Financial Constraints, Managerial Incentives and the Scope of the Firm*

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Abstract

The recent seminal work of Gabaix (2011) raises a puzzling question: If centralization—putting different projects under the same roof—reduces diversification for investors, how does this situation reconcile with the seemingly contradictory fact that it also boosts a firm's borrowing capacity? To address this puzzle, we propose a theory where centralization exposes projects under the same roof to common liquidity shocks arising from the same CEO. We show that, in contrast to the conventional wisdom, such common liquidity shocks enhances rather than reduces the firm's ability to relax financial constraints because relative to independent shocks, since common liquidity shocks can better take advantage of cross pledging possibilities.

Keywords: Credit rationing, Firm Scope, Managerial Incentives, Pledgeable Income

JEL codes: G32, L25, D82

1 Introduction

In this paper, we study the following question: How does organizational design influence the willingness of investors to contribute financing to investment projects? Specifically, we consider a simple case with two projects and contrast two basic organizational structures. The first is centralization, in which the two projects jointly obtain financing from outsider investors. The second is decentralization, in which each project raises funds separately.

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The traditional wisdom, including Myers (1968), Levy and Sarnat (1970), and Adler and Dumas (1975), is that organizational structure is irrelevant to investors in a frictionless environment because they always achieve the same diversification as a centralized firm by holding a portfolio of decentralized firms. This traditional wisdom leads to the long-standing consensus in macroeconomics that aggregate volatility does not depend on how firms are organized in the economy. However, the recent seminal work of Gabaix (2011) reverses this consensus. He finds that that organizational structure is a critical concern for aggregate volatility and centralized firms rather than decentralized firms contribute significantly to the aggregate volatility.

His observation implies that investors realize less diversification if they hold a centralized firm than a portfolio of comparable decentralized firms. He argues that this is because projects within the same firm inherit some common, firm-specific shocks. Common shocks come from "a decision of the firm's research department, of the firm's chief executive officer, of how to process shipments, inventories, ..."or from "changes in capacity utilization, and, particularly, strikes". One might fear such common shocks in centralized firms reduces diversification and thus would reduce firms' financing capacity,[1] which contradicts the well-accepted empirical observation that centralization boosts borrowing capacity.[2] This contradiction raises a puzzle: why does centralization boost financing capacity even if it reduces diversification?

The main objective of this paper is to propose a theory to address this puzzle and show that financial constraints sometimes are relaxed by common shocks in centralized firms, particularly common liquidity shocks. In this paper, we consider a three-period model with two types of players, managers and investors, as well as two projects. The managers are penniless and protected by limited liability and the investors have deep pockets. In period 0, the two projects are operated in either a centralized firm under a single manager or two decentralized firms with two different managers. Both projects require the same amount of initial investment from the investors.

In period 1, each project is subject to a random liquidity shock that requires an additional liquidity injection. This liquidity shock is assumed to be manager specific. Manager-specific shocks may stem from the CEO's death, divorce, heterogeneous abilities, change in his psychological beliefs or information set in managing the firm, and others. As argued by Gabaix (2011), one important source of common firm-specific shocks for projects is the CEO. Indeed, a growing number of empirical studies, such as Bertrand and Schoar (2003) and Bloom and Van Reenen (2007), underscores managers as a key driver of productivity. Thus, bringing projects under the same roof make them more likely subject to common CEO shocks. For each project, after observing the shock, investors decide whether or not to inject new funds to withstand the shock and continue the project.

[1] The literature, at least since Lewellen (1971), emphasized that more diversified projects generate more financial leeway due to the coinsurance effect.

[2] This observation was empirically documented, in terms of higher leverage (Berger and Ofek (1995)), greater investment scale (Hubbard and Palia (1999)), lower cost of capital (Hann, Ogneva, and Ozbas (2013)), and better ability to deal with the credit crunch of the recent financial crisis (Kuppuswamy and Villalonga (2010)).

In period 2, any continued project is subject to moral hazard. Its manager privately chooses between exerting effort and shirking, as in Holmstrom and Tirole (1998). Credit constraints arise for the standard reason that the manager must be granted a minimum incentive rent which reduces income pledgeability and thus make it unprofitable for the investors. In period 2, if one manager is in charge of both projects, optimally reducing the incentive rent involves a reward only when both projects are successful. This mechanism, referred to as "cross-pledging" in Tirole (2006), implies that the rent left to the manager in charge of two projects is smaller than twice the rent left to the manager in charge of a single project. Actually, the benefits of cross pledging are enhanced by common liquidity shocks faced by projects in period 1, thus we find that common liquidity shocks among projects relaxes, rather than tightens, financial constraints.

To see the rationale for this result, consider the following, ultra-simplified, version of our model: The manager-specific liquidity shock can be, with equal probability, 0 or ∞.[3] In the latter case, the project must be abandoned, since it is too expensive to continue. In period 1, each project generates an expected value Y if it is continued and 0 otherwise. In addition, denote the rent given to the manager in charge of one project r_1 and the rent to the manager in charge of two projects r_2. Due to cross pledging, $r_2 < 2r_1$. In the centralized case, the two projects are subject to a common shock. Hence, both projects are continued or liquidated together with equal probability. In period 0, the expected pledgeable income for the investors is $\frac{1}{2}(2Y - r_2)$. In the decentralized case, the two projects are subject to two independent shocks. Thus, we have both projects continued with probability $\frac{1}{4}$, one continued and the other liquidated with probability $\frac{1}{2}$, and both liquidated with probability $\frac{1}{4}$. In order to take advantage of cross-pledging, the two projects are merged in period 1 if they are continued together. As a result, in period 0, the expected pledgeable income for the investors is $\frac{1}{4}(2Y - r_2) + \frac{1}{2}(Y - r_1)$. Since $r_2 < 2r_1$, the investors obtain a larger expected income if projects are within a centralized firm than in two decentralized firms.

The driving force is that, because of the cross-pledging effect, pledgeable income is increasing and convex in the number of viable projects.[4] Relative to independent shocks, common liquidity shocks induces a mean-preserving spread in the distribution of the number of viable projects, and therefore increases income pledgeability and relaxes financial constraints. Thus, centralization can relax financial constraints even if it reduces diversification.

In addition to address this puzzle, this paper further discusses the two organizational structures from the perspective of total firm value. The total value is the sum of the investors' payoff and managerial rent. The advantage of centralization in generating more value to investors does not necessarily imply that it generates more total value. We find that whether centralization increases or decreases value also depends on manager-specific shocks. If credit constraint is the main concern, centralization always dominates decentralization. However, if credit constraint is

[3]In this paper, the magnitude of shock represents the amount of liquidity need in period 1. Hence, when the amount of liquidity need is larger, the shock is more severe.

[4]Since $r_2 < 2r_1$, $2Y - r_2 > 2(Y - r_1)$, i.e., the pledgeable income in case of two viable projects is greater than twice of the pledgeable income in case of one viable project.

not an issue, centralization is more likely to dominate decentralization when large liquidity shocks are more likely to occur.

