Termination and Coordination in Partnerships

Deborah Minehart
Boston University
Boston, MA 02115
minehart@bu.edu

Zvika Neeman
Boston University
Boston, MA 02115
zvika@bu.edu

It is common practice for firms to pool their expertise by forming partnerships such as joint ventures and strategic alliances. A central organization problem in such partnerships is that managers may behave noncooperatively in order to advance the interests of their parent firms. We ask whether contracts can be designed so that managers will maximize total profits. We characterize first best contracts for a variety of environments and show that efficiency imposes some restrictions on the ownership shares. In addition, we evaluate the performance of two termination contracts that are widely used in practice: the shotgun rule and price competition. We find that although these contracts do not achieve full efficiency, they both perform well. We provide insight into when each rule is more efficient.

1. Introduction

It has become common practice for firms to pool their expertise in partnerships such as joint ventures and strategic alliances. A central organizational problem in partnerships is that rather than coordinating their efforts, managers may behave noncooperatively to advance the interests of their parent firms. This problem is extensively discussed in the literature on strategic alliances.[1] Harrigan (1988), for example, reports that less than half of cooperative alliances are

We wish to thank Albert Ma and Michael Riordan for very useful comments. We also wish to thank Bob Anderson, Eddie Dekel, Ben Hermalin, Michael Katz, Rachel Kranton, Matthew Rabin, and Suzanne Scotchmer for criticism on earlier drafts. Two anonymous referees and a coeditor provided useful comments.

1. See, for example, Hall (1984), Harrigan (1985), Hladik (1984), Killing (1983), Kogut (1989), and Goldenberg (1988).

Journal of Economics & Management Strategy, Volume 8, Number 2, Summer 1999, 191–221

considered successful by all parents. In light of this evidence, we ask whether contracts can be designed so that partnerships maximize joint profits.

We consider a model where firms' valuations of a partnership are private information, reflecting what they know about their ability to market and use the output. The valuations are drawn from distributions that are endogenously determined by the effort choices of the firms. The combination of moral hazard and asymmetric information gives rise to two problems. First, a firm may wish to expend effort in enhancing its own private valuation at the expense of the partner's valuation. Second, when the partnership is dissolved, the firm with the lower valuation may inefficiently assume full ownership. Full efficiency requires solving both of these problems.

Many alliances in research and development fit the structure of our model. For example, firms with complementary core competencies form alliances to conduct joint work on new products. Once a product is developed, however, the complementarity between partners disappears and the partnership terminates. In biotechnology, one partner is often a large pharmaceutical and the other a small R & D boutique. If the project yields a product that is useful to the pharmaceutical, the pharmaceutical buys out the boutique and takes the product through the marketing and distribution stages.[2] Otherwise, the boutique may obtain full rights to the product and move on to seek an alternate pharmaceutical partner. A more subtle example is alliances that are used as precursers to acquisitions. In these alliances firms work together for a period to explore the possibility of a buyout.[3]

In our model, there are two partners. Each partner has an agenda. The two agendas are represented by a binary effort choice. When effort is coordinated, both partners follow the same agenda. As a consequence, one partner is "dominant" in the sense that it is more likely to have a high private valuation. For instance, in a biotechnology alliance, the dominant partner is most likely to be the pharmaceutical company. In an alliance that is a precurser to an acquisition, the dominant partner is the firm that hopes to make the acquisition.

We consider environments where private valuations are uniformly distributed across intervals that depend on the efforts. We find that first best contracts exist for a reasonable subset of these

2. For an empirical study of technology transfer in this type of alliance, see Pisano and Mang (1991).

3. Bleeke and Ernst (1995) and Nanda and Williamson (1995) document this type of alliance.

environments. We find that the main contractual difficulty is the problem of inducing effort coordination. A partnership can always be terminated efficiently, but effort may not always be coordinated. We discuss how changes in the underlying parameters of the valuation distributions affect the difficulty of the effort coordination problem. We develop a simple sufficiency condition for existence of a first best contract according to which the dominant partner must be sufficiently dominant.

We also show that efficiency imposes some restrictions on the ownership structure of the partnership. We identify a division of ownership shares for which the partnership can always be dissolved efficiently. Under this division, *the dominant firm has the larger share*. The result extends a result by Cramton et al. (1987) which says that when partners' valuations are drawn from symmetric distributions, the equal-shares partnership can always be dissolved efficiently. The intuition for our result is straightforward. The dominant firm is more likely to assume full ownership at termination. If this firm begins with a higher initial ownership share, then the expected number of shares traded at termination is low. The shares that maximize efficiency at dissolution essentially minimize the occurrence of trade.[4]

In the second part of our analysis, we evaluate the performance of two termination rules that are commonly used to dissolve partnerships. Under the first rule, one partner proposes a price and the other decides whether to buy or sell at that price. We refer to this as the *shotgun rule*. Under the second rule, both partners submit bids and the high bidder buys the shares of the low bidder at a price equal to the higher bid. We refer to this rule as *price competition*. A contract is given by a termination rule together with an arbitrary division of ownership shares. For each rule, we characterize the contract (i.e., the ownership shares) that maximize joint profits.

We find that although these contracts do not achieve full efficiency in our environments, they both perform well. As in our first-best analysis, we find that the shares that maximize efficiency in dissolution give the dominant firm a larger share. This is true for both rules and follows from the same intuition as for the first best contracts. These shares however are not optimal for effort coordination. Intuitively, the closer the subordinate firm is to being a residual

4. With informational asymmetries, agents can potentially earn rents from their private information. When there is less need for trade, there are fewer possibilities for rent seeking, and so incentives leading to efficient trade are easier to establish. The *least* auspicious share structure gives the dominant firm a share of zero. In this case a result of Myerson and Satterthwaite (1983) shows that dissolution is never efficient.

claimant (full ownership), the more willing it is to maximize joint profits (by coordinating effort). Under both rules, the choice of shares thus involves a trade-off. To maximize termination efficiency, the dominant firm should have a larger share. To induce effort coordination, the subordinate firm may need to have a larger share. The optimal shares balance these opposing tendencies.

Neither rule terminates the partnership will full efficiency. However, we find that with the share structures that are optimal for termination, the efficiency losses are very small. The more important comparison between the rules is in how they coordinate effort. In the environments we consider, we find that the shotgun rule is better than price competition at inducing effort coordination. The reason is that when effort is coordinated, the dominant firm is likely to have the higher valuation for the partnership. The subordinate firm must be able to collect some of this value to benefit from coordination. Under the shotgun rule, the subordinate firm can simply propose a high price for its shares. That is, the subordinate firm can use its position as proposer to claim some of the dominant firm's returns.[5] Under price competition, the subordinate firm's pricing strategy is constrained by the pricing strategy of the dominant firm. If the dominant firm is bidding low, the subordinate firm must also bid low or run the risk of acquiring the partnership itself. Consequently, the subordinate firm is less able to benefit when the dominant firm receives high valuations.

We find that the shotgun rule is generally the better of the two rules, because of the importance of effort coordination. However, the rules cannot be ranked. Price competition is slightly more efficient at termination, because the price reflects the bids of both partners rather than just one. In this sense price competition is more similar to an auction. When effort coordination is easy to achieve, price competition is often the better rule.

Our work contributes to the literature on termination of partnerships (Cramton et al., 1987; McAfee 1992) in two ways. First, the previous literature considers only the question of whether assets will be allocated efficiently at termination. We analyze the feedback effect that these rules have on firms' efforts. Effort coordination turns out to be a difficult problem and one that conflicts with termination efficiency. A priori, contracts that perform well at allocating the assets may be undesirable because they discourage efficient investment in the partnership. We show that in contrast to McAfee (1992), in some

5. We assume that the subordinate firm is the proposer and the dominant firm is the chooser. The shotgun rule would not perform as well if the roles were reversed.

environments the shotgun rule outperforms price competition.[6] Second, we extend their results on the efficiency of partnership termination to the case of asymmetric distributions. As discussed above, we extend the result of Cramton et al. (1987) on efficient shares for partnership dissolution. We also show that neither the relative-efficiency ranking of price competition and the shotgun rule (McAfee, 1992, pp. 268–269) nor the efficiency of price competition is robust to this change.

