The Financing of Alliance Entrepreneurship

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ABSTRACT

It is popular nowadays for entrepreneurial firms to advance their entrepreneurship outside their boundaries through alliances. This paper studies how the financing of the entrepreneurship changes with the emergence of this new organizational form. We model a financially constrained entrepreneur and a deep-pocket incumbent developing an innovative product through strategic alliance, which generates externalities on the incumbent. We confirms Zingales (2000)'s argument that traditional corporate finance theories may not work efficiently in new organizational structures and find that i) financial constraints of the entrepreneur can be tightened by an increase in his endowment or a reduction in agency conflicts, which contrasts with traditional theories; and ii) the main agency conflict of the entrepreneurship is the free-riding problem among collaborators rather than those between investors and managers. We suggest introducing an outside investor to deal with this agency conflict by taking away more revenue in case of failure than in case of success. The incentive-compatible financial claims in alliances implementing the optimal financial contract involve the use of debt, equity, warrants, convertible debt, and preferred equity, which are consistent with empirical observations.

Keywords: Financial Contracting, Externality, Security Design, Alliance Entrepreneurship

JEL Codes: G32, D86, D82

> "The greatest change on corporate structure—and in the way business is being conducted—may be the accelerating growth of relationships based not on ownership but on partnership...semi-formal alliances of all sorts." (Peter Drucker, Wall Street Journal, April 20, 1995, p. A1)

1. Introduction

Nowadays it is very popular for entrepreneurial firms to form strategic alliances to advance their entrepreneurship outside their boundaries. From Figure 1, we can see that the number of newly established strategic alliances each year has increased dramatically, from around 50 in 1985 to around 2800 in 2005. A prevailing form of alliances involves links between small entrepreneurial firms and larger established ones, or between new corporate ventures and other companies outside their group (Gompers and Lerner (1998), Robinson and Stuart (2007a) and Dushnitsky and Lavie (2010)).

How does the financing of the entrepreneurship change with the emergence of this new organizational form—strategic alliance? This is a central, challenging question that corporate finance theorists face today. Traditional corporate finance theories are based on the underlying assumption that a firm's boundary is clear-cut, that is, that businesses are conducted within boundaries, while alliance entrepreneurship expands business outside boundaries. In his survey, Zingales (2000) argues that "although the existing [corporate finance] theories have delivered very important and useful insights, they seem to be quite ineffective in helping us cope with the new type of firms that is emerging."[1] Thus, the objective of this paper is to introduce a new theory to study the financial decisions of the alliance entrepreneurship.

In this paper, we consider a two-period model in which an entrepreneur has an innovative idea to develop a new product and seeks to form a strategic alliance with an incumbent. At

[1] See lines 3-5 in the abstract of Zingales (2000).

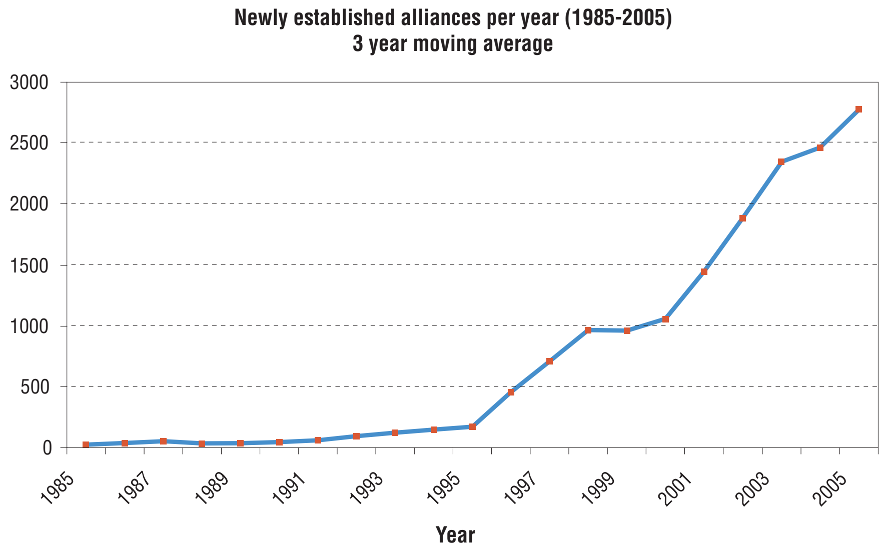


Figure 1. Number of newly established alliances (Source: The second state of alliance management study (2007) in association of strategic alliance professionals).

period 0, the development requires an initial investment I. The entrepreneur has a limited endowment. Therefore, he needs financing from the incumbent. After the investment, both the entrepreneur and incumbent privately exert effort, which is costly. We assume increasing and convex cost functions for both collaborators. At period 1, the product matures. The probability of success is determined by the entrepreneur's and the incumbent's efforts. That is, both agents can exert more effort to increase the probability of success. In addition, the innovative product generates externalities for the incumbent. Externalities can stem from many sources, such as ex-post product market competition, knowledge transfers, and cross-market synergies. In our paper, if the innovation generates more value, i.e., externality, to the incumbent in case of success than in case of failure, we say that the innovation complements the incumbent. Otherwise, we say that the innovation substitutes (or cannibalizes) the incumbent. The market interest rate is normalized to 0.

In this model, we we employ a two-agent model rather than a one-agent model as in Jensen and Meckling (1976) because we believe that in alliances collaboration is a key element in the success of a project. Second, the project generates externalities for the incumbent, which echoes the argument of Baker, Gibbons, and Murphy (2002) that externalities are a primary concern when firms form and structure strategic alliances. The introduction of externalities allows our model to incorporate firms' strategic considerations in alliances.

In this paper, we propose using the Lagrange multiplier of the participation constraint of external capital providers as a measure of financial constraint. We know that in an environment with friction, a firm's external capital will be more costly than its internal capital. The cost of external capital includes not only the explicit interest but also implicit costs. One typical example of implicit cost is incentive distortions. That is, to raise a sufficient amount of external capital to finance its projects, a firm must provide investors with a large share of future cash flows, which dramatically reduces the amount left for the manager and thereby jeopardizes his incentives. How can we measure the financial constraint by capturing both explicit and implicit costs? The Lagrange multiplier measures the change in a firm's value by easing the participation constraint of its external capital providers, which is the marginal cost of external capital.

Our theory yields two main results. First, we find that some conventional wisdoms based on the traditional form of organization may not always hold and that they can sometimes even be reversed in alliances. For instance, conventional wisdom argues that an increase in the entrepreneur's endowment eases his financial constraints. This argument, however, does not always hold if innovation generates externalities for the financier, herein the incumbent. This is because in the traditional setup, the financier has an outside option value 0 and he just needs to breakeven. However, in our alliance setup the incumbent's participation constraint is affected by the externalities. With externalities, innovation affects the value of the incumbent even if he does not participate in the strategic alliance. The effect of the endowment on financing constraints also depends on how the endowment affects this outside option value. If the innovation complements the incumbent, an increase in the endowment raises the incumbent's outside option. This tightens his participation constraint, which reduces and can sometimes offset the positive effect of an increase in endowment in relaxing financial constraints. The offsetting scenario happens if the marginal effect of the endowment on the incumbent's outside option is greater than 1.

In addition, we also find that a reduction in agency conflicts may sometimes surprisingly tighten a firm's financial constraints. In a standard principal–agent model, the revenue difference between success and failure can measure agency conflicts. If this revenue difference increases, agency conflicts will be less severe because it is easier and less costly for the principal to monitor the agent. In this case, agents will exert more effort and a firm will be less financially constrained. However, in strategic alliances, this result does not always hold. The easing of financial constraints because of a reduction in agency conflicts can be reduced and sometimes even offset by the following two counter effects. First, when the revenue difference widens, the incumbent exerts more effort, but this raises his marginal cost of effort, which in turn tightens his participation constraint. Second, when the revenue difference widens, in the standalone case, the agency conflict between the entrepreneur and the outside investor is also less severe. Thus, the project is more likely to be successful. If the innovation complements the incumbent, this raises the outside option value of the incumbent and thereby tightens his participation constraint. If these two effects dominate, a reduction in agency conflicts can tighten a firm's financial constraint.

Second, in the two-agent framework, the main concern in alliances is the agency conflict between the collaborators, i.e., the free-riding problem, rather than the conflicts between investors and managers. To deal with the free-riding problem, we suggest introducing a third party. The intuitive logic behind this is that in our model, the total output is affected by the efforts of both agents. However, we only observe the final output rather than the efforts of the two. If either the entrepreneur or the incumbent exerts more effort, he will increase the probability of success of the project. However, the outcome of his hard work is shared with the other party, while the cost of exerting the effort is solely his. Therefore, this free-riding problem leads to under-provision of effort by both the entrepreneur and the incumbent. In our framework, we suggest introducing a third party—an outside investor—who takes away more money in case of failure than in the case of a success. In this case, even though the income generated by one agent's hard work is still shared with the other, he will be severely punished if he does not exert effort. This punishment in case of failure ensures that the entrepreneur and the incumbent both provide sufficient effort, in a similar spirit to the mechanism in Holmstrom (1982).

The above two results imply that our preliminary attempt at a new theory confirms on the one hand the argument of Zingales (2000) that traditional corporate finance theories "seem to be quite ineffective in helping us cope with the new type of firms that is emerging" and on the other calls for more research in the financing of entrepreneurship with new organizational forms.

Lastly, Robinson and Stuart (2007a) document that strategic alliances usually have a much more complex financial structure than traditional firms, including multiple securities, such as debt, equity, convertible debt, preferred equity, and warrants. To check whether our theory generates consistent predictions empirically, we implement our optimal contract with proper financial claims. We find that if the innovation substitutes or slightly complements the incumbent, the incumbent should hold preferred equity (convertible debt) or equity in the entrepreneur firm, and if the innovation largely complements the incumbent, the incumbent should hold put warrants possibly together with debt in the entrepreneur firm. Our implementation results rationalize the use of preferred equity, convertible debt, and warrants in the entrepreneur firm for the incumbent, which is consistent with empirical observations in corporate venture capital contracts by Cumming (2006) and in biotech strategic alliances by Robinson and Stuart (2007a). Meanwhile, our results show that pure debt securities are more likely to occur in strategic alliance contracts than in venture capital contracts as described by Casamatta (2003). This phenomenon is also evidenced by Cumming (2006). He finds that Canadian corporate venture capitalists are more likely to use non-convertible debt than Canadian limited partnership venture capitalists.

This paper relates to the literature on venture capital, i.e., Bascha and Walz (2001), Casamatta (2003), Kanniainen and Keuschnigg (2003), Schmidt (2003), Denis (2004), and

Repullo and Suarez (2004). Our paper uses a similar benchmark model as Casamatta (2003), by introducing duel roles for the incumbent firm in strategic alliances. However, different from venture capitalists, in our paper the incumbent also considers the strategic consequences, i.e., the externalities, of the alliance on his own business.

This paper also relates to the literature of corporate governance in strategic alliances (Aghion and Tirole (1994), Dasgupta and Tao (2000), Elfenbein and Lerner (2003), Dessein (2005), Robinson and Stuart (2007b), Lerner, Shane, and Tsai (2003), and Malmendier and Lerner (2010)). These studies mainly emphasize the hold-up problem and examine how the optimal allocation of property rights and control rights among partners in strategic alliances mitigate this. Our paper differs from these studies in two aspects: i) we emphasize that the externalities of strategic alliances on parent firms based on the findings of Baker et al. (2002), rather than hold-up problems, are the main issue emphasized by practitioners; and ii) we focus on the financial aspects of strategic alliances.

