, however, cannot specify the level

[1]The concept of private benefits of control has been extensively employed to address the issue of the bundling or separation of income rights and control rights in the context of IPO and the market for corporate control (Grossman and Hart, 1988; Harris and Raviv, 1988; Hart, 1995; Zingales, 1995; Mello and Parsons, 1998).

[2]Unlike GHM, we introduce the possibility of revenue sharing. We do so because revenue sharing is a common practice in joint ventures (Dasgupta and Tao, 2000; Hauswald and Hege, 2002). Partial ownership of a firm (e.g., a 30% equity ownership in a joint venture) is necessarily associated with the rights to claim part of the firm's profit streams. By assuming that only control rights are contractible, GHM do not distinguish between ownership and control. However, ownership of an asset is often regarded to also entail the claim on the returns (or, more precisely, residual income) from the asset (Alchian and Demsetz, 1972). Hart (1995) offers a few informal but insightful remarks on the relationship between residual income and control. First, he notes that residual income may be difficult to measure and sometimes may not even be well-defined; and if it is measurable, it is not always bundled together with

of investments or the ex post production action. But, the contract can allocate among the two parties the rights to control the ex post action. If only one of the parties has the control rights, she has the opportunity to use the rights to acquire some private benefits at a loss to the joint venture. The size of the private benefits is inversely related to the revenue of the project. It is the socially inefficient extraction of private benefits that gives rise to the cost of control. Control rights can also be held jointly by the two parties, meaning that each has the veto power over the ex post action. Under joint control, no party can extract private benefits from the project by unilaterally choosing the ex post action in her own favor.

In the above setting, we identify the optimal structure of revenue sharing and control allocation, which are simultaneously determined in the model. Giving full control to one of the parties of the joint venture has two countervailing effects. On one hand, the controlling party can guarantee herself a payoff that is not less than the contractual share of the revenue and this provides her incentives for the ex ante investment. On the other hand, unilateral control also has a negative effect on ex ante efficiencies as the controlling party can use her power to distort the choice of the ex post action from its efficient level in order to extract private benefits. Efficient renegotiation will lead to the choice of the optimal ex post action; but such renegotiation can distort ex ante investment incentives. When there are ample opportunities for both parties to acquire private benefits of control and incentives to invest by both of them are important, joint control becomes optimal. Joint control, of course, also entails incentive distortions. The relative magnitude of these distortions in comparison with the distortions from private benefits of control determines the optimal control allocation.

Our analysis provides an explanation for a theoretically puzzling feature of joint ventures, i.e., many of them are owned 50:50 by the two companies setting them up (Bleeke and Ernst, 1991; Hauswald and Hege, 2002). In situations with double-sided moral hazard such as joint ventures, franchise contracting and share cropping, revenue-sharing

residual control. He then proceeds to give a few justifications for why residual income and residual control are often bundled together. In particular, Hart comments that residual income and residual control may not be separable because the party having residual control may be able to divert some of the income away for her own private benefit.

parameters should supposedly be adjusted to reflect the relative importance of providing incentives to both parties (Eswaran and Kotwal, 1985; Bhattacharyya and Lafontaine, 1995). Viewed from this perspective, the 50:50 joint ownership that gives each partner an equal share of revenue would appear to provide sub-optimal incentives unless incentive provisions for both partners are equally important. Another feature of the 50:50 ownership is that it often gives the two partners the same control rights (i.e., veto rights) over important decisions of the joint venture. In other words, the two partners not only share equally the revenue but also the control rights. This close linkage between revenue shares and control rights requires explanations.

A number of recent papers (Chiu, 1998; de Meza and Lockwood, 1998; Rajan and Zingales, 1998) have also demonstrated the adverse effects of ownership on specific investments. The first two of these papers use a strategic bargaining game with outside options for the ex post negotiation to show that investment incentives may be lowered by asset ownership. Rajan and Zingales (1998) derive the adverse effects of ownership from the assumption that a party's outside options may negatively depend on the level of the party's ex ante investment. They, in particular, argue that when whole ownership has a negative effect on a party's outside options, joint ownership can be optimal as it grants veto power on the use of assets to each party and hence reduces their incentives to invest in outside options.

Cai (2003) and Halonen (2002) explicitly develop a theory of joint asset ownership. Cai (2003) extends the GHM model to situations where the level of investment specificity is endogenously determined. He shows that when specific investments and general investments are substitutes, joint ownership is optimal in most cases. Halonen (2002) embeds the GHM model in a repeated game setting in which joint ownership has the advantage of providing the highest punishment for deviation from optimal investments.[3]

In a related paper on joint ventures from the incomplete contracting perspective, Dasgupta and Tao (1998) propose a theory of equity joint ventures by distinguishing

[3] As in GHM, no distinction is made in the above cited literature between ownership and control. In this paper, we distinguish between the revenue claim element and the control element of ownership.

between marketable equities and unmarketable revenue-sharing contracts. In another paper, Dasgupta and Tao (2000) explain partial ownership in an upstream firm by a downstream firm as a device to increase the former's incentive to choose relationship-specific investments over general investments. But both papers treat ownership as a share of revenue and either ignore control rights or simply assume that the majority shareholder has the control rights, which they interpret as the power to make a take-it-or-leave-it offer in bilateral bargaining.

A more closely related paper is by Hauswald and Hege (2002), who also use the tradeoff between the incentive effects of revenue sharing and the negative consequences of unilateral control to show why and when 50:50 joint ownership can be optimal. The empirical implications of their model and the evidence they provide are largely consistent with our model. However, theirs is a static model with a Leontief production function, and particularly, they assume rather than prove the direct relationship between revenue shares and control.

The rest of the paper proceeds as follows. Section 2 lays out the model. Section 3 characterizes the optimal revenue sharing and control allocation. Section 4 concludes the paper with remarks on the empirical implication of our main result. All the proofs are in the Appendix.

# 2. The Model

## 2.1. Timing and Notations

We consider a two-period model involving two risk-neutral parties: $\mathrm{M}_1$ and $\mathrm{M}_2$. In period 1 (ex ante), each party can make an investment to develop a joint project: $e_1$ for $\mathrm{M}_1$ and $e_2$ for $\mathrm{M}_2$. Following Kim and Wang (1998), we define a composite investment, represented by $h = h(e_1, e_2)$. Let $c_1(e_1)$ and $c_2(e_2)$ denote the disutilities of $\mathrm{M}_1$'s and $\mathrm{M}_2$'s investment, respectively.

Let $\mathbb{R}$ be the space of real numbers, $\mathbb{R}_+$ be the space of non-negative real numbers, and $\mathbb{E}$ be the space of investment, which, for simplicity, is taken to be a subset of $\mathbb{R}$. We make the following technical assumptions.

**Assumption 1.** $h(e_1, e_2) \in \mathbb{R}$ is strictly increasing in $e_1$ and $e_2$.

**Assumption 2.** $c_1(e_1) \in \mathbb{R}_+$ and $c_2(e_2) \in \mathbb{R}_+$ are convex and strictly increasing in $e_1$ and $e_2$ respectively.