Structurally, the model we consider is related to the holdup problem, which goes back to Klein et al. (1978) and Williamson (1979). This problem has been examined in a variety of institutional contexts.[7] Most of the existing literature, however, assumes independence: each firms' effort affects only its valuation. In these models, moral hazard arises because effort is costly. Our research contributes to the literature by examining effort incentives in a setting where the distributions of agents' private information are interdependent. In our model, effort is costless and a moral hazard arises precisely from the lack of independence—in enhancing its own valuation, a firm diminishes its partner's valuation. The only other place that we have seen an assumption of this type is Che and Hausch (1996). Che and Hausch examine a holdup problem in which a seller's effort determines a buyer's valuation of a good. The valuation is observable prior to trade, but not contractible. They find that first best contracts exist in this environment.

Finally, an alternative contractual solution to our holdup problem is merger. In a full merger, the moral-hazard problem that we consider could be solved by eliminating one of the two managements. However, administrative restructuring is costly. Moreover, if the productive period of joint work has an end date after which it becomes advantageous to dissolve the merger, the costs of restructuring must be incurred twice. It is therefore when the economic benefit of joint work is temporary (as in our model) that a merger is least likely to be an optimal organizational form.

6. McAfee also considers a third rule, the *loser's-bid auction*, where both partners submit bids and the high bidder buys the shares of the low bidder at a price equal to the lower bid. McAfee finds that the "winner's-bid auction" (our price competition) is better than the loser's-bid auction in a symmetric environment. Although similar to a second-price auction, the rule does not induce the partners to bid their true valuations.

7. Grossman and Hart (1986) show that joint ownership can lead to inefficiently low levels of investment by both firms. Rogerson (1984) and Shavell (1980) study the performance of common court remedies for breach of contract in inducing efficient investment. Hermalin and Katz (1993) argue that simple contracts can achieve the first best when courts merely act as contract enforcers. Rogerson (1992) presents a general analysis proving the existence of first-best mechanisms that solve holdup problems.

The paper is organized as follows. In the next section, we set up the model. In Section 3, we discuss first best contracts. In Section 4, we consider simple termination rules. Section 5 discusses robustness of the results, and Section 6 concludes.

2. The Model

We model the partnership as a two-stage game with two firms. Each firm begins the game with an ownership share representing a claim on output. In the first stage, firms contribute to the partnership by choosing efforts that affect joint profits. In the second stage, firms privately learn their own valuation of the output. After firms learn their valuations, they terminate the partnership. If one partner has a higher valuation, then it is efficient for that partner to claim the entire output. The game structure is common knowledge.

Timing in the model is shown in Figure 1.

2.1. Effort

We label the firms A and B. Suppose that each decides on an effort that is unobservable and hence not contractible. We denote the efforts by $e_A, e_B \in \{A, B\}$. The binary effort set represents two distinct *agendas*. The choice between agendas is costless, indicating a direction rather than a level of work. While the general problem of providing incentives for agents to work hard arises in all firm structures, partnerships, in addition, are distinguished by the divided loyalties of split management. The diverging goals of the partners, captured here by directional effort, can lead to inefficiency.

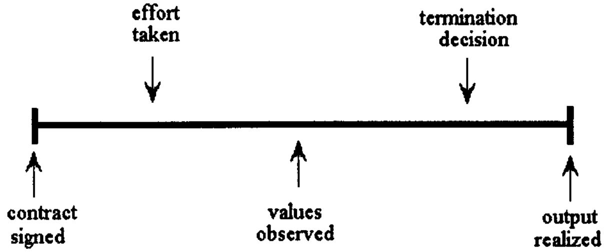

FIGURE 1. THE TIMELINE

In order to maximize joint profits the firms must follow firm A's agenda, so that $e_A = e_B = A$.[8] We refer to firm A as the *dominant firm* and to firm B as the *subordinate firm*. Examples where one of the two partners is dominant includes alliances in the biotechnology industry between small research and development companies and large pharmaceuticals. In many of these alliances, the pharmaceutical firm has a natural advantage at taking a jointly developed drug through the clinical testing and marketing processes. As another example, in joint ventures between a domestic and a foreign firm, the domestic firm often has a natural advantage in domestic marketing of the jointly developed product.

If the joint venture's output had an objective observable value, then a very simple contract would induce firms to coordinate to the choice $(e_A, e_B) = (A, A)$. Because effort is costless, any contract that splits *ex post* joint profits according to a fixed division would suffice. However, if the two firms value the output differently, and if in addition these valuations are private information, a coordination difficulty might arise. If firm B's expected private valuation of the venture is higher when following its own agenda $(e_B = B)$ than when following firm A's agenda $(e_B = A)$, then firm B might choose not to coordinate at the expense of joint profits.

The heart of the problem is providing the subordinate firm B incentives to coordinate to the dominant firm A's agenda. Thus we will suppress the dominant firm's coordination incentives, assuming that only firm B has an effort choice. We then ask the simpler question of whether it is always possible to write a contract under which firm B is willing to choose $e = A$ in an equilibrium.

2.2. Valuations

The relationship between effort and the valuations of output is stochastic. This assumption captures the uncertainty in new product development and R & D. It is because of this uncertainty that termination is an important source of concern in partnership contracts. In stage 2, after firm B has chosen its direction of effort, the firms privately learn their valuations. The valuations are given by random variables $V_A(e)$ and $V_B(e)$ that are distributed according to $F_i^e(v)$, $i = \{A, B\}$, with supports $[\underline{v}_i, \overline{v}_i]$ and densities $f_i^e(v)$, where $e \in \{A, B\}$ denotes firm B's choice of effort. Conditional on the effort choice, the

8. This assumption entails no loss of generality. The case that $e_A = e_B = B$ maximizes joint profits is identical to the case we consider, and if joint profit maximization requires the firms to pursue their own agendas, the incentive problem is eliminated.

valuations are independent. While a firm knows its own valuation, it does not know the valuation of its partner. However, in equilibrium, both firms know firm B's choice of effort direction e. Hence, in equilibrium, firm i's belief about the distribution of firm j's valuation is given by the distribution $F_j^e(v)$. [When the effort choice is clear from the context, we will denote the distribution and its density by $F_i(v)$ and $f_i(v)$, respectively.]

We will assume that by following its own agenda, firm B maximizes its own valuation at the expense of firm A's valuation. That is:

- $V_A(A)$ first-order stochastically dominates $V_A(B)$, but
- $V_B(B)$ first-order stochastically dominates $V_B(A)$.

The realized value of the partnership depends on who claims the output. If firm A claims all the output, then the value v_A is realized. If the firms split the output with firm A receiving a share s, then the realized value is $sv_A + (1 - s)v_B$.[9] Joint profit maximization requires that the firm with the higher value claim the entire output. If achieved, this yields an *ex post* "efficient" valuation of $\max\{v_A, v_B\}$. The value $\max\{v_A, v_B\}$ has a cumulative distribution function given by $F_A^e(v)F_B^e(v)$. We denote this random variable by $\max\{V_A(e), V_B(e)\}$. Our assumption that joint profit maximization requires $e = A$ now becomes

- $\max\{V_A(A), V_B(A)\}$ first-order stochastically dominates $\max\{V_A(B), V_B(B)\}$.

For tractability in our analysis, we will consider uniform distributions of firm valuations. We specify these distributions to be consistent with the above assumptions.

Assumption U:

- $V_A(A)$ is uniformly distributed over $[0, a]$,
- $V_A(B)$ is uniformly distributed over $[0, a']$,
- $V_B(A)$ is uniformly distributed over $[0, b]$,
- $V_B(B)$ is uniformly distributed over $[0, b']$,

where $a \geq a'$, $b' \geq b$, $a \geq b$, and $ab \geq a'b'$.

9. In some cases, it may not be physically possible to split the output of a joint venture. However, in many cases this assumption is a reasonable abstraction of split ownership. For instance, if partners comarket a jointly developed product in different geographical markets, then they can split the output by dividing customer lists.