Our work also relates to papers that focus on the strategic implications of inter-firm equity stakes. Existing literature has documented that inter-firm equity stakes are used to support exchanges (Pisano (1989)), deter entry and mitigate competition (Reynolds and Snapp (1986), Chen and Ross (2000), Clayton and Jorgensen (2005), and Mathews (2006)), promote future corporate control activities (Mathews (2007)), and facilitate information acquisition and monitoring (Allen and Philips (2000), Filson and Morales (2006), and Habib and Mella-Barral (2007)). Our paper differs by taking an optimal contracting approach and designing optimal securities to address the free-riding problems of collaborators and ex-post externalities.

The remainder of the paper is organized as follows. Section 2 introduces the basic model. Section 3 studies the standalone case. Section 4 analyzes the strategic alliance case. Section 5 focuses on how to implement the optimal contract through proper financial claims. Section 6 concludes the paper. All formal proofs are in the Appendix.

2. The Model

We assume there are three risk-neutral players: an entrepreneur, an incumbent, and an outside investor. The entrepreneur has an innovative idea to develop a new product. He has only a limited endowment E_A, and he is protected by limited liability, while the incumbent and the outside investor are deep pocketed.

We consider a two-period model, that is, $t = 0$, 1. At date 0, the new product requires an initial investment I at date 0. At date 1, the project can either succeed or fail. If the project is successful, it generates revenue R_u for the entrepreneur and externality Y_u for the incumbent. If it fails, it generates R_d for the entrepreneur and Y_d for the incumbent.

The probability of the success of the innovation depends on whether it is operated by the entrepreneur alone or by a strategic alliance of the entrepreneur and incumbent. In the case of a standalone operation, after the initial investment at date 0, the entrepreneur privately chooses his effort level $a \in [0, 1]$, and the project succeeds with probability a at date 1. In the case of strategic alliances, as in Casamatta (2003), both the entrepreneur and the incumbent privately choose their effort levels $a \in [0, 1]$ and $b \in [0, 1]$. The project succeeds with probability $\min\{a+b, 1\}$ and fails with probability $\max\{1-(a+b), 0\}$. Similar to Casamatta (2003), the two agents' efforts are assumed to be perfect substitutes. This assumption simplifies our analysis without loss of generality, since the main results are robust even if we build complementarity of both agents' efforts into the production function. Refer the detailed proof of robustness in Appendix D.

Both efforts are costly. $C_A(a)$ and $C_B(b)$ denote the entrepreneur's and the incumbent's disutilities of effort, where

$$C_A(a) = \frac{1}{2}Aa^2, \tag{1}$$

and

$$C_B(b) = \frac{1}{2}Bb^2. \tag{2}$$

The interest rate is normalized to zero. In addition, $0 < A < B$, indicating that the entrepreneur is more efficient in developing this new product than the incumbent is.[2]

The introduction of the externalities is motivated by the argument of Baker et al. (2002) that the spillover effects of the joint project on the incumbent firm is a major consideration in forming strategic alliances. The externalities are a reduced form of potentially very complicated interactions between the entrepreneur and the incumbent, including product market competition, knowledge transfer, cross-market synergies, licensing, and acquisitions. This reduced form consideration of externalities, as in Hellmann (2002), not only simplifies but also generalizes our analysis. In addition, we assume that due to the complexity, the externalities cannot be contracted upon. $Y_u - Y_d$ measures the change in the value of the incumbent's existing business if the innovation were to succeed. If $Y_u - Y_d > 0$, then the innovation complements the incumbent. If $Y_u - Y_d < 0$, then the innovation substitutes or cannibalizes the incumbent.

In our setup, the collaboration between the two parties is modeled in a similar manner as in Casamatta (2003), where both parties must exert costly unobservable effort to increase the probability of success for the new product. However, our model departs in one crucial aspect. In Casamatta (2003), the venture capitalist cares only about the financial returns. In contrast, in this paper, the incumbent also considers the strategic consequences of the innovation for his own business because of externalities.[3]

3. Standalone Operation

Before considering strategic alliances, we first study the case of a standalone operation. This is because the study on standalone operations allows us to generate the outside option value for the incumbent, which is an important element in determining his entry decision in

[2]Lerner et al. (2003) find that strategic alliances, which assign less control rights to $R\&D$ firms and more control rights to the big established firm, are significantly less successful. This result is consistent with our assumption that the entrepreneur firm is more efficient in developing the product.

[3]In the current version of the paper, we do not incorporate the monotonicity constraint as in Casamatta (2003) that the payoff of each player must be a non-decreasing function of the company's payoff. This consideration greatly simplifies our computation without loss of generality. According to our analysis, this monotonicity constraint is inessential for our main results.

the strategic alliance case. This point will become clear in Section 4.

In the case of standalone operations, at date 0, the entrepreneur makes a take-it-or-leave-it offer to the outside investor. The contract specifies the following: i) the initial investment I_A and I_O from the entrepreneur and the outside investor, respectively, where $I_A + I_O = I$; and ii) the split of final payoff at date 1: R_i^A to the entrepreneur and $R_i - R_i^A$ to the outside investor in state i, where $i = u, d$.

The entrepreneur chooses his effort level to maximize his expected utility. His incentive compatibility constraint (IC_A^s) is

$$a \in \arg\max_a \quad aR_u^A + (1-a)R_d^A - \frac{1}{2}Aa^2 - I_A, \tag{3}$$

According to the first-order condition of (3), the level of effort a is

$$a = \frac{1}{A}(R_u^A - R_d^A), \tag{4}$$

which increases with the entrepreneur's revenue difference between the two states $R_u^A - R_d^A$.

To ensure that the outside investor is willing to participate in the innovation, he must earn a non-negative profit. His participation constraint (PC_O^s) is

$$a(R_u - R_u^A) + (1-a)(R_d - R_d^A) - I_O \geq 0. \tag{5}$$

The contract is chosen to maximize the entrepreneur's profit given his incentive constraint, the participation constraint of the outside investor, and other feasibility constraints.

The maximization program is

$$\begin{aligned} \max_{R_u^A, R_d^A, I_A, I_O} \quad & aR_u^A + (1-a)R_d^A - \frac{1}{2}Aa^2 - I_A \\ s.t. \quad & IC_A^s \\ & PC_O^s \\ & I_A + I_O = I \\ & I_A \leq E_A \\ & R_u^A, R_d^A \geq 0, \end{aligned} \tag{6}$$

where the last condition reflects the limited liability protection for the entrepreneur.

Solving this, we obtain

$$a = \begin{cases} \dfrac{R_u - R_d}{A} & E_A \geq I - R_d \\ \dfrac{R_u - R_d + \sqrt{(R_u - R_d)^2 + 4A(E_A - I + R_d)}}{2A} & E_A < I - R_d. \end{cases} \tag{7}$$

This equation implies that if $E_A \geq I - R_d$, the entrepreneur is not financially constrained. He exerts the same level of effort as in the case without moral hazard. If $E_A < I - R_d$, the entrepreneur is financially constrained. His effort level increases with his endowment.

In the standalone case, the incumbent passively receives the externality of the innovation. The expected externality for the incumbent is

$$U_B = Y_d + a(Y_u - Y_d), \tag{8}$$

where a is determined by equation (7).

LEMMA 1:

If $Y_u - Y_d < 0$, the outside option value U_B obtained by the incumbent decreases with the entrepreneur's endowment E_A. If $Y_u - Y_d > 0$, his outside option value U_B increases with E_A.

This lemma is intuitive. If the innovation substitutes the incumbent, successful innovations impose costs on the incumbent. Therefore, the incumbent would prefer the entrepreneur to be financially weak to reduce his probability of success. Hence, the incumbent's outside option value decreases with the entrepreneur's financial strength. If the innovation complements the incumbent, we have the opposite result.

4. Strategic Alliance

In this section, we turn to the case of a strategic alliance through which both the entrepreneur and the incumbent exert effort together to develop the new product. At date 0, the entrepreneur makes a take-it-or-leave-it offer to the incumbent and the outside investor, which specifies the following: i) the initial investment I_A, I_B, and I_O from the entrepreneur, incumbent, and outside investor, respectively, where $I_A + I_B + I_O = I$; and ii) the split of the final payoff R_i: R_i^A, R_i^B, and R_i^O to the entrepreneur, incumbent, and outside investor, respectively, at state i, where $i = u, d$ and $R_i^A + R_i^B + R_i^O = R_i$. The assumption that the entrepreneur makes a take-it-or-leave-it offer simplifies our analysis and is also consistent with the empirical observation in Allen and Philips (2000). They document a significant increase in the stock price of the entrepreneur firm but no significant change in the stock price of the incumbent firm when they form strategic alliances, which indicates that all the benefit goes to the entrepreneur firm.

In our setup, we make the following assumption:

ASSUMPTION 1:

$$0 < (\frac{1}{A} + \frac{1}{B})(R_u - R_d + Y_u - Y_d) \leq 1, \tag{9}$$

The left-hand side inequality ensures that if the innovation cannibalizes the incumbent, its magnitude is limited so that strategic alliances is still a feasible organizational structure.[4] The right-hand side inequality ensures that the constraint $\min\{a + b, 1\} \leq 1$ is not binding

[4] This left-hand side inequality can also be written as $Y_u - Y_d > -(R_u - R_d)$.

at first-best.

In the case with moral hazard, the way in which the cash flow is shared determines how much effort is provided by each agent. For the entrepreneur, the level of effort is given by his incentive compatibility constraint IC_A:

$$a \in \arg\max_{a} \quad (a+b)R_u^A + (1-(a+b))R_d^A - \frac{1}{2}Aa^2 - I_A, \tag{10}$$

which means that the entrepreneur chooses his effort to maximize his expected profit given the contract, his rational expectation of the effort level of the incumbent, and his cost of effort. Similarly, the incentive compatibility constraint of the incumbent IC_B is

$$b \in \arg\max_{b} \quad (a+b)(R_u^B + Y_u) + (1-(a+b))(R_d^B + Y_d) - \frac{1}{2}Bb^2 - I_B - U_B. \tag{11}$$

By solving the first-order conditions of IC_A and IC_B, we obtain the optimal levels of effort a and b:

$$a = \frac{1}{A}(R_u^A - R_d^A), \tag{12}$$

and

$$b = \frac{1}{B}(R_u^B - R_d^B + Y_u - Y_d). \tag{13}$$

The entrepreneur also requires financial support from the incumbent and the outside investor. To make them willing to provide financing, the participation constraints must ensure that they recoup their investment.

The participation constraint for the incumbent PC_B is

$$R_d^B + Y_d + (a+b)(R_u^B - R_d^B + Y_u - Y_d) - \frac{1}{2}Bb^2 - I_B \geq U_B. \tag{14}$$

The left-hand side represents the expected total revenue of the incumbent, which includes the externality. The right-hand side represents the reservation utility that the incumbent obtains in the case of a standalone operation. Note that U_B is endogenous since it depends on the actions of the entrepreneur in the case of a standalone operation.

The participation constraint for the outside investor PC_O is

$$R_d^O + (a+b)\left(R_u^O - R_d^O\right) - I_O \geq 0. \tag{15}$$

The reservation income for the outside investor in the case of a standalone operation is 0.