In period 2 (ex post), some further action $a \in \mathbb{A}$, where $\mathbb{A}$ denotes the space of feasible actions, needs to be taken, such as deciding on a specific type of product to produce or hiring a suitable manager to run the project. This action itself is assumed to be costless but affects the revenue of the project and may potentially generate private benefits to one of the two parties as well. The project yields at the end of period 2 a random revenue $X$, the range of which belongs to $\mathbb{R}_+$. The realization of $X$ is determined by the composite investment effort $h(e_1, e_2)$, the ex post action $a$ and the state of nature $\omega \in \Omega$, where $\Omega$ denotes the space of the states of nature. $\omega$ is realized at the end of period 1 or at the beginning of period 2, i.e., after the investments are made but before the action is taken. Formally, $X \equiv X(a, \omega, h)$.

Let $a^*(\omega, h)$ denote the unique revenue-maximizing action, and $X^*(\omega, h) \equiv X(a^*, \omega, h)$ denote the maximum revenue, all conditional on $h$ and $\omega$. Let the random variable $X^*$ be described by a distribution function $F(x, h)$ with $f(x, h)$ being the corresponding density function.[4] Thus the ex ante expected maximum revenue is

$$R(e_1, e_2) \equiv E(X^*) = \int x f[x, h(e_1, e_2)] dx. \tag{1}$$

We assume

**Assumption 3.** $R(e_1, e_2)$ is concave and strictly increasing separately in $e_1$ and $e_2$.

[4]Note that our formulation of the composite investment $h(e_1, e_2)$ is quite general compared to, e.g., that of Bhattacharyya and Lafontaine (1995), who, to use our notations, assume $X^* = h(e_1, e_2) + \varepsilon$. Let $f(\cdot)$ be the density function of $\varepsilon$. Then, the density function of $X^*$ is $f[x - h(e_1, e_2)]$, which is a special case of $f[x, h(e_1, e_2)]$ in our model.

## 2.2. Information Structure

Following GHM, we assume that ex ante investments $e_1$ and $e_2$, their disutilities $c_1(e_1)$ and $c_2(e_2)$, the state of nature $\omega$ and the ex post action $a$ are not contractible ex ante.[5] The ex ante investments may be unobservable to the third party and hence cannot be contracted. $\omega$ may represent a highly complex state of the world, including, for example, the state of consumer preferences. It is thus prohibitively costly to write a contract contingent on $\omega$ in sufficiently precise terms to make it enforceable by the court. The nature of the ex post action may be difficult to foresee or describe ex ante at date 1. For example, suppose the joint project is for the production of a technologically sophisticated widget. Before the state of nature is realized about the preferences of potential buyers for specific types of widgets, it is often impossible to know in advance the details of the widget that should be produced. Unlike GHM, however, we assume that revenue $X$ is publicly observable and is ex ante contractible.

Furthermore, like GHM, we assume that $\omega$, once realized, is observable to both parties and that $a$ is contractible ex post. While $a$ is not contractible ex ante, the ex post control rights over $a$ is contractible ex ante. We consider three types of control allocation: $M_1$ control, $M_2$ control, and joint control. In the case of joint control, each party has the veto rights over $a$; and if the two parties cannot reach an agreement on $a$, then no revenue will be generated. In the case of unilateral (single-party) control, the controlling party can unilaterally choose $a$ to maximize her own ex post payoff. Moreover, the controlling party can acquire an unverifiable private benefit. The non-controlling party is, however, assumed to enjoy no private benefit.[6]

[5] For standard justifications for incomplete contracts, see Williamson (1985) and Hart (1995). We are aware of the objection by Maskin and Tirole (1999), who argue that unverifiability does not necessarily preclude the existence of an ex ante efficient information elicitation mechanism (contract) that makes the unverifiable information de facto verifiable. We have nothing to say on the objection but follow GHM and exclude the possibility of using a message contingent mechanism. For formal foundations of incomplete contracting, see Hart and Moore (1999) and Segal (1999).

[6] It will be clear later that our results are not affected by this assumption (see footnote 12).

## 2.3. Private Benefits of Control

Let $B_i(a, \omega, h)$ denote the (nonnegative) private benefits of control to $\mathrm{M}_i$. We assume, for simplicity, that private benefits take the following linear form:[7]

$$B_i(a, \omega, h) = b_i[X^*(\omega, h) - X(a, \omega, h)] \quad \text{for } i = 1 \text{ and } 2, \tag{2}$$

where $b_i \in [0, 1)$ is a parameter measuring $\mathrm{M}_i$'s ability to acquire private benefits of control, and $X^*(\omega, h) - X(a, \omega, h)$ is the lost revenue as a result of a suboptimal action $a$. In other words, for every such action, the controlling party can acquire a private benefit that is a constant proportion of the lost revenue.[8] Clearly, $B_i(a^*, \omega, h) = 0$, meaning that it is socially inefficient for the controlling party to acquire any private benefit and that the ex post efficient action $a^*$ entails no private benefit to the controlling party. Let $a^0(\omega, h)$ be the maximizer of $B_i(a, \omega, h)$. Without loss of generality, we assume $X(a^0, \omega, h) = 0$, implying that $a^0$ is also the most inefficient action. Thus,

$$B_i(a^0, \omega, h) = b_i X^*(\omega, h) \quad \text{for } i = 1 \text{ and } 2. \tag{3}$$

Examples of unverifiable private benefits of control abound. For instance, the controlling party can use her decision power to sell the widget at an unnecessarily low price to a firm in which she or her relatives have a personal stake. This private benefit, however, can be difficult to verify if the widget is not a standard product and hence has no market price to which it can be compared. This action is inefficient from the perspective of maximizing the total revenue of the project because the private benefit the controlling party enjoys is only a fraction of the price concession she makes to the third party. Alternatively, the controlling party can choose to produce a specific type of widget that suits a related firm's need rather than a widget for an unrelated firm at a higher price.

## 2.4. Ex Ante Contracting and Ex Post Bargaining

[7] This interpretation of the private benefit of control follows Hart (1988), who, in showing the role of asset ownership, considers a number of scenarios where the owner of an asset is assumed to be able either to siphon off a fraction of the asset's return at no extra cost or to manipulate accounting costs and receive a fraction of the extra costs as a private benefit. These scenarios are special cases of our model.

[8] In the appendix, we show that this linear formulation does not affect our qualitative results.