2.3. Ownership

We model ownership as a claim on output. Let the ownership shares of the two firms be given by $\theta_A \in [0,1]$, and $\theta_B = 1 - \theta_A$. We assume that these shares are given at the start of the partnership. When the partnership terminates, firm i has the right to retain the portion θ_i of output for a realized value of $\theta_i v_i$. In order to achieve an efficient division of output, these shares will have to be altered *ex post* so that the firm with the higher valuation receives the entire output. However, the initial ownership shares are still important, since they determine a minimum payoff that each firm must receive at termination.

2.4. Contracts

In the first part of our analysis, we ask whether there exists a contract that guarantees an efficient outcome to the partnership. To address this question we use the theory of Bayesian mechanism design. By the revelation principle (see, e.g., Myerson, 1985) any outcome that is achieved as an equilibrium outcome under any contractual agreement can be represented by a truth-telling equilibrium under some direct revelation mechanism. Our question is whether there exists a direct relevant mechanism in which partners first coordinate their efforts and then terminate the partnership efficiently.

The following notation is standard. Let s denote a firm's ownership share at termination. (This will generally differ from the firm's initial ownership share.) If the firm has valuation v and receives a monetary transfer t, then its payoff at termination is given by

$$sv + t.$$

A direct revelation mechanism $\langle s, t \rangle$ consists of functions $s_i, t_i : (v_i, v_j) \to \mathbb{R}$ for $i = A, B$ where $s_i(v_A, v_B) \geq 0$ and $s_A(v_A, v_B) + s_B(v_A, v_B) = 1$ for all $(v_A, v_B) \in [\underline{v}_A, \overline{v}_A] \times [\underline{v}_B, \overline{v}_B]$. Let $S_i^e(v_i) = E[s_i(v_i, V_j(e))]$ denote firm i's expected posttermination share of the partnership when it reports v_i and firm B's effort choice is e. Similarly, let $T_i^e(v_i) = E[t_i(v_i, V_j(e))]$ denote firm i's expected monetary transfer when it reports v_i and firm B's effort choice is e.

We require the contract between the firms to be *ex post* budget-balanced. Namely, the partnership cannot rely on any outside subsidies to finance its dissolution. This is satisfied if

$$t_A(v_A, v_B) + t_B(v_A, v_B) = 0 \qquad \forall (v_A, v_B) \in [\underline{v}_A, \overline{v}_A] \times [\underline{v}_B, \overline{v}_B].$$

Suppose that firm B chooses the effort direction A. For truth telling to be an equilibrium of the game, the mechanism must be incentive-compatible. It has to induce both firms to report their valuations truthfully. The incentive-compatibility constraint is given by[10]

$$S_i^A(v_i)\cdot v_i + T_i^A(v_i) \geq S_i^A(\hat{v}_i)\cdot v_i + T_i^A(\hat{v}_i)$$
$$\forall i \in \{A, B\}, \qquad \forall v_i, \hat{v}_i \in [\underline{v}_i, \overline{v}_i].$$

In addition, the mechanism has to induce firm B to coordinate its effort by choosing the effort direction A. That is, firm B cannot benefit by choosing the effort direction B and then lying about its valuation of the partnership. This *effort constraint* for firm B is given by[11]

$$E\left[S_B^A(V_B(A))\cdot V_B(A) + T_B^A(V_B(A))\right]$$
$$\geq E\left[S_B^B(L(V_B(B)))\cdot V_B(B) + T_B^B(L(V_B(B)))\right]$$

for every (measurable) lying strategy $L:[0, b'] \to [0, b]$.

The initial ownership shares also determine a contractual constraint. After learning its private valuation v_i, we assume that a firm with ownership share θ_i may choose between claiming its output for a payoff of $\theta_i v_i$ and participating in the mechanism. We therefore require the mechanism $\langle s, t\rangle$ to satisfy the *interim* individual rationality constraint

$$S_i^A(v_i)\cdot v_i + T_i^A(v_i) \geq \theta_i v_i \qquad \forall v_i \in [\underline{v}_i, \overline{v}_i].$$

Finally, the mechanism is *ex post efficient* if it induces the efficient effort $e = A$ and upon termination assigns the ownership of the venture to the firm that values it most. That is, the *ex post* ownership share s has to satisfy

$$s_A(v_A, v_B) = \begin{cases} 1, & v_A > v_B, \\ 0, & v_A < v_B. \end{cases}$$

10. Note that we use the notation of Bayesian incentive compatibility rather than the more appealing notion of incentive compatibility in dominant strategies. As Green and Laffont (1979) showed, dominant incentive-compatible mechanisms cannot satisfy *ex post* budget balance.

11. When players in a game take actions that affect the distributions of types, then the revelation principle allows us to restrict attention to mechanisms in which truth telling occurs given the equilibrium action, but not given other actions. For this reason, we must consider the possibility that firm B lies given $e = B$.

3. First-Best Analysis

In this section, we address the question of whether there exists an *ex post* budget-balanced contract that coordinates firms' effort, is individually rational for each firm, and terminates the partnership efficiently.

Despite the simplicity of our model, it is difficult to obtain a complete characterization of environments where such contracts exist. The essence of the coordination problem is *dependence*: the subordinate firm B's choice of effort affects the dominant firm A's valuation. If firm B's effort affected only its own valuation, then as Rogerson (1992) shows, a standard D'Aspremont–Gérard-Varet (1979) mechanism would always implement the joint-profit-maximization outcome in this model.

The problem that arises in this model is that a mechanism that is incentive-compatible conditional on firm B choosing the effort direction A might violate B's effort constraint. That is, firm B may benefit from choosing the effort direction B and then lying about its valuation of the partnership. Standard techniques that are based on the revelation principle (see, e.g., Lemma 3 in the appendix) allow us to identify T_A^A and T_B^A up to a constant. These techniques, however, do not allow us to further restrict either the underlying function $t_B(v_A, v_B)$ or the expected payment $T_B^B(v_B)$. In fact, there exists an infinite-dimensional space of potential mechanisms yielding the correct expected payments when $e = A$ and varying payments when $e = B$. Some of these may satisfy the effort constraint, while others may not. The direct revelation principle is thus of limited help in deciding whether the efficient choice of effort is implementable. Given this, it is hard to pin down a necessary condition for simultaneous satisfaction of both incentive compatibility and the effort constraint. We therefore focus on the sufficiency question and ask whether any of a family of reasonable potential mechanisms induce firm B to choose the efficient effort.[12]

Consider the family of mechanisms $\langle s^*, t^n \rangle$ where s_A^* is given by the termination efficiency condition. The transfer payment t^n is

12. For discrete distributions of valuations, it is possible to formulate the problem as a linear programming problem. For specific parameters, we can then completely characterize the environments for which first best contracts exist by solving the problem numerically. However, a significant degree of intuition is lost in this approach.

given by

$$t_B^n(v_A, v_B) = \left(\frac{b^2}{6a} - \frac{v_B^2}{2a}\right) g_n(v_A) + \frac{v_A^2}{2b} - \frac{a^2}{6b}$$

and

$$t_A^n(v_A, v_B) = -t_B^n(v_A, v_B),$$

where

$$g_n(v_A) = \begin{cases} \dfrac{a - a'n}{a - a'} & \text{for} \quad a' < v_A \leq a, \\ n & \text{for} \quad 0 \leq v_A \leq a', \end{cases}$$

and n is a positive number.

It is straightforward to show that the above contracts induce firms to report their valuations truthfully when $e = A$. By construction, they terminate the partnership efficiently and are budget-balanced. Therefore they solve the contractual problem provided they (1) induce $e = A$ and (2) are individually rational for both firms.

