R&D Financing and the Boundary and Ownership Structure of the Firm[1]

Haizhou Huang

International Monetary Found

Chenggang Xu

Department of Economics, London School of Economics

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Abstract

This paper analyzes the impact of a firm's external financial environment and the feature of its investment projects on the firm's boundary and ownership structure. Our theory highlights the costs of a full ownership over an asset in destroying the owner's commitment capacity. More specifically, if a firm finances a risky R&D project jointly with other financiers, informational asymmetries and conflicts of interest among co-financiers can be used as a commitment device to stop a bad project when it is discovered; but such a commitment would be lost if a firm choose to own and finance a project. Trading the costs of full ownership with those of a partial ownership through joint financing, which depend on the external financial environment, large firms in a developed financial environment optimally choose to a full ownership of less risky R&D projects. In an underdeveloped financial environment, however, joint ownership is often too costly to be chosen regardless the risk level of R&D projects.

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1. INTRODUCTION

What determines the boundary of a firm when research and development (R&D) is involved? More specifically, if a R&D project is closely related to a large firm's business, should this firm own the R&D project or contract it out? This question is closely related to the question raised by Coase (1937): What determines the boundary of a firm? A great deal of theories have been developed to address this question.[2]

The question raised by Coase is based on observations that a large number of transactions, which seemingly can be traded efficiently in markets (by applying standard price theory), are carried out within a firm. Here, our observation is that there are many cases in which integrating a R&D project to a large-firm may seem to be more desirable (by applying theories of the firm and/or of information) yet this firm chooses to not to. In this paper, we analyze what affects a large firm's decision on wether or not to integrate a R&D project. More specifically, we identify conditions under which a large firm prefers to integrate a R&D project – to finance it internally; and those conditions under which the firm prefers to finance the project externally and jointly with other financiers.

The question we raise in this paper is motivated by several stylized facts and is inspired by the existing theories of the boundary of the firm and of R&D financing. It is documented that large corporations tend to restrict their internal R&D activities in less uncertain and less novel projects that they devote more attention to perfection-related or cost-reduction-related innovation and less attention to new-product-related innovation (Scherer, 1991, 1992); they often choose not to integrate high-uncertain R&D projects but finance them as stand-alone small firms jointly with other financiers.[3] Consistently,

[2] See Hart (1995) and Holmstrom and Roberts (1998) for recent surveys.

[3] A typical externally financed small high-tech firm has several investors, such as corporate and independent venture capitalists and others. Based on a sample of 271 biotech firms, Lerner (1994) reports that syndication is common in all rounds of investments and the average number of investors in the first round of investment is about 3 (the number is further larger in later stages). Schilit reported that most venture capital firms syndicate with one another, and that between 70% and 90% of the venture capital backed projects had multi-investors (Schilit, 1991, pp.76-77). Barry et al. (1990) reported that all 433

"idea-rich small firms originate a disproportionate share of innovations" (Scherer, 1992).[4] This is particularly true in high-tech industries, such as in bio-tech,[5] and the computer, telecommunications industries.[6]

Applying the theory developed by Grossman and Hart (1986) and Hart and Moore (1990) to the question, if a R&D project is complementary to the core business of a large firm, then it is efficient for the project being integrated with the firm. Moreover, Schumpeter argued that by integration large corporations can be more efficient in innovation because

venture-capital-backed firms which had initial public offerings between 1978 and 1987 in the U.S. (this is an exhaustive data set for this category) had many investors, including venture capitalists (VC), large firms, and other funds. A typical firm in this data set involved three venture capital investors; and had two VCs sat on its board (accounted for one-third of all seats). A survey of venture capital in New England (one of the two areas in the U.S. with the highest VC concentration), shows the average number of investors for each high-tech start up firm (more than one half of which were in bio-tech) was close to four, and only about one-eighth of the surveyed firms were financed by one investor (*Boston Globe,* September 19, 1993).

[4]In the United States, firms with 500 employees or less accounted for about 40 percent of all technical innovations in manufacturing in 1982 (Acs and Audretsch, 1988). A majority of the 100 most important innovations during the 1900-1950 period were introduced by small firms (Jewkes, et al., 1969). Among 21 major software, 18 originated in small start-up firms, although the best-selling software was marketed by large established firms (Prusa and Schmitz, 1991).

[5]In 1994, 1995, and 1996, Merck, the best performing large pharmaceutical company (in terms of Dow performance) in the US spent \$1.2 billion, \$1.3 billion, and \$1.5 billion respectively for R&D; and respectively developed 10, 8, and 8 new drugs (in late-stage clinical trials). In contrast, small firms achieved more than Merck at far lower costs. In those years, 130 publicly traded small bio-tech companies in the U.S. spent \$3.1 billion, \$3.4 billion, and \$3.9 billion; and respectively developed 60, 100, and 220 new drugs (*Fortune*, No. 6, March 31, 1997).

[6]An overwhelmingly large majority of today's major computer companies, such as Intel, Microsoft, Apple Computer, Digital Equipment, Compaq Computer, Lotus Development, and Sun Microsystems were all small firms and were financed by outside investors (including corporate venture capital, independent venture capitalists, and many other sources) in the 1970s and the 1980s. However, the amount of R&D investment and capital expenditures in all of these small firms together was less than that in one large firm. For example, in 1988 IBM's investment for R&D and capital expenditures was about \$9 billion, while in the same year the total investment for R&D and capital expenditures from U.S. professional venture capitalists to small firms in all industries, including computer and bio-tech industries, was only about \$3 billion (Sahlman, 1990).

they have the wealth to provide internal funds (Schumpeter, 1950).[7] Consistently, it has been well argued that the informational asymmetries related to external financing can make an investment more costly due to moral hazard and adverse selection problems between the entrepreneur and the financiers (e.g., Stiglitz and Weiss, 1981; Myers and Majluf, 1984; and Kamien and Schwartz, 1978). Furthermore, given that a R&D project involves a large sunk cost (low liquidation value), with external financing the moral hazard and adverse selection problems are more severe (Bernanke and Gertler, 1989; Calomiris and Hubbard, 1990; Hubbard and Kashyap, 1992). Then the question is, if a large-firm is not constrained by wealth to self-finance a R&D project which is complementary to its core business,[8] why should it ever choose to finance R&D projects externally?

In this paper we provide a theory to link the boundary of a firm to its external financial environment and the feature of R&D projects. We argue that the optimal allocation of a firm's boundary depends on the external financial environment and the features of R&D projects. In our theory, we suppose that the uncertainties associated with an R&D project can only be reduced when the project is carried out. Therefore, ex-post selection is more effective than ex-ante selection. However, an ex-post screening mechanism requires a commitment that a bad project will be stopped even when refinancing the bad project is ex-post profitable (which means that the earlier sunk costs of the project are not taken into consideration in an ex-post decision). We show that non-integration, in which a firm finances a project externally with other financiers, can be deployed as a commitment device

[7] Obviously he changed his early view about small firms' advantages in originating innovations late on (Schumpeter, 1934).