This paper contributes to the literature on the relation between financing constraints and organizational structure. One segment of that literature is based on the trade-off theory of capital structure (Lewellen (1971), Higgins (1971), Scott (1977), Sarig (1985), Leland (2007), and Banal-Estanol, Ottaviani, and Winton (2013)). The other segment is the internal capital market literature based on agency conflicts (Gertner, Scharfstein, and Stein (1994), Stein (1997), Scharfstein and Stein (2000), Rajan, Servaes, and Zingales (2000), Stein (2002), and Inderst and Muller (2003)). The present paper also underscores agency conflicts but differs by introducing manager-specific liquidity shocks. This different approach enables us to find that common liquidity shocks faced by projects can be good rather than bad for financial constraints, and address the puzzle mentioned at the beginning.

This paper is also associated with studies on the relation between managerial characteristics and organizational structure. Van den Steen (2005) shows that a manager with strong beliefs about the right course of action will attract, through sorting in the labor market, employees with similar beliefs. Dessein (2013) argues that "a central challenge in the firm boundary literature is to provide a theory in which management plays an important role". This paper is one of the first theory to show that managerial characteristics are a major concern for optimal organizational structure. The key difference to the present paper is that rather than focusing on managerial vision or direction, we focus on manager-specific shocks and their effect on organizational structure.

The remainder of the paper is organized as follows. Section 2 introduces the model. Section 3 studies the relation between organizational structure and financial constraints. Section 4 analyzes the relation between organizational structure and firm value. Section 5 discusses the robustness of the results. Section 6 presents the empirical implications and the conclusion is in Section 7. All formal proofs are in the Appendix.

2 The Model

There are two types of players, investors and managers, as well as two symmetric projects, A and B. Both types of players are risk neutral. The investors have deep pockets, but do not have the necessary skills to operate any project. In contrast, the managers are penniless and protected by limited liability, but they are able to manage the projects. The market interest rate is normalized to 0.

We consider a three period model, $t = 0, 1, 2$. The timeline is summarized in Figure 1. in period 0, the two projects can be managed in two decentralized firms or within a centralized firm. In the former case, the two projects are operated by two different managers. In the latter case, the two projects are operated by the same manager. Each project requires an initial investment I.

Once the manager starts overseeing the firm, things may go wrong. The manager brings a random liquidity shock to all the projects under his management in period 1. Its magnitude is unknown to all parties in period 0 but revealed to the public in

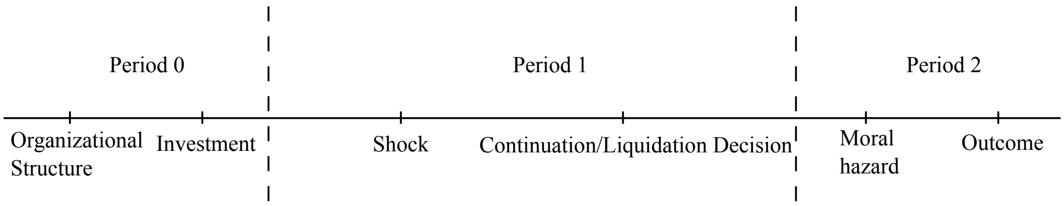


Figure 1. Timeline

period 1. The manager-specific shock ρ is distributed according to a cdf $F(\cdot)$ over $[0, +\infty)$ (with a pdf $f(\cdot)$).[5] In the decentralized case, the two projects are managed by two different managers, hence the shocks of the two projects are independent. In the centralized case, the two projects are managed by a single manager and thus face a common shock.

To continue the project and reap the final cash-flow, the investors must inject additional liquidity ρ to cover the shock. Otherwise, the project is liquidated, the additional expense ρ is avoided, but the final cash-flow will be lost. After observing the two shocks, the investors need to make a decision about whether to continue or to liquidate.

In period 2, any continued project is subject to moral hazard in that its manager privately chooses between effort and shirking à la Holmstrom and Tirole (1998). If the manager exerts effort, the probability of success is P; if he shirks, this probability is lowered to $P-\Delta$ but he enjoys a non-transferable private benefit B.[6] The project matures in period 2, delivering a revenue R if it succeeds but no revenue if it fails.

Our model departs from the fixed-investment liquidity model in Tirole (2006) in two crucial respects.[7] First, the shock in our model is manager-specific rather than project-specific. This is very crucial in the sense that projects face a common liquidity shock if they are jointly managed at the initial stage while independent shocks if they are separately managed. After Bertrand and Schoar (2003), a growing empirical literature has underscored the importance of manager-specific shocks.[8] Manager-specific shocks can stem from a CEO's death, divorce, heterogenous abilities, change in psychological belief or information set in managing the firm, etc. Second, in Tirole (2006), the managers are assumed to have all the bargaining power. In contrast, we assume that the investors have all the bargaining power.

[5] Our results are robust in a more general setup where ρ can be either positive or negative. If it is positive, additional liquidity needs to be injected, otherwise, the project receives a positive interim revenue.

[6] One possible explanation is that private benefits stem from the private use of the firm's assets by the manager. This is equivalent to casting the model in terms of the cost of effort.

[7] See Chapter 5 of Tirole (2006). The original model assumes that each manager has an initial endowment of A. If the investors delegate the two projects to two different managers, the total initial endowment of the two projects is $2A$. If the investors delegate the two projects to a single manager, the total initial endowment of the two projects is only A. This asymmetry of endowment in different organizational structures is inconvenient for the modeling in this paper. Hence, we set $A = 0$.

[8] See Adams, Almeida, and Ferreira (2005), Malmendier and Tate (2005), Bloom and Van Reenen (2007) and Kaplan, Klebanov, and Sorensen (2012).

This assumption is inconsequential for our results. The only reason for making this assumption is that it greatly simplifies the contracting problem, which is similar to Inderst and Muller (2003). See Section 5.1 for a discussion of this issue.

As a benchmark, we consider a case without moral hazard, it is easy to show that regardless of organizational structure, a project will always be continued as long as its shock is lower than the continuation value, i.e., $\rho \leq PR$. In this case, organizational structure is irrelevant for value. The expected value of each project is $F(PR)PR - \int_0^{PR} \rho f(\rho)d\rho - I = \int_0^{PR} F(\rho)d\rho - I$.

Assumption 1. $\int_0^{PR} F(\rho)d\rho - I > 0$.

Assumption 1 implies that both projects have positive NPVs.

However, this irrelevance result does not hold in an environment with frictions. In the case with moral hazard, credit constraints arise for the standard reason that the manager must be granted a minimum incentive rent which reduces income pledgeability and thus make the investors less willing to provide financing. In the following, we will study how organizational structure affects financing capacity.

3 Organizational Structure and Financial Constraint

In period 2, the project is subject to moral hazard in that the manager privately chooses between effort and shirking. In order to induce effort, the manager must be granted a positive rent. The income of the project cannot be totally pledged to the investors.

In our model, there are two possible cases in period 2: *i*) one manager only operates one project; *ii*) one manager operates both projects. In the first case, the manager is granted R_b in case of success and 0 in case of failure. The incentive compatibility constraint which guarantees that the manager prefers exerting effort rather than consuming private benefits is $R_b \geq \frac{B}{\Delta}$. Thus, the maximum pledgeable income left for the investors is $P(R - \frac{B}{\Delta})$, denoted by a.