To gain intuition for the form of these mechanisms, note that if $e = A$, *ex post* efficient termination and incentive compatibility imply (see Lemma 3 in the appendix) that $T_A(v_A)$ equals $-v_A^2/2b$ up to a constant and $T_B(v_B)$ equals $-v_B^2/2a$ up to a constant. This suggests using a transfer payment $t_B(v_A, v_B) = v_A^2/2b - v_B^2/2a$ that is determined up to a constant. In order to induce firm B to choose the effort direction A, we introduce the function $g_n(v_A)$ into this transfer payment. The function $g_n(v_A)$ is equal to (a large and positive) n for small values of v_A and equal to (a small or negative) $(a - a'n)/(a - a')$ for large values of v_A. If firm B chooses the effort direction A, the expectation of $g_n(v_A)$ is one, and so B's payment is independent of n. If firm B chooses the effort direction B, the likelihood that v_A assumes small values increases. When $(b^2/6a - \hat{v}_B^2/2a)g_n(v_A)$ is negative, it reduces firm B's payment significantly[13] and so strengthens B's incentive to choose the effort direction A. In the next proposition, we describe the n that gives firm B the strongest incentives to follow A's agenda. The optimal n cannot be too large. If n is very large, then firm B may wish to choose the effort direction B and subsequently report a small $\hat{v}_B$ so that $(b^2/6a - \hat{v}_B^2/2a)g_n(v_A)$ is positive. In fact, as

13. The factor $b^2/6a - v_B^2/2a$ is negative for all but relatively small values of v_B.

the next proposition shows, the optimal n is such that $n = (a/a')(b'/b) > 0 > (a - a'n)/(a - a')$.[14]

3.1. Effort Coordination

For now, we relax the individual rationality constraint. In the following proposition, we determine the value of n for which the contract $\langle s^*, t^n \rangle$ maximizes firm B's incentive to choose $e = A$. We use this to provide a necessary and sufficient condition for the contract $\langle s^*, t^n \rangle$ to be *ex post* efficient.

Let

$$\rho = \frac{(b'/b)a - a'}{a - a'}.$$

The choice of effort affects both firms' valuations. That is, firm B's incentive to coordinate is determined both by the direct effect of effort on $E[V_B]$ and the indirect effect on $E[V_A]$. The parameter ρ measures the direct effect of effort on $E[V_B]$. It is increasing in b'/b. In the extreme case that there is no direct effect at all, we have that $b = b'$ and $\rho = 1$.

Proposition 1: *Suppose that the distributions of firms' valuations satisfy the inequality*

$$\frac{a^2a' + a(a')^2}{2} \geq \rho b^3. \tag{S}$$

Then the mechanism $\langle s^*, t^n \rangle$ where $n = (a/a')(b'/b)$ is ex post budget-balanced, efficient, and Bayesian incentive-compatible.

We prove the proposition in the appendix. Intuition for the condition (S) is given as follows. Suppose that there is no direct effect of effort on firm B's valuation, so that $\rho = 1$. Choosing $e = A$ maximizes firm A's expected valuation at no direct cost to firm B. However, firm B is more likely to acquire the output when $e = B$. The possibility of acquiring the output for a payment lower than its private valuation generates an incentive to deviate. From (S) we see that if firm B's expected valuation is sufficient small, then B does not deviate.

14. Because $[V_B^2/2a - b^2/6a = 0$, firm A's expected transfer is equal to $-v_A^2/2b$ up to a constant. Given this, it is easy to show that firm A has no incentive to misreport v_A. (See the proof of Proposition 1 in the appendix.)

Holding ρ fixed at $\rho = 1$, we consider how changes in the distributional parameters affect firm B's incentive to coordinate. Increasing a strengthens this incentive [that is, weakens condition (S)]. Coordination is more valuable for higher a. Surprisingly, increasing a' also strengthens this coordination incentive. Although a coordination failure involves greater joint profits, firm B's ability to acquire the output on favorable terms is reduced.

An increase in $b = b'$ weakens the incentive to coordinate. For both effort choices, firm B contributes more to joint profits and its chance of acquiring the output is increased. The increase in firm B's payoff is greater when $e = B$, because firm A provides less competition for the output at termination.

For $\rho > 1$, the analysis is more complex. An increase in b' weakens firm B's incentive to coordinate (through an increase in ρ). Not only does $e = B$ result in greater joint profits, but firm B is more likely to acquire the output. An increase in a also unambiguously strengthens firm B's incentive to coordinate. An increase in B however has an ambiguous effect. On the one hand, coordination becomes relatively more valuable. On the other hand, when it deviates firm B must report a valuation less than or equal to b. It cannot report a higher valuation $v_B \in (b, b']$. By enabling the firm to report higher valuations, an increase in b can enhance the payoff from deviating. If (and only if) b is sufficiently small relative to b', then an increase in b increases the incentive to deviate. An increase in a' also has an ambiguous effect when $\rho > 1$. The incentive to coordinate is strengthened for the same reason as when $\rho = 1$ if (and only if) a' is sufficiently small. Otherwise, the improvement in joint profits that results from an increase in a' weakened the incentive to coordinate.

By weakening condition (S), we obtain the following corollary. The proof relies strongly on the stochastic dominance properties embodied in Assumption U (Section 2.2).[15]

Corollary 1: *Suppose that the distributions of firms' valuations satisfy the inequalities $a \geq 2b$ and $a' \geq b'$. Then the mechanism $\langle s^*, t^n \rangle$, where $n = (a/a')(b'/b)$, is ex post budget-balanced, efficient, and Bayesian incentive-compatible.*

The corollary says that if the dominant firm is sufficiently dominant then a first best contract exits. The corollary requires that firm A's individual valuation distribution is dominant both when effort is coordinated and when it is not. A high value of a and a low

15. It is clear from the proof of the proposition that a first best contract exists if condition (S) is satisfied even if stochastic dominance fails.

value of b' mean that the advantage of coordinating effort is high and firm B's ability to gain by not coordinating effort is low. That a low value of b and a high value of a' can help follows from our previous discussion.

With individual rationality relaxed, Proposition 1 provides a sufficient condition identifying environments for which a contract implementing the first best outcome exists. Because the space of incentive-compatible mechanisms does not admit a simple characterization, we cannot verify that a first best contract fails to exist in those environments that do not satisfy the condition. However, we can show that the first best contract fails to exist for discrete versions of some of these environments.[16]

3.2. Individual Rationality

We now examine the way in which the ownership shares affects the feasibility of the first best contract. That is, we ask for what ownership structures the contracts $\langle s^*, t^n \rangle$ are individually rational. For any partnership, there exist many ownership shares that are not consistent with any individually rational and incentive compatible contract. Suppose, for instance, that one partner initially owns all of the partnership. Then at termination, the incentive problem can be stated as a trading problem. The partners should switch over the ownership to the other partner if that partner has the higher of two valuations. As Myerson and Satterthwaite (1983) showed, this type of trade is always inefficient. On the other hand, Cramton et al. (1987) showed that if the partners have identically distributed valuations, then equal share ownership structures can always be dissolved efficiently.

We extend this result to asymmetric distributions. We find that there is always an ownership structure (θ_A^*, θ_B^*) for which it is possible to terminate the partnership efficiently while respecting individual rationality. If Proposition 1 holds, we find that the contract $\langle s^*, t^n \rangle$ is individually rational given these shares. The ownership shares are not equal (as in Cramton et al.). Rather we find that the dominant firm A owns a larger share. We also show that there is an open convex set of ownership structures that can be dissolved effi-

16. For discrete environments, we can prove that no first best contract exists by formulating the problem as a linear programming problem that does not admit a solution. Suppose that the valuations are either 0 or 1 with probabilities that depend on B's effort. If the probabilities that B's valuation is 1 and A's valuation is 0 are both sufficiently high when $e = B$, then there is no first best contract. This environment corresponds to a low value of a' and a high value of b'.

ciently. Proposition 2 holds for any distributions of private valuations that are continuous with positive density. That is, we can relax Assumption U for this result.

Proposition 2: *The set of partnerships that can be dissolved efficiently is a nonempty convex set centered around the unique point* (θ_A^*, θ_B^*) *that satisfies*

$$F_B^{-1}(\theta_A) = F_A^{-1}(\theta_B) \quad \textit{and} \quad \theta_A + \theta_B = 1.$$

Here $\theta_B^* \leq \theta_A^*$. *Under Assumption U,* $(\theta_A^*, \theta_B^*) = ((a/a+b),(b/a+b))$.