The financial contract is chosen to maximize the expected profit of the entrepreneur given the incentive constraints, participation constraints, and other feasibility constraints:

$$\begin{aligned} \max_{R_u^A, R_d^A, R_u^B, R_d^B, R_u^O, R_d^O, I_A, I_B, I_O} \quad & R_d^A + (a+b)(R_u^A - R_d^A) - \frac{1}{2}Aa^2 - I_A \\ s.t. \quad & IC_A, IC_B, PC_B, PC_O \\ & I = I_O + I_A + I_B \\ & R_i^A + R_i^B + R_i^O = R_i, i = u, d \\ & I_A \leq E_A \\ & R_u^A, R_d^A \geq 0. \end{aligned} \tag{16}$$

To maximize the profit of the entrepreneur, the participation constraints of the incumbent and the outside investor must be binding. Therefore, the total profit of the entrepreneur is equivalent to the difference between the total profit generated by the innovation, including the externality, and U_B. Let $U = R_u^A - R_d^A$ and $V = R_u^B - R_d^B + Y_u - Y_d$. The maximization problem can be re-written as

$$\max_{R_d^A, U, V} \quad R_d + Y_d + (\frac{U}{A} + \frac{V}{B})(R_u - R_d + Y_u - Y_d) - \frac{1}{2A}U^2 - \frac{1}{2B}V^2 - I - U_B \tag{17}$$

$$s.t. \quad R_d + Y_d - R_d^A + (\frac{U}{A} + \frac{V}{B})(R_u - R_d + Y_u - Y_d - U) - \frac{1}{2B}V^2 - U_B \geq I - E_A \quad (*)$$

$$R_d^A, U \geq 0, \quad (**)$$

where condition $(*)$ is obtained by rearranging constraints PC_B, PC_O, $I = I_O + I_A + I_B$ and $I_A \leq E_A$, and condition (**) reflects limited liability protection for the entrepreneur.

The Lagrange of Program (17) can be written as

$$\begin{aligned} L = & R_d + Y_d + (\frac{U}{A} + \frac{V}{B})(R_u - R_d + Y_u - Y_d) - \frac{1}{2A}U^2 - \frac{1}{2B}V^2 - I - U_B + \\ & \lambda \left\{ R_d + Y_d - R_d^A + (\frac{U}{A} + \frac{V}{B})(R_u - R_d + Y_u - Y_d - U) - \frac{1}{2B}V^2 - U_B - I + E_A \right\}. \end{aligned} \tag{18}$$

The first-order conditions are

$$\frac{\partial L}{\partial R_d^A} = -\lambda \leq 0, \tag{19}$$

$$\frac{\partial L}{\partial U} = \frac{1}{A}(R_u - R_d + Y_u - Y_d) - \frac{1}{A}U + \lambda\{\frac{1}{A}(R_u - R_d + Y_u - Y_d - U) - (\frac{U}{A} + \frac{V}{B})\} = 0, \tag{20}$$

$$\frac{\partial L}{\partial V} = \frac{1}{B}(R_u - R_d + Y_u - Y_d) - \frac{1}{B}V + \lambda\{\frac{1}{B}(R_u - R_d + Y_u - Y_d - U) - \frac{V}{B}\} = 0, \tag{21}$$

and the complementary slackness condition is

$$\lambda \left\{ R_d + Y_d + (\frac{U}{A} + \frac{V}{B})(R_u - R_d + Y_u - Y_d - U) - \frac{1}{2B}V^2 - U_B - I + E_A \right\} = 0. \tag{22}$$

4.1. Financial Constraints

In an environment with friction, a firm's external capital is more costly than its internal capital. The financial constraint of a firm is defined as the wedge between the external and internal costs of capital. How to measure a firm's financial constraint is a central question in corporate finance. Fazzari, Hubbard, and Peterson (1988) suggest dividend policies, whereas Kaplan and Zingales (1997) propose their own classification scheme based on more detailed financial and operational reports. These practical measures only qualitatively and indirectly reflect the wedge between the external and internal costs of capital.

In our setup, the market interest rate is normalized to 0. However, the cost of external capital includes both explicit and implicit costs. The implicit costs come from the agency conflict. That is, to raise sufficient external capital, the financially constrained entrepreneur must repay a large amount of future cash flows to capital providers, and the amount left for himself is greatly reduced, which thereby reduces his incentive to work. We propose the Lagrange multiplier λ as a measure of financial constraint because λ measures the change in the value of the entrepreneur given a relaxation in the participation constraint of the external capital providers, which is the marginal cost of external capital. Since the internal cost of capital is the same as the market interest rate. λ perfectly reflects the wedge between the cost of external capital and that of internal capital.

Denote $I^* = R_d + Y_d - \frac{1}{2B}(R_u - R_d + Y_u - Y_d)^2 - U_B$, which represents the maximum outside financing that the incumbent and the outside investor can provide together given the effort levels as in the case without moral hazard.[5]

PROPOSITION 1: *If $E_A \geq I - I^*$, the entrepreneur is not financially constrained, i.e., $\lambda = 0$. If $E_A < I - I^*$, the entrepreneur is financially constrained, i.e., $\lambda > 0$. The tightness*

[5]Under moral hazard, to induce the same effort from the entrepreneur as without moral hazard, the minimum revenue that the entrepreneur must obtain is $R_u - R_d + Y_u - Y_d$ in case of success and 0 in case of failure. Therefore, the maximum expected income left for the incumbent and the outside investor is $R_d + Y_d$ in both states. For the incumbent, in order to make him exert the same level of effort as the case without moral hazard, he must also receive the total revenue difference $V = R_u - R_d + Y_u - Y_d$. That is, $R_u^B - R_d^B = R_u - R_d$. Thus, when the incumbent participates in a strategic alliance, it also costs him a disutility of effort $\frac{1}{2B}(R_u - R_d + Y_u - Y_d)^2$ and an outside option value U_B. Therefore, the maximum pledgeable income left for the incumbent and the outside investor given the effort levels as without moral hazard, is $R_d + Y_d - \frac{1}{2B}(R_u - R_d + Y_u - Y_d)^2 - U_B$, corresponding to the maximum outside capital that they are willing to contribute.

of the financial constraint λ satisfies

$$\left[f(\lambda, A, B) + \frac{1}{2B}\right](R_u - R_d + Y_u - Y_d)^2 = I - E_A - I^*, \tag{23}$$

where $f(\lambda, A, B) = \dfrac{(1+\lambda)(2A^2\lambda - AB(\lambda-1)^2(\lambda+1) + 2B^2\lambda(1+\lambda)^2)}{2A(-A\lambda^2 + B(1+3\lambda+2\lambda^2))^2}$, *increasing in* λ.

The shadow value of the outside investment constraint λ reflects the conflict between the incentive and the investment constraint. If it is more difficult for the entrepreneur to obtain outside capital from the incumbent and the outside investor, λ will become larger.

Based on equation (23), we will now use comparative statics to study the effect of different parameters on the tightness of the financial constraint.

First, we study the effect of the endowment on the tightness of the financial constraint. Differentiating λ with E_A in equation (23), we obtain the following proposition and corollary.

PROPOSITION 2: *The change in the financial constraint of the entrepreneur with his endowment is captured by the following equation:*

$$\frac{\partial\lambda}{\partial E_A} = \frac{-1 + \dfrac{\partial U_B}{\partial E_A}}{\Phi_0}, \tag{24}$$

where $\Phi_0 = f_\lambda(\lambda, A, B)(R_u - R_d + Y_u - Y_d)^2$.

If $\dfrac{\partial U_B}{\partial E_A} > 1$, *an increase in the endowment* E_A *tightens the financial constraint of the entrepreneur.*

If $\dfrac{\partial U_B}{\partial E_A} < 1$, *an increase in the endowment* E_A *relaxes the financial constraint of the entrepreneur.*

COROLLARY 1:

If $Y_u - Y_d < 0$, *an increase in the endowment* E_A *reduces the outside option value* U_B, *i.e.,* $\frac{\partial U_B}{\partial E_A} < 0$. *This further strengthens the entrepreneur's ability to relax his financial constraints.*

If $Y_u - Y_d > 0$, *an increase in the endowment* E_A *raises the incumbent's outside option*

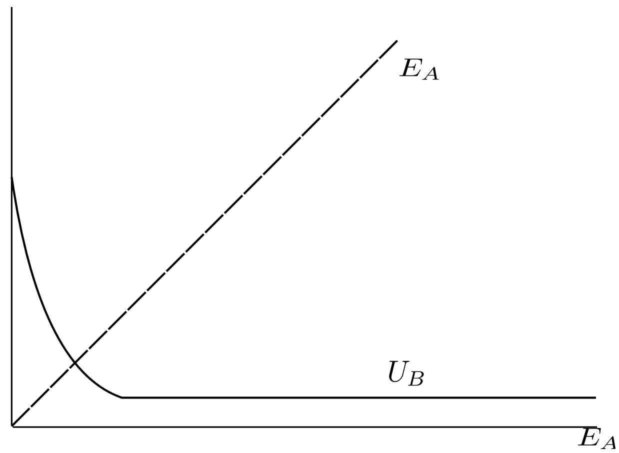
U_B, i.e., $\frac{\partial U_B}{\partial E_A} \geq 0$*. The financial constraint is still relaxed by an increase in the entrepreneur's endowment if* $Y_u - Y_d \leq \sqrt{(R_u - R_d)^2 - 4A(I - R_d)}$*. Otherwise, the financial constraint is tightened by an increase in the entrepreneur's endowment if the latter is low in the sense that* $E_A \in [0, I - R_d + \min\{\frac{(Y_u - Y_d)^2 - (R_u - R_d)^2}{4A}, 0\})$*.*

The above results challenge the traditional view that an increase in the entrepreneur's endowment always relaxes financial constraints. Our result indicates that if the entrepreneurship generates an externality for the financier, the effect of the internal endowment on financial constraints can be non-monotonic.

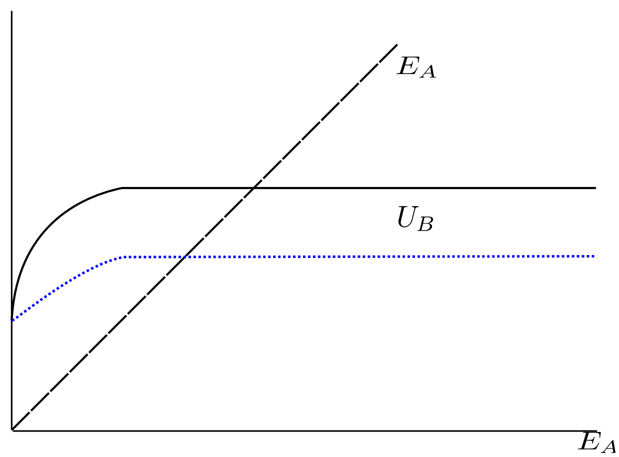
If $Y_u - Y_d < 0$, i.e., the innovation substitutes the incumbent, an increase in the entrepreneur's endowment leads to an increase in the probability of success in the standalone case. Hence, as the endowment increases, the outside option value U_B the incumbent receives declines. This loosens his participation constraint PC_B, which strengthens the positive effect on relaxing financial constraints of an increase in endowment. This is depicted in Figure 2(a).

In contrast, if $Y_u - Y_d > 0$, i.e., the innovation complements the incumbent, the outside option value U_B increases with E_A. This tightens the incumbent's participation constraint, which reduces and can sometimes offset the positive effect on relaxing financial constraints of an increase in endowment. The change in the financial constraint depends on the marginal effect of the endowment on the outside option value U_B. If this marginal effect is greater than 1, the outside option value U_B increases more quickly than the endowment. In this case, the financial constraint tightens with the endowment. Otherwise, the financial constraint eases.