[8] Indeed, the micro-processor and the operating system are complementary to the IBM PC, and IBM had the financial capacity to finance the related R&D. But IBM contracted out all the micro-processor and operating system R&D projects to Intel and Microsoft in the 1970s when they both were small firms. Moreover, in general, large firms are not wealth constrained in financing R&D projects internally. Several independent investigations find that for large firms, such as Fortune 500 firms, there is no correlation between internally financed investments and R&D (Scherer, 1965; Mueller, 1967; Elliot, 1971), or there is a very low correlation (Hall, 1992). Consistent with these results, more recent work finds that the larger the firm, the lower the correlation (Himmelberg and Petersen, 1994).

for a large-firm to terminate bad projects when they are discovered ex post.[9] With an integration, however, a large firm may loss this commitment capacity. That is, there is a cost of possessing a full ownership over a R&D project, which is the owner's loss of commitment capacity. Moreover, the more uncertain a R&D project, the larger is the cost of integration. Therefore, the allocation of the boundary of a firm is determined by the trade-off between the efficiency gain from solving the commitment problem — gaining the capacity to make ex-post selections — and the institutional cost of external financing. Here, the institutional cost of external financing refers to those moral hazard and adverse selection problems which have been extensively discussed in the literature. As a result of this trade-off, if a project is relatively certain, integration, i.e., internal financing, is more efficient; if a project is more uncertain, non-integration, i.e., external financing, is more efficient.

Our theory is built upon Dewatripont-Maskin model (1995) of soft budget constraints (a la Kornai, 1980), which is centered on an institution's lack of commitment to terminate an unprofitable project ex-post. We provide a new contractual foundation for hardening budget constraints that investors are not constrained by the liquidity of wealth to finance a project alone if they so choose. The new contractual foundation allows us to expand the soft budget constraint paradigm to the issue we address in this paper, and many other issues which we briefly discuss in the conclusion of the paper.

In the spirit of Hart and Moore (1995) and Bolton and Scharfstein (1996), conflicts of interest between the multi-investors play important roles in our model. However, we focus on the commitment problem and endogenize a renegotiation-proof institution.

Our theory also sheds light on syndicated financing. It is documented that "syndicated loan market [is] not only one of the largest, but also one of the fastest growing sources of corporate financing available today" and "the market has been growing at a compound

[9] It has been documented that informational asymmetries and conflicts of interest between co-investors increase the ex post cost of refinancing a project and destroy value when a firm is under re-organization (e.g., Weiss and Wruck, 1998; for a court case regarding converting a reorganization into liquidation due to conflicts of interest between investors, see U.S. Bankruptcy Court for the Western District of Michigan, 1997).

annual rate of more than 10% per year over the last decade." In year 2000 banks extended \$2 trillion of syndicated loans (Esty and Megginson, 2001) – in contrast the total amount of loans and leases in bank credit in the U.S. in the same year was \$3.88 trillion and the total value of bank assets was about \$6 trillion. [**In reality as long as there are several financiers involved and they have different specializations, then their information and interests are naturally different. According to Esty and Megginson (2001), Our theory also helps to explain the paramount importance of such a financial phenomena from a theoretical perspective.**[10]]

Our theory complements to a recent literature on R&D financing that studies the issue from the perspective of knowledge transfer (e.g., Allen and Gale (1999); Bhattacharya and Chiesa (1995)). This strand of literature concernes about difficulties in transferring knowledge and looks for ways to make knowledge transfer easier. Our theory argues about different side of an informational asymmetry between co-financiers that difficulties in knowledge transfer can be benefitial to financiers in helping termination of bad R&D investment promptly.

The rest of the paper is organized as follows. In Section 2 we set up the model. In Section 3 we endogenize the commitment problem in integration and find a solution for the commitment problem in non-integration. Section 4 compares the efficiencies of integrated and non-integrated R&D. Finally, Section 5 discusses the conceptual implications of our results for economic growth and financial crisis, and presents some concluding remarks.

[10] One can easily see the paramount importance of syndicated loans as a financial phenomenon if the amount of syndicated loans (\$2 trillion of in 2000) is compared with the total amount of loans and leases in bank credit in the U.S. (\$3.88 trillion, December 2000).

2. MODEL

We consider an economy where there are numerous entrepreneurs and large-firms.[11] Each entrepreneur has a new idea for an R&D project, but he has no wealth to finance it. There is no wealth constraint on the side of the large firm to finance R&D projects. When an entrepreneur proposes a project to a large-firm, if the firm is interested in the project it can choose to either integrate the project by purchasing the project and hiring the entrepreneur – finance it internally, or to not integrate it but finance it externally and jointly with others.

We suppose that among all the projects proposed by entrepreneurs, λ percentage of them are a good type and $1-\lambda$ percentage of them are a bad type. A good project takes two periods to finish and requires a total investment of I_1+I_2, where I_t is the required investment in period t and I_1 and I_2 are sunk.[12] And a good project is profitable, $\widehat{V} > I_1 + I_2$. A bad project produces no return after second period. But it can be reorganized in the third period and the reorganization costs I_3. Thus, it takes three periods for completion and requires a total investment of $I_1 + I_2 + I_3$.

Because a good project will be completed at date 2 regardless of integration or non-integration. Thus, from the perspective of financing decision there is no difference between different ownership cases. In the rest of the paper, we will focus on the case of bad projects.

We suppose that the returns from a completed bad project under the best possible reorganization strategy generated at date 3 can be greater than those of the last period investment, however, it is not efficient to be undertaken after date 1. Therefore, at date 2 a decision has to be made by the financier(s) regarding a bad project: either to refinance it or to liquidate it. To focus on this point, we suppose that at date 0 all projects are worthy of

[11] In this paper we do not distinguish between large firms and financiers in general (e.g., independent venture capitalists). We suppose that each financier has enough wealth to finance R&D projects. In fact, a major source of financing R&D is corporate venture capital which finances external projects for the benefit of the patent corporation (e.g., Schilit (1991, p.68)). Moreover, the venture capital subsidiaries of large firms have "deep pockets."

[12] We can regard zero as a normalized liquidation value. Our results will not be altered if we allow I_1 and I_2 to be partially sunk and the liquidation value to be positive.

being financed, and we assume that the discount rate is zero.

With respect to information, we assume that ex-ante the distribution of the types of all projects is common knowledge, but neither the large firms nor the entrepreneurs know precisely each project's type. At date 1, after working on a project for one period the entrepreneur discovers the type of the project, but the large firm(s) still do not know its type. That is, there is an informational asymmetry between the entrepreneur and the large-firm(s) at date 1.[13]

We suppose that an entrepreneur receives a private benefit b_t from working on a project, where $t = 1, 2, 3$ denotes the date when the project is either completed or terminated. Specifically, if the entrepreneur quits the project at date 1, he gets a low private benefit, $b_1 > 0$. At date 2, a completed good project generates a private benefit, $b_{2g} > b_1$, to the entrepreneur. A bad project will not generate any outcome at date 2 and it will be either liquidated or reorganized. If it is liquidated, the entrepreneur gets a still lower private benefit b_{2b}, where $0 \leq b_{2b} < b_1$. If a bad project is reorganized, it will be completed at date 3 without costs the entrepreneur's effort. A completed bad project generate a private benefit $b_3 \in (b_1, b_{2g})$, and $b_3 > b_{2g}$.[14]

Presumably, there are two strategies to reorganize a bad project during the third period, but only one of them can generate a profit ex-post. The selection of the right decision depends on signals s_A and s_B, where $s_J \in [\underline{s}, \overline{s}]$, $\underline{s} < \overline{s}$ and $J = A$, B. Here, we suppose that signal s_J can only be observed by the financier after I_3 is invested.[15]

In the simplest case, we look at a case that A wishes to find a co-financier B to be a commitment device to co-finance a project (or similarly, B looks for A who has a different specialization from that of B). Then the following are the conditions that joint financing by

[13] This assumption is realistic because a R&D project is something new so other agents can only know its features later than the entrepreneur who works on it.