The intuition behind the proposition is that the ownership structure must be close to the *ex post* efficient ownership structure. Because A is the dominant firm, it is most likely to be the owner of the partnership in an *ex post* ownership structure; hence $\theta_B^* \leq \frac{1}{2} \leq \theta_A^*$. The shares that maximize efficiency at dissolution essentially minimize the occurrence of trade.

The following result follows immediately from the Proof of Proposition 2.

Corollary 2: *If a budget-balanced, efficient, and Bayesian incentive-compatible contract exists, then it is also individually rational for a nonempty convex set of shares centered around the point* (θ_A^*, θ_B^*).

Example 1: Direct analysis shows that for the environments that are described in Proposition 1, the mechanism $\langle s^*, t^n \rangle$ is individually rational with respect to any ownership structure (θ_A, θ_B) that satisfies $\theta_A \leq \min\{a/\sqrt{3b}, 1\}$ and $\theta_B \leq \min\{b/\sqrt{3a}, (3+b)/6a\}$.

4. Simple Contracts

First-best contracts have the disadvantage of being complex in the sense that they depend on the parameters of the environment (which in this case are a, a', b, and b'). We are therefore interested in studying what is the extent of efficiency loss that is associated with using simple contracts that are independent of the particular environment in which the firms interact. In this section we analyze the performance of a restricted set of simple contracts. These contracts are stylized versions of contracts that are commonly used in partnerships. We consider their performance in environments for which a first-best contract exists. Consequently we may use maximized joint profits as a performance benchmark. The contracts we consider combine a fixed termination game with an arbitrary division of ownership shares. At termination the firms can renegotiate their initial ownership shares, but this renegotiation follows a fixed set of bargaining rules. We consider two institutional arrangements. In the first, which we refer to as the shotgun rule, one partner names a price and the other partner decides whether to buy or sell his shares at that price. In the second, the firms engage in a price competition to determine which firm will sell its share to the other and at what price.

4.1. The Shotgun Rule

The shotgun rule, also known as the ''Texas auction'' and the ''cake-cutting rule,'' is one of the most common termination rules. In our analysis we first look at its ability to dissolve the partnership efficiently. We then consider this incentive for effort coordination.

The shotgun mechanism specifies a proposer (P) and a chooser (C). At the date of termination, the proposer sets a price. The chooser has three options. It can sell its share to the proposer for the specified price, buy the proposer's share for the specified price, or refuse to trade. The right to refuse to trade guarantees the individual rationality of the shotgun rule.[17]

Let θ_P denote the proposer's share, and let p be the proposed price. The chooser's strategy is to buy the venture if the price is lower than its valuation and to sell its share if the price is higher than its valuation. The proposer's expected profit when its valuation is v_P is

$$\Pi_P(v_P, p) = \left[v_P - (1-\theta_P)^p\right] F_C(p) + \theta_P p[1 - F_C(p)]. \tag{4.1}$$

Define the function $p(v_P)$ by

$$p(v_P) = \arg\max_p \Pi_P(v_P, p).$$

The following lemma characterizes the properties of the price function.[18]

Lemma 1: *The function* $p(v_P) = \min\{\frac{1}{2}(v_P + \theta_P \overline{v}_C), \overline{v}_C\}$ *is the unique solution for* p *to* $(d/dp)\Pi_P(v_P, p) = 0$, *is continuous and nondecreasing,*

17. It is easy to see that (1) for any proposed price and any valuation of the chooser, the chooser will always be (weakly) better off trading than not trading, and (2) the proposer always prefers setting a price to not trading. Thus the proposer's individual rationality constraint is also trivially satisfied.

18. A version of this lemma holds for any distributions of valuations that satisfy the standard hazard-rate conditions. See McAfee (1992) for details.

and satisfies $p(\overline{v}_P) \leq \overline{v}_C$ *and* $p(0) \geq 0$. *Define* $v^* = F_C^{-1}(\theta_P)$. *Then* $p(v) > v$ *for* $v \in [0, v^*)$, $p(v) < v$ *for* $v \in (v^*, \overline{v}^P]$, *and* $p(v^*) = v^*$. *The critical value* v^* *is an increasing function of* θ_P.

That v^* is increasing in θ_P is immediate from its definition. However, there is a useful intuition associated with this result. When the proposer sells (buys) shares, it prefers a higher (lower) price. If θ_P increases, the proposer trades more shares when it sells and fewer shares when it buys. This increases the proposer's incentive to "price high," and so v^* increases.

We next consider the incentive for effort coordination. We will assume that firm B is the proposer.[19] We will also assume that $a > b = 1$ and that $a' = b' = l\sqrt{a}$ for $0 < l < 1$. The parameter l measures the value of coordination. We can apply Proposition 1 to show that a first-best contract exists for these parameters.

The following proposition characterizes optimal ownership shares (θ_A, θ_B). These shares maximize the joint profits.

Proposition 3: *For every* $a > 1$, *there exists a critical value* $l^* \in [0, 1$ *such that*:

(a) *When* $l \leq l^*$, *the optimal shares are* $(\theta_A, \theta_B) = (1 - 1/2a, 1/2a)$. *Firm B chooses* $e = A$, *and the shares maximize efficiency at termination.*
(b) *When* $l^* < l$, *the optimal shares are* (θ_A, θ_B), *where* $\theta_B > 1/2a$ *is the smallest share that induces firm B to choose* $e = A$.

The shares that maximize efficient dissolution are $(\theta_A, \theta_B) = (1 - 1/2a, 1/2a)$. The dominant firm A should have the biggest share, just as in our analysis of first best contracts. However, these shares may not lead firm B to coordinate effort. It may be necessary to give firm B a larger share. A large share θ_B helps because it makes selling to firm A for a high price very attractive. Another way to state this idea is that the larger is firm B's share, the closer it is to being a residual claimant.

To evaluate the performance of the shotgun rule, we compare joint profits with first-best joint profits. In the following example, we assume that $a = 2$, $b = 1$, and $a' = b' = l\sqrt{a}$. We show that the shotgun rule achieves nearly full efficiency for all values of l, and that this efficiency is decreasing in l.

19. The results for the case that firm A is the proposer are similar, but (as we discuss later) the rule does not perform as well.

Example 2: When $a = 2$, $l^* = 0.35$. First-best joint profits are $E[\max\{v_A, v_B\}] = 1.083$. Under the shotgun rule with optimal shares, the ratio of joint profits to first-best profits is 99.5% for $l \leq 0.35$. For $l \geq 0.35$, joint profits are decreasing in l down to 96.5%. (See Fig. 2 in Section 4.3).

The results for other values of $a > 1$ are similar. As a increases, dissolution efficiency must be increasingly sacrificed in order to obtain effort coordination. This is because the optimal shares for dissolution become more lopsided, giving less ownership to firm B and hence working against effort coordination. However, the value of effort coordination also increases as a increases. This second effort is stronger and the optimal shares always coordinate effort. As a increases, the shotgun rule continues to perform well. When $a = 3$, for instance, the ratio of joint profits to first-best profits ranges between 99.7% and 94.9%.

If firm A is the proposer, the shotgun contract does not perform as well. Firm A will never choose a price higher than firm B's highest valuation b. This limits the ability of firm B to make a profit by selling its shares for a high price. Because effort coordination is more difficult, the optimal share contracts achieve lower joint profits.

4.2. Price Competition

Next we consider a second common termination rule, price competition. This rule is also known as a first-price or winner's-bid auction. At termination, both firms bid for the partnership. The firm whose bid is higher buys the other firm's share at a price that is equal to the higher bid.

When the firms have identical distributions of valuations, price competition dissolves the partnership efficiently (Crampton et al., 1987; McAfee, 1992). Although both partners understate their true valuations, monotonicity of the symmetric equilibrium pricing strategies implies that the partner with the higher valuation submits a higher bid. We find that this efficiency result is not robust to the introduction of asymmetry. When partners are not identical, they will employ different equilibrium bidding strategies. As a general intuition, the dominant firm will understate its valuations by more. As a consequence of this asymmetry, there will be some states of the world in which firm A has a higher valuation, but submits a lower bid and does not obtain the partnership.