In Figure 2(b), the dotted line indicates that the financial constraint always loosens if the endowment increases since $\frac{\partial U_B}{\partial E_A} < 1$. As indicated in Corollary 1, this happens when the innovation only slightly complements the incumbent. Otherwise, the financial constraint initially tightens and then loosens as implied in the solid line because the marginal effect is initially greater than 1 and eventually falls to 0.



(a) $Y_u - Y_d \leq 0$



(b) $Y_u - Y_d > 0$

Figure 2. This shows how the incumbent's outside option value evolves with the entrepreneur's endowment. The solid line depicts the outside option value U_B that the incumbent receives in the case of a stand-alone operation. The dashed line is the entrepreneur's endowment E_A. In (b), the dotted line also represents the outside option value of the incumbent U_B. For the dotted line, the marginal effect of endowment E_A on U_B is always lower than 1, while for the solid line, this marginal effect is initially greater than 1 and then falls to 0.

Second, we study the effect of agency conflicts on financial constraints. By differentiating λ with $R_u - R_d$ in equation (23), we obtain the following proposition:

PROPOSITION 3: *The change in the financial constraint of the entrepreneur with $R_u - R_d$ is captured by the following equation:*

$$\frac{\partial \lambda}{\partial (R_u - R_d)} = \frac{\Phi_1 + \Phi_2 + \Phi_3}{\Phi_0}, \tag{25}$$

where Φ_0 is the same as in Proposition 2, and

$$\begin{aligned}
\Phi_1 =& -2\left[f(\lambda, A, B) + \frac{1}{2B}\right](R_u - R_d + Y_u - Y_d),\\
\Phi_2 =& \frac{1}{B}(R_u - R_d + Y_u - Y_d),\\
\Phi_3 =& \frac{\partial U_B}{\partial (R_u - R_d)}.
\end{aligned}$$

If $\Phi_1 + \Phi_2 + \Phi_3 > 0$, the financial constraint of the entrepreneur tightens with an increase in $R_u - R_d$.

If $\Phi_1 + \Phi_2 + \Phi_3 < 0$, the financial constraint of the entrepreneur loosens with an increase in $R_u - R_d$.

In a standard principal–agent model, when the revenue difference between success and failure $R_u - R_d$ increases, it becomes easier and less costly for the principal to monitor the agent. In this case, the agency conflicts are less severe; thus, the entrepreneur should be less financially constrained. However, in strategic alliances, the result that financial constraints are less severe with the revenue difference $R_u - R_d$, does not always hold.

In a strategic alliance, $R_u - R_d$ affects the tightness of the entrepreneur's financial constraint through three channels. The first channel is the traditional one. If you only focus on the left-hand side of Equation (23), the marginal effect of $R_u - R_d$ on λ is $\Phi_1/\Phi_0 < 0$.[6] This implies that an increase in $R_u - R_d$ mitigates information asymmetries, thereby relaxing

[6]See $\Phi_1/\Phi_0 < 0$ in the proof of Proposition 3 in the Appendix.

financial constraints.

The two other channels arise from differences in alliance financing relative to the traditional financing. To make the incumbent willing to participate in the collaboration, the final income that accrues to him at date 1 must be sufficient to cover not only his initial financing contribution, as in the traditional case, but also his effort disutility and the outside option value. The second channel relates to the effort disutility of the incumbent. The marginal effect of $R_u - R_d$ on λ through this channel is $\Phi_2/\Phi_0 > 0$. It implies that when the revenue difference between the two states widens, the incumbent must exert more effort on the project. This raises his marginal cost of effort, which in turn tightens his participation constraint. The third channel operates through the outside option value of the incumbent. The marginal effect of $R_u - R_d$ on λ through this channel is Φ_3/Φ_0, which is positive if $Y_u - Y_d > 0$ and negative if $Y_u - Y_d < 0$. This implies that when the revenue difference between the two states widens, the project is more likely to be successful in the standalone case. If the innovation complements (substitutes) the incumbent, this would raise (reduce) the outside option value of the incumbent and thereby tighten (relax) his participation constraint.

Thus, the net effect of $R_u - R_d$ on the financial constraint depends on the magnitude of the effects from these three different channels. If the opposite effect dominates, it is not surprising that an increase in $R_u - R_d$ tightens the financial constraint.

Third, we will discuss the effect of $Y_u - Y_d$ on the entrepreneur's financial constraint.

PROPOSITION 4: *The change in the financial constraint of the entrepreneur with $Y_u - Y_d$ is captured by the following equation:*

$$\frac{\partial \lambda}{\partial (Y_u - Y_d)} = \frac{\Phi_1 + \Phi_2 + \Phi_3'}{\Phi_0}, \tag{26}$$

where Φ_0, Φ_1, and Φ_2 are the same as in propositions 2 and 3, and

$$\Phi_3' = \frac{\partial U_B}{\partial (Y_u - Y_d)}.$$

If $\Phi_1 + \Phi_2 + \Phi_3' > 0$*, the financial constraint of the entrepreneur tightens with an increase in* $Y_u - Y_d$*.*

If $\Phi_1 + \Phi_2 + \Phi_3' < 0$*, the financial constraint of the entrepreneur loosens with an increase in* $Y_u - Y_d$*.*

An increase in $Y_u - Y_d$ can either relax or tighten the financial constraint as $R_u - R_d$. $Y_u - Y_d$ also affects the financial constraint through three channels. First, an increase in $Y_u - Y_d$ motivates the incumbent to exert more effort without the prospect of greater revenues from the entrepreneur. Second, an increase in $Y_u - Y_d$ raises the incumbent's disutility of effort. Third, an increase in $Y_u - Y_d$ raises the spillovers the incumbent receives in the standalone case. The last two channels reduce the incumbent's willingness to participate in the alliance. If the last two effects dominate, an increase in $Y_u - Y_d$ tightens the financial constraint.

4.2. Agency Conflicts and the Role of the Outside Investor

In our setup, both the incumbent and the outside investor have deep pockets. The incumbent provides external financing and effort, while the outside investor provides only external financing. It seems intuitively right that the participation of the outside investor is not necessary since external financing can be provided fully by the incumbent. However, we will argue in the following proposition that the outside investor is necessary for incentive reasons. Let $W = R_u^O - R_d^O$ represent the revenue difference between the two states for the outside investor.

PROPOSITION 5: *In the optimal contract, the outside investor must obtain a higher payoff in case of failure than in case of success, that is,* $W < 0$.[7]

The intuitive reason here is that both the entrepreneur's and the incumbent's efforts

[7] The introduction of the outside investor is still necessary even when we incorporate the monotonicity constraint as in Casamatta (2003) that the payoff of the outside investor must be a non-decreasing function of the firm's payoff. According to our analysis, we find that when the externality is negative, the outside investor can obtain a higher payoff in case of failure than in case of success by holding securities in the incumbent without violating the monotonicity constraint.

are not observable. If either the entrepreneur or the incumbent exerts more effort, he will increase the probability of success of the project. However, the outcome of his hard work will be shared with the other party, while the cost of exerting the effort is borne solely by him. Therefore, this free-riding problem leads to an under-provision of effort by both the entrepreneur and the incumbent. If we introduce an outside investor, even though the income generated by one agent's hard work is shared with the other, he will be severely punished if he does not exert effort since the outside investor will take more money away in case of failure. This punishment in case of failure works as a mechanism to ensure that both the entrepreneur and the incumbent provide sufficient effort. Therefore, in our setup, the outside investor is necessary for incentive reasons. In our paper, the outside investor is like the budget breaker in Holmstrom (1982). However, since our focus is on financing, we want to further investigate what kind of securities should be granted to the outside investor to generate a higher payoff in case of failure than in case of success. This will be analyzed in the following section.

5. Implementation of Optimal Financial Contracts

Robinson and Stuart (2007a) document that entrepreneurial firms in strategic alliances usually have a much more complex financial structure than traditional firms with multiple securities, such as debt, equity, convertible debt, preferred equity, and warrants. To check whether our theory generates consistent predictions empirically, we implement the optimal contract through proper financial claims. The objective of this section is to design financial claims that provide proper incentives for the entrepreneur and the incumbent. The following proposition states that the design of financial claims depends on the spillover effect on the incumbent:

PROPOSITION 6:

1. In the case where $Y_u - Y_d < 0$, the incumbent holds preferred equity or equity and the *outside investor holds put warrants in the entrepreneur firm.*

2. *In the case where* $Y_u - Y_d \geq 0$*, the outside investor always holds put warrants in the entrepreneur firm. The incumbent holds the same type of financial claims as in the case where* $Y_u - Y_d < 0$ *if* $Y_u - Y_d < V$*,*[8] *while he holds debt and put warrants or only put warrants in the entrepreneur firm if* $Y_u - Y_d > V$*.*

In an alliance, the main agency conflict is the free-riding problem between the two collaborators. To deal with this agency problem, the outside investor must obtain a negative revenue difference between the two states, i.e., $W < 0$. Designing the financial claims of the outside investor so they satisfy this criterion is a major concern in the implementation. The outside investor can be granted put warrants in the entrepreneur firm to obtain a larger payoff in a bad state.

The levels of effort for the entrepreneur and the incumbent are determined by the revenue difference between success and failure. When the innovation substitutes the incumbent, the revenue difference in the entrepreneur firm $R_u - R_d > 0$ and that in the incumbent firm is $Y_u - Y_d < 0$. In this case, the externality in the incumbent firm cannot induce any effort from the incumbent. Therefore, the incumbent must hold equity or preferred equity in the entrepreneur firm.

When the innovation slightly complements the incumbent, i.e., $0 < Y_u - Y_d < V$, the incumbent cannot be sufficiently incentivized by receiving only the externality. Thus, the incumbent still needs to hold equity or preferred equity in the entrepreneur firm. However, when the innovation largely complements the incubment, i.e., $Y_u - Y_d > V$, the complementary spillover effect is so large that it will induce too much effort from the incumbent. In this case, the incumbent should hold some put warrants (and possibly debt) in the entrepreneur firm to reduce his incentives to the optimal level.

The specific financial instruments the incumbent holds in the entrepreneur firm, such as preferred equity or common equity when $Y_u - Y_d < V$ or put warrants with or without debt

[8] V is the total revenue difference of the incumbent we have obtained in the optimal contract section. Its solution is as Equation (B.3) in the Appendix.

when $Y_u - Y_d > V$, depend on the investment contributions of the incumbent.

PROPOSITION 7:

There exists a threshold investment I_B^*,[9] *such that,*

1) In the case where $Y_u - Y_d < V$*, if* $I_B < I_B^*$,[10] *the entrepreneur holds preferred equity while the incumbent holds common equity in the entrepreneur firm. If* $I_B > I_B^*$*, the entrepreneur holds common equity while the incumbent holds preferred equity in the entrepreneur firm.*

2) In the case where $Y_u - Y_d > V$*, if* $I_B < I_B^*$*, the entrepreneur holds equity while the incumbent only holds put warrants in the entrepreneur firm. If* $I_B > I_B^*$*, the entrepreneur still holds equity while the incumbent holds debt and put warrants in the entrepreneur firm.*

In our model, with the same expected final income, equity (put warrants) provides more powerful incentives than preferred equity (put warrant and debt). If the amount of investment from the incumbent is small, i.e., $I_B < I_B^*$, and so is the expected income, the incumbent must be given claims with higher-powered incentives to induce (reduce) enough effort. Thus, he is granted equity if $Y_u - Y_d < V$ and put warrants if $Y_u - Y_d > V$. If the amount of investment from the incumbent is large, i.e., $I_B > I_B^*$, and so is the expected income, the incumbent must hold less-powered incentives to induce (reduce) reasonable amount of effort. Thus, he is granted preferred equity if $Y_u - Y_d < V$ and put warrants together with debt if $Y_u - Y_d > V$.