In the second case, based on the analysis of Tirole (2006), the optimal incentive scheme is that the manager only receives a reward $\hat{R}_b$ when both projects are successful and 0 otherwise. The incentive compatible bonus that the manager obtains in case of two successes, which ensures that the manager prefers exerting effort on both projects rather than shirking on one or both, must satisfy $\hat{R}_b \geq \frac{2B}{(2P-\Delta)\Delta}$. Thus, the maximum pledgeable income left for the investors is $2\left[P(R - \frac{P}{2P-\Delta}\frac{B}{\Delta})\right]$. Denote $P(R - \frac{P}{2P-\Delta}\frac{B}{\Delta})$ by b, which represents the maximum pledgeable income to the investors generated by each project.

We obtain that $b > a$, which implies that the manager can pledge more income to the investors per project if operating both projects than if operating only one project. The intuition is that, when two projects are separately managed, the manager is rewarded when any project is successful, but when the two projects are jointly managed, the manager is rewarded only when both are successful. Thus, the latter case reduces the agency rents and increases income pledgeability: this is referred to as "cross-pledging" (Tirole (2006)).[9]

3.1 Decentralized Financing

In the decentralized case, the two projects are operated separately by two different managers in period 0. in period 1, the liquidity shocks ρ_A and ρ_B faced by the two projects are independent. On observing the two shocks, the investors need to decide which project to continue and which to liquidate. There are four possible choices for the investors in period 1: *i*) continue both projects; *ii*) continue project A while liquidating project B; *iii*) continue project B while liquidating project A; *iv*) liquidate both. If both projects are continued together, it is preferable that they be merged, due to the benefit of cross-pledging.[10] We assume that an ex-post merger of two decentralized firms is always costless and politically feasible.[11] This assumption is inconsequential for our results. The reason we make this assumption is that it not only simplifies our analysis but also helps us clarify the underlying economic forces (see Section 5.3 for a detailed discussion).

Here, we currently ignore any specific sharing rule among the investors, and only consider their total profit. This is due to the fact that as long as the action is profitable, there always exists some specific rule to split the cost and the income to benefit all investors. The total profit to the investors in period 1 is $2b - \rho_A - \rho_B$ in case *i*, $a - \rho_A$ in case *ii*, $a - \rho_B$ in case *iii*, and 0 in case *iv*. Write $c = 2b - a$. If both projects are bundled, the pledgeable income per project is b, with a the marginal pledgeable income for the first project and c the marginal pledgeable income for the second project, where $a < b < c$.

Based on our analysis, the conditions for the continuation or liquidation of the two projects, as in Figure 2, are as follows.[12]

Lemma 1.
In the decentralized case,
i) the two projects are merged and continued together if $\rho_A + \rho_B \leq 2b$ *and* $\rho_A, \rho_B \leq c$*;*
ii) project A is continued but project B is liquidated if $\rho_A \leq a$ *and* $\rho_B > c$*;*
iii) project B is continued but project A is liquidated if $\rho_B \leq a$ *and* $\rho_A > c$*;*
iv) both projects are liquidated if $\rho_A + \rho_B > 2b$ *and* $\rho_A, \rho_B > a$*.*

Without moral hazard, the continuation of one project only depends on its own shock. However, Lemma 1 implies that with moral hazard, the two projects' continuations become interdependent due to the cross-pledging effect.

[9]Please see the details of the mechanism in the Appendix D.

[10]Given merged, one manager is in charge of both projects, while the other is fired. One might fear that the possibility of dismissal in this case would affect the managers' incentives ex-ante. In this model, the shock is exogenous. Thus, ex-ante incentive problems do not exist. The absence of ex-ante incentive problems allows us to clarify the main mechanism without adding another layer of complexity. This assumption is the same as in Tirole (2006).

[11]The ex-post merger is used to deal with liquidity shocks, which has a similar spirit as liquidity mergers in Almeida, Campello, and Hackbarth (2011).

[12]See proof in Appendix.

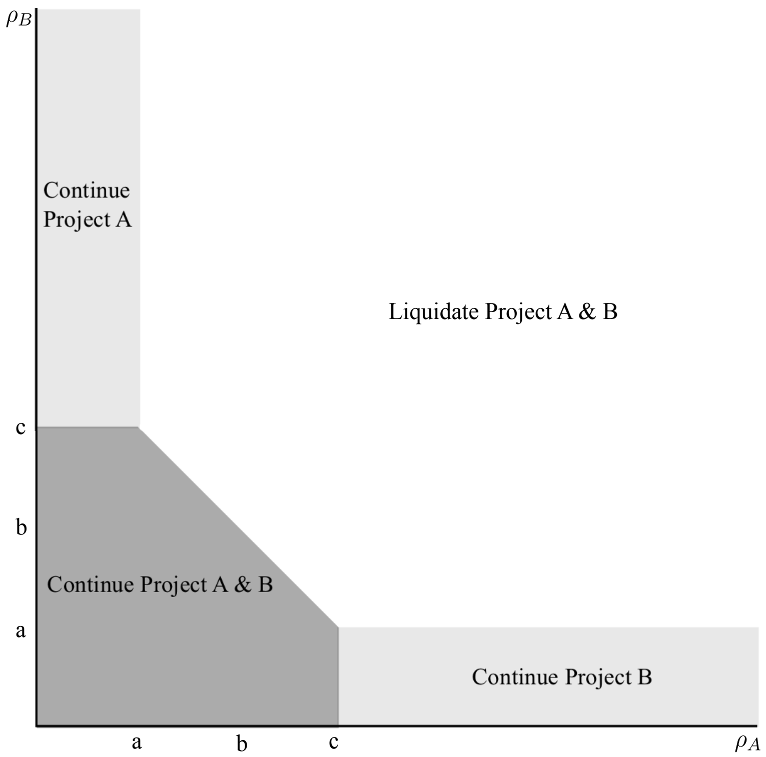


Figure 2. In the decentralized case, the two projects are merged and continued together in the dark gray area, i.e., $\rho_A + \rho_B \leq 2b$ and $\rho_A, \rho_B \leq c$; one project is continued and the other is liquidated in the light gray area, i.e., $\rho_i \leq a$ and $\rho_{-i} > c$, where $i = A, B$; both are liquidated in the white area, i.e., $\rho_A + \rho_B > 2b$ and $\rho_A, \rho_B > a$.

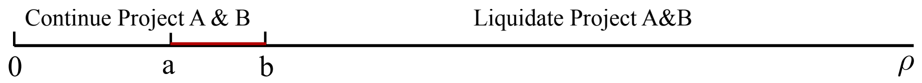


Figure 3. In the centralized case, both projects are continued if $\rho_A = \rho_B \leq b$, but both are liquidated if $\rho_A = \rho_B > b$.

Based on the interim continuation and liquidation conditions, we can easily obtain the continuation probability per project. Since the two projects are symmetric, we consider project A as an example. In Figure 2, project A is continued with project B in the dark gray area. This probability is

$$q_1 = F(a)F(c) + \int_a^c \int_0^{2b-\rho_A} f(\rho_A) f(\rho_B) d\rho_B d\rho_A. \tag{1}$$

In the upper light gray area, project A is continued alone. This probability is

$$q_2 = F(a)(1 - F(c)). \tag{2}$$

Thus, the total continuation probability for project A is $q_1 + q_2$.