Another consequence of asymmetry is that closed-form solutions for the equilibrium strategies of the partners do not exist. In our analysis, we therefore analyze a simpler game where the firms are restricted to using bidding strategies that are linear in the valuation of the partnership. The restriction to linear strategies gives us *approximate* equilibria of the game.[20] Rather than present a full analysis, we give intuition and then present concrete results for the parameters $a = 2$, $b = 1$.

First we consider termination. We find that to maximize efficiency at termination, it is optimal for the dominant firm to have a larger share. Again the intuition is the same as in our analysis of the first-best contracts. However when firm A is strictly dominant, termination is never fully efficient.

Second, we consider coordination. In order to coordinate effort, it may be necessary to reduce the dominant firm's share below that which is optimal for termination. As with the shotgun rule, when firm B has a large share, it cares a lot about the profit it makes by selling out to firm A for a high price when firm A has a high valuation.

In the next example, we consider the case that $a = 2$, $b = 1$, and $a' = b' = l\sqrt{a}$. For most values of l, price competition coordinates effort and achieves nearly full efficiency at dissolution. For very high values of l, however, effort is not coordinated.

Example 3: When $a = 2$, first best joint profits are given by $E[\max\{v_A, v_B\}] = 1.083$. Under price competition with optimal shares, effort is coordinated for $l \leq 0.85$. The ratio of joint profits to first best profits is 99.9% at $l = 0$. Joint profits are decreasing in l down to 93.8% at $l = 0.85$. For $l > 0.85$, effort is not coordinated. The ratio of joint profits to first best profits increases from 53.4% at $l = 0.85$ to 87% at $l = 1$. (See Fig. 2.)

The optimal contract coordinates effort as long as this is possible. For $l > 0.85$, there is no assignment of positive shares that induces firm B to coordinate effort. When effort is not coordinated, the firms' valuations have symmetric distributions. The optimal share structure is $(\frac{1}{2}, \frac{1}{2})$, and termination is efficient. But the loss in efficiency due to the coordination failure is significant.

20. We adopted this assumption to obtain analytic expressions for the equilibrium strategies. This in turn allows us to perform comparative statics. Without this assumption, equilibrium strategies can only be solved for numerically. The restriction can be motivated by appealing to bounded-rationality arguments. The firms may prefer to have an a priori bidding rule in the price competition—a rule that is specified before the firms learn their valuations. If, in addition, the allowable complexity of the rule is constrained, then the restriction to linear rules is plausible. The equilibrium in linear strategies is an ε-equilibrium of the general game for an ε that is generally quite small. For example, in the case where $a = 2$ and $b = 1$, ε ranges between 3% and 7% depending on the shares.

For $l \leq 0.85$, the effort constraint is binding. The shares that maximize efficiency at termination are $(\theta_A, \theta_B) = (1, 0)$. This is because A's understating its bid generates most of the inefficiency at termination. The shares $(1, 0)$ completely remove firm A's incentive to understate its bid. However, these extremal shares never coordinate effort. The optimal share is computed by increasing firm B's share until it is just willing to coordinate effort.

For other values of a the analysis is similar. Price competition generally does well at dissolving the partnership. The only real problem is that it may fail to coordinate effort. As a increases, it becomes easier to coordinate effort because coordination is more valuable. This improves the performance of the rule. For example, when $a = 3$, even the shares $(1, 0)$ succeed in coordinating effort. Joint profits are now 99.7% of first best profits for all values of l.

4.3. Comparison of the Shotgun Rule and Price Competition

Here we compare the performance of the two termination rules.

McAfee's (1992) efficiency result for price competition does not extend to asymmetric distributions. In our asymetric environments $(a > b)$, neither price competition nor the shotgun rule achieves efficient termination for any choice of ownership shares. Price competition does generally do slightly better than the shotgun rule at termination, because the trading price is based on the bids of both partners and so is able to get closer to the true value of the partnership. The differences in termination performance are however very small. Both rules do well at termination.

The more important comparison between the rules is how they coordinate effort. The shotgun rule has a strong advantage. The essence of the coordination problem is as follows. When effort is coordinated, firm A is likely to have a high valuation of the partnership. Firm B must be able to collect some of this value in order to be willing to coordinate. Under the shotgun rule, firm B can simply propose a high price. Under price competition, it is hard for firm B to benefit from a high v_A. If firm A is bidding low, then firm B will bid low as well. Bidding high would not achieve the objective of selling at a high price. Instead, firm B would run the risk of acquiring the partnership. Because it is harder for firm B to benefit from a high v_A, it is harder to find shares for which price competition induces coordination.

When $a = 2$ and $b = 1$, joint profits as a function of l under the shotgun rule and price competition are shown in Figure 2.

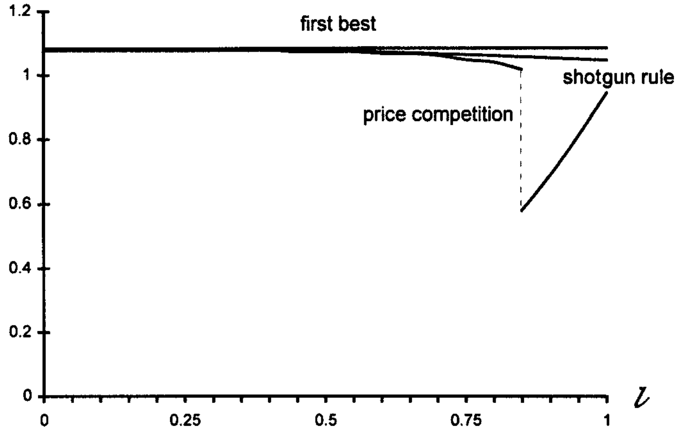

FIGURE 2. JOINT PROFITS UNDER THE SHOTGUN RULE AND PRICE COMPETITION

Because the shotgun rule is better at effort coordination, it is in a sense the better rule. However, formally the two institutions cannot be ranked. When l is low ($l \leq 0.45$), price competition is a slightly better institution.[21] The effort constraint is easily satisfied, and price competition is slightly better at termination. When $0.45 < l < 0.85$, the shotgun rule is better because it is able to coordinate effort at less cost in termination efficiency. For $l > 0.85$, price competition is unable to induce effort coordination. The shotgun rule is much more efficient in this range. As discussed above, as the value of a increases, the efficiency of price competition vis-à-vis the shotgun rule improves.

5. Robustness

In our analysis, we have restricted attention to uniform distributions of firms' private valuation. A natural question is how the results extend to more general distributions. Because the intuitions that we have developed do not depend on the structure of the uniform distributions, we expect that they do extend to more general environments. In the analysis of first best contracts, in particular, it should in general be easier to meet the balanced-budget, efficiency, and incentive constraints when the dominant firm is more dominant (Corollary

21. The difference is too small to illustrate in the figure.

1). That is, increasing the strength of either distribution $V_A(A)$ or $V_A(B)$ should make effort coordination easier to achieve. The stronger $V_A(A)$ is relative to $V_B(B)$, the more valuable it is for firm B to choose $e = A$. Other things being equal, this should increase firm B's incentive to choose $e = A$. The stronger $V_A(B)$ is relative to $V_B(B)$, the more difficult it is for firm B to gain by choosing $e = B$. This should also increase firm B's incentive to coordinate effort.

In the analysis of simple contracts, the shotgun rule should in general be better at coordinating effort, and price competition should be better at termination. For example, the insight that firm B is in a good position to capture rents from firm A when it is the proposer is not related to the structure of the uniform distribution. If the distribution of firm A's valuation v_A were tightly concentrated around a single (large) value $\overline{v}$, then firm B could propose a price slightly below $\overline{v}$ and earn almost all of the surplus on its shares. With regard to efficiency of the simple contracts, there may be distributions for which both the rules perform more and less well. The uniform distributions were chosen for simplicity and do not have any particular compatibility with these rules.[22]

6. Conclusion

We have examined the ability of contracts to induce profit maximization in partnerships. We find that a first best contract maximizing joint profits for a wide range of environments. We have also compared the performance of two common termination rules. We find that both rules can perform well if ownership shares are chosen appropriately. In the environments we consider, we find that the rules cannot be ranked. The shotgun rule is better at inducing effort coordination, but price competition dissolves the partnership more efficiently. A testable implication is that the shotgun rule is a better termination rule than price competition when the coordination of effort is important. Thus one might expect to see the shotgun rule in research joint ventures where effort involves an intellectual-property component, because it seems likely that this type of expert effort is particularly difficult to observe.