Propositions 6 and 7 rationalize the use of preferred equity or convertible debt in the entrepreneur firm for the incumbent.[11] This is consistent with the empirical observation of widely used convertible claims or preferred stocks in corporate venture capital contracts by Cumming (2006) and in biotech strategic alliances by Robinson and Stuart (2007a).

[9]Please see the details of I_B^* in equation (C.3).

[10]I_B is the investment contribution from the incumbent we have obtained in the optimal contract section. Its solution is $I_B = R_d^B + Y_d + (\frac{U}{A} + \frac{V}{B})V - \frac{1}{2B}V^2 - U_B$, where $R_d^B \geq 0$, and U and V are determined by equations (B.2) and (B.3) in the Appendix.

[11]This paper does not differentiate between preferred equity and convertible debt, just as in Casamatta (2003).

Compared to the results for venture capital contracts in Casamatta (2003), we find that pure debt securities are more likely to occur if the incumbent rather than the venture capitalist participates in the innovation. This phenomenon is also evidenced by Cumming (2006), who finds that Canadian corporate venture capitalists are more likely to use non-convertible debt than Canadian limited partnership venture capitalists.

6. Concluding Remarks

The popularity of strategic alliance represents a great change in corporate structure, especially in the way entrepreneurship is conducted. As Zingales (2000) argues, traditional corporate finance theories may not work efficiently for the new type of firm that is emerging. The main contribution of this paper is that it introduces a new theory to study the financial decisions of the entrepreneurship in strategic alliances by employing a two-agent framework to model collaboration and introducing externalities to incorporate firms' strategic considerations.

We obtain three main results. First, the relationship between the endowment of the entrepreneur (or the severity of agency conflicts) and financial constraints may not be monotonic as traditional corporate finance theories predict. Second, in alliances the main concern is the agency conflicts between the collaborators rather than the agency conflicts between investors and managers. We suggest introducing an outside investor to deal with this agency conflict by taking away more revenue in case of failure than in case of success. These two results imply that our preliminary attempt at a new theory on the one hand confirms the argument of Zingales (2000) that traditional corporate finance theories "seem to be quite ineffective in helping us cope with the new type of firms that is emerging" and on the other inspires future research in corporate finance on the entrepreneurship with new organizational forms. Third, Robinson and Stuart (2007a) document that entrepreneurial firms in strategic alliances usually have a much more complex financial structure than traditional firms. To check whether our theory generates consistent predictions, we implement the optimal contract through proper financial claims. We find that the incentive-compatible financial claims of strategic alliances include debt, equity, preferred equity, convertible debt, and warrants, which are consistent with empirical observations.

In addition, we believe that our model yields additional insights on why in practice many firms collaborate with their competitors despite the potential cannibalization from the competitors (e.g., Hamel, Doz, and Prahalad (1989), Hamel (1991), and Dhanaraj, Lyles, and Lai (2007)). Our results imply that relative to the cannibalization effect, the innovative project in the competitor is very promising since it will generate much higher payoffs if it turns out to be a success. The firm wishes to contribute to his competitor's project because he can gain an opportunity to join and share future benefits from this promising project, which outweighs the spillover cost. One good example is that, Eli Lilly and Company is one of the largest pharmaceutical firms in the world and maintains a strong position in diabetes care. In 1998, Lilly formed an alliance with a Japanese pharmaceutical firm, Beta, to help promote Beta's novel drug for diabetes treatment in the United States. Of course, the success of this drug would pose competitive threats to Lily's existing drugs for diabetes treatments. However, the alliance allowed Lilly to join in this promising project and share decent returns from the sales of the new drug, which exceeded the spillover costs on its existing drugs. By 2004, this drug had become a big success, reaching annual sales of near \$ 2 billion and representing 52% of the U.S. market in its category.

Appendix A. Optimal Contracts in Stand-alone Operation

The participation constraint of the outside investor PC_O is always binding. If it were not, increasing I_O would increase the entrepreneur's expected income without affecting the entrepreneur's incentives. In this case, the profit obtained by the entrepreneur is exactly the NPV of the project. Thus, Program (6) can be transformed to:

$$\begin{aligned} \max_{R_u^A, R_d^A, I_A, I_O} \quad & R_d + a(R_u - R_d) - \frac{1}{2}Aa^2 - I \\ s.t. \quad & IC_A^s \\ & PC_O^s \\ & I_A + I_O = I \\ & I_A \leq E_A \\ & R_u^A \geq 0 \\ & R_d^A \geq 0. \end{aligned} \tag{A.1}$$

Denote $U = R_u^A - R_d^A$. Based on the incentive compatibility constraint of IC_A, $a = \frac{1}{A}U$. Replacing a, I_A and I_O, the above program can be rewritten as

$$\begin{aligned} \max_{U, R_d^A} \quad & R_d + \frac{1}{A}U(R_u - R_d) - \frac{1}{2A}U^2 - I \\ s.t. \quad & R_d - R_d^A + \frac{1}{A}U(R_u - R_d - U) \geq I - E_A \\ & R_d^A, U \geq 0. \end{aligned} \tag{A.2}$$

We know that $I_O = R_d - R_d^A + \frac{U}{A}(R_u - R_d - U)$, which is a concave function of U and a decreasing function of R_d^A. The maximum investment that can be provided by the outside investor $I_O^{\max} = R_d + \frac{1}{4A}(R_u - R_d)^2$. The assumption that $R_d + \frac{1}{4A}(R_u - R_d)^2 > I$ implies the outside investor is still willing to finance the project even if the entrepreneur has no endowment.

The Lagrange of the Program (A.2)

$$L = R_d + \frac{1}{A}U(R_u - R_d) - \frac{1}{2A}U^2 - I + \lambda(R_d - R_d^A + \frac{1}{A}U(R_u - R_d - U) - I + E_A). \quad \text{(A.3)}$$

First, consider the case where $\lambda = 0$. First-order conditions of Lagrange L give that $U = R_u - R_d$, which is exactly the same as the case without moral hazard. In addition, we also need to make sure that

$$R_d - R_d^A + \frac{1}{A}U(R_u - R_d - U) - I + E_A \geq 0. \quad \text{(A.4)}$$

Plug $U = R_u - R_d$ into the above inequality, we obtain $R_d - R_d^A - I + E_A \geq 0$. Because $R_d^A \geq 0$, the solution that $U = R_u - R_d$ and $\lambda = 0$ is feasible if and only if

$$E_A \geq I - R_d. \quad \text{(A.5)}$$

In this case, the optimal contract can be implemented by: the outside investor holds debt with face value with $R_d - R_d^A$, where $0 \leq R_d^A < R_d - I + E_A$, and the entrepreneur holds the equity.

If $E_A < I - R_d$, $\lambda > 0$. The level of effort in the case without moral hazard is not attainable. The entrepreneur always invests E_A and the outside investor invests $I - E_A$. The constraint $R_d - R_d^A + \frac{U}{A}(R_u - R_d - U) = I - E_A$ is always binding. The first-order conditions of Lagrange L give $R_d^A = 0$ and

$$U = \frac{1}{2}\left[R_u - R_d + \sqrt{(R_u - R_d)^2 + 4A(E_A - I + R_d)}\right]. \quad \text{(A.6)}$$

In this case, the optimal contract can be implemented by: the outside investor holds a risky debt with face value $R_u - U$, which is greater than R_d, and the entrepreneur holds the equity. Q.E.D.

Appendix B. Optimal Contracts in Strategic Alliances

By solving Program (17), we already obtained the first-order conditions and complementary slackness conditions as equations (19), (20), (21) and (22). Based on $I_B + I_O = R_d + Y_d - R_d^A + (\frac{U}{A} + \frac{V}{B})(R_u - R_d + Y_u - Y_d - U) - \frac{1}{2B}V^2 - U_B$, the maximum investment that provided by the incumbent and the outside investor together is $R_d + Y_d + \frac{B}{2A(2B-A)}(R_u - R_d + Y_u - Y_d)^2 - U_B$ by setting $U = \frac{B-A}{2B-A}(R_u - R_d + Y_u - Y_d)$ and $V = \frac{B}{2B-A}(R_u - R_d + Y_u - Y_d)$. We assume that $R_d + Y_d + \frac{B}{2A(2B-A)}(R_u - R_d + Y_u - Y_d)^2 - U_B \geq I$ to make sure that the incumbent and the outside investors are willing to provide financing even if the entrepreneur has no endowment.

First, consider the case where $\lambda = 0$. The first-order conditions yield that $U = V = R_u - R_d + Y_u - Y_d$, which are exactly the same as in the case without moral hazard. In this case, the solutions that $\lambda = 0$ and $U = V = R_u - R_d + Y_u - Y_d$ must satisfy the feasible constraint that

$$I^* \geq I - E_A, \tag{B.1}$$

where $I^* = R_d + Y_d - \frac{1}{2B}(R_u - R_d + Y_u - Y_d)^2 - U_B$, representing the maximum investment that the incumbent and the outside investor can provide together without distorting the incentives.

Second, we turn to the case where $I^* < I - E_A$. In this case, $\lambda > 0$. The first order condition (19) yields $R_d^A = 0$.

Based on first order conditions (20) and (21), we obtain that

$$U = g_1(\lambda, A, B)(R_u - R_d + Y_u - Y_d), \tag{B.2}$$

and

$$V = g_2(\lambda, A, B)(R_u - R_d + Y_u - Y_d). \tag{B.3}$$

where $g_1(\lambda, A, B) = \frac{(1+\lambda)(B-(A-B)\lambda)}{B(1+3\lambda+2\lambda^2)-A\lambda^2} > 0$ and $g_2(\lambda, A, B) = \frac{B(1+\lambda)^2}{B(1+3\lambda+2\lambda^2)-A\lambda^2} > 0$.

In addition, the complementary condition yields

$$R_d + Y_d + (\frac{U}{A} + \frac{V}{B})\,(R_u - R_d + Y_u - Y_d - U) - \frac{1}{2B}V^2 - U_B = I - E_A. \tag{B.4}$$

Proof of Proposition 1:

Substituting equations (B.2) and (B.3) into equation(B.4), we obtain that

$$\left[f(\lambda, A, B) + \frac{1}{2}B\right](R_u - R_d + Y_u - Y_d)^2 = I - E_A - I^*, \tag{B.5}$$

where $f(\lambda, A, B) = \dfrac{(1+\lambda)(2A^2\lambda - AB(\lambda-1)^2(\lambda+1) + 2B^2\lambda(1+\lambda)^2)}{2A(-A\lambda^2 + B(1+3\lambda+2\lambda^2))^2}$.

Since $f_\lambda(\lambda, A, B) > 0$, $f(\lambda, A, B)$ is increasing in λ.