[14] The relationship $b_3 > b_{2g}$ can be regarded as a reduced form of the following relationship: suppose completing a good project at date 2 requires more efforts than completing a bad project at date 3; and the cost of the additional efforts is e such that $b_3 > b_{2g} - e$.

[15] The assumption that s_J can only be observed after I_3 is invested is not essential in the model. Its role is to rule out mixed strategies, which would complicate the model without providing more insight.

A and B can serve a commitment purpose. These conditions concern how reorganization strategies are related to information s_A and s_B. First, A is specialized in technology $\mathfrak{A}$, and B is specialized in technology $\mathfrak{B}$, such that A can only observe s_A and B can only observe s_B.[16] Second, the relationship between A and B satisfies the following efficiency condition (A-1.1): strategy b makes the project ex-post profitable if the value of signal s_A is higher than the value of s_B; and strategy a makes the project ex-post profitable if the value of signal s_A is lower than that of s_B. Formally,

$$\begin{cases} V_A^b(s_A, s_B) + V_B^b(s_A, s_B) > I_3 > V_A^a(s_A, s_B) + V_B^a(s_A, s_B), \text{ if } s_A > s_B; \\ V_A^b(s_A, s_B) + V_B^b(s_A, s_B) = V_A^a(s_A, s_B) + V_B^a(s_A, s_B) = I_3, \text{ if } s_A = s_B; \\ V_A^a(s_A, s_B) + V_B^a(s_A, s_B) > I_3 > V_A^b(s_A, s_B) + V_B^b(s_A, s_B), \text{ if } s_A < s_B. \end{cases} \quad \text{(A-1.1)}$$

[16] There are many ways to justify or to endogenize the information asymmetry between A and B after date 3. One possible way is the following. Suppose, for each project, there are two signals, $\bar{s}_A$ and $\bar{s}_B$, on different aspects of the project that can be observed by the financiers in the first two periods. If the two signals $\bar{s}_A$ and $\bar{s}_B$ are observed by the financiers, they will receive a positive profit from a good project, i.e., $\widehat{V} > I_1 + I_2$ (e.g., through financing the R&D project large firms intend to use the technology developed by the project, thus the information). Without the information, the investors will get a positive but smaller return. With their specialities, financier A can observe $\bar{s}_A$ with no costs, but has to pay a cost c_A (e.g., to hire a consultant) to observe signal $\bar{s}_B$; and vice versa. Therefore, if the two financiers decide to syndicate their investments in an R&D project, they can collect $\bar{s}_A$ and $\bar{s}_B$ without incurring costs. However, in the case of internal financing, the large firm has to pay the cost to get information about which the firm is not specialized. We suppose that signal s_J can only be observed by the investor who has observed $\bar{s}_J$ earlier, after I_3 is invested. Another way to generate the informational asymmetry is if there is an item in the contract, or there are some other reasons, which prevents the co-financiers from sharing information. In the following we provide a hypothetical case to illustrate how different specialities of two financiers can generate asymmetric information between them. For example, IBM and Kodak might have interests to co-finance a R&D project for a new type of memory chip which might have a great impact on the development of computers and digital cameras (similarly, several large pharmaceutical companies may have an interest in co-finance a new bio-tech project which may have a revolutionary impact on diabetes or cancers drugs). Due to their idiosyncratic interests and specialties, IBM and Kodak may draw different information from the same project. Similar illustrations may also be provided for the case of multiple specialized financial institution co-financing, such as co-financing provided by different venture capital firms specializing in various technologies (such as alliance between biotechnology and pharmaceutical firms as studies by Lerner and Merges (1998)); or co-financing provided by venture capital firms, large firms, or mutual funds, etc.

where $V_J^j(s_A, s_B)$ is the payoff of the reorganized project enjoyed by large firm J when strategy j is taken, and $j = a$ or b and $J = A$ or B.[17]

Moreover, the relationship between A and B satisfies the second efficiency condition (A-1.2): the outcome of a wrong strategy is bad enough that the expected net payoff of randomizing between the two strategies is worse than liquidation, i.e.,

$$qV^b(s_A, s_B) + (1-q)V^a(s_A, s_B) - I_3 < 0 \qquad \text{(A-1.2)}$$

where, $V^a(s_A, s_B) = V_A^a(s_A, s_B) + V_B^a(s_A, s_B)$, $V^b(s_A, s_B) = V_A^b(s_A, s_B) + V_B^b(s_A, s_B)$ and $q = \Pr(s_A > s_B)$.[18]

Finally, the two co-financiers A and B have a conflict of interest (condition (A-2)) in choosing reorganization strategies. In the case that the value of s_A is higher, it is more beneficial to financier A if the project is reorganized under strategy a than under strategy b; and vice versa. This condition implies that each financier J has an incentive to use strategy j if their own signal value becomes higher. That is, for any $s^h > s^l$,

$$\begin{aligned} V_A^a(s_A^h, s_B) - V_A^a(s_A^l, s_B) &> V_A^b(s_A^h, s_B) - V_A^b(s_A^l, s_B) > 0, \qquad \text{(A-2.1)} \\ V_B^b(s_A, s_B^h) - V_B^b(s_A, s_B^l) &> V_B^a(s_A, s_B^h) - V_B^a(s_A, s_B^l) > 0. \qquad \text{(A-2.2)} \end{aligned}$$

In the following we provide an example to illustrate that above assumptions are relevant to real life business.

Example: *Suppose a project is to develop a revolutionary gene-therapy-based drug for a broad range of heart diseases. Financier A is specialized in traditional drugs in heart diseases (e.g. a large pharmaceutical company) and has access to information on marketing/retailing this type of drug* $\widetilde{s}_A$. *Financier B is specialized in evaluating gene-therapy technology (e.g. a venture capitalist specialized in the field) and has access to information on cost of gene-therapy products* $\widetilde{s}_B$. *Thus, if A finances the project alone (e.g. a large firm purchases the R&D project), then A will collect* $\widetilde{s}_A$ *without cost and* $\widetilde{s}_B$ *with extra costs (e.g. cost*

[17] We can relax assumption (A-1.1) so that if signal s_A is higher than s_B, strategy b always makes the project more profitable ex post than strategy a and some times only strategy b makes the project profitable ex post; and vice versa. In so doing, our results would not be affected qualitatively.