The corresponding expected liquidity injected to withstand the shock is

$$E\rho = \int_0^a \rho_A f(\rho_A) d\rho_A + \int_a^c \int_0^{2b-\rho_A} \rho_A f(\rho_A) f(\rho_B) d\rho_B d\rho_A. \tag{3}$$

Due to the symmetry, project B has the same continuation probability and expected liquidity injection in period 1. The distribution of the continuations of the two projects is in Figure 4(a).

Therefore, the ex-ante expected value per project in period 0 is

$$(q_1 + q_2)PR - E\rho - I, \tag{4}$$

and the ex-ante expected return to the investors per project is

$$q_1 b + q_2 a - E\rho - I. \tag{5}$$

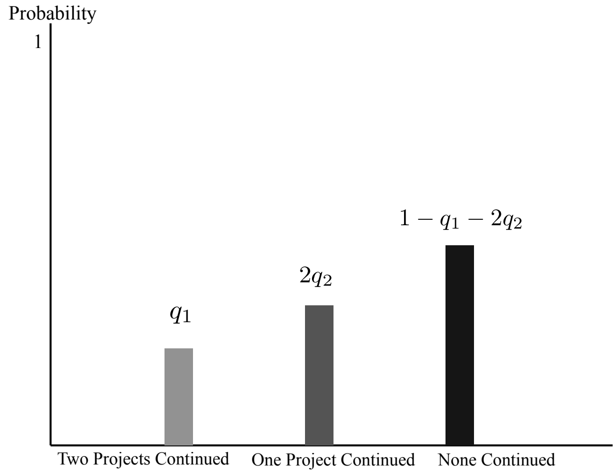
The pledgeable income to the investors is b if the project is continued with the other, but it is a if the project is continued alone.

3.2 Centralized Financing

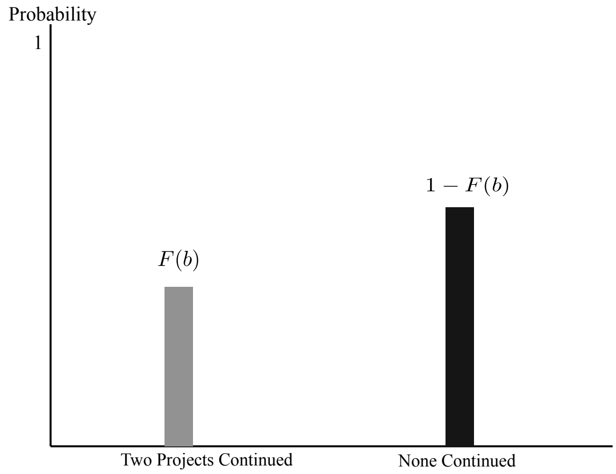
In the centralized case, in period 0 both projects are managed by the same manager. In period 1, the two projects face a common liquidity shock, thus they are either continued or liquidated together. It is never optimal to spin off the two projects ex-post, since the cross-pledging benefit only exists when the two projects are jointly operated. The pledgeable income per project is b when both projects are continued together. Therefore, the interim continuation conditions of the two projects, as in Figure 3, are as follows.

Lemma 2.

In the centralized case, the two projects are continued together if $\rho_A = \rho_B \leq b$, otherwise, both are liquidated.



(a) Decentralized Financing



(b) Centralized Financing

Figure 4. In the decentralized case, both projects are continued with probability q_1, one project is continued but the other is liquidated with probability $2q_2$, and both are liquidated with probability $1 - q_1 - 2q_2$. In the centralized case, both projects are continued with probability $F(b)$, and both liquidated with probability $1 - F(b)$.

The distribution of the continuations of the two projects is in Figure 4(b). Therefore, in the centralized case, the ex-ante expected value per project in period 0 is

$$F(b)PR - \int_0^b \rho f(\rho) d\rho - I, \tag{6}$$

where $F(b)$ is the continuation probability and $\int_0^b \rho f(\rho) d\rho$ is the expected liquidity injection to cover the shock.

The ex-ante expected return to the investors per project is

$$F(b)b - \int_0^b \rho f(\rho) d\rho - I. \tag{7}$$

For the investors, they obtain pledgeable income b per project if both are continued and 0 otherwise.

3.3 Financing Capacity

In this subsection, we study which organizational structure is better at relaxing financial constraint. With moral hazard, the income of the project cannot be totally pledged to the investors, and credit rationing may occur. We use the pledgeable income to measure the financing capacity. This is because, if the investors are able to obtain more pledgeable income, they will be more willing to provide financing, which thereby relax financial constraints.

Write PI_C and PI_D for the total expected pledgeable income per project in the centralized and decentralized case respectively, where $PI_C = F(b)b - \int_0^b \rho f(\rho) d\rho$ and $PI_D = q_1 b + q_2 a - E\rho$.

Proposition 1. *$PI_C > PI_D$ holds, implying that centralization has a larger financing capacity than decentralization. This is because in centralization, common liquidity shocks face by projects can better take advantage of cross pledging possibilities.*

The underlying mechanism behind Proposition 1 is as follows. In our framework, since merger is a possible resolution policy for decentralized firms to deal with shocks, decentralization is also able to take advantage of cross pledging. Thus, the advantage of centralization in boosting financing capacity does not come from allowing for the possibility of cross-pledging. It is actually common liquidity shocks in centralized firm that is providing the benefit. The intuition is that, because of cross pledging, pledgeable income in period 2 is increasing and convex in the number of viable projects. Relative to independent shocks, common liquidity shocks in centralization induces a mean-preserving spread in the distribution of the number of viable projects, which can better take advantage of cross pledging possibilities, and thereby raises the financing capacity of projects in a centralized firm. Thus, this result helps us to address the puzzle of why centralization relaxes financial constraints even if it reduces diversification for investors.

4 Organizational Structure and Firm Value

In this section, we turn to study how organizational structure affect total firm value rather than shareholder value as in the previous section.

From Proposition 1, it is straightforward to obtain the following Corollary.

Corollary 1.

i) If $PI_D \geq I$, the projects can always obtain financing in period 0 *regardless of the organizational structure.*

ii) If $PI_D < I \leq PI_C$, the projects can only obtain financing in period 0 *if they are jointly operated under the same roof.*

iii) If $PI_C < I$, the projects can never be financed in period 0 *regardless of the organizational structure.*

Corollary 1 indicates that if the initial investment need is large, the projects can only be initiated in a centralized firm. In this case, centralization dominates decentralization due to its larger financing capacity. Nevertheless, if the initial investment is small, the projects can always be initiated regardless of the organizational structure. In this case, which organizational structure is better depends on their relative abilities in mitigating ex-post inefficient liquidations in period 1. With moral hazard, inefficient liquidation occurs in period 1 if the shock of the project is lower than its full value but greater than the pledgeable income to the investors. In the following, we study which organizational structure is better at mitigating ex-post inefficient liquidations.