At the beginning of period 1, the two parties can, given our contractibility assumptions, sign a contract to allocate the revenue as well as the control rights over the ex post action. We suppose that the initial contract agreed upon by the two parties is efficient ex ante. This is the case when both parties have a deep pocket and information is symmetric. In order to reach an agreement on such a contract, a lump-sum transfer payment between the two parties may be needed. The amount of such a payment depends on each party's ex ante bargaining power. Since it has no incentive effect, we will ignore it throughout the paper. Let $\mathcal{S}$ be the set of feasible revenue-sharing rules, defined by $\mathcal{S} \equiv \left\{ s : \mathbb{R}_{+} \rightarrow \mathbb{R}_{+} \right\}$. The revenue-sharing part of the contract gives each party a share of revenue: $s_1(X) \in \mathcal{S}$ for $\mathrm{M}_1$ and $X - s_1(X)$ for $\mathrm{M}_2$. We will restrict our attention to linear, budget-balancing revenue-sharing contracts.[9]

After the investments are made and the state of nature is realized by the end of period 1, the two parties may bargain over the ex post action $a$. This bargaining always takes place in the case of joint control. It may also take place in the case of unilateral control when the ex ante contract fails to motivate the controlling party to take the efficient action. Since $a$ is ex post contractible, the two parties would want to take advantage of the opportunity to ensure that the ex post action is efficient. During ex post bargaining, the initial revenue-sharing rule may be modified (i.e., renegotiated) to reflect each party's ex post bargaining position. Following GHM, we will use the Nash bargaining solution to solve for the ex post bargaining outcome.

To summarize, we use a time line (Figure 1) to illustrate the sequence of events.

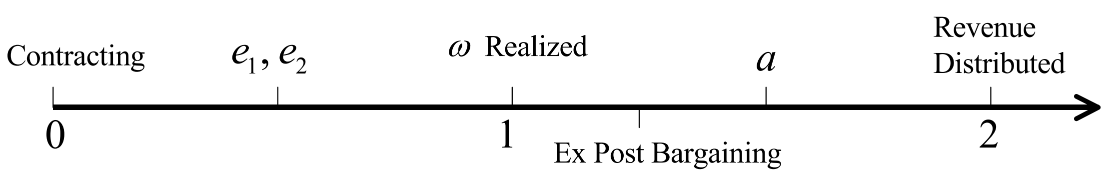


Figure 1. The Timing of Events

[9]The linearity assumption is rather natural in a double moral hazard setup. In fact, several authors have shown that a linear contract is optimal in one-period double moral hazard models (Bhattacharyya and Lafontaine, 1995; Kim and Wang, 1998; and Romano, 1994). We will also show that a linear revenue-sharing contract can achieve the second-best outcome in our model if it is possible to contract on the ex post action (see Proposition 1).

# 3. Analysis

In this section, we first derive the second-best benchmark outcome, assuming that the ex post action is contractible. In 3.2, we analyze the optimal revenue sharing and control allocation under incomplete contracting. In 3.3, we use an example to derive more specific results for an indeterminate case in the general setup.

## 3.1. The Second-Best Benchmark

If the ex post action can be contracted ex ante, then the allocation of control rights becomes irrelevant. The initial contract would be chosen to maximize the total expected revenue. The following proposition characterizes the second-best revenue-sharing rule under the condition that the ex ante contract can specify the efficient second-period action.[10]

**Proposition 1.** *If the ex post action $a$ is contractible ex ante, then with Assumptions 1–3, there exists an ex ante contract with a linear revenue-sharing rule*

$$s_i^*(x) = \alpha_i^* x, \tag{4}$$

*where $0 < \alpha_i^* < 1$, that induces the second-best investments $e_1^*$ and $e_2^*$.*

The second-best sharing rule $\alpha_i^*$ and investments $e_1^*$ and $e_2^*$ are formally defined by Program (A3) in the Appendix. Without loss of generality, we assume throughout the paper that $\alpha_1^* < 1/2$, which can be interpreted as $M_2$'s investment incentive being relatively more important than $M_1$'s.

Since $a$ must be decided ex post in period 2, there is no guarantee that the second-best outcome can be achieved. Particularly, the second-best revenue-sharing rule may be renegotiated ex post after the investments are sunk.

[10] Bhattacharyya and Lafontaine (1995) are perhaps the first to prove a result similar to Proposition 1 for a more special production function. Romano (1994) shows that a linear pricing contract can be optimal in dealing with the double moral hazard problem in the context of retail price maintenance. Kim and Wang (1998) provide a more general result without a proof. In the appendix, we provide a rigorous proof under weaker conditions for the general result in Kim and Wang.

## 3.2. Optimal Revenue Sharing and Control Allocation

We employ subgame perfect equilibrium as the equilibrium concept in analyzing the two-period game. Using the backward induction principle, we first analyze ex post bargaining and then derive the ex ante optimal contract.

In period 2, after $e_1$ and $e_2$ are sunk, the two parties can bargain over $a$ and renegotiate the initial revenue-sharing rule. Following GHM, we take the no-bargaining outcome as the disagreement point for the Nash bargaining solution and assume that the two parties split the gains from ex post renegotiation.

In the case of joint control, $a$ must be decided jointly by both parties and the no-bargaining outcome is zero revenue for each party. Nash bargaining leads to an agreement on the efficient action, i.e., $a = a^*$, and an equal split of the total revenue $X$ regardless of the initial revenue-sharing rule.

In the case of unilateral control, the no-bargaining outcome is determined by the initial contract as well as the ex post action the controlling party would choose unilaterally in the absence of ex post bargaining. Suppose that one of the parties, say $\mathrm{M}_i$, is allocated ex ante with the control rights and that her contractual share of revenue is $\alpha_i$. Without bargaining, $\mathrm{M}_i$ would choose $a$ to maximize her own private payoff:

$$\max_{a \in \mathbb{A}} \alpha_i X(a, \omega, h) + b_i[X^*(\omega, h) - X(a, \omega, h)] \equiv b_i X^*(\omega, h) + (\alpha_i - b_i) X(a, \omega, h). \quad (5)$$

This yields $a = a^*$ if $\alpha_i \geq b_i$ or $a = a^0$ if $\alpha_i < b_i$.[11] In the former case, the ex post outcome is efficient, and hence there is no room for mutually beneficial renegotiation. In the latter case, however, $\mathrm{M}_i$'s choice of $a$ is inefficient, and hence the two parties will resort to renegotiation in order to reach an ex post efficient agreement. The ex post

[11]Throughout the paper, we assume that the controlling party chooses $a^*$ instead of $a^0$ when she is indifferent between the two choices (for example, when $\alpha_i = b_i$ in this case); and we do not explicitly distinguish among outcomes that differ only when $\alpha_i = b_i$.

payoff for $\mathrm{M}_i$ after efficient renegotiation is[12]

$$b_i X^*(\omega,h) + \frac{1}{2}\left[X^*(\omega,h) - b_i X^*(\omega,h)\right] = \frac{1+b_i}{2} X^*(\omega,h). \tag{6}$$

Before we characterize the optimal ex ante contract, we introduce two lemmas regarding the revenue-sharing element of the contract.

**Lemma 1.** *If a revenue-sharing rule is not renegotiation-proof ex post, then it is (weakly) dominated by one that is renegotiation-proof.*

Given the above lemma, we can, without loss of generality, restrict our attention to renegotiation-proof sharing rules. In other words, we assume that a renegotiation-proof sharing rule will be chosen over a non-renegotiation-proof one when they achieve the same outcome. This can be justified when there is a small "ink cost" to each party if they engage in ex post renegotiation of the initial sharing rule. It is so small that no renegotiation will be deterred by such a cost. It is nevertheless a cost so that a renegotiation-proof sharing rule is slightly preferred over a non-renegotiation-proof one when they achieve the same outcome.