[18] Any randomization based on $\widetilde{q} \in [0,1]$ and $\widetilde{q} \neq q$ cannot get a better result than (A-1.2).

of hiring experts). If A and B finance the project jointly, A and B will gather relevant information based on their expertise without extra cost. If the project is a good one it will be completed at date 2 regardless weather it is financed by A alone or jointy by A and B. In the case that the project is a bad one, existing reorganization strategies are the following: strategy a – replacing the pure gene-therapy-based approach with a mixed technology (e.g. a technology mixed between gene-therapy approach and traditional ones); or strategy b – narrowing down the application target to a smaller range of heart diseases while keeping the pure gene-therapy technology. Which reorganization strategy makes the project ex-post efficient depends on the demand for the potential new drug – signal s_A; and the cost of producing the potential new drug – signal s_B. Moreover, s_A and s_B will be learned based on knowledge of $\widetilde{s}_A$ and $\widetilde{s}_B$. If $s_A > s_B$ (the revenue generated by the demand from some heart disease patients is higher than the cost of producing the drug by using related gene-therapy technology) then strategy b is efficient. Otherwise, strategy a is efficient to reduce cost of new drug. In this example, we suppose that $q = 0.7$ and $I_3 = 109$. The other parameter values and corresponding payoffs are shown in the following table.

	signal s_A	signal s_B	payoff V_A^a	payoff V_A^b	payoff V_B^a	payoff V_B^b
s_A^l case	0.6	0.4	40	45	40	65
s_A^h case	0.7	0.4	48	47	40	65

It is easy to see that condition (A-1.2) is satisfied; and given $s_A > s_B$ in both cases, applying condition (A-1.1) strategy b is ex post efficient.

Given the above conditions, if a project is externally co-financed, ex-post if the co-financiers want to reorganize a bad project, they need to find a scheme to share their private information. This is equivalent to saying that B needs to find a scheme to buy s_A from A, or vice-versa. Without a loss of generality, B will buy the private information s_A from A only when the price that B has to pay, $T(s_A, s_B)$, is not too high.

Now we summarize the timing of the game as follows:

- Date 0: All parties know the distribution of the projects but no one knows which project is good and which project is bad. The large-firm(s) offer a take-it-or-leave-it contract to the entrepreneur. If the contract is signed the large firm(s) will invest I_1 units of money into the project during period 1, and the large-firm(s) will start to observe $\bar{s}_A$ and $\bar{s}_B$.

- Date 1: By working on the project, the entrepreneur becomes aware of the type of the project, but the large firm(s) still does not know the type. If the entrepreneur stops the project he gets a private benefit $b_1 > 0$; otherwise, if the project is continued, I_2 units of investment are required from the large firm(s).

- Date 2: The type of project becomes public knowledge:

  - If the project is a good type, it will be completed on date 2 and will generate a return of $\widehat{V}$ to the large firm after the large firm observes $\bar{s}_A$ and $\bar{s}_B$; and a private benefit of $b_{2g} > b_1$ to the entrepreneur but costs him $e > 0$;
  - if it is a bad project, a decision whether or not to liquidate or to reorganize has to be made.
    * If the project is liquidated the large firm(s) get(s) zero and the entrepreneur gets $b_{2b} < b_1$; otherwise,
    * if the project is reorganized, I_3 units of investment are required.

- After investing I_3, signals s_A and s_B are observed by the large firm(s) and a reorganization strategy is chosen based on the signals.

- Date 3: A bad project is completed and generates a return of V to the large firm(s) and a return of $b_1 < b_3 < b_{2g}$ to the entrepreneur.

3. REFINANCING DECISIONS

Given that refinancing a (bad) project after date 2 is ex-ante inefficient, only those institutions that are able to commit to stopping bad projects are efficient in dealing with highly uncertain innovative projects. In this section, we show that non-integration, i.e., external co-financing, provides a commitment device to stop bad projects but integration does not have the commitment device.

3.1 Non-integration

We start with the co-financiers' refinancing decision at date 2 and then consider the entrepreneur's investment decision at date 1. At date 2, when the two financiers discover that the project is a bad one, they should decide either to liquidate or to reorganize (i.e., the financiers assign a probability of p to refinance the project[19]). If they decide to reorganize the project, they will invest I_3. Then signals s_A and s_B are observed by the two financiers respectively and they need to decide what reorganization strategy should be selected (i.e., the financiers assign probabilities of $1 - q(s_A, s_B)$ and $q(s_A, s_B)$ to use reorganization strategy a and b respectively).

We now show that the asymmetric information between the two financiers will make refinancing ex-post inefficient, thus they will terminate bad projects at date 2.

Proposition 1 *Under assumptions (A-1) and (A-2), under non-integration all bad projects are liquidated at date 2.*

Proof. We show that if financier J is able to observe only s_J ($J = A$ or B) after I_3 is invested, under (A-1) and (A-2) there is no efficient incentive compatible scheme $q(s_A, s_B)$ and $T(s_A, s_B)$ which can induce financier J to tell the true value of s_J; thus there is no efficient scheme to reorganize the project. As a result, the financiers choose to liquidate the bad project.

In the following proof, we first analyze financier A's incentive problem. For this purpose, we fix s_B at an arbitrary value $s^* \in (0, 1)$.

Given compensation scheme $T(s_A, s_B)$ and strategy $q(s_A, s_B)$, financier A should tell the truth only if the expected payoff of doing so is not worse than false reporting. That is, the

[19] For example, if their decision is to definitely liquidate the project, they assign $p = 0$.

incentive compatibility (IC) condition is:

$$\begin{aligned} & q(s_A, s_B)V_A^b(s_A, s_B) + (1 - q(s_A, s_B))\, V_A^a(s_A, s_B) + T(s_A, s_B) \\ \geq\ & q(\widehat{s}_A, s_B)V_A^b(s_A, s_B) + (1 - q(\widehat{s}_A, s_B))\, V_A^a(s_A, s_B) + T(\widehat{s}_A, s_B), \end{aligned}$$

where $\widehat{s}_A$ is the false report of the signal.

In the case that the information $s_A = s_A^h > s^*$, the IC is

$$\begin{aligned} & q(s_A^h, s_B)V_A^b(s_A^h, s_B) + \left(1 - q(s_A^h, s_B)\right) V_A^a(s_A^h, s_B) + T(s_A^h, s_B) \\ \geq\ & q(s_A^l, s_B)V_A^b(s_A^h, s_B) + \left(1 - q(s_A^l, s_B)\right) V_A^a(s_A^h, s_B) + T(s_A^l, s_B), \end{aligned}$$

that is,

$$\begin{aligned} T(s_A^h, s_B) - T(s_A^l, s_B) \ \geq\ & \left(q(s_A^l, s_B) - q(s_A^h, s_B)\right) V_A^b(s_A^h, s_B) + \\ & \left(q(s_A^h, s_B) - q(s_A^l, s_B)\right) V_A^a(s_A^h, s_B). \end{aligned} \tag{1}$$

The IC for A's information $s_A = s_A^l < s^*$ is:

$$\begin{aligned} & q(s_A^l, s_B)V_A^b(s_A^l, s_B) + \left(1 - q(s_A^l, s_B)\right) V_A^a(s_A^l, s_B) + T(s_A^l, s_B) \\ \geq\ & q(s_A^h, s_B)V_A^b(s_A^l, s_B) + \left(1 - q(s_A^h, s_B)\right) V_A^a(s_A^l, s_B) + T(s_A^h, s_B), \end{aligned}$$

that is,

$$\begin{aligned} & \left(q(s_A^l, s_B) - q(s_A^h, s_B)\right) V_A^b(s_A^l, s_B) + \left(q(s_A^h, s_B) - q(s_A^l, s_B)\right) V_A^a(s_A^l, s_B) \\ \geq\ & T(s_A^h, s_B) - T(s_A^l, s_B). \end{aligned} \tag{2}$$

The IC conditions (1) and (2) imply

$$\begin{aligned} & \left(q(s_A^l, s_B) - q(s_A^h, s_B)\right) V_A^b(s_A^l, s_B) + \left(q(s_A^h, s_B) - q(s_A^l, s_B)\right) V_A^a(s_A^l, s_B) \\ \geq\ & \left(q(s_A^l, s_B) - q(s_A^h, s_B)\right) V_A^b(s_A^h, s_B) + \left(q(s_A^h, s_B) - q(s_A^l, s_B)\right) V_A^a(s_A^h, s_B), \end{aligned}$$

or,

$$\begin{aligned} & \left(q(s_A^h, s_B) - q(s_A^l, s_B)\right) \left(V_A^a(s_A^h, s_B) - V_A^a(s_A^l, s_B)\right) \\ \leq\ & \left(q(s_A^h, s_B) - q(s_A^l, s_B)\right) \left(V_A^b(s_A^h, s_B) - V_A^b(s_A^l, s_B)\right). \end{aligned}$$

According to (A-2.1), $V_A^a(s_A^h, s_B) - V_A^a(s_A^l, s_B) > V_A^b(s_A^h, s_B) - V_A^b(s_A^l, s_B) > 0$. Thus, the incentive compatibility implies $q(s_A^h, s_B) \leq q(s_A^l, s_B)$, i.e., $q(s_A^l, s_B)$ should be non-increasing in s_A.