Due to symmetry, we take project A as an example, and study how its continuation depends on the organizational structure. When its shock is too low $\rho_A \leq a$ (too high $\rho_A > c$), the project is always continued (liquidated) regardless of the organizational structure. However, when $a < \rho_A \leq c$, the continuation of project A depends on whether it is managed in a centralized firm or in a decentralized firm. If $a < \rho_A \leq b$, project A is always continued in a centralized firm, but is liquidated in a decentralized firm if the other shock turns out to be large, i.e., $\rho_B > 2b - \rho_A$. In this case, project A is less likely to be continued in the decentralized case than in the centralized case. The decrease in the probability of continuation is $\int_a^b \int_{2b-\rho_A}^{+\infty} f(\rho_A) f(\rho_B) d\rho_B d\rho_A$ as the light gray area in Figure 5. If $b < \rho_A \leq c$, the project is always liquidated in the centralized case, but it is continued in the decentralized case if the other shock turns out to be small, i.e., $\rho_B \leq 2b - \rho_A$. In this case, project A is more likely to be continued in the decentralized case than in the centralized case. The increase in the probability of continuation is $\int_b^c \int_0^{2b-\rho_A} f(\rho_A) f(\rho_B) d\rho_B d\rho_A$ as the dark gray area in Figure 5.

Proposition 2.

The benefit in ex-post continuation of decentralization relative to centralization is that the project with shock $\rho_i \in (b, c]$ is continued if the other project's shock turns out to be $\rho_{-i} \leq 2b - \rho_i$ under decentralization, while always liquidated under centralization; the cost in ex-post continuation is that the project with shock $\rho_i \in (a, b]$ is liquidated if the other's shock turns out to be $\rho_{-i} > 2b - \rho_i$ under decentralization, while always continued under centralization.

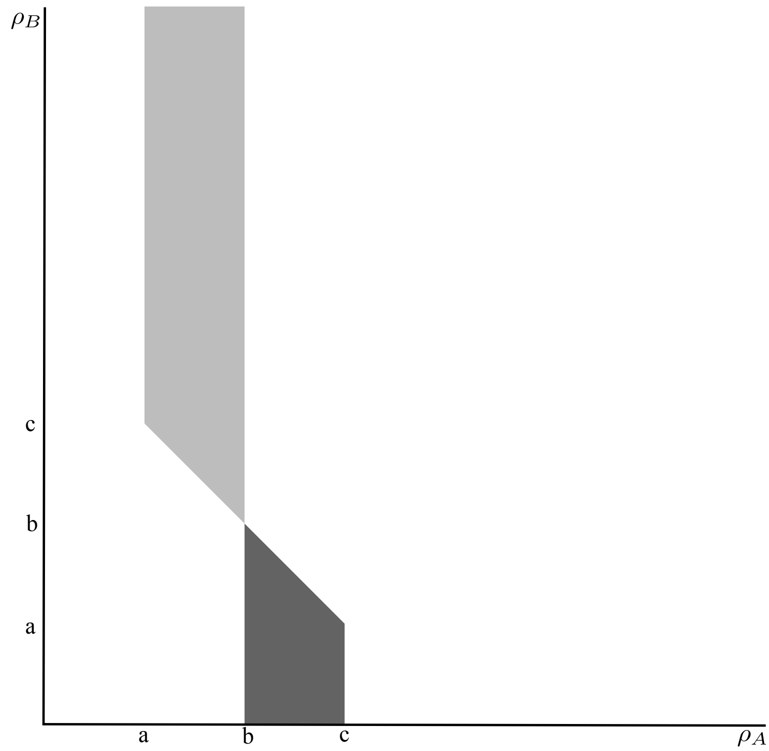


Figure 5. The light gray area equals to the difference between the continuation probability of project A in the centralized case and its continuation probability in the decentralized case. Under centralization, project A is always continued, while under decentralization, project A is continued iff $\rho_B \in [0, 2b - \rho_A)$. Thus, the light gray area represents the relative cost of decentralization to centralization. The dark gray area equals to the difference between the continuation probability of project A in the decentralized case and its continuation probability in the centralized case. Under centralization, project A is never continued, while under decentralization, project A is continued if $\rho_B \in [0, 2b - \rho_A]$. Thus, the dark gray area represents the relative benefit of decentralization to centralization.

The rationale behind Proposition 2 is that if the project is operated together with the other project within a centralized firm, the shock of other project is exactly the same. However, if the project is operated in a separate firm, the magnitude of the other project's shock can be small or large. If the other shock turns out to be small, the project is more likely to be continued in the decentralized case than in the centralized case. If the other shock turns out to be large, we obtain the opposite result. In centralized firms, the project can be continued only if its shock is lower than b. In decentralized firms, the project, even with a shock larger than b, can be continued if the other turns out to have a small shock. Alternatively, the project, even with a shock lower than b, can be liquidated if the other turns out to have a large shock.

The difference between the light gray area and the dark gray area in Figure 5 represents the difference in the continuation probability per project between centralization and decentralization, which is

$$dp = \int_a^b \int_{2b-\rho_A}^{+\infty} f(\rho_A)f(\rho_B)d\rho_B d\rho_A - \int_b^c \int_0^{2b-\rho_A} f(\rho_A)f(\rho_B)d\rho_B d\rho_A. \tag{8}$$

The value difference per project between the two organizational structures, which is represented in the following equation:

$$\begin{aligned} dv = &\int_a^b \int_{2b-\rho_A}^{+\infty} (PR-\rho_A)f(\rho_A)f(\rho_B)d\rho_B d\rho_A \\ &- \int_b^c \int_0^{2b-\rho_A} (PR-\rho_A)f(\rho_A)f(\rho_B)d\rho_B d\rho_A. \end{aligned} \tag{9}$$

From equations (8) and (9), we can see that whether centralization or decentralization generates more continuation or value depends on the distribution of shock $f(\cdot)$. Figure 5 tells us that if shocks are more likely to be large, centralization becomes more able to mitigate ex-post inefficient liquidation than decentralization. In the following, we study this point in detail by taking a specific distribution.

Proposition 3.

If the shock is uniformly distributed over $[0, \phi]$,

i) relative to centralized firms, the continuation probability for each project in decentralized firms is the same if $\phi \in [0, b]$, *larger if* $\phi \in (b, 2b]$, *and smaller if* $\phi \in (2b, +\infty)$*;*

ii) relative to centralized firms, the value per project generated by decentralized firms is the same if $\phi \in [0, b]$, *larger if* $\phi \in (b, \phi^*]$, *and smaller if* $\phi \in (\phi^*, +\infty)$, *where* $\phi^* \in (b, 2b)$.

This result tells us that in the case where $I \leq PI_D$, centralized firms can generate higher value than decentralized firms if $\phi > \phi^*$, i.e., shocks are likely to be large. In summary, if the initial investment need is large, centralization always dominates decentralization due to its larger financing capacity. If the initial investment need is small, centralization is more likely to be better if the shocks are more likely to be large.

5 Discussion

In this section, we will discuss the robustness of the main results.

5.1 A Competitive Capital Market

In our model, we assume that investors have all the bargaining power. In this subsection, we will relax this assumption and discuss the robustness of our results when the manager has all the bargaining power, i.e., in a competitive capital market.

In a competitive capital market, the manager maximizes his profit subject to the investors' break-even constraint. The break-even constraint is such that the expected pledgeable income for the investors is equal to their initial investment, i.e., $PI = I$. This break-even constraint ensures that the manager obtains all the profit from the project. In this case, the manager wants to continue the project as long as its shock is not greater than the continuation value PR as the first-best. However, this optimal solution cannot be attained if this continuation condition violates the investors' break-even constraint.