The above equation can be rewritten as

$$f(\lambda, A, B)(R_u - R_d + Y_u - Y_d)^2 = I - E_A - (R_d + Y_d) + U_B. \tag{B.6}$$

Since $f(0, A, B) = -\frac{1}{2B}$ and $\lim_{\lambda\to\infty} f(\lambda, A, B) = \frac{B}{2A(2B-A)}$, $f(\lambda, A, B) \in (-\frac{1}{2B}, \frac{B}{2A(2B-A)})$.

$I^* < I - E_A$ can be rewritten as $I - E_A - (R_d + Y_d) + U_B > -\frac{1}{2B}(R_u - R_d + Y_u - Y_d)^2$.

The assumption that $R_d + Y_d + \frac{B}{2A(2B-A)}(R_u - R_d + Y_u - Y_d)^2 - U_B > I$ implies that $I - E_A - (R_d + Y_d) + U_B < \frac{B}{2A(2B-A)}(R_u - R_d + Y_u - Y_d)^2$.

As a result, there always exists a unique $\lambda \in (0, +\infty)$ given $-\frac{1}{2B}(R_u - R_d + Y_u - Y_d)^2 < I - E_A - (R_d + Y_d) + U_B < \frac{B}{2A(2B-A)}(R_u - R_d + Y_u - Y_d)^2$. Q.E.D.

Proof of Proposition 2: Differentiate equation (23) with respect to E_A, we obtain

$$\frac{\partial\lambda}{\partial E_A} = \frac{-1 + \frac{\partial U_B}{\partial E_A}}{f_\lambda(\lambda, A, B)(R_u - R_d + Y_u - Y_d)^2}. \tag{B.7}$$

Since $f_\lambda(\lambda, A, B) > 0$, the sign of $\frac{\partial\lambda}{\partial E_A}$ is determined by the sign of $-1 + \frac{\partial U_B}{\partial E_A}$. If $\frac{\partial U_B}{\partial E_A} > 1$, the increase in the entrepreneur's endowment tightens his financial constraint, otherwise, it loosens his financial constraint.

Proof of Corollary 1: Based on equation (8), we can obtain $\frac{\partial U_B}{\partial E_A}$ as

$$\frac{\partial U_B}{\partial E_A} = \begin{cases} 0 & E_A \geq I - R_d \\ \dfrac{Y_u - Y_d}{\sqrt{(R_u - R_d)^2 + 4A(E_A - I + R_d)}} & E_A < I - R_d. \end{cases} \tag{B.8}$$

In the case where $Y_u - Y_d \leq 0$, $\frac{\partial U_B}{\partial E_A} \leq 0$. The increase in E_A reduces the incumbent's outside option value and thus relaxes the entrepreneur's financial constraint.

In the case where $Y_u - Y_d > 0$, If $E_A \geq I - R_d$, $\frac{\partial U_B}{\partial E_A} = 0$. If $E_A < I - R_d$, $\frac{\partial U_B}{\partial E_A}$ reaches its maximum when $E_A = 0$.

$$\max \frac{\partial U_B}{\partial E_A} = \frac{Y_u - Y_d}{\sqrt{(R_u - R_d)^2 + 4A(-I + R_d)}}, \tag{B.9}$$

and approaches its minimum when $E_A = I - R_d$

$$\min \frac{\partial U_B}{\partial E_A} = \frac{Y_u - Y_d}{R_u - R_d}. \tag{B.10}$$

If $0 < Y_u - Y_d \leq \sqrt{(R_u - R_d)^2 - 4A(I - R_d)}$, $\frac{\partial U_B}{\partial E_A} \leq 1$ always holds.

If $Y_u - Y_d \geq R_u - R_d$, $\frac{\partial U_B}{\partial E_A} > 1$ holds if $\forall E_A \in [0, I - R_d)$, otherwise, $\frac{\partial U_B}{\partial E_A} = 0$.

If $\sqrt{(R_u - R_d)^2 - 4A(I - R_d)} < Y_u - Y_d < R_u - R_d$, $\frac{\partial U_B}{\partial E_A} > 1$ holds if and only if

$$Y_u - Y_d > \sqrt{(R_u - R_d)^2 + 4A(E_A - I + R_d)}. \tag{B.11}$$

In other words, $\frac{\partial U_B}{\partial E_A} > 1$ iff

$$E_A < I - R_d + \frac{(Y_u - Y_d)^2 - (R_u - R_d)^2}{4A}. \tag{B.12}$$

Otherwise, $\frac{\partial U_B}{\partial E_A} \leq 1$. Q.E.D.

Proof of Proposition 3: Differentiate equation (23) with respect to $R_u - R_d$, we obtain

$$\begin{aligned}\frac{\partial \lambda}{\partial (R_u - R_d)} &= \frac{-2\left[f(\lambda, A, B) + \frac{1}{2B}\right](R_u - R_d + Y_u - Y_d) + \frac{1}{B}(R_u - R_d + Y_u - Y_d) + \frac{\partial U_B}{\partial (R_u - R_d)}}{f_\lambda(\lambda, A, B)(R_u - R_d + Y_u - Y_d)^2} \\ &= \frac{-2f(\lambda, A, B)(R_u - R_d + Y_u - Y_d) + \frac{\partial U_B}{\partial (R_u - R_d)}}{f_\lambda(\lambda, A, B)(R_u - R_d + Y_u - Y_d)^2}.\end{aligned} \tag{B.13}$$

Since $f_\lambda(\lambda, A, B) > 0$, the sign of $\frac{\partial \lambda}{\partial (R_u - R_d)}$ is determined by the sign of $-2f(\lambda, A, B)(R_u - R_d + Y_u - Y_d) + \frac{\partial U_B}{\partial (R_u - R_d)}$. If $\frac{\partial U_B}{\partial (R_u - R_d)} > 2f(\lambda, A, B)(R_u - R_d + Y_u - Y_d)$, the increase in the entrepreneur's endowment tightens his financial constraint, otherwise, it loosens his financial constraint.

Since $f(\lambda, A, B) > -\frac{1}{2B}$, $-2\left[f(\lambda, A, B) + \frac{1}{2B}\right](R_u - R_d + Y_u - Y_d) < 0$. In addition, $\frac{1}{B}(R_u - R_d + Y_u - Y_d) > 0$. In the following, we check the sign of $\frac{\partial U_B}{\partial (R_u - R_d)}$. Based on equation (8), we can obtain $\frac{\partial U_B}{\partial (R_u - R_d)}$ as

$$\frac{\partial U_B}{\partial (R_u - R_d)} = \begin{cases} \frac{1}{A}(Y_u - Y_d) & E_A \geq I - R_d \\ \frac{1}{2A}\left(1 + \frac{R_u - R_d}{\sqrt{(R_u - R_d)^2 + 4A(E_A - I + R_d)}}\right)(Y_u - Y_d) & E_A < I - R_d, \end{cases} \tag{B.14}$$

which is a continuous function. If $Y_u - Y_d > 0$, $\frac{\partial U_B}{\partial (R_u - R_d)} > 0$. If $Y_u - Y_d < 0$, $\frac{\partial U_B}{\partial (R_u - R_d)} < 0$.

Proof of Proposition 4: Differentiate equation (23) with respect to $Y_u - Y_d$, we obtain

$$\begin{aligned}\frac{\partial \lambda}{\partial (Y_u - Y_d)} &= \frac{-2\left[f(\lambda, A, B) + \frac{1}{2B}\right](R_u - R_d + Y_u - Y_d) + \frac{1}{B}(R_u - R_d + Y_u - Y_d) + \frac{\partial U_B}{\partial (Y_u - Y_d)}}{f_\lambda(\lambda, A, B)(R_u - R_d + Y_u - Y_d)^2} \\ &= \frac{-2f(\lambda, A, B)(R_u - R_d + Y_u - Y_d) + \frac{\partial U_B}{\partial (Y_u - Y_d)}}{f_\lambda(\lambda, A, B)(R_u - R_d + Y_u - Y_d)^2}.\end{aligned} \tag{B.15}$$

Since $f_\lambda(\lambda, A, B) > 0$, the sign of $\frac{\partial \lambda}{\partial (R_u - R_d)}$ is determined by the sign of $-2f(\lambda, A, B)(R_u - R_d + Y_u - Y_d) + \frac{\partial U_B}{\partial (Y_u - Y_d)}$. If $\frac{\partial U_B}{\partial (Y_u - Y_d)} > 2f(\lambda, A, B)(R_u - R_d + Y_u - Y_d)$, the increase in the entrepreneur's endowment tightens his financial constraint, otherwise, it loosens his financial constraint.

We know that $-2\left[f(\lambda, A, B) + \frac{1}{2B}\right](R_u - R_d + Y_u - Y_d) > 0$ and $\frac{1}{B}(R_u - R_d + Y_u - Y_d)$. In the following, we check the sign of $\frac{\partial U_B}{\partial (Y_u - Y_d)}$. Based on equation (8), we can obtain

$$\frac{\partial U_B}{\partial (Y_u - Y_d)} = \begin{cases} \frac{1}{A}(R_u - R_d) & E_A \geq I - R_d \\ \frac{1}{2A}(R_u - R_d) + \sqrt{(R_u - R_d)^2 + 4A(E_A - I + R_d)}) & E_A < I - R_d, \end{cases} \tag{B.16}$$

which is a continuous function. It is easy to see that $\frac{\partial U_B}{\partial (Y_u - Y_d)} > 0$. Q.E.D.

Proof of Proposition 5:

$$\begin{aligned} W &= R_u - R_d + Y_u - Y_d - (U + V) \\ &= R_u - R_d + Y_u - Y_d - (g_1(\lambda, A, B) + g_2(\lambda, A, B))(R_u - R_d + Y_u - Y_d) \\ &= (1 - g_1(\lambda, A, B) - g_2(\lambda, A, B))(R_u - R_d + Y_u - Y_d) \\ &= -\frac{B + (B - A)\lambda}{B(1 + 3\lambda + 2\lambda^2) - A\lambda^2} < 0. \end{aligned} \tag{B.17}$$

Q.E.D.

Appendix C. Implementation of Optimal Financial Contracts

In the following, we will consider how to design the financial claims for the three participants to generate the right incentives for the entrepreneur and the incumbent.

The three parties share the final output of the entrepreneur firm. The outside investor obtains 0 in case of success and $-W$ in case of failure. Thus, the revenue left for the other two collaborators are R_u and $R_d + W$ respectively. Since $R_d + W$ can be positive or negative, we consider a case where the initial investment requirement is $I - W$, where I is the initial investment of the project, while $-W$ is the the amount of cash retained in the company. In this case, the revenue left for the incumbent and the entrepreneur together at date 1 is $R_u - W$ and R_d respectively. Let α be the fraction of equity the entrepreneur holds and $1-\alpha$ be the fraction of equity the incumbent holds.[12] Define D the revenue the entrepreneur receives in case of failure.

$C.1 \quad Y_u - Y_d < 0$

If $E_A < I - I^*$, the entrepreneur is financially constrained. In this case, $D = R_d^A = 0$, $\alpha = \frac{U}{R_u - W}$. The entrepreneur obtains 0 in case of failure and U in case of success, while the incumbent receives R_d and $R_u - U - W$ respectively. Since $(1-\alpha)R_d < R_d < (1-\alpha)(R_u - W)$, indicating that the dividend the incumbent receives is greater than his share of equity in case of failure and is equal to his share of equity in case of success. Thus, the incumbent firm holds preferred equity while the entrepreneur firm holds common equity. In this case, the outside investment provided by the incumbent and the outside investor $I' = I - E_A - W > I^* - W$.