The second lemma is a useful result regarding the optimal revenue-sharing rule among a class of renegotiation-proof sharing rules that are not second-best. It will be used to prove the main result. Note that a revenue-sharing rule $\alpha_i$ is renegotiation-proof if and only if $\alpha_i \geq b_i$ in the case of unilateral control or $\alpha_i = 1/2$ in the case of joint control.

**Lemma 2.** *If $\alpha_i = k \in (\alpha_i^*,\ 1]$ for $i \in \{1,2\}$ is a renegotiation-proof revenue-sharing rule, then it is also the most efficient one among all renegotiation-proof revenue-sharing rules $\alpha_i \geq k$.*

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[12] It is possible that the non-controling party may also get some private benefits resulting from the controlling party's choice of an inefficient ex post action. Let $b_i'(X^* - X)$ be such benefits for the non-controlling party. Clearly, we need $b_i + b_i' < 1$. The post-renegotiation revenue share for the controlling party $\mathrm{M}_i$ then becomes $\frac{1+b_i-b_i'}{2}$, which is greater than $b_i$. Based on this result, it can be verified that all of the following results remain to hold.

Lemma 2 is intuitive.[13] It simply says that the further a renegotiation-proof revenue-sharing rule deviates from the second-best one, the less efficient it becomes.

The following proposition characterizes the optimal ex ante contract.

**Proposition 2.** *Let* $(\alpha_1^*, \alpha_2^*)$, *where* $\alpha_1^* < \frac{1}{2}$, *be the second-best sharing rule.*

**(1)** *If* $\alpha_i^* \geq b_i$ *holds for either* $i = 1$ *or* $i = 2$ *but not both, then an ex ante contract that specifies* $\alpha_i = \alpha_i^*$ *and gives* $M_i$ *the control rights is the unique optimal contract and implements the second-best outcome.*

**(2)** *If* $\alpha_i^* \geq b_i$ *holds for both* $i = 1$ *and* $i = 2$, *then an ex ante contract that specifies* $\alpha_i = \alpha_i^*$ *and gives either one of the parties the control rights implements the second-best outcome.*

**(3)** *If* $\alpha_i^* < b_i$ *holds for both* $i = 1$ *and* $i = 2$, *then the second-best outcome cannot be achieved. Depending on the parameters, either unilateral control or joint control can be optimal. In the case of control by* $M_i$, *the optimal share of revenue for* $M_i$ *is* $\alpha_i = b_i$. *Furthermore, if* $b_1 < 1/2$, *then* $M_1$ *control is more efficient than joint control; and if* $b_1 > 1/2$, *then joint control is more efficient than* $M_1$ *control.*

[13] Equivalently, if $\alpha_i = k \in [0, \alpha_i^*]$ for $i \in \{1, 2\}$ is a renegotiation-proof revenue-sharing rule, then it is also the most efficient one among all renegotiation-proof revenue-sharing rules $\alpha_i \leq k$.

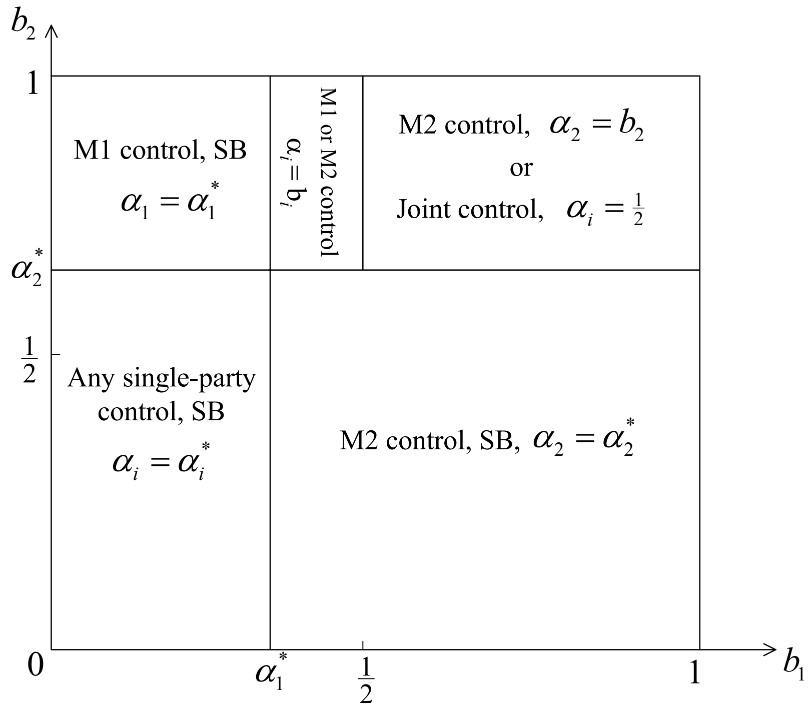


Figure 2. Illustration of Proposition 2

Figure 2 illustrates the above results, which are all intuitive. Part (1) of the proposition says that control rights should be given to the party for whom the private benefit acquired for each dollar of the total revenue lost as a result of a sub-optimal action is no greater than her second-best contractual share of revenue. The condition $\alpha_i^* \geq b_i$ ensures that the second-best revenue-sharing agreement $\alpha_i = \alpha_i^*$ will not be renegotiated because the controlling party M$_i$ would voluntarily choose the ex post efficient action. Part (2) simply says that if this condition holds for both parties, then unilateral control by either party is optimal and the second-best revenue sharing rule is self-enforcing.

Part (3) of the proposition is due to the fact that if the above condition fails to hold for both parties, meaning that it is relatively easy for both parties to acquire private benefits from having unilateral control, then the second-best revenue-sharing rule would not be renegotiation-proof under any control regime. In the case of joint control, all the sharing rules except for the 50:50 rule would be renegotiated ex post. In the case of unilateral control, the second-best sharing rule would be renegotiated because, otherwise, the controlling party would have incentives to choose an inefficient action given that the private benefit acquired from such an action more than offsets the loss in her contractual share of revenue. The second-best outcome, therefore, is not attainable.

In case (3) of Proposition 2, the optimal allocation of revenue and control is indeterminate. However, we know that in the case of unilateral control by $M_i$, the optimal sharing rule is $\alpha_i = b_i$. To see this, note that any sharing rule $\alpha_i > b_i > \alpha_i^*$ is, by Lemma 2, less efficient than $\alpha_i = b_i$. Also note that any sharing rule $\alpha_i < b_i$ would be renegotiated and, from equation (6), the effective ex post sharing rule would be $\alpha_i = (1 + b_i)/2 > b_i$, which is again less efficient than the ex ante sharing rule $\alpha_i = b_i$. The reason for $M_1$ control to be more efficient than joint control when $b_1 < 1/2$ is that $M_1$ control implies $\alpha_1 = b_1 > \alpha_1^*$ while joint control implies $\alpha_1 = 1/2 > b_1$. By Lemma 2, the former outcome is more efficient than the latter.