22. One interesting way to extend our analysis would be to fix a simple contract and to calculate upper and lower bounds for efficiency over all possible distributions of valuations. This is however beyond the scope of the present paper.

Appendix: Proofs

Proof of Proposition 1: *Ex post* budget balance is immediate. We show that $\langle s^*, t^n\rangle$ is Bayesian incentive-compatible. We first show that $\langle s^*, t^n\rangle$ induces Bayesian incentive-compatible dissolution if firm B has chosen the effort direction A. We have to show that $\Pi_i^A(v_i, v_i) \geq \Pi_i^A(v_i, \hat{v}_i)$ for $i \in \{A, B\}$ and all $v_i, \hat{v}_i \in [\underline{v}_i, \overline{v}_i]$, where Π_i^A is firm i's expected profit under the mechanism $\langle s^*, t^n\rangle$ when its valuation of the venture is v_i and it reports $\hat{v}_i$ after the effort A has been chosen. Straightforward calculation gives

$$\Pi_A^A(v_A, \hat{v}_A) = \frac{1}{2b}\hat{v}_A(2v_A - \hat{v}_A) + \frac{a^2}{6b},$$

$$\Pi_B^A(v_B, \hat{v}_B) = \frac{1}{2a}\hat{v}_B(2v_B - \hat{v}_B) + \frac{b^2}{6a}.$$

It immediately follows that for every $v_A \in [\underline{v}_A, \overline{v}_A]$, $\Pi_A^A(v_A, \hat{v}_A)$ is maximized at $\hat{v}_A = v_A$, and for every $v_B \in [\underline{v}_B, \overline{v}_B]$, $\Pi_B^A(v_B, \hat{v}_B)$ is maximized at $\hat{v}_B = v_B$.

When firm B chooses the effort direction A, the firms' interim expected payoffs are given by

$$\Pi_A^A(v_A, v_A) = \frac{v_A^2}{2b} + \frac{a^2}{6b},$$

$$\Pi_B^A(v_B, v_B) = \frac{v_B^2}{2a} + \frac{b^2}{6a}.$$

We now show that under $\langle s^*, t^n\rangle$, firm B's best response to firm A's choice of effort A is to choose effort A. If B chooses effort direction A, its expected profit is

$$E\left[\Pi_B^A\right] = \frac{b^2}{3a}.$$

If it chooses effort direction B, then, in the dissolution stage, it is better off lying and reporting the $\hat{v}_B$ that solves

$$\max_{\hat{v}_B \in [0, b]} E\left[\Pi_B^B(v_B, \hat{v}_B)\right]$$

than reporting its true valuation v_B.[23] For each $v_B \in [0, b]$, B solves

$$\max_{\hat{v}_B \in [0,b]} \left(\hat{v}_B \frac{v_B}{a'} - \frac{n\hat{v}_B^2}{2a} + \frac{nb^2}{6a} + \frac{(a')^2}{6b} - \frac{a^2}{6b} \right)$$

and as a result chooses to report $\hat{v}_B = \min\{(a/a'n)v_B, b\}$. This gives it an *ex ante* expected utility of

$$E[\Pi_B^B] = \frac{a'b^3}{6a^2b'}n^2 - \frac{b^2}{3a}n + \frac{bb'}{2a'} + \frac{(a')^2}{6b} - \frac{a^2}{6b}.$$

This is quadratic in n, and attains a minimum at $n = (a/a')(b'/b)$. Thus, the optimal mechanism among the family $\{\langle s^*, t^n \rangle\}$ is the one where $n = (a/a')(b'/b)$. Substituting the optimal n into B's *ex ante* expected utility gives

$$E[\Pi_B^B] = \frac{(a')^2}{6b} + \frac{bb'}{3a'} - \frac{a^2}{6b}.$$

B therefore will choose the effort direction A if and only if

$$\frac{a^2}{6b} + \frac{b^2}{3a} \geq \frac{(a')^2}{6b} + \frac{bb'}{3a'}. \tag{7.1}$$

Rewriting

$$\frac{(a-a')(a+a')}{6b} \geq \frac{b^2((b'/b)a - a')}{3aa'}.$$

Dividing through by $a - a' > 0$ gives the condition (S). (By assumption $a \geq a'$. If $a = a'$, then since $ab \geq a'b'$, we must also have that $b = b'$, and so there is no difference between $e = A$ and $e = B$. The effort choice is degenerate in this case, and a first-best contract exists.) □

Proof of Corollary 1: The right-hand side of the inequality (7.1) is increasing in b' for all a'. By the stochastic dominance assumption,

23. Note that after choosing effort direction B instead of A, firm B cannot exercise its ownership right and claim its part of the partnership, because, since $\langle s, t^n \rangle$ is individually rational after it chooses effort A, doing so will prove that it chose effort B and violated the terms of the contract.

$ab \geq a'b'$; therefore, for all a', the right-hand side is maximized when $b' = ab/a'$, and we can eliminate b' from the right-hand side to obtain an inequality that implies the inequality (7.1). That is, $(a')^2/6b + bb'/3a' \leq f(a')$, where $f(a') = (a')^2/6b + ab^2/3(a')^2$. The function f is convex in a' and is therefore maximized at a corner solution. Suppose that the following conditions holds:

$$\frac{a(a')^2}{2} \geq b^3. \tag{7.2}$$

Then $a' \in \left[\sqrt{2b^3/a}, a\right]$. Both the corner values $a' = a$ and $a' = \sqrt{2b^3/a}$ satisfy (7.1), so (7.1) holds and the mechanism $\langle s^*, t^n \rangle$ coordinates effort. The conclusion of the proposition follows by noting that $a \geq 2b$ and $a' \geq b'$ satisfy condition (7.2). (Recall that by assumption $b' \geq b$.) □

Proof of Proposition 2: The proof uses the next three lemmas.[24]

Lemma 2: *The termination mechanism $\langle s, t \rangle$ is incentive-compatible if and only if S_i, $i \in \{A, B\}$, is increasing and*

$$T_i(v_i) - T_i(\hat{v}_i) = \int_{v_i}^{\hat{v}_i} u\, dS_i(u) \qquad \forall i \in \{A, B\},\ v_i, \hat{v}_i \in [\underline{v}_i, \overline{v}_i].$$

Lemma 3: *An incentive-compatible termination rule $\langle s, t \rangle$ is individually rational if and only if $T_i(v_i^*) \geq 0$ for $i \in \{A, B\}$, where $v_i^* = \frac{1}{2}(\inf V_i^* + \sup V_i^*) \in [\underline{v}_i, \overline{v}_i]$ and $V_i^* = \{v_i : S_i(u) < F_j(v_i)\ \forall u < \theta_i,\ S_i(w) > F_j(v_i)\ \forall w > \theta_i\}$.*

Lemma 4: *For any share function s such that S_i, $i \in \{A, B\}$, are increasing, there exists a transfer function t such that $\langle s, t \rangle$ is incentive-compatible and individually rational if and only if*

$$\sum_{i \in \{A, B\}} \left(\int_{v_i^*}^{\overline{v}_i} [1 - F_i(u)] u\, dS_i(u) - \int_{\underline{v}_i}^{v_i^*} F_i(u) u\, dS_i(u) \right) \geq 0. \tag{7.3}$$

Note that $S_i(v_i) = \Pr(v_i > V_j) = F_j(v_i)$ and v_i^* satisfies $S_i(v_i^*) = F_j(v_i^*) = \theta_i$ and so $v_i^* = F_j^{-1}(\theta_i)$. Use the left-hand side of (7.3) to define $\phi: \mathbb{R}^2 \to \mathbb{R}$ by

$$\phi(\theta) = \sum_{i \in \{A,B\}} \left(\int_{v_i^*}^{\overline{v}_i} v_i f_j(v_i)\, dv_i - \int_{\underline{v}}^{\overline{v}} v_i f_j(v_i) F_i(v_i)\, dv_i \right).$$

24. We refer the reader to Cramton et al. (1987) for proofs of these lemmas.

It follows from the last lemma that a partnership with ownership structure $(\theta, 1-\theta)$ can be dissolved efficiently and subject to individual rationality if and only if $\phi(\theta) \geq 0$.