If $E_A \geq I - I^*$, the entrepreneur is not financially constrained. In this case, the entrepreneur obtains D in case of failure and $D + U$ in case of success, while the incumbent receives $R_d - D$ and $R_u - U - W - D$ respectively. If the incumbent holds preferred equity

[12] Equity may be common equity or preferred equity.

while the entrepreneur holds common equity, it indicates that

$$(1-\alpha)R_d < R_d - D < (1-\alpha)(R_u - W), \tag{C.1}$$

where $\alpha = \frac{D+U}{R_u-W}$. The above inequality yields that $D < \frac{U}{R_u-R_d-W}R_d$.

In this case, there exists a threshold $I^{**} = I^* - W - \frac{U}{R_u-R_d-W}R_d$. If $I' > I^{**}$, the incumbent holds preferred equity while the entrepreneur holds common equity. Similarly, if $I' \leq I^{**}$, the incumbent holds common equity while the entrepreneur holds preferred equity.

One type of securities that can generate more income in case of failure rather than success is put warrants. We assume that the outside investor is granted the right to sell β fraction of equity to the entrepreneur firm at unit price K at date 1 after the realization of the final output but before distributing cash flows to the collaborators. Set K the total common equity value in case of success. In case of success, the investor cannot obtain any profit from exercising the put warrants since the equity price is equal to the exercise price. The outside investor will choose to exercise the put warrants in case of success since equity has a lower price than exercise price. In the case where $I' > I^{**}$, $K = U + D$. If the project succeeds, the outside investor gets 0. If the project fails, the value of put warrants is $\beta(K - D) = \beta(U + D - D) = -W$. Thus, $\beta = \frac{-W}{U}$. In the case where $I' \leq I^{**}$, $K = R_u - W - U - D$. If the project succeeds, the put warrants have no value. If the project fails, the value of the put warrants is $\beta(R_u - W - U - D - R_d + D) = -W$. Thus, $\beta = \frac{-W}{V-(Y_u-Y_d)}$.

C.2 $Y_u - Y_d \geq 0$

Now we turn to the case with positive externality.

CASE 1: $Y_u - Y_d < V$

In this case, the incumbent is not sufficiently incentivized by the externality he receives. Thus, he must hold equity or preferred equity in the entrepreneur firm.

If $E_A < I - I^*$, similarly we find that the incumbent firm holds preferred equity while the entrepreneur firm holds common equity. In this case, the outside investment provided by the incumbent and the outside investor $I' = I - E_A - W > I^* - W$.

If $E_A \geq I - I^*$, the entrepreneur is not financially constrained. In this case, the entrepreneur obtains D in case of failure and $D + U$ in case of success, while the incumbent receives $R_d - D$ and $R_u - W - D - U$ respectively. In this case, $R_d^A = D$. If the incumbent holds preferred equity while the entrepreneur holds common equity, it indicates that

$$(1-\alpha)R_d < R_d - D < (1-\alpha)(R_u - W), \tag{C.2}$$

where $\alpha = \frac{D+U}{R_u - W}$. The above inequality yields that $D < \frac{U}{R_u - R_d - W} R_d$. Thus, the threshold investment $I^{**} = I^* - W - \frac{U}{R_u - R_d - W} R_d$. If $I' > I^{**}$, the incumbent holds preferred equity while the entrepreneur holds common equity. If $I' \leq I^{**}$, the incumbent holds common equity while the entrepreneur holds preferred equity.

The put warrants still grant the outside investor the right to selling β fraction of equity to the entrepreneur firm at unit price K at date 1 after the realization of the final output but before distributing cash flows to the collaborators. In the case where $I' > I^{**}$, $K = U + D$. If the project succeeds, the put warrants have no value. If the project fails, the value of put warrants is $\beta(K - D) = \beta(U + D - D) = -W$. Thus, $\beta = \frac{-W}{U}$. In the case where $I' \leq I^{**}$, $K = R_u - W - D - U$. If the project succeeds, the put warrants have no value. If the project fails, the value of the put warrants is $\beta(R_u - W - D - U - R_d + D) = -W$. Thus, $\beta = \frac{-W}{V - (Y_u - Y_d)}$. In this case, we find that the results are the same as the case where $Y_u - Y_d < 0$.

<u>CASE 2: $Y_u - Y_d > V$</u>

In this case, the externality is so large that it will induce too much effort from the incumbent. In this case, the incumbent should not be granted with securities such as equity or preferred equity which generates even more incentives for him to exert effort, but be granted with put warrants which can reduce his incentives to the optimal level.

If $E_A < I - I^*$, the entrepreneur is financially constrained. In this case, $D = R_d^A = 0$ and $\alpha = 1$. The entrepreneur obtains 0 in case of failure and U in case of success, while the incumbent receives R_d and $R_u - U - W$ respectively (Assume $R_u - U - W > 0$). It is easy to find that $R_d > R_u - U - W$ when $Y_u - Y_d > V$. In this case, the incumbent holds debt with face value $R_u - W - U$. In addition, the incumbent also holds put warrants which generate him 0 in case of success and $Y_u - Y_d - V$ in case of failure. The outside investor holds put warrants which generate him 0 in case of success and $-W$ in case of failure. In this case, the outside investment provided by the incumbent and the outside investor $I' = I - E_A - W > I^* - W$.

If $E_A \geq I - I^*$, the entrepreneur is financially constrained. In this case, $R_d^A = D$ and $\alpha = 1$. The entrepreneur obtains D in case of failure and $U + D$ in case of success, while the incumbent receives $R_d - D$ and $R_u - U - W - D$ respectively. In this case, incumbent holds debt with face value $R_u - W - U - D$ in the entrepreneur firm if $D < R_u - W - U$. Thus, there exists a threshold $I^{**} = I^* - W - (R_u - W - U) = I^* - R_u + U$. If $I' > I^{**}$, the incumbent holds debt and put warrants while the entrepreneur holds common equity. Otherwise, the incumbent holds put warrants and the entrepreneur holds common equity.

Similarly, we assume that the incumbent and the outside investor are granted respectively the right to sell α and β fraction of equity to the entrepreneur firm at unit price K at date 1 after the realization of the final output but before distributing cash flows to the collaborators. Set Set K the total common equity value in case of success. In case of success, the incumbent and the outside investor cannot obtain any profit from exercising the put warrants since the equity price is equal to the exercise price. They will choose to exercise the put warrants only in case of success since equity has a lower price than exercise price. If the project succeeds, both the incumbent and the outside investor gets 0. If the project fails, the value of put warrants for the incumbent is $\alpha(K - D) = \alpha U = Y_u - Y_d - V$, the value for the outside investor is $\beta(K - D) = \beta U = -W$. Thus, $\alpha = \frac{Y_u - Y_d - V}{U}$ and $\beta = \frac{-W}{U}$.

Since we know that $I_O = -\left[1 - (\frac{1}{A}U + \frac{1}{B}V)\right] W$, we can also state that there exists a threshold investment from the incumbent I_B^*, where $I_B^* = I^{**} + \left[1 - (\frac{1}{A}U + \frac{1}{B}V)\right] W$, that is

$$I_B^* = \begin{cases} I^* - W - \frac{U}{R_u - R_d - W} R_d + \left[1 - (\frac{1}{A}U + \frac{1}{B}V)\right] W & Y_u - Y_d < V \\ I^* - W - R_d + \left[1 - (\frac{1}{A}U + \frac{1}{B}V)\right] W & V \geq Y_u - Y_d, \end{cases} \tag{C.3}$$

such that, in the case where$Y_u - Y_d < V$, if $I > I_B^*$, the incumbent holds preferred equity while the entrepreneur holds common equity in the entrepreneur firm. Otherwise, the incumbent holds common equity while the entrepreneur holds preferred equity; in the case where $Y_u - Y_d > V$, if $I > I_B^*$, the incumbent holds debt and put warrants while the entrepreneur holds common equity in the entrepreneur firm. Otherwise, the incumbent only holds put warrants while the entrepreneur holds common equity.

Appendix D. Robust Check: Complementary Efforts

To capture the complementarity effect of the efforts of both agents in the production function, we first assume that the probability of success of the project is equal to $a + \gamma ab$, in which case we can obtain analytical solutions and prove the robustness of the results. In addition, we also study the case in which the probability of success is equal to $a + b + \gamma ab$. In this case, there is no analytical solutions due to the non-linearity and we check the robustness of the results by using numerical methods in a wide range of parameters.

PROOF: Denote $X = R_u - R_d + Y_u - Y_d$

CASE I: The probability of success is equal to $a + \gamma ab$, where $\gamma > 0$. In addition, we assume that $AB - \gamma^2 X^2 > 0$ and $\frac{AB^2 X}{(AB - \gamma^2 X^2)^2} \in [0, 1]$, which ensures that $a, b \in [0, 1]$ and $a + b + \gamma ab \in [0, 1]$.

The incentive compatibility constraint of the entrepreneur IC_A is

$$\max_a \quad (a + \gamma ab)R_u^A + (1 - a - \gamma ab)R_d^A - \frac{1}{2}Aa^2 - I_A, \tag{D.1}$$

and we obtain that

$$U = R_u^A - R_d^A = \frac{Aa}{1 + \gamma b}. \tag{D.2}$$

The incentive compatibility constraint of the incumbent IC_B is

$$\max_b \quad (a + \gamma ab)(R_u^B + Y_u) + (1 - a - \gamma ab)(R_d^B + Y_d) - \frac{1}{2}Bb^2 - I_B, \tag{D.3}$$

and we obtain that

$$V = R_u^B - R_d^B + Y_u - Y_d = \frac{Bb}{\gamma a}. \tag{D.4}$$

The participation constraint of the incumbent PC_B is

$$(a + \gamma ab)(R_u^B + Y_u) + (1 - a - \gamma ab)(R_d^B + Y_d) - \frac{1}{2}Bb^2 \geq I_B + U_B. \tag{D.5}$$

The participation constraint of the outside investor PC_O is

$$(a + \gamma ab)R_u^O + (1 - a - \gamma ab)R_d^O \geq I_O. \tag{D.6}$$

The financial contract maximizes the expected profit of the entrepreneur given the incentive constraints, the participation constraints, and other feasibility constraints.

$$
\begin{aligned}
\max_{R_u^A, R_d^A, R_u^B, R_d^B, R_u^O, R_d^O, I_A, I_B, I_O} \quad & (a+\gamma ab)R_u^A + (1-a-\gamma ab)R_d^A - \frac{1}{2}Aa^2 - I_A \\
s.t. \quad & IC_A, IC_B, PC_B, PC_O \\
& R_i^A + R_i^B + R_i^O = R_i, i = u, d \\
& I_A + I_B + I_O = I \\
& I_A \leq E_A \\
& R_u^A, R_d^A \geq 0.
\end{aligned}
\tag{D.7}
$$

The program can be rewritten as

$$
\begin{aligned}
\max_{R_d^A, a, b} \quad & R_d + Y_d + (a+\gamma ab)X - \frac{1}{2}Aa^2 - \frac{1}{2}Bb^2 - I - U_B \\
s.t. \quad & R_d + Y_d - R_d^A + (a+\gamma ab)(X - \frac{Aa}{1+\gamma b}) - \frac{1}{2}Bb^2 - U_B \geq I - E_A \\
& R_d^A, a \geq 0.
\end{aligned}
\tag{D.8}
$$

The Lagrange of the program is

$$
\begin{aligned}
L = & R_d + Y_d + (a+\gamma ab)X - \frac{1}{2}Aa^2 - \frac{1}{2}Bb^2 - I - U_B \\
& + \lambda \left[R_d + Y_d - R_d^A + (a+\gamma ab)(X - \frac{Aa}{1+\gamma b}) - \frac{1}{2}Bb^2 - U_B - I + E_A \right]
\end{aligned}
\tag{D.9}
$$

The first-order conditions are

$$
\frac{\partial L}{\partial a} = (1+\gamma b)X - Aa + \lambda \left[(1+\gamma b)X - 2Aa \right] = 0, \tag{D.10}
$$

and

$$
\frac{\partial L}{\partial b} = \gamma aX - Bb + \lambda \left[\gamma aX - Bb \right] = 0. \tag{D.11}
$$

First, we consider the case in which $\lambda = 0$,

$$a = \frac{BX}{AB - \gamma^2 X^2}, \tag{D.12}$$

and

$$b = \frac{\gamma X^2}{AB - \gamma^2 X^2}. \tag{D.13}$$

Thus, we obtain

$$U = R_u^A - R_d^A = \frac{Aa}{1 + \gamma b} = X, \tag{D.14}$$

and

$$V = R_u^B - R_d^B + Y_u - Y_d = \frac{Bb}{\gamma a} = X. \tag{D.15}$$

Thus,

$$W = R_u - R_d - U - (V - Y_u - Y_d) = -X < 0, \tag{D.16}$$

indicating that the outside investor obtains a higher payoff in case of failure than in case of success.