Proposition 2 shows that revenue sharing and control allocation must be optimally combined to provide investment incentives. Majority control, minority control and joint control can all be optimal depending on the relative importance of each party's investment incentives as well as on their respective abilities to acquire private benefits of control. The party whose ex ante investment incentives are relatively more important (i.e., $M_2$) should be given at least 50% of revenue, but it is sometimes optimal for the minority shareholder, who is also the party whose investment incentive is less important (i.e., $M_1$), or for both parties to have the control rights.

It is worth noting that in GHM (particularly, Hart and Moore, 1990; Hart, 1995), ex ante investments are in relationship-specific human capital, whereas in our model, specific investments can be either in human capital or embodied in the physical assets of the joint venture.[14] In the former case, both parties' participation in the second period is required to realize the value of the joint venture. In the latter case, we need to assume that the ex post action needs to be taken by one or both of the parties who are insiders in the second period to realize the value of the project, implying that it cannot be sold at its potential value to an outsider, and hence the initial contract cannot be conditional on such value. Note that, in the case of unilateral control, requiring non-controlling party's

[14] Hart (1995, pp.68-9) illustrates with an example why investments in physical assets may lead to joint ownership. However, in his example, a simple 50:50 revenue-sharing agreement or a random ownership can achieve the same outcome.

participation in the second period does not give her extra bargaining power in ex post renegotiation. The status quo of the renegotiation game is determined by the initial contract on revenue sharing and control allocation. Quitting from the joint venture (i.e., non-participation) is not a credible threat during renegotiation as she receives a share of revenue from participating.

## 3.3. An Example

In case (3) of Proposition 2, we cannot determine the optimal allocation of control rights. In the following, we use an example with specific functional forms to derive definite results for the case.

Let the composite investment be of the form:

$$h(e_1, e_2) = \mu_1 e_1 + \mu_2 e_2, \tag{7}$$

where $\mu_1$ and $\mu_2$ are two positive constants, and $e_1$ and $e_2$ are both non-negative. $h(e_1, e_2)$ clearly satisfies Assumption 1. Also, let

$$X^*(\omega, h) = A(\omega)h, \tag{8}$$

where $A(\omega) > 0$ and $E[A(\omega)] = 1$. Thus, we have

$$R(e_1, e_2) = \mu_1 e_1 + \mu_2 e_2, \tag{9}$$

which satisfies Assumption 3. In other words, the expected total revenue is equal to a weighted average of investments.[15] Let the cost of investment be $c_i(e_i) = \frac{1}{2}e_i^2$, which satisfies Assumption 2.

We can easily compute the second-best investments, defined by Program (A3) in Appendix A.1:

$$e_1^* = \frac{\mu_1^3}{\mu_1^2 + \mu_2^2}, \qquad e_2^* = \frac{\mu_2^3}{\mu_1^2 + \mu_2^2}; \tag{10}$$

[15] We assume a linear functional form for the composite investment and the expected revenue function for easy calculation. There is one caveat; i.e., the pre-condition for the above setup is that the two parties both participate in the project in period 1. Thus when $e_1 = 0$, it does not mean that $M_1$ does not participate.

and the second-best revenue-sharing rule, also defined in Appendix A.1:

$$\alpha_1^* = \frac{e_1^*}{\mu_1} = \frac{\mu_1^2}{\mu_1^2 + \mu_2^2}, \quad \alpha_2^* = \frac{e_2^*}{\mu_2} = \frac{\mu_2^2}{\mu_1^2 + \mu_2^2}. \tag{11}$$

Since we have assumed $\alpha_2^* > 1/2 > \alpha_1^*$, we also assume $\mu_2 > \mu_1$, which means that $\mathrm{M}_2$ is more productive than $\mathrm{M}_1$ or her investment is more important.

By calculating and comparing the total expected revenues under different control regimes respectively, we have the following results.

**Proposition 3.** *Suppose* $b_i > \alpha_i^*$ *for* $i \in \{1, 2\}$.

**(1)** *If* $b_1 < 1/2$ *and* $b_2 > b_1 + \alpha_2^* - \alpha_1^*$, $M_1$ *control is optimal.*

**(2)** *If* $b_2 < 2\alpha_2^* - \frac{1}{2}$ *and* $b_2 < b_1 + \alpha_2^* - \alpha_1^*$, *then* $M_2$ *control is optimal.*

**(3)** *If* $b_1 > 1/2$ *and* $b_2 > 2\alpha_2^* - \frac{1}{2}$, *then joint control is optimal.*

In the example, the efficient allocation of revenue and control for all combinations of $(b_1, b_2)$ in the region $[0,\ 1] \times [0,\ 1]$ is well defined and illustrated in Figure 3. Note that joint control (i.e., 50:50 ownership) is optimal only if $\alpha_2^* < 3/4$ and both $b_1$ and $b_2$ are relatively large. The intuition is the following. Joint control in general also entails incentive distortions. These distortions would be worthwhile to incur if the distortions from private benefits of control are even greater. This happens when it is very easy for both parties to acquire private benefits of control. Moreover, incentive distortions from joint control are reduced when investment incentives for both parties are important (i.e., $\alpha_2^*$ is relatively close to 1/2).

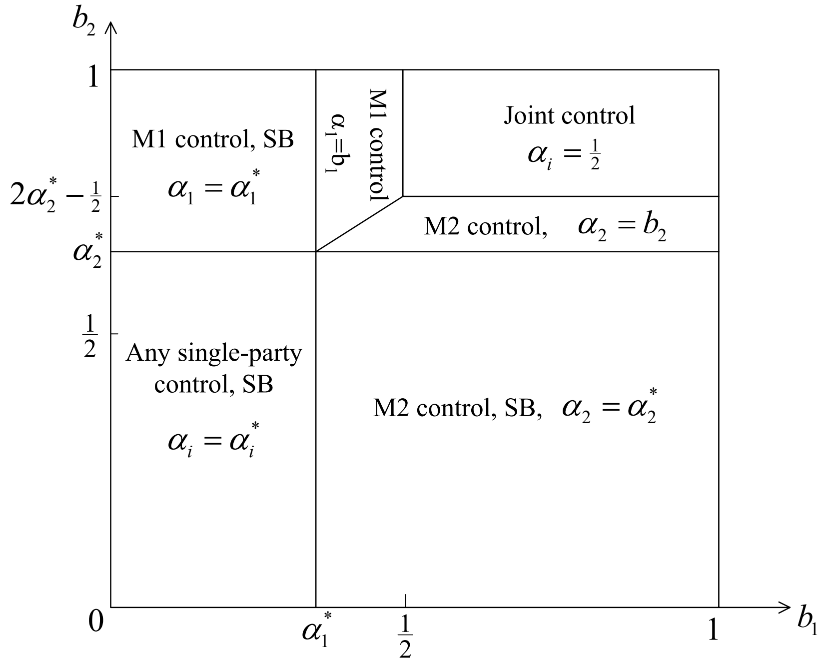


Figure 3. Illustration of Proposition 3

# 4. Conclusion

In this paper, we explore the implication of the possible adverse effects of unilateral control on the optimal allocation of control rights and revenue in a dynamic model of joint venture. We identify conditions under which joint ownership and control become optimal when unilateral control gives the controlling party opportunities to inefficiently extract private benefits at the expense of the joint revenue. Moreover, this adverse consequence of control may also lead to the separation of share ownership and control, i.e., it may be optimal for the minority owner to have the control rights.