We study the maximum investment that the investors can provide, which is equal to the maximum pledgeable income that they can obtain. In our initial setup, we minimize the rents to the managers and maximize the income to the investors. In other words, we have already obtained the maximum pledgeable income. Hence, the maximum investment per project that the investors can provide is PI_D in the case of decentralization, and PI_C in the case of centralization.

First, consider the case where $PI_D < I \leq PI_C$. The projects can only be initiated if they are jointly managed. In a centralized firm, the maximum investment PI_C that investors are willing to provide is greater than the required investment. When the investors have all the bargaining power, they obtain PI_C and the maximum shock that can be withstood is b. However, in a competitive market, the investors should break-even, i.e., they cannot gain more than their initial investment contribution. Thus their pledgeable income is reduced to the initial investment by increasing the maximum shock that can be withstood. Denote the maximum shock that can be withstood in the competitive market by ρ', which satisfies the investors' break-even condition.

$$F(\rho')b - \int_0^{\rho'} \rho f(\rho) d\rho - I = 0. \tag{10}$$

We can show that $b < \rho' \leq PR$.

Second, consider the case where $PI_D \geq I$. The projects are always initiated regardless of the organizational structure. In a competitive capital market, the investors break even and their pledgeable income is less than PI_D. Thus, the maximum shock that can be withstood is also larger than that in our initial model.

From the previous analysis, we can see that even though firms can absorb larger shocks in a competitive capital market, the main conclusion that centralization is better at relaxing financial constraints is still robust since the maximum pledgeable income that can generated by different organizational structure is still the same.

However, this does not imply that centralization always dominates from the perspective of total value, as in our initial model. In the following, I will illustrate this point through a simple example.

Consider the specific case where the shock can either be 0 or ϱ, with equal probability. Assume that $b > 2I$ and $2(b-I) < \varrho < \min\{3b-4I, c\}$, ensuring that projects are initiated regardless of the organizational structure, and continued except when both are distressed.[13] In the centralized case, the projects are either continued or liquidated together with equal probability. The total expected payoff is $PR - 2I$. In the decentralized case, the projects are continued together except the case where both are hit by shocks. The probability of continuation per project is $\frac{3}{4}$. The probability of liquidity injection per project is $\frac{1}{4}$. Thus, the expected total payoff is $\frac{3}{2}PR - \frac{1}{2}\varrho - 2I$. We can see that the expected payoff in the decentralized case is larger than that in the centralized case. Thus, centralization may destroy value.

5.2 Hedging

With moral hazard, inefficient liquidation can arise since investors may not be willing to inject liquidity to withstand the shock even if it is lower than the continuation value. This naturally raises the question as to whether or not it is best for firms to hedge ex-ante by hoarding liquidity or by using credit lines, to deal with the shortage in liquidity ex-post. This issue was addressed in Holmstrom and Tirole (1998). Their main assumption is that managers have all the bargaining power, and this, in turn, generates the need for hedging.

We turn to the simple one-project case in Tirole (2006) to discuss the intuition of hedging policies in Holmstrom and Tirole (1998). The project is optimal to be continued at intermediate date if and only if $\rho < \rho^*$. The manager's expected payoff is

$$U_M = F(\rho^*)PR - \int_0^{\rho^*} \rho f(\rho)d\rho - I. \tag{11}$$

The break-even condition for the investors is

$$F(\rho^*)a - \int_0^{\rho^*} \rho f(\rho)d\rho - I = 0. \tag{12}$$

The manager maximizes U_M subject to the investors' break-even condition. We find that $a < \rho^* \leq PR$. The optimal contract is such that the investors should provide liquidity as long as $\rho \leq \rho^*$. However, at date 1, the maximum pledgeable income the investors can obtain is a. They are not willing to provide liquidity if $\rho > a$. The

[13] In the centralized case, both projects are either hit by a shock together or not, with equal probability. If the investors withstand the shocks, their maximum profit is $2(b - \frac{1}{2}\varrho - I)$. If they do not, their maximum profit is $b - 2I$. Given the two conditions, projects are continued only when both are not hit by shocks. In the decentralized case, the two shocks are independent. If the investors absorb shocks in all situations, their maximum profit is $2(b - \frac{1}{2}\varrho - I)$. If the investors absorb shocks only when one project is distressed, their maximum profit is $\frac{1}{4}2b + \frac{1}{2}(2b - \varrho) - 2I = \frac{3}{2}b - \frac{1}{2}\varrho - 2I$. If the investors do not absorb shocks, their maximum profit is $\frac{1}{4}2b + \frac{1}{2}a - 2I = \frac{1}{2}(a+b) - 2I$. With the two conditions, only the intermediate case does not violate the investors' break-even constraint. As a result, the projects are only liquidated when both are hit by shocks.

conflict of interest between the ex-ante and ex-post decisions of the investors results in the need for firms to hedge ex-ante against the shortage of liquidity ex-post.

In this paper, however, we assume that the investors have all the bargaining power, thus the conflict of interest between ex-ante and ex-post decisions of the investors no longer exists. The problem faced by the investors is similar to a real option problem. Any hedging policy would reduce the option value. With this assumption, we can focus the discussion on the optimal design of organizational structure to deal with ex-post shocks.

5.3 Costly Ex-post Merger

In this subsection, we extend our basic setup to incorporate a cost regarding ex-post mergers and discuss the robustness of our results. We assume a fixed cost C for an ex-post merger. It could stem from the change of the manager.[14] In the centralized case, the manager is always the same at different periods. Hence, the introduction of the ex-post merger cost has no impact. But in the decentralized case, this cost arises when two stand-alone firms merge. In the following, we first study how this cost affects the continuation and liquidation decisions.

If $C \geq 2(b-a)$, the cost is larger than the gain of the pledgeable income from the ex-post merger. The two decentralized firms would never be merged in period 1. Each project is continued if and only if its shock is lower than a.

If $C < 2(b-a)$, the cost is lower than the gain. Thus, the two decentralized firms will still be merged in period 1 if both are continued, but the pledgeable income that the investors can obtain from the ex-post merger is scaled down to $2b - C$. The optimal continuation and liquidation decisions become: *i*) continue and merge both projects if $\rho_A, \rho_B \leq c - C$ and $\rho_A + \rho_B \leq 2b - C$; *ii*) continue project i and liquidate project $-i$ if $\rho_i \leq a$ and $\rho_{-i} > c - C$ $(i = A, B)$; or *iii*) liquidate both if $\rho_A + \rho_B > 2b - C$ and $\rho_A, \rho_B > a$.

Due to this ex-post merger cost, decentralization becomes even less able to exploit the cross-pledging benefit. This deters continuation and reduces the pledgeable income to investors. Hence, the conclusion, that centralization is better at relaxing financial constraints is still robust. Similarly, this does not imply that centralization always dominates from the perspective of total value. Centralization can destroy value if the cost is not large. This is because in this case the comparative advantage of decentralization relative to centralization in dealing with ex-post inefficient liquidations can dominates sometimes.

6 Empirical Implications

This section summarizes the empirical implications. The first implication follows directly from Proposition 1.

[14]When an ex-post merger happens, one manager is fired. Hence the project he managed before should be transferred to the other manager. This new manager may be not familiar with the project and this can incur some learning cost.