From the participation constraint, we also find that $\lambda = 0$ holds if and only if

$$R_d + Y_d - \frac{B\gamma^2 X^4}{2(AB - \gamma^2 X^2)^2} - U_B \geq I - E_A. \tag{D.17}$$

Therefore, if $R_d + Y_d - \frac{B\gamma^2 X^4}{2(AB - \gamma^2 X^2)^2} - U_B \geq I - E_A$, $\lambda = 0$, i.e., the entrepreneur is not financially constrained. In this case, $U = V = X$ and $W = -X$.

Second, we turn to the case in hwhich $R_d + Y_d - \frac{B\gamma^2 X^4}{2(AB - \gamma^2 X^2)^2} - U_B < I - E_A$, $\lambda > 0$, i.e., the entrepreneur is financially constrained.

Based on equations (D.10) and (D.11), we obtain

$$a = \frac{B(1+\lambda)X}{AB(1+2\lambda) - \gamma^2 X^2 (1+\lambda)}, \tag{D.18}$$

and

$$b = \frac{\gamma(1+\lambda)X^2}{AB(1+2\lambda) - \gamma^2 X^2(1+\lambda)}. \tag{D.19}$$

Plugging the above two equations into the participation constraint of Program (D.8), we obtain

$$g(\lambda, A, B, \gamma, X) = I - E_A + U_B - (R_d + Y_d), \tag{D.20}$$

where

$$g(\lambda, A, B, \gamma, X) = \frac{BX^2(1+\lambda)\left(2AB\lambda - \gamma^2(1+\lambda)X^2\right)}{2\left(X^2\gamma^2(1+\lambda) - A(B+2B\lambda)\right)^2}. \tag{D.21}$$

In addition, since $AB - \gamma^2 X^2 > 0$, we obtain that

$$g_\lambda(\lambda, A, B, \gamma, X) = \frac{A^2B^3X^2}{\left(AB(1+2\lambda) - X^2\gamma^2(1+\lambda)\right)^3} > 0. \tag{D.22}$$

From equation (D.20), we study the effect of E_A, $R_u - R_d$ and $Y_u - Y_d$ on the entrepreneur's financial constraint:

$$\frac{\partial \lambda}{\partial E_A} = \frac{-1 + \frac{\partial U_B}{\partial E_A}}{g_\lambda}, \tag{D.23}$$

which implies that an increase in the entrepreneur's endowment tightens his financial constraint if $\frac{\partial U_B}{\partial E_A} > 1$ or loosens his financial constraint if $\frac{\partial U_B}{\partial E_A} < 1$.

$$\begin{aligned} \frac{\partial \lambda}{\partial (R_u - R_d)} &= \frac{-g_X + \frac{\partial U_B}{\partial (R_u - R_d)}}{g_\lambda} \\ &= \frac{2(1+\lambda)(AB\lambda(1+2\lambda) - X^2\gamma^2(1+\lambda)^2)}{ABX} + \frac{\frac{\partial U_B}{\partial (R_u - R_d)}}{g_\lambda}, \end{aligned} \tag{D.24}$$

can be positive or negative. Thus, an increase in $R_u - R_d$ can tighten or loosen the entrepreneur's financial constraint.

$$
\begin{aligned}
\frac{\partial \lambda}{\partial (Y_u - Y_d)} &= \frac{-g_X + \frac{\partial U_B}{\partial (Y_u - Y_d)}}{g_\lambda} \\
&= \frac{2(1+\lambda)(AB\lambda(1+2\lambda) - X^2\gamma^2(1+\lambda)^2)}{ABX} + \frac{\frac{\partial U_B}{\partial (Y_u - Y_d)}}{g_\lambda},
\end{aligned}
\tag{D.25}
$$

can be positive or negative. Thus, an increase in $Y_u - Y_d$ can tighten or loosen the entrepreneur's financial constraint.

In addition, we also want to check whether $W < 0$ holds. We compute the value of U and V by plugging the value of a and b from equations (D.18) and (D.19) and obtain

$$
U = \frac{Aa}{1+\gamma b} = \frac{1+\lambda}{1+2\lambda} X, \tag{D.26}
$$

and

$$
V = \frac{Bb}{\gamma a} = X. \tag{D.27}
$$

Thus,

$$
W = X - U - V = -\frac{1+\lambda}{1+2\lambda} X < 0. \tag{D.28}
$$

Therefore, we have shown that with complementarity effect, all the main results in the paper still hold.

REFERENCES

Aghion, Philippe, and Jean Tirole, 1994, The management of innovation, *Quarterly Journal of Economics* 109, 1185–1209.

Allen, Jeffrey W., and Gordon M. Philips, 2000, Corporate equity ownership, strategic alliances, and product market relationships, *Journal of Finance* 55, 2791–2815.

Baker, George, Robert Gibbons, and Kevin J. Murphy, 2002, Relational contracts in strategic alliances, *Unpublished Results* .

Bascha, Andreas, and Uwe Walz, 2001, Convertible securities and optimal exit decisions in venture capital finance, *Journal of Corporate Finance* 7, 285–306.

Casamatta, Catherine, 2003, Financing and advising: Optimal financial contracts with venture capitalists, *Journal of Finance* 58, 2059–2083.

Chen, Zhiqi, and Thomas W. Ross, 2000, Strategic alliances, shared facilities, and entry deterrence, *Rand Journal of Economics* 31, 326–344.

Clayton, Matthew J., and Bjorn N. Jorgensen, 2005, Optimal cross holding with externalities and strategic interactions, *Journal of Business* 78, 1505–1522.

Cumming, Douglas, 2006, Corporate venture capital contracts, *Journal of Alternative Investments* 9, 40–53.

Dasgupta, Sudipto, and Zhigang Tao, 2000, Bargaining, bonding, and partial ownership, *International Economic Review* 41, 609–635.

Denis, David J., 2004, Entrepreneurial finance: an overview of the issues and evidence, *Journal of Corporate Finance* 10, 301–326.

Dessein, Wouter, 2005, Information and control in ventures and alliances, *Journal of Finance* 60, 2513–2549.

Dhanaraj, Charles, Marjorie Lyles, and Yupeng Lai, 2007, Innovation without walls: alliance management at eli lilly and company .

Dushnitsky, Gary, and Dovev Lavie, 2010, How alliance formation shapes corproate venture capital investment in the software industry: a resource-based perspective, *Strategic Entrepreneurship Journal* 4, 22–48.

Elfenbein, Dan, and Josh Lerner, 2003, Ownership and control rights in internet portal alliances, 1995-1999, *Rand Journal of Economics* 34, 356–369.

Fazzari, Steven M., R. Glenn Hubbard, and Bruce C. Peterson, 1988, Financing constraints and corporate investment, *Brookings Papers on Economic Activity* 1, 141–195.

Filson, Darren, and Rosa Morales, 2006, Equity links and information acquisition in biotechnology alliances, *Journal of Economic Behavior & Organization* 59, 1–28.

Gompers, Paul A., and Josh Lerner, 1998, The determinants of corporate venture capital successes: Organizational structure, incentives, and complementarities, *NBER Working Paper* W6752.

Habib, Michel A., and Pierre Mella-Barral, 2007, The role of knowhow acquisition in the formation and duration of joint ventures, *Review of Financial Studies* 20, 189–233.

Hamel, Gary, 1991, Competition for competence and interpartner learning within international strategic alliances, *Strategic Management Journal* 12, 83–103.

Hamel, Gary, Yves L. Doz, and C.K. Prahalad, 1989, Collaborate with your competitors–and win, *Harvard Business Review* 67, 133–139.

Hellmann, Thomas, 2002, A theory of strategic venture investing, *Journal of Financial Economics* 64, 285–314.

Holmstrom, Bengt, 1982, Moral hazard in teams, *The Bell Journal of Economics* 13, 324–340.

Jensen, Michael C., and William H. Meckling, 1976, Theory of the firm: managerial behavior, agency costs and ownership structure, *Journal of Financial Economics* 3, 305–360.

Kanniainen, Vesa, and Christian Keuschnigg, 2003, The optimal portfolio of start-up firms in venture capital finance, *Journal of Corproate Finance* 9, 521–534.

Kaplan, Steven N., and Luigi Zingales, 1997, Do investment-cash flow sensitivities provide useful measures of financing constraints, *Quarterly Journal of Economics* 112, 169–215.

Lerner, Josh, Hilary Shane, and Alexander Tsai, 2003, Do equity financing cycles matter? Evidence from biotechnology alliances, *Journal of Financial Economics* 67, 411–446.

Malmendier, Ulrike, and Josh Lerner, 2010, Contractibility and contract design in strategic alliances, *American Economic Review* 100, 214–246.

Mathews, Richmond D., 2006, Strategic alliances, equity stakes and entry deterrence, *Journal of Financial Economics* 80, 35–79.

Mathews, Richmond D., 2007, Optimal equity stakes and corporate control, *Review of Financial Studies* 20, 1059–1086.

Pisano, Gary P., 1989, Using equity participation to support exchange: evidence from biotechnology industry, *Journal of Law, Economics, & Organization* 5, 109–126.

Repullo, Rafael, and Javier Suarez, 2004, Venture capital finance: a security design approach, *Review of Finance* 8, 75–108.

Reynolds, Robert J., and Bruce R. Snapp, 1986, The competitive effects of partial equity interests and joint ventures, *International Journal of Industrial Organization* 4, 141–153.

Robinson, David T., and Toby E. Stuart, 2007a, Financial contracting in biotech strategic alliances, *Journal of Law and Economics* 50, 559–596.

Robinson, David T., and Toby E. Stuart, 2007b, Network effects in the governance of strategic alliances, *Journal of Law, Economics, & Organization* 23, 242–273.

Schmidt, Klaus M., 2003, Convertible securities and venture capital finance, *Journal of Finance* 58, 1139–1166.

Zingales, Luigi, 2000, In search of new foundations, *Journal of Finance* 55, 1623–1653.