However, by (A-1), for any given s_B when s_A increases from $s_A < s_B$ to $s_A > s_B$, for any $q(s_A, s_B) = \bar{q}$, where $\bar{q} \in [0, 1)$ is a constant, the efficiency can be improved by increasing $\bar{q}$, i.e. by $\bar{q} + \varepsilon$, where $\varepsilon > 0$. Thus, the efficiency requires $q(s_A, s_B)$ to be non-decreasing in s_A.

Therefore, the only possible scheme of $q(s_A, s_B)$ which may satisfy both IC and the efficiency requirement is to keep $q(s_A, s_B)$ constant, i.e., $q(s_A, s_B) = \bar{q}$. It is obvious that for any $\bar{q} \in [0, 1]$, reorganization based on any $\bar{q} \neq q = \Pr(s_A > s_B)$ is worse than q. However, by (A-1.2), a reorganization decision based on q is worse than liquidation.

The case of financier B can be proven by symmetry.

Given the above results, any randomization between liquidation and reorganization at date 2 will be worse than liquidation. Thus, the probability of liquidation is $1 - p = 1$. ■

The intuition behind this proposition is the following. The incentives of A lead to a condition that for any given value of s_B, the higher is the value of s_A, the less likely strategy b should be used. However, the efficiency condition (A-1.1) implies that for any given value of s_B, the higher is the value of s_A, the more likely strategy b should be used. The only reconciliation between these two conditions is to keep the probability of using strategy b independent from signal s_A, but the efficiency condition (A-1.2) says that this kind of reorganization will incur losses ex-post, thus it is worse than liquidation.

In the following we use the same example to illustrate how the commitment mechanism of external co-financing works.

Example (continued): *Given the parameters that $I_3 = 109$ and*

	signal s_A	signal s_B	payoff V_A^a	payoff V_A^b	payoff V_B^a	payoff V_B^b
s_A^l case	0.6	0.4	40	45	40	65
s_A^h case	0.7	0.4	48	47	40	65

only strategy b is ex post efficient for both cases. However, when s_A increases from s_A^l to

s_A^h, *A's payoff increases more if strategy a is used than that of strategy b (condition (A-2)). Thus, A has an incentive to under report s_A to increase the chance that strategy a will be used. This is the critical condition that drives the result of Proposition 1.*

This proposition says that when a bad project is revealed to the large firm at date 2, there exists no efficient reorganization scheme which can be agreed upon by both financiers. That is, as a result of the informational asymmetry and conflicts of interest between the two financiers, external co-financing can serve as an ex-post commitment device to stop bad projects. This insight is consistent with the insight of Maskin (1992) in the context of auction with private information in that an information asymmetry between two parties can make auctions inefficient.

This commitment to liquidate bad projects has a deterrent effect on entrepreneurs who have bad projects. Afraid of further losses by hiding bad news, an entrepreneur with a bad project will choose to quit once he discovers it is a bad one because the losses incurred by quitting at date 1 are smaller than those at date 2, i.e., $b_{2b} < b_1$. To summarize, we have the following result:

Corollary 1 *Under external co-financing, entrepreneurs are induced to stop bad projects at date 1 but not a good project.*

The model sheds light on syndicated financing. In reality as long as there are several financiers involved and they have different specializations, then their information and interests are naturally different. That is, the fact that conditions (A-1) and (A-2) are likely satisfied, even without financiers' prior knowledge of any details about these conditions, helps financiers to stop bad projects promptly. Given that banks extended $2 trillion of syndicated loans in 2000 (Esty and Megginson, 2001), our theory also helps to explain the paramount importance of such a financial phenomena from a theoretical perspective.

R&D financing and the boundary of the firm has also been studied from the perspective of knowledge transfer (see Allen and Gale (1999) and Bhattacharya and Chiesa (1995), among others). This strand of literature is concerned about difficulties in transferring knowledge and tries to make knowledge transfer possible. Our theory provides a complementary theoretical answer, which argues that an informational asymmetry between co-financiers that prevents a knowledge transfer can also have benefits to financiers, because if used wisely, the difficulty in knowledge transfer can stop bad R&D investment promptly.

3.2 Integration

We again begin our analysis with the refinancing decision at date 2 and then consider the entrepreneur's investment decision at date 1. Under integration, a project is internally financed. In that case, the large firm will have all the information s_A and s_B and will be able to use this information to choose an ex-post efficient strategy to reorganize the project such that payoff $V^*(s_A, s_B)$ is greater than the ex-post cost of refinancing, I_3. Therefore, the firm is not able to commit to terminating a bad project ex-post.

Moreover, the fact that the large firm cannot commit to terminating a bad project affects the entrepreneur's ex-ante incentives to reveal information. When the entrepreneur at date 1 discovers that his project is a bad one, he expects that the project will always be continued and refinanced by the financier at date 2. Consequently, if he quits the project, he gets private benefit b_1; if he continues the project, the bad project will always be refinanced by the financier and will generate a private benefit $b_3 > b_1$ for the entrepreneur.

Proposition 2 *Under assumption (A-1), at equilibrium a financier does not reward an entrepreneur to reveal the type of a project at date 1 and does not liquidate bad projects at date 2. As a result bad projects are always re-organized by the single financier.*

Proof. When a project is financed by a single financier, the financier will have all the information s_A and s_B and will be able to use this information to choose an ex-post efficient strategy to reorganize the project such that payoff $V^*(s_A, s_B)$ is greater than the ex-post cost of refinancing, I_3. Therefore, when the financier leans the bad type of a project at date 2, given that earlier investments are sunk and $V^*(s_A, s_B) > I_3$, the financier will chose to reorganize a bad project.

However, when the entrepreneur at date 1 discovers that his project is a bad one, he expects that the project will be continued by the financier at date 2 and anticipates a private benefit $b_3 > b_1$. Therefore, the entrepreneur will choose not to tell the type of a project if it is bad. In the following we show that at equilibrium the financier will choose not to reward the entrepreneur to reveal the project type at date 1.