Implication 1*: Centralized firms are able to relax more financial constraints than comparable decentralized firms.*

The relaxation of financial constraints is reflected in different ways. Berger and Ofek (1995) find that centralized firms are significantly more leveraged than their comparable standalone firms. In contrast, Comment and Jarrell (1995) find no significant association between leverage and centralization. These mixed observations do not necessarily indicate that centralized firms have no advantage in relaxing financial constraints. In fact, relaxing financial constraints may also be reflected in a reduction in cost of capital rather than an increase in leverage. Hann et al. (2013) find that, on average, centralized firms have a lower cost of capital than comparable portfolios of standalone firms. In addition, the benefit of centralized firms may be more evident in an environment in which credit rationing is the main concern of the firm, as in our setup. Kuppuswamy and Villalonga (2010) treat the 2007-2009 crisis as an exogenous shock of credit rationing for firms and find that ccentralized firms had significantly lower cash ratios, better credit ratings, and were more leveraged relative to comparable stand-alone firms.

The first implication can also be obtained from other theories. In order to distinguish our main mechanism, we suggest the following implication.

Implication 2*: If the CEO is more powerful, the firm is able to relax more financial constraints.*

When the CEO of the firm becomes more powerful, he has more influence on the operations of the entire firm. Different divisions or projects are more likely to affected by the common shocks from this CEO. Thus, shocks across divisions become more correlated when the CEO is more powerful, which is consistent with the observation of Adams et al. (2005) that firm performance is more volatile with more powerful CEOs. In this case, we should expect firms with more powerful CEOs to be more able to raise funds from investors. As far as we know, this implication is new and has not been tested yet. To test this implication, we can use the CEO power measure from Adams et al. (2005) and study its relation with the firm's ability to relax financial constraints.

In addition, according to equations PI_C and PI_D, the pledgeable income of projects under both centralization and decentralization decreases with the severity of agency problems, i.e., private benefit B. This argument with Corollary 1 indicates the following implication.

Implication 3*: If the agency problems between firms and investors are more severe, centralized firms become more prevalent and decentralized firms become less prevalent.*

Propositions 2 and 3 imply the following implication.

Implication 4*: When the agency problems between firms and investors are less severe, decentralization is more prevalent, whereas centralization is less prevalent if the manager-specific shock is more likely to be small.*

These two empirical implications are consistent with the dramatic reversal of the empirical view toward conglomerate mergers: positive during the 1960s and negative in the 1980s and 1990s. According to Hubbard and Palia (1999), information deficiency of the capital market was a significant concern for firms during the 1960s. Implication 2 argues that centralization creates value in this environment, which is consistent with the popularity of conglomerate mergers during this period. Bhide (1990) argues that given technological, economic and regulatory changes during the 1970s and 1980s, information asymmetries become less of an issue in corporate financing. Implication 3 implies that, during this period, centralization should be less popular and decentralization should be more popular if the manager-specific shocks are likely to be small. During this period, the increased competition in the managerial labor market (Murphy and Zabojnik (2004)) and the improvement in CEO education (Palia (2000)) likely reduced the likelihood of large manager-specific shocks. In this context, my model predicts that centralization becomes less prevalent whereas decentralization becomes more prevalent, which is consistent with the trend of corporate focus and diverstitures documented by Comment and Jarrell (1995).

As far as we know, implication 4, which studies the relationship between organizational structure and the manager-specific shocks, is yet to be directly tested. To test the implication 4, we need a measure for manager-specific shocks. In reality, a firm's performance is affected not only by managers but also by factors unrelated to managers, such as macro policies, industry-wide shocks, and others. One possible way to measure manager-specific shocks is to decompose the firm's total shocks into two sources, as Li (2002) and Bushman, Dai, and Wang (2010): shocks from managers and shocks from sources unrelated to managers. We then test our implication by studying how the organizational structure changes with manager-specific shocks.

7 Conclusion

To address the puzzle of why centralized firms are better at relaxing financial constraints even if they reduce diversification for investors, we propose a theory where centralization expose projects to common liquidity shocks. The main contribution of the paper is: we show that, in contrast to the conventional wisdom, common liquidity shocks can help boost their financing capacity. This finding helps us addresses the puzzle mentioned above. In addition, we also study the optimal organizational structure from the perspective of firm value, we find that whether centralization creates or destroys value relative to decentralization depends on the distribution of manager specific shocks.

Moreover, we believe that our model might yield additional insights on the literature on conglomerate mergers. In the literature, there is a hot debate over the existence of the "diversification discount". In the 1990s, many researchers documented the existence of the "diversification discount",[15] but some other researchers reversed that view after the 2000 and found that its existence is highly contin-

[15]See Lang and Stulz (1994), Berger and Ofek (1995), and Servaes (1996).

gent on the self-selection problem, geographic location, data, statistical methods, and other factors.[16] The literature simply views diversification as centralization, i.e., bundling different projects under the same roof. However, as far as we know, whether centralization creates greater diversification for investors than a portfolio of comparable decentralized firms has not been directly tested. To enhance our understanding of the "diversification discount", we may first need to test whether centralization can really generate more diversification or not than decentralization.

8 Appendix

A Proof of Lemma 1

Continue both projects if $2b-\rho_A-\rho_B \geq a-\rho_A$, $2b-\rho_A-\rho_B \geq a-\rho_B$ and $2b-\rho_A-\rho_B \geq 0$. These three inequalities hold when $\rho_A+\rho_B \leq 2b$ and $\rho_A, \rho_B \leq c$.

Continue project A while liquidating project B if $a-\rho_A > 2b-\rho_A-\rho_B$, $a-\rho_A > a-\rho_B$ and $a-\rho_A \geq 0$. These three inequalities hold when $\rho_A \leq a$ and $\rho_B > c$.

Similarly, continue project B while liquidating project A if $\rho_B \leq a$ and $\rho_A > c$.

Liquidate both projects if $2b-\rho_A-\rho_B < 0$, $a-\rho_A < 0$ and $a-\rho_B < 0$. These three inequalities hold when $\rho_A+\rho_B > 2b$ and $\rho_A, \rho_B > a$. Q.E.D.

B Proof of Proposition 1

In the centralized case, the expected return or the expected pledgeable income to investors can be rewritten as

$$\begin{aligned} PI_C =& F(b)b - \int_0^b \rho f(\rho) d\rho - I \\ =& \int_0^b (b-\rho) f(\rho) d\rho - I \\ =& \int_0^b \int_0^{+\infty} (b-\rho_A) f(\rho_A) f(\rho_B) d\rho_B d\rho_A - I \\ =& \underbrace{\int_0^a \int_0^{+\infty} (b-\rho_A) f(\rho_A) f(\rho_B) d\rho_B d\rho_A}_{①} \\ &+ \underbrace{\int_a^b \int_0^{+\infty} (b-\rho_A) f(\rho_A) f(\rho_B) d\rho_B d\rho_A}_{②} - I. \end{aligned} \tag{13}$$

[16] See Lamont and Polk (2001), Campa and Kedia (2002), Graham, Lemmon, and Wolf (2002), Villalonga (2004a), and Villalonga (2004b).