The empirical implication of our result about the optimality of joint ownership and control is consistent with the evidence presented in Hauswald and Hege (2002). In that paper, the authors use a large sample of U.S. joint ventures to test the determinants of their ownership and control allocations. They use a measure of relatedness (in terms of industry and national origin) between parent companies and joint ventures as the proxy for the value extraction potential, and use the relative ratio of resource (investment) costs as a measure of similarity between the parents. Their empirical tests show that the likelihood of a joint venture opting for 50:50 ownership and joint control increases when there is a large value extraction potential and when the parents of the venture are more similar. In our model, similarities between the parent companies may be interpreted as implying that investment incentives for both parties of the joint venture are important. In our example, the relative importance of investment incentives by the two parties is determined by the relative importance of their contributions to the venture. In the general model, the difference in investment incentives for the two parties can also come from their difference in the costs of investments as in Hauswald and Hege (2002).

# Appendix

## A.1. Proof of Proposition 1

We first define the following notations to be used throughout the appendix:

$$R_1'(e_1, e_2) = \frac{\partial R(e_1,e_2)}{\partial e_1},\ R_2'(e_1, e_2) = \frac{\partial R(e_1,e_2)}{\partial e_2},\ R_1''(e_1, e_2) = \frac{\partial^2 R(e_1,e_2)}{\partial^2 e_1},\ R_2''(e_1, e_2) = \frac{\partial^2 R(e_1,e_2)}{\partial^2 e_2};$$
$$h_1'(e_1, e_2) = \frac{\partial h(e_1,e_2)}{\partial e_1},\ h_2'(e_1, e_2) = \frac{\partial h(e_1,e_2)}{\partial e_2},\ h_1''(e_1, e_2) = \frac{\partial^2 h(e_1,e_2)}{\partial^2 e_1},\ h_2''(e_1, e_2) = \frac{\partial^2 h(e_1,e_2)}{\partial^2 e_2}.$$

Given that an ex ante contract can specify the efficient ex post action, we only need to show that there exists a linear sharing rule that induces the second-best ex ante investments.

The problem of maximizing the total expected revenue can be written as

$$\max_{s_i \in \mathcal{S},\, e_1, e_2 \in \mathbb{E}} \quad R(e_1, e_2) - c_1(e_1) - c_2(e_2) \tag{A1}$$

$$\text{s.t.} \quad h_1' \int s_1(x) f_h[x, h(e_1, e_2)]dx = c_1'(e_1), \tag{A1a}$$

$$h_2' \int s_2(x) f_h[x, h(e_1, e_2)]dx = c_2'(e_2), \tag{A1b}$$

$$h_1'' \int s_1(x) f_h[x, h(e_1, e_2)]dx + (h_1')^2 \int s_1(x) f_{hh}[x, h(e_1, e_2)]dx < c_1''(e_1), \tag{A1c}$$

$$h_2'' \int s_2(x) f_h[x, h(e_1, e_2)]dx + (h_2')^2 \int s_2(x) f_{hh}[x, h(e_1, e_2)]dx < c_2''(e_2), \tag{A1d}$$

$$s_1(x) + s_2(x) = x, \text{ for all } x \in \mathbb{R}_+, \tag{A1e}$$

where (A1a) and (A1b) are the first-order conditions for $M_1$ and $M_2$'s incentive problems respectively, and (A1c) and (A1d) are the corresponding second-order conditions. We will first ignore the inequality constraints (A1c) and (A1d); we will later prove that they are satisfied by the solution to problem (A1) without them. Substituting (A1e) into (A1b) and then (A1b) into (A1a) implies

$$R_1'(e_1, e_2) = c_1'(e_1) + \frac{h_1'(e_1, e_2)}{h_2'(e_1, e_2)} c_2'(e_2).$$

Thus problem (A1) without the second-order conditions becomes

$$\begin{array}{rl} \max\limits_{s_2 \in \mathcal{S},\, e_1, e_2 \in \mathbb{E}} & R(e_1, e_2) - c_1(e_1) - c_2(e_2) \\ \text{s.t.} & R_1'(e_1, e_2) = c_1'(e_1) + \frac{h_1'(e_1, e_2)}{h_2'(e_1, e_2)} c_2'(e_2), \\ & h_2'(e_1, e_2) \int s_2(x) f_h[x, h(e_1, e_2)]dx = c_2'(e_2). \end{array} \tag{A2}$$

Let $(e_1^*, e_2^*)$ be the solution to the above problem without the second constraint, i.e., the solution to the following problem:

$$\begin{array}{rl} \max\limits_{e_1, e_2 \in \mathbb{E}} & R(e_1, e_2) - c_1(e_1) - c_2(e_2) \\ \text{s.t.} & R_1'(e_1, e_2) = c_1'(e_1) + \frac{h_1'(e_1, e_2)}{h_2'(e_1, e_2)} c_2'(e_2). \end{array} \tag{A3}$$

Note that in the above problem, the optimum does not depend on the revenue-sharing rule.

Given $(e_1^*, e_2^*)$, we look for a contract $s_2(x)$ that satisfies the second condition of problem (A2). There are many such contracts. In particular, a sharing contract of the form $s_2(x) = \alpha_2 x$ will do. The second constraint of (A2) then becomes

$$\alpha_2 R_2'(e_1^*, e_2^*) = c_2'(e_2^*).$$

Let $s_2^*(x) = \alpha_2^* x$, where

$$\alpha_2^* = \frac{c_2'(e_2^*)}{R_2'(e_1^*, e_2^*)}.$$

Clearly, $(e_1^*, e_2^*, s_2^*)$ is a solution to problem (A2), i.e., a solution to problem (A1) without constraints (A1c) and (A1d). We now check whether the second-order conditions (A1c) and (A1d) are satisfied by this solution. Substituting $s_2^*(x) = \alpha_2^* x$ into the left-hand side of (A1d), we have

$$h_2'' \int s_2^*(x) f_h[x, h(e_1, e_2)]dx + (h_2')^2 \int s_2^*(x) f_{hh}[x, h(e_1, e_2)]dx = \alpha_2^* R_2''(e_1^*, e_2^*),$$

which, by Assumptions 2 and 3, is non-positive and less than $c_2''(e_2^*)$. Condition (A1d) is thus satisfied by the solution $(e_1^*, e_2^*, s_2^*)$, which, for a similar reason, also satisfies condition (A1c). Therefore, we can conclude that $(e_1^*, e_2^*, s_2^*)$ is a solution to problem (A1).