Suppose a financier offers a reward, τ, to an entrepreneur at date 1 to induce him to tell the type of a project. There are several possible reward schemes: $\tau_1 \geq b_3 - b_1$; $\tau_2 \in (b_{2g} - b_1, b_3 - b_1)$; $\tau_3 < b_{2g} - b_1$. Given $b_1 < b_{2g} < b_3$, under the reward τ_1 an entrepreneur will report all project as bad ones in order to collect the reward and the financier is not able to verify the truthfulness from projects stopped at date 1. If the reward is set at τ_2 the entrepreneur will report good projects as bad ones to collect the reward; and will report bad projects as good ones since by doing so a bad project will be continued. If the reward is τ_3 an entrepreneur will report all projects as good ones anticipating continuation of bad projects. However, for the financier no reward is the cheapest for the same outcome of τ_3. Obviously no reward dominates τ_1,τ_2 and τ_3. ■

An interesting insight from this result reveals that without conflicts of interest and informational asymmetries on the financier side, single financier financing is not able to solve the asymmetric information problem between the financier and the entrepreneur due to the lack of commitment to liquidate bad projects.[20]

Our model can be interpreted broadly. A key to the model is the number of agents who collect information and make the reorganization decision. There are many different institutions corresponding to our model of integration, that is they are featured by single agent coordinated financing. Examples include 'main-bank' coordinated financing in Japan, government-coordinated financing in South Korea, or a centralized economy, where the state bank (or the government) finances all the projects and collects all the information.

[20] This result is similar to that of Dewatripont and Maskin (1995). The major difference between their result and ours is that there is no wealth constraint on the investors in our model; moreover, in our model the two investors are involved simultaneously, while in their model the investors are involved sequentially.

4. EFFICIENCIES

The above section shows the benefits associated with non integration or external co-financing. However, there are extra costs associated with non integration relative to integration or internal financing. The asymmetric information between a start-up firm and its financiers gives rise to both moral hazard and adverse selection problems. As a result, if commitment not a major problem, non integration may be more costly than integration.

In this section, we establish the trade-off between the benefits and costs associated with non integration. To keep our model simple and to focus on our major contribution, we treat the problems incurred by non integration as institutional costs in a reduced form.[21] We denote each period's institutional cost of non integration as c^N and the cost of collecting signals in the case of integration as c^I. We assume that both c^N and c^I are exogenously given, and $c^N > c^I$.

According to Proposition 1, in the case of non integration, in equilibrium all bad projects will be dropped by the entrepreneur at date 1. Moreover, for any project proposed randomly from the project pool, with probability λ a project is a good one, generates an expected return $\widehat{V}$, and requires investments $I_1 + c^N + I_2 + c^N$; with probability $1 - \lambda$ a project is a bad one, generates an expected return V, and requires investment $I_1 + c^N$ only. Thus, the expected profits from an externally financed project are,

$$\begin{aligned} \pi^N &= \lambda(\widehat{V} - I_1 - I_2 - 2c^N) + (1 - \lambda)(-I_1 - c^N) \\ &= -I_1 + \lambda(\widehat{V} - I_2) - (1 + \lambda)c^N. \end{aligned}$$

Using Proposition 2, in the case of integration a bad project will always be refinanced. Given that with probability λ a project is a good one, generates an expected return $\widehat{V}$, and requires investments $I_1 + I_2$; and with probability $(1 - \lambda)$ a project is a bad one, generates an expected return V and requires investments $I_1 + I_2 + I_3$, the expected profits from an

[21] Following the literature of finance or theory of the firm, there are many ways to endogenize this institutional cost within our framework.

internally financed project are:

$$\pi^I = -I_1 - c^I + \lambda(\widehat{V} - I_2) + (1-\lambda)(V - I_2 - I_3).$$

The difference between the profits from an internally financed project and the profits from an externally financed project are

$$\pi^I - \pi^N = -(1-\lambda)(I_2 + I_3 - V) + (1+\lambda)c^N - c^I.$$

In contrast, it is easy to see that if liquidation does not deter an entrepreneur from continuing a bad project at date 1, the expected payoff from non integration would be $\pi^N = \lambda(\widehat{V} - I_1 - I_2 - 2c^N) + (1-\lambda)(-I_1 - c^N)$. In such a case, liquidation would not be efficient. This is because

$$\pi^I - \pi^N = 2c^N - c^I + (1-\lambda)(V - I_3) > 0.$$

To summarize the result, we have the following:

Corollary 2 *Without a deterrent effect, liquidation alone is less efficient than reorganization. However, with a deterrent effect, the institution which commits to liquidation can be more efficient.*

Similar to the literature on bankruptcy (e.g., Aghion, Hart, and Moore, 1992), we show that liquidation per se can be less efficient than reorganization. But unlike the above, we emphasize the ex-ante expectational effects of different 'bankruptcy procedures.' We demonstrate that a commitment to liquidate bad projects plays a fundamental role in deterring entrepreneurs from hiding private information. Therefore, an institution which commits to liquidate bad projects can be more efficient.

However, even with a deterrent effect, non integration may still be less efficient than integration. This is because the difference in the net benefits between integration and non integration depends on the institutional cost of non integration, c^N;[22] the uncertainties of

[22] The institutional cost of external financing varies depending on the financial institution (examples can be find in La Porta, Lopez de-Silanes, Shleifer, and Vishny, 1997).

the projects, λ; the required investment in the second and third periods, I_2 and I_3; and the realized value of a bad project when it is completed, V. In the following we conduct a comparative static analysis of the difference between π^I and π^N.

The equation $\pi^I - \pi^N = -(1-\lambda)(I_2 + I_3 - V) + (1+\lambda)c^N - c^I$ shows the trade-off between internal and non integration. On the one hand, there is a saving of investment in a bad project under non integration, $(1-\lambda)(I_2 + I_3 - V)$. On the other hand, there is an extra cost of non integration, $c^N(1+\lambda)$. From this trade-off, we solve for a threshold level λ^* which makes $\pi^I = \pi^N$. Then we have

$$\lambda^* = \begin{cases} \frac{I_2+I_3-(V+c^N+c^I)}{c^N+I_2+I_3-V}, & \text{if } c^N < I_2 + I_3 - V + c^I; \\ 1, & \text{if } c^N \geq I_2 + I_3 - V + c^I, \end{cases}$$

such that if λ, the probability that a project is bad, is greater than λ^*, non integration is more efficient than integration, and vice versa. Investigating λ^* leads to the following lemma. It shows extreme cases where an allocation of the efficient boundary of a firm is independent of the uncertainty of the project.

Lemma 1 *If $c^N - c^I = 0$, non integration is always more efficient; if $c^N - c^I \geq I_2 + I_3 - V$, integration is always more efficient; if $0 < c^N - c^I < I_2 + I_3 - V$, an allocation of the efficient boundary of a firm depends on λ.*

Against the threshold level of uncertainty λ^*, it follows:

$$\begin{cases} \pi^I > \pi^N, & \text{if } \lambda < \lambda^*, \\ \pi^I \leq \pi^N, & \text{if } \lambda \geq \lambda^*. \end{cases}$$

It is also easy to see that $\frac{\partial}{\partial \lambda}\{\pi^I - \pi^N\} < 0$. That is, the advantage of non integration vis-a-vis that of integration increases with the uncertainty of the project type as long as non integration is able to harden budget constraints. In the following we summarize the results regarding the optimal strategies for carrying out a R&D project when firms face different degrees of uncertainties and comparative static results.

Proposition 3 *If $0 < c^N - c^I < I_2 + I_3 - V$, there is a critical level of uncertainty of* *the project, λ^*, such that if uncertainty is low, that is, $\lambda < \lambda^*$, integration is more efficient than non integration; otherwise, non integration is more efficient.*

Proposition 4 *If $0 < c^N - c^I < I_2 + I_3 - V$, the advantage of non integration over integration increases as*

1. *(a) λ increases;*

   (b) the institutional cost of non integration, c^N, decreases;

   (c) the costs of required investment at the second and third periods, I_2 and I_3 respectively, increase; and

   (d) the return from a bad project, V, decreases.

The above propositions suggest that the boundary of a firm is related to the financial institutions and the features of R&D. The creation and development of modern financial intermediaries, which greatly reduce the costs of non integration, give firms broader choices to deal with R&D projects. Venture capital financing is an example. In a financially developed economy with low costs of non integration, to explore high uncertain R&D projects, large firms will keep them outside. When the uncertainty decreases, large firms will bring those projects in. As a result, high uncertain R&D projects tend to be carried out by independent externally financed small firms; while low uncertain projects tend to be concentrated in large firms. In contrast, in a financially underdeveloped economy with high institutional costs of external financing, firms have no choice but to integrate, since internal financing is always superior.

Moreover, most high-tech projects, in such fields as computers, software, bio-tech, etc., are characterized by high uncertainties. Thus, the concentration of venture capital financing in high-tech industries closely matches our results.

Furthermore, when the uncertainty of a project is lower, and/or the costs of required incremental investments decrease, and/or the final return from a bad project increases, our results indicate that integration is more efficient. These predictions are consistent with the observation that large corporations tend to purchase innovative projects at later stages when uncertainties are much lower and the returns from reorganized bad projects are not too low. Our results thus can explain why cash-rich large corporations devote more attention to perfection-related or cost-reduction-related innovation and less attention to new-product-related innovation, and why corporate executives tend to restrict their R&D activities in less uncertain and less novel projects (Scherer, 1991, 1992).

When cash-rich large corporations are interested in investing in R&D, our theory shows that it is in their interest to co-finance such projects externally. This may help to explain why in the 1970s IBM contracted out its first generation PC CPU chips to Intel and its operating system to Microsoft; and why Merck did not take over one-third of the publicly traded small bio-tech companies which produced almost ten times more new drugs than her, while spending approximately the same amount of money for R&D.

5. CONCLUDING REMARKS

In this paper we argue that the inefficient elements in non integration, such as informational asymmetries and conflicts of interest among firms, can be strategically employed to prevent renegotiation, and thus can help firms commit themselves to terminating bad projects which can only be discovered ex-post. With such a credible threat, non integration may help to deter bad projects at an early stage. In contrast, if a R&D project is internally financed, the commitment device does not exist. A disadvantage of non integration compared with integration is an extra cost caused by moral hazard and adverse selection problems, which measure the cost of external capital markets; this is viewed as an institutional cost.

Our theory has implications to property rights theory. Complement to the literature about costs and benefits of ownership (e.g., Grossman and Hart, 1986; Hart and Moore, 1990), a general message of our theory is that having a full ownership over an asset may destroy the owner's commitment to liquidate the asset when continuing owning it would be worse off.

Our results sheds light on the stylized fact that internally financed R&D projects by large companies are usually safe projects. This is because the very attractive feature of a large company – that is, no binding financial constraints for R&D and no serious conflicts of interest in financial decisions – prevents them from committing to an efficient ex-post selection of projects. Indeed, this insight is consistent with empirical studies which show that large corporations have a tendency to maintain the stability of their R&D organization; moreover, their R&D budgeting is usually not based on individual projects, which implies a smoothing of revenue across projects (Mansfield, 1968, p.62, and Reeves, 1958). It also sheds light on syndicated financing, and helps to understand the paramount importance of such a financial phenomena from a theoretical perspective.

Our theory is complement to another strand of literature on R&D financing and the boundary of the firm that studies the issue from the perspective of knowledge transfer and tries to make knowledge transfer possible. Our theory provides a complementary theoretical answer, which argues that an informational asymmetry between co-financiers that prevents a knowledge transfer can actually bring in benefits to financiers, because if used wisely, the difficulty in knowledge transfer can stop bad R&D investment promptly.

Our results also have important implications for centralized economies. With the whole economy is integrated, in centralized economies R&D projects are always financed internally. Moreover, we show that the optimal financing strategy for less uncertain R&D projects, such as in machine building, chemicals, steel, and other heavy industries, is to finance projects internally. Thus we predict that there should be no substantial difference in R&D in those industries between a decentralized economy and a centralized economy. In reality, centralized economies indeed perform reasonably well in R&D for those industries.

In high-tech industries, such as computers, electronics, or bio-tech, where R&D projects can be very uncertain,[23] however, non integration is more efficient. A high degree of integration in a centralized economy implies serious inefficiencies for R&D projects in these areas due to the lack of an ex-post screening mechanism. In fact, the most striking examples to support our insight are the devastating failures of serious efforts on the part of the Soviet

[23] Most of the basic scientific principles for computers, integrated circuits, and bio-tech were developed parallel to R&D projects in those fields. This made the uncertainty of such projects very high.

Union to catch up with the West in computers and electronics, despite their strategic and military importance.

Our theory has implications for economic growth. The central role of financial institutions on technological change on economic growth has been recognized since Schumpeter (1934). In the new growth theory, the role of R&D in growth is endogenized through inputs to technological change and knowledge accumulation while the role of financial institutions are ignored. Nevertheless, we observe financial institutions playing important roles to affect the efficiency of R&D and growth. Our theory has implications to the role of financial institutions on growth (Huang and Xu, 1999).

For firms in catching-up economies, imitating or perfecting existing technologies are the best strategies. With the low uncertainty of imitation, our theory implies that single financier financing is more efficient for work on catching-up projects. Thus, financial institutions which make internal financing R&D easier can greatly accelerate the catching-up process, such as in Japan in the 1960s to the early 1980s, and in South Korea and in other East Asian economies in the 1980s and the 1990s. However, high-tech firms in the most advanced economies face frontiers of technological innovation which are associated with high uncertainties. Our theory predicts that multi-financier financing should be more efficient, but low institutional costs for multi-financier financing are critical. Venture capital institutions may be one such institution to reduce these costs. In contrast, some of those financial institutions which are efficient in financing catching-up (imitation or perfection) projects may not be efficient in financing technologically more advanced projects. Huang and Xu (1999) develop a theory to examine how financial institutions affect technological innovation and thus affect growth. In their model economic growth is affected by the efficiency and riskiness of R&D which are endogenized through financial institutions that generate hard- or soft-budget constraints.

Moreover, our theory provides a novel way to understand financial crisis from an institutional perspective (Huang and Xu, 1998). Due to the adverse effects of the soft budget constraint associated with project uncertainties, bad projects do not stop, and bad loans accumulate. Moreover, bank lending to bad projects is always justified. Therefore, the prevailing soft budgeting in an economy distorts information, such that the inter-bank lending market faces a “lemon” problem. If we suppose that the availability of information about bank project quality is critical for the operation of the financial market to provide loans to illiquid banks, the lemon problem in the lending market may contribute to bank run contagions and may lead to the collapse of the lending market and induce a run on the economy. In contrast, an economy with a predominance of hard budget constraints has mechanisms which allow information to be disclosed timely from the firms to the banks, and to the financial market. Thus bank runs can be stopped, contagious risks contained, and financial crisis prevented. Moreover, Huang and Xu (1998a) show the tragedy of a ‘soft-budget constraint trap’ in an SBC economy. That is, due to the lemon problem in the financial system, without changing the institution in a fundamental way, the best a government can do in an SBC economy is to bail out all the illiquid banks.

Finally, some remarks about our approach are in order. In order to keep our model simple, we have chosen to use a reduced form of the institutional cost of non integration, which is a measurement of the imperfection of capital market. It is related to another dimension of the informational asymmetry between the financiers and the entrepreneur which may result in moral hazard and adverse selection problems for the entrepreneur. Depending on capital market development and other institutional settings, such as the legal system, the institutional cost may vary across countries and over time (La Porta, et al, 1997). There exists extensive economic and finance literature which provides the rationale for such institutional costs (e.g., Arrow, 1962; Stiglitz and Weiss, 1981; and Myers and Majluf, 1984). Thus, it is not difficult to develop a model with fully endogenized institutional costs with richer results.

With respect to our reduced form treatment of the entrepreneurs’ private benefits, it should be pointed out that this can be replaced by endogenized compensations to the entrepreneur and all of the above results will not be changed qualitatively.

REFERENCES

[1] Acs, Zoltan, and David B. Audretsch (1988), "Innovation in Large and Small Firms: An Empirical Analysis," *American Economic Review*, 78.

[2] Aghion, Philippe, Oliver Hart, and John Moore (1992), "The economics of bankruptcy reform," *Journal of Law, Economics, and Organization,* Oct, 8(3):523-546.

[3] Aghion, Philippe and Jean Tirole (1994), "The Management of Innovation," *Quarterly Journal of Economics*; 109(4): 1185-1209.

[4] Allen, Franklin and Douglas Gale (1999), "Diversity of Opinion and Financial of New Technologies," *Journal of Financial Intermediation*; 8: 68-89.

[5] Barry, Christopher B., Chris J. Muscarella, John W. Peavy III, and Michael R. Vetsuypens (1990), "The Role of Venture Capital in the Creation of Public Companies: Evidence from the Going-public Process," *Journal of Financial Economics,* **27**, October.

[6] Bernanke, Ben, and Mark Gertler (1989), "Agency Costs, Net Worth and Business Fluctuations," *American Economic Review*, 79:14-31.

[7] Bhattacharya, S. and G. Chiesa (1995), "Financial Intermediation with Proprietary Information," *Journal of Financial Intermediation*; 4: 328-357.

[8] Bolton, Patrick, and David S. Scharfstein, (1996), "Optimal Debt Structure and the Number of Creditors," *Journal of Political Economy*, 104(1).

[9] Calomiris, Charles W., and R. Glenn Hubbard (1990), "Firm Heterogeneity, Internal Finance, and "Credit Rationing"," *Economic Journal*, March.

[10] Dewatripont, Mathias, and Eric Maskin (1995), "Credit and Efficiency in Centralized and Decentralized Economies," *Review of Economic Studies*, October.

[11] Elliot, J. W. (1971), "Funds Flow vs. Expectational Theories of Research and Development Expenditure in the Firm," *Southern Economic Journal*, 37.

[12] Esty, Benjamin C. and William L. Megginson (2001), "Syndicate Structure as a Response to Political Risk in the Project Finance Loan Market," unpublished, Harvard Business School.

[13] Grossman, S. and O. D. Hart (1986), "The Costs and Benefits of Ownership: A Theory of Vertical and Lateral Integration," *Journal of Political Economy*, 94(4).

[14] Hart, Oliver (1995), *Firms, Contracts and Financial Structure*, Clarendon Press, Oxford, England.

[15] Hart, O. D. and J. Moore (1990), "Property Rights and the Nature of the Firm," *Journal of Political Economy*, 98(6), 1990.

[16] Hart, Oliver and John Moore (1995), "Debt and Seniority: an Analysis of the Role of Hard Claims in Constraining Management," *American Economic Review,* June, 85 (3):567-586.

[17] Himmelberg, Charles P., and Bruce C. Pertersen (1994), "R&D and Internal Finance: A Panel Study of Small Firms in High-tech Industry," *Review of Economics and Statistics*, 38-51.

[18] Holmstrom, Bengt and John Roberts (1998), "The Boundaries of the Firm Revisited," *Journal of Economic Perspectives*, Vol. 2 (4): 73-94.

[19] Huang, Haizhou and Chenggang Xu (1999a), "Financial Institutions, Financial Contagion, and Financial Crises," *Harvard University CID Working Paper no. 21, July 1999. IMF Working Papers 00/92.*

[20] Huang, Haizhou and Chenggang Xu (1999b), "Institutions, Innovations, and Growth," *American Economic Review*, 89(2): 438-43.

[21] Hubbard, R. Glenn and Anil Kashyap (1992), "Internal Net Worth and the Investment Process: An Application to U.S. Agriculture," *Journal of Political Economy,* 100(3):506-34.

[22] Jewkes, J., D. Sawers, and R. Stillerman (1969), *The Sources of Invention*, London: Macmillan.

[23] Kamien, Morton I., and Nancy L. Schwartz (1978), "Self-financing of an R&D Project," *American Economic Review*, 68.

[24] Kornai, Janos (1980), *Economics of Shortage*, North Holland.

[25] LaPorta, Rafael, Florencio Lopez de-Silanes, Andrei Shleifer and Robert Vishny, (1997), "Legal Determinants of External Finance," *Journal of Finance,*.52(3):1131-50.

[26] Lerner, Joshua (1994), "The Syndication of Venture Capital Investments", *Financial Management*, Vol. 23, No. 3, Autumn, 16-27.

[27] Lerner, Joshua and Robert P. Merges (1998), "The Cost of Technology Alliances: An Empirical Analysis of the Biotechnology Industry," *Journal of Industrial Economics*, 46: 125-156.

[28] Lonie, A., B. Nixon, and D. Collison, (1993), "Internal and External Financial Constraints on Investment in Innovative Technology," in Swann, P. (eds.), New Technologies and the Firm, London: Routledge.

[29] Mansfield, E. J., (1968), *The Economics of Technological Change*, London: Norton.

[30] Maskin, Eric (1992), "Auction and Privatization," in Siebert, H., eds. *Privatization*, pp. 115-136.

[31] Mueller, Dennis C. (1967), "The Firm's Decision Process: An Econometric Investigation," *Quarterly Journal of Economics*, 81.

[32] Myers, Stewart C., and Nicholas S. Majluf, (1984), "Corporate Financing and Investment Decisions when Firms Have Information and Investors Do Not," *Journal of Financial Economics*, 13.

[33] Qian, Yingyi, and Chenggang Xu (1998), "Innovation and Bureaucracy Under Soft and Hard Budget Constraints," *Review of Economic Studies*, 1, 1998.

[34] Prusa, T. and J. Schmitz (1991), "Are New Firms an Important Source of Innovation? Evidence from the PC Software Industry," *Economic Letters*, 35(3):339-342.

[35] Reeves, E. D. (1958), "Development of Research Budget," *Research Management*, 1:133-42.

[36] Sahlman, William (1990), "The Structure and Governance of Venture-Capital Organizations," *Journal of Financial Economics*, **27**, October.

[37] Scherer, F. M. (1965), "Firm Size, Market Structure, Opportunity, and the Output of Patented Inventions," *American Economic Review*, 55.

[38] Scherer, F. M. (1