In the decentralized case, the expected return to investors can be rewritten as

$$
\begin{aligned}
PI_D &= q_1 b + q_2 a - E\rho - I \\
&= \underbrace{\int_0^a \int_0^c (b-\rho_A) f(\rho_A) f(\rho_B) d\rho_B d\rho_A + \int_0^a \int_c^{+\infty} (a-\rho_A) f(\rho_A) f(\rho_B) d\rho_B d\rho_A}_{①'} \\
&+ \underbrace{\int_a^b \int_0^{2b-\rho_A} (b-\rho_A) f(\rho_A) f(\rho_B) d\rho_B d\rho_A}_{②'} \\
&+ \underbrace{\int_b^c \int_0^{2b-\rho_A} (b-\rho_A) f(\rho_A) f(\rho_B) d\rho_B d\rho_A}_{③'} - I.
\end{aligned}
\tag{14}
$$

It is easy to see that ① > ①', ② > ②' and ③' < 0, hence the investors obtain a larger expected return in the centralized case. Q.E.D.

C Proof of Proposition 3

Proof of Proposition 3 i).

The shock of each project is uniformly distributed according to $[0, \phi]$. The density function is $\frac{1}{\phi}$.

1) If $\phi \leq b$, $dp = 0 - 0 = 0$.

2) If $b < \phi \leq c$, $dp = \int_{2b-\phi}^{b} \int_{2b-\rho_A}^{\phi} \frac{1}{\phi^2} d\rho_B d\rho_A - \int_b^{\phi} \int_0^{2b-\rho_A} \frac{1}{\phi^2} d\rho_B d\rho_A = \frac{(\phi-2b)(\phi-b)}{\phi^2} < 0$.

3) If $\phi > c$, $dp = \int_a^b \int_{2b-\rho_A}^{\phi} \frac{1}{\phi^2} d\rho_B d\rho_A - \int_b^c \int_0^{2b-\rho_A} \frac{1}{\phi^2} d\rho_B d\rho_A = \frac{(b-a)(\phi-2b)}{\phi^2}$. We obtain that $dp \leq 0$ if $c < \phi \leq 2b$, otherwise, $dp > 0$.

Thus, if $\phi \leq b$, $dp = 0$; if $b < \phi \leq 2b$, $dp \leq 0$; if $\phi > 2b$, $dp > 0$. Q.E.D.

Proof of Proposition 3 ii).

1) If $\phi \leq b$, $dv = 0 - 0 = 0$.

2) If $b < \phi \leq c$,

$$
\begin{aligned}
dv &= \int_{2b-\phi}^{b} \int_{2b-\rho_A}^{\phi} (PR - \rho_A) \frac{1}{\phi^2} d\rho_B d\rho_A - \int_b^{\phi} \int_0^{2b-\rho_A} (PR - \rho_A) \frac{1}{\phi^2} d\rho_B d\rho_A \\
&= \frac{(\phi-b)(\phi-2b)}{\phi^2} PR - \frac{(\phi-b)(\phi^2 + b\phi - 8b^2)}{6\phi^2} \\
&= \frac{\phi-b}{6\phi^2}(-\phi^2 + (6PR - b)\phi + 8b^2 - 12bPR).
\end{aligned}
$$

If $a^2 + 6aPR - 5ab - 2b^2 \geq 0$, we can show that $dv \leq 0$ when $\phi \in [b, c]$. Otherwise, there exists $\phi^* = \frac{1}{2}[(6PR - b) - \sqrt{3(11b^2 - 20bPR + 12(PR)^2)}]$, such that when $\phi \in [b, \phi^*]$, $dv \leq 0$, and when $\phi \in [\phi^*, c]$, $dv > 0$.

3) If $\phi > c$,

$$dv = \int_a^b \int_{2b-\rho_A}^{\phi} (PR - \rho_A)\frac{1}{\phi^2} d\rho_B d\rho_A - \int_b^c \int_0^{2b-\rho_A} (PR - \rho_A)\frac{1}{\phi^2} d\rho_B d\rho_A$$
$$= \frac{(b-a)(\phi - 2b)}{\phi^2} PR - \frac{-4a^3 + 3a^2(4b - \phi) + b^2(-8b + 3\phi)}{6\phi^2}$$
$$= \frac{b-a}{6\phi^2}\{(6PR - 3(a+b))\phi - (12bPR + 4a^2 - 8b^2 - 8ab)\}$$

If $a^2 + 6aPR - 5ab - 2b^2 \geq 0$, we can show that there exists a ϕ^*, where $\phi^* = \frac{12bPR+4a^2-8b^2-8ab}{6PR-3(a+b)} \geq c$, such that when $\phi \in (c, \phi^*]$, $dv \leq 0$ and when $\phi \in (\phi^*, +\infty)$, $dv > 0$. Otherwise, we can show that $dv > 0$ when $\phi \in (c, +\infty)$.

Thus, if $\phi \in [0, b]$, $dv = 0$; if $\phi \in (b, \phi^*]$, $dv \leq 0$; and if $\phi \in (\phi^*, +\infty)$, $dv > 0$, where $\phi^* \in (b, 2b)$. Actually, if $a^2 + 6aPR - 5ab - 2b^2 \geq 0$, $\phi^* = \frac{12bPR+4a^2-8b^2-8ab}{6PR-3(a+b)} \in [c, 2b)$, otherwise $\phi^* = \frac{1}{2}[(6PR - b) - \sqrt{3(11b^2 - 20bPR + 12(PR)^2)}] \in (b, c)$. Q.E.D.

D Cross Pledging Mechanism

At period 2, the project is subject to moral hazard in that the manager privately chooses between effort and shirking. In order to induce effort, the manager must be granted a positive rent. The income of the project cannot be totally pledged to the investors.

In the model, there are two possible cases at period 2: *i*) one manager only operates one project; *ii*) one manager operates both projects. In the first case, the manager is granted R_b in case of success and 0 in case of failure. The incentive compatibility constraint which guarantees that the manager prefers exerting effort rather than consuming private benefits is

$$\Delta R_b \geq B. \tag{15}$$

To minimize the inefficiency, the manager must be granted a minimum rent. Thus, the manager is rewarded $\frac{B}{\Delta}$ in case of success and 0 in case of failure. The maximum pledgeable income to the investors is $a = P(R - \frac{B}{\Delta})$.

In the second case, the manager receives a reward $\hat{R}_b$ when both projects are successful and 0 otherwise. The condition for the manager to prefer exerting effort on both projects rather than on one is

$$P^2 \hat{R}_b \geq P(P - \Delta)\hat{R}_b + B, \tag{16}$$

and the condition which guarantees that the manager works on both rather than on neither is

$$P^2 \hat{R}_b \geq (P - \Delta)^2 \hat{R}_b + 2B. \tag{17}$$

It is easy to show that condition (16) is redundant given condition (17). Thus, the incentive compatible bonus that the manager obtains in case of two successes satisfies

$$\hat{R}_b \geq \frac{2B}{(2P - \Delta)\Delta}. \tag{18}$$

In this case, the manager is granted $\frac{2B}{(2P-\Delta)\Delta}$ if both projects succeed and 0 otherwise. The maximum pledgeable income to the investors per project is $P(R - \frac{P}{2P-\Delta}\frac{B}{\Delta})$, denoted by b.

It is easy to show that $a < b$, i.e., the manager can pledge more income to the investors per project if operating both projects than when operating only one project.

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