Furthermore, substituting (A1a) into (A1b) yields

$$R_2'(e_1, e_2) = c_2'(e_2) + \frac{h_2'(e_1, e_2)}{h_1'(e_1, e_2)} c_1'(e_1).$$

By Assumptions 1 and 2, we have $0 < \alpha_2^* < 1$. Also, since the first-best solution $(e_1^{**}, e_2^{**})$ satisfies

$$R_1'(e_1^{**}, e_2^{**}) = c_1'(e_1^{**}) = c_2'(e_2^{**}),$$

$(e_1^*, e_2^*)$ is not first-best.

## A.2. Proof of Lemma 1

Consider a revenue-sharing rule $\alpha_i$. Suppose M$_i$ has control. If $\alpha_i \geq b_i$, it is renegotiation-proof. Only a sharing rule with $\alpha_i < b_i$ would result in ex post renegotiation. The effective share of revenue for M$_i$ after renegotiation would be $\widehat{\alpha}_i = \frac{1+b_i}{2} > b_i$. Thus an ex ante renegotiation-proof sharing rule $\widehat{\alpha}_i$ can achieve the same outcome as the initial sharing rule $\alpha_i$, and the former would be slightly more efficient than the latter if there is a small "ink cost" of renegotiation. The same result holds when the other party has control. In the case of joint control, a sharing rule $\alpha_i \neq 1/2$ will be renegotiated ex post and the effective share of revenue for each party after renegotiation would be $1/2$. Therefore, under joint control, all sharing rules are (weakly) dominated by the 50:50 sharing rule.

## A.3. Proof of Lemma 2

Suppose $\alpha_2 = k$ is renegotiation-proof. Consider, without loss of generality, all the renegotiation-proof sharing rules $\alpha_2 \geq k > \alpha_2^*$. We need to show that among them, $\alpha_2 = k$ maximizes the total expected revenue. Because these sharing rules are renegotiation-proof, they are self-enforcing in the second period and $a = a^*$ will be chosen. Therefore, we only need to show $\alpha_2 = k$ is the solution to the following maximization problem:

$$\begin{aligned} \max_{\alpha_2 \geq k,\, e_1, e_2 \in \mathbb{E}} \quad & R(e_1, e_2) - c_1(e_1) - c_2(e_2) \\ \text{s.t.} \quad & R_1'(e_1, e_2) = c_1'(e_1) + \tfrac{h_1'(e_1,e_2)}{h_2'(e_1,e_2)} c_2'(e_2), \\ & \alpha_2 R_2'(e_1, e_2) = c_2'(e_2). \end{aligned} \tag{A4}$$

First we show that the above problem is equivalent to the following problem:

$$\begin{aligned} \max_{\alpha_2 \geq k,\, e_1, e_2 \in \mathbb{E}} \quad & R(e_1, e_2) - c_1(e_1) - c_2(e_2) \\ \text{s.t.} \quad & R_1'(e_1, e_2) = c_1'(e_1) + \tfrac{h_1'(e_1,e_2)}{h_2'(e_1,e_2)} c_2'(e_2), \\ & \alpha_2 R_2'(e_1, e_2) \leq c_2'(e_2). \end{aligned} \tag{A5}$$

To see this, let the solution to (A5) be $(\hat{e}_1, \hat{e}_2, \hat{\alpha}_2)$. If $\hat{\alpha}_2 R_2'(\hat{e}_1, \hat{e}_2) < c_2'(\hat{e}_2)$, then it would also be the solution to the problem without the condition $\alpha_2 R_2'(e_1, e_2) \leq c_2'(e_2)$. From

(A3), $(\hat{e}_1, \hat{e}_2)$ would be equal to $(e_1^*, e_2^*)$, which implies $k \leq \hat{\alpha}_2 \leq \frac{c_2'(\hat{e}_2)}{R_2'(\hat{e}_1, \hat{e}_2)} = \frac{c_2'(e_2^*)}{R_2(e_1^*, e_2^*)} = \alpha_2^*$. But this contradicts the assumption that $\alpha_2^* < k$. Thus, the inequality condition in (A5) must be binding, which means that problems (A4) and (A5) are equivalent.

The Lagrangian function for (A5) is

$$\mathcal{L} = R(e_1, e_2) - c_1(e_1) - c_2(e_2) + \lambda \left[\alpha_2 R_2'(e_1, e_2) - c_2'(e_2)\right]$$
$$+\mu \left[R_1'(e_1, e_2) - c_1'(e_1) - \frac{h_1'(e_1, e_2)}{h_2'(e_1, e_2)} c_2'(e_2)\right],$$

where $\lambda \leq 0$. Suppose $\lambda = 0$. Then the above Lagrangian function is equivalent to the one for the maximization problem (A3), implying that the solution to (A5), $(\hat{e}_1, \hat{e}_2, \hat{\alpha}_2)$, is the same as that to (A3) and hence is the second-best solution, i.e., $(\hat{e}_1, \hat{e}_2) = (e_1^*, e_2^*)$. But this leads to a contradiction as we have shown above. Thus, $\lambda < 0$.[16] Because $\frac{\partial \mathcal{L}}{\partial \alpha_2} = \lambda R_2'(e_1, e_2) < 0$, the optimal $\alpha_2$ for (A5) must be as small as possible, i.e., $\hat{\alpha}_2 = k$.

## A.4. Proof of Proposition 2

(1) Since $\alpha_i^* \geq b_i$, a revenue-sharing rule $\alpha_i = \alpha_i^* \geq b_i$ is renegotiation-proof and implements the second-best outcome. Clearly, all other revenue-sharing rules with $\alpha_i \geq b_i$ are less efficient. The sharing rules with $\alpha_i < b_i \leq \alpha_i^*$ are not renegotiation-proof.

(2) This part is immediately implied by part (1).

(3)First consider the case of unilateral control by $\mathrm{M}_i$. Given that $\alpha_i^* < b_i$, all the sharing rules with $\alpha_i \geq b_i$ are, by Lemma 2, Pareto-dominated by the sharing rule $\alpha_i = b_i$. On the other hand, any sharing rule with $\alpha_i < b_i$ is not renegotiation-proof. Therefore, if $\mathrm{M}_i$ is given the control rights, then the optimal sharing rule is $\alpha_i = b_i$. Since $b_i > \alpha_i^*$, the second-best outcome cannot be implemented under unilateral control.

[16] The reason we need to show the equivalence between (A4) and (A5) should now be clear. Note that the Lagrangian function for (A4) is the same as the one for (A5) except that $\lambda$ can be either negative or positive. Thus we need to use (A5) to find out the sign of $\lambda$.

Next consider the case of joint control. A joint control contract with or without a revenue sharing rule is equivalent to a renegotiation-proof contract that stipulates joint control and an equal share of revenue between two parties (i.e., $\alpha_1 = 1/2$), which, clearly, cannot implement the second-best outcome.

Now suppose $\alpha_1^* < b_1 < 1/2$. A renegotiation-proof joint control contract with $\alpha_1 = 1/2$ is, by Lemma 2, Pareto-dominated by a renegotiation-proof contract that allocates M$_1$ with the control rights and a share of revenue $\alpha_1 = b_1$. In other words, M$_1$ control dominates joint control.

Suppose $b_1 > 1/2$. Any contract that allocates M$_1$ with the control rights must optimally have the renegotiation-proof sharing rule $\alpha_1 = b_1$. Because $b_1 > 1/2 > \alpha_1^*$, by Lemma 2, such a contract is Pareto-dominated by a joint control contract with $\alpha_1 = 1/2$.

## A.5. Proof of Proposition 3

We prove the proposition by calculating and then comparing the total expected revenues under different control regimes.

Under M$_1$ control, the optimal sharing rule is $\alpha_1 = b_1$ (and $\alpha_2 = 1 - b_1$). M$_i$ would choose investment $e_i$ to solve the following problem

$$\max_{e_1, e_2 \in \mathbb{E}} b_i R(e_1, e_2) - c_1(e_1) - c_2(e_2),$$

which yields $e_1 = b_1\mu_1$, $e_2 = (1 - b_1)\mu_2$. It can be calculated that the total expected revenue is

$$V_1 \equiv \left[\left(b_1 - \frac{1}{2}\right)\alpha_1^* + \frac{1 - b_1^2}{2}\right](\mu_1^2 + \mu_2^2).$$

Under M$_2$ control, the optimal sharing rule is $\alpha_2 = b_2$ (and $\alpha_1 = 1 - b_2$). Such a contract yields $e_1 = (1 - b_2)\mu_1$, and $e_2 = b_2\mu_2$. The total expected revenue is

$$V_2 \equiv \left[\left(b_2 - \frac{1}{2}\right)\alpha_2^* + \frac{1 - b_2^2}{2}\right]\left(\mu_1^2 + \mu_2^2\right).$$

Under joint control, the sharing rule is $\alpha_i = \frac{1}{2}$. Again, we can similarly find $e_1 = \frac{\mu_1}{2}$, and $e_2 = \frac{\mu_2}{2}$. The total expected revenue is

$$V_J \equiv \frac{3}{8}\left(\mu_1^2 + \mu_2^2\right).$$

In the region defined by $b_2 > \alpha_2^*$ and $b_1 > \frac{1}{2}$, we compare joint control with M$_2$ control. If joint control is more efficient, we have $V_J > V_2$, which is equivalent to

$$\frac{3}{8} > \left(b_2 - \frac{1}{2}\right)\alpha_2^* + \frac{1-b_2^2}{2},$$

which, in turn, is equivalent to

$$\left(\frac{1}{2} - \alpha_2^*\right)^2 < (\alpha_2^* - b_2)^2 \qquad \text{or} \qquad \alpha_2^* - \frac{1}{2} < b_2 - \alpha_2^*.$$

That is, if $b_2 > 2\alpha_2^* - \frac{1}{2}$, we have $V_J > V_2$; otherwise $V_J \leq V_2$.

In the region defined by $\alpha_1^* < b_1 < \frac{1}{2}$ and $b_2 > \alpha_2^*$, we compare M$_1$ control with M$_2$ control. The inequality $V_1 > V_2$ is equivalent to

$$\left(b_1 - \frac{1}{2}\right)\alpha_1^* + \frac{1-b_1^2}{2} > \left(b_2 - \frac{1}{2}\right)\alpha_2^* + \frac{1-b_2^2}{2},$$

which, in turn, is equivalent to

$$\left(\alpha_1^* - \frac{1}{2}\right)^2 - (b_1 - \alpha_1^*)^2 > \left(\alpha_2^* - \frac{1}{2}\right)^2 - (b_2 - \alpha_2^*)^2.$$

Since $\left(\alpha_1^* - \frac{1}{2}\right)^2 = \left(\alpha_2^* - \frac{1}{2}\right)^2$, we have

$$V_1 > V_2 \quad \Leftrightarrow \quad b_1 - \alpha_1^* < b_2 - \alpha_2^*.$$

Thus, if and only if $b_2 > b_1 + \alpha_2^* - \alpha_1^*$, M$_1$ control is more efficient than M$_2$ control. The linear line $b_2 = b_1 + \alpha_2^* - \alpha_1^*$ passes through points $(\alpha_1^*, \alpha_2^*)$ and $\left(\frac{1}{2}, 2\alpha_2^* - \frac{1}{2}\right)$.

## A.6. A nonlinear formulation of the private benefits of control

In modeling private benefits of control, we have used a linear formulation, which greatly simplifies our analysis. We now show that our qualitative result on the optimality of joint ownership does not depend on this assumption. The basic intuition remains to be that when it is very easy for the controlling party to divert the value of the joint venture under unilateral control, she will do so unless she receives most of the revenue from the contract. This would be very inefficient either way if the non-controlling party's investment is also very important.

Now consider a nonlinear formulation of private benefits of control. Let $q(a, \omega, h) \equiv [X^*(\omega, h) - X(a, \omega, h)]/X^*(\omega, h)$. Thus $q(a, \omega, h)X^*(a, \omega, h)$ denote the diverted value. Under unilateral control, the controlling party can be thought of as being able to act as if she can choose a $q$ between 0 and 1 and acquire a private benefit $B_i(q, \omega, h)$. Assume that both parties, when given the control rights, have the same ability to extract private benefits: $B_i = qX^* - kq^2X^*/2$, where $k > 0$ is a constant measuring the controlling party's ability to divert value from the joint venture. This nonlinear formulation can be interpreted as that the controlling party can "cream off" a fraction of the potential total revenue, i.e. $qX^*$, at a deadweight loss of $kq^2X^*/2$. In the absence of renegotiation, the controlling party $\mathrm{M}_i$ would choose $q$ in the second period to maximize $\alpha_i(1-q)X^* + qX^* - kq^2X^*/2$. This yields

$$q = \begin{cases} (1-\alpha_i)/k & \text{if } k \geq 1-\alpha_i \\ 1 & \text{if } k < 1-\alpha_i \end{cases}.$$

Therefore, unless $\alpha_i = 1$, the controlling party would have incentives to acquire private benefits. In other words, unlike in the linear case, all revenue-sharing rules with $\alpha_i \neq 1$ will be renegotiated in equilibrium. The post-renegotiation share of revenue for the controlling party is $\widehat{\alpha}_i = \alpha_i(1-q) + q - kq^2/4$. Given $k$, if $\alpha_i < 1-k$, then $q = 1$ and $\widehat{\alpha}_i = 1 - k/4$. If $\alpha_i \geq 1-k$, then $q = (1-\alpha_i)/k$, and, as can be easily verified, $\widehat{\alpha}_i = \alpha_i + (3/4)(1-\alpha_i)^2/k$. Thus, if $k$ is very small, say, close to zero, then the effective share of revenue for the controlling party gets close to one. Thus the non-controlling party's investment incentives would be very low. When both parties' investments are important, this outcome resulting from unilateral control is clearly less efficient than joint control.

In a similar manner, we can use the above nonlinear formulation of the private benefits of control to identify conditions for the optimality of unilateral control by either of the two parties.

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