To see that the set of ownership structures that can be dissolved efficiently is convex, it is enough to check that ϕ is concave. We have

$$\frac{\partial \phi}{\partial \theta_i} = -v_i^* f_j(v_i^*) \frac{dv_i^*}{d\theta_i} = -v_i^*,$$

$$\frac{\partial^2 \phi}{\partial \theta_i \, \partial \theta_j} = 0,$$

and

$$\frac{\partial^2 \phi}{\partial \theta_i^2} = -\frac{dv_i^*}{d\theta_i} < 0.$$

If any ownership structure can be dissolved, then the ownership structure that maximizes $\phi(\theta)$ can be dissolved. That is, the structure that is the easiest to dissolve efficiently is given as the solution to

$$\max \phi(\theta_A, \theta_B) \qquad \text{subject to} \quad \theta_A + \theta_B = 1.$$

Because ϕ is concave, the solution to the first-order conditions is the solution to the problem.

$$L = \phi(\theta) + \sum_{i \in \{A, B\}} \lambda_i \theta_i + \lambda(\theta_A + \theta_B),$$

$$\frac{dL}{d\theta_A} : -F_B^{-1}(\theta_A) + \lambda_A + \lambda = 0,$$

$$\frac{dL}{d\theta_B} : -F_A^{-1}(\theta_B) + \lambda_B + \lambda = 0,$$

$$\lambda_i \geq 0,$$

$$\lambda_i \theta_i = 0,$$

$$\theta_A + \theta_B = 1.$$

The solution is given by

$$F_B^{-1}(\theta_A) = F_A^{-1}(\theta_B) \quad \text{and} \quad \theta_A + \theta_B = 1.$$

To see that the set of partnerships that can be dissolved is nonempty, note that a partnership with an ownership structure that is given by $\theta^* = (\theta_A^*, \theta_B^*)$ can be dissolved efficiently. This is equivalent to showing that $\phi(\theta^*) \geq 0$.

We have

$$\phi(\theta^*) = \int_{v^*}^{\overline{v}} v[f_A(v) + f_B(v)]\,dv$$

$$-\int_{\underline{v}}^{\overline{v}} v[f_A(v)F_B(v) + f_B(v)F_A(v)]\,dv,$$

where we are using the equality $v^* = v_A^* = v_B^*$. Integrating each term by parts gives

$$\phi(\theta^*) = \left(2\overline{v} - v^*(\theta_A^* + \theta_B^*) - \int_{v^*}^{\overline{v}} [F_A(v) + F_B(v)]\,dv\right)$$

$$-\left(\overline{v} - \int_{\underline{v}}^{\overline{v}} F_A(v)F_B(v)\,dv\right)$$

$$= \overline{v} - v^* - \int_{v^*}^{\overline{v}} [F_A(v) + F_B(v)]\,dv + \int_{\underline{v}}^{\overline{v}} F_A(v)F_B(v)\,dv$$

$$= \int_{v^*}^{\overline{v}} [1 - F_A(v) - F_B(v)]\,dv + \int_{\underline{v}}^{\overline{v}} F_A(v)F_B(v)\,dv$$

$$= \int_{v^*}^{\overline{v}} [1 - F_A(v)][1 - F_B(v)]\,dv + \int_{\underline{v}}^{v^*} F_A(v)F_B(v)\,dv \geq 0.$$

Finally, we show that $\theta_B^* \leq \frac{1}{2} \leq \theta_A^*$. By assumption, partner A's valuation first-order stochastically dominates partner B's valuation. So $F_A(x) \leq F_B(x)$ for all $x \in \mathbb{R}$. Suppose that $F_B^{-1}(\theta_A^*) = F_A^{-1}(\theta_B^*) = x^*$. It follows that $\theta_A^* = F_B(x^*) \geq F_A(x^*) = \theta_B^*$. Then $\theta_A + \theta_B = 1$ implies $\theta_B^* \leq \frac{1}{2} \leq \theta_A^*$. □

Proof of Corollary 2: The proof follows immediately from careful observation of the proof of the previous proposition. □

Proof of Lemma 1: Note that

$$\frac{d}{dp}\Pi_P(v_P, p) = f_C(p)[v_P - p] + \theta_P - F_C(p).$$

Thus $(d/dp)\Pi_P(v_P, p) = 0$ implies

$$\frac{d^2}{dp^2}\Pi_P(v_P, p) = \frac{F_C(p) - \theta_P}{f_C(p)} f_C'(p) - 2f_C(p),$$

and $(d^2/dp^2)\Pi_P(v_P, p) < 0$ if and only if $F_C(p)f_C'(p)/f_C^2(p) - 2 - \theta_p f_C'(p)/f_C^2(p) < 0$. For uniform distributions of the chooser's valuation, this inequality holds trivially. (More generally it follows from standard hazard-rate conditions.) Thus there is at most one solution to $(d/dp)\Pi_P(v_P, p) = 0$. Moreover, because

$$\frac{d}{dp}\Pi_P(v_P, 0) = f_C(0)v_P + \theta_P > 0$$

and

$$\frac{d}{dp}\Pi_P(v_P, \max\{\overline{v}_P, \overline{v}_C\})$$

$$= f_C(\max\{\overline{v}_P, \overline{v}_C\})[v_P - \max\{\overline{v}_P, \overline{v}_C\}] + \theta_P - 1 < 0$$

and $d\Pi_P/dp$ is continuous, such a solution exists.

$(\partial^2/\partial p\, \partial v)\Pi_P(v_P, p) = f_C(p) \geq 0$, so $p(v_P)$ is nondecreasing. Now, suppose $p(v_P) > v_P$. Then

$$0 = f_C(p(v_P))[v_P - p(v_P)] + \theta_p - F_C(p(v_P))$$

$$< \theta_P - F_C(p(v_P)).$$

Thus $F_C(p(v_P)) < \theta_P$; that is, $p(v_P) > v_P$ implies $p(v_P) < v^*$. Similarly, by reversing the inequalities above, we obtain that $p(v_P) < v_P$ implies $p(v_P) > v^*$. Finally, $(d/dp)\Pi_P(v^*, v^*) = 0$, so $p(v^*) < v^*$.

It is immediate from the definition $v^* = F_C^{-1}(\theta_P)$ that the critical valuation v^* is increasing as a function of θ_P. □

Proof of Proposition 3: First we show that the optimal shares for termination are given by $(\theta_A, \theta_B) = (1 - 1/2a, 1/2a)$. Suppose that firm B is the proposer. The pricing function is given by $p(v_B) = \frac{1}{2}(v_B + a\theta_B)$. The losses from trade are

$$L = \int_{\underline{v}_P}^{\overline{v}_P} \int_{v_P}^{p(v_P)} (v_C - v_P)\, dF_C(v_C)\, dF_P(v_P).$$

Plugging the pricing function in and simplifying, we obtain

$$L = \frac{b^2}{24a} - \tfrac{1}{8} b\theta_B + \tfrac{1}{8} a\theta_B^2.$$

The minimum is obtained at $\theta_B = \frac{1}{2} b/a = 1/2a$ for $b = 1$.

To complete the proof, we show by calculation that $(\theta_A, \theta_B) = (1 - 1/2a, 1/2a)$ coordinates effort for $l \le l^*$. We then show again by calculation that for $l^* \le l \le l^{**}$ it is optimal to increase from B's share above $1/2a$ just enough to coordinate effort. We define l^{**} setting joint profits under this share structure and effort coordination equal to joint profits under the share structure $(\theta_A, \theta_B) = (\frac{1}{2}, \frac{1}{2})$ and no effort coordination. These calculations are straightforward and available from the authors on request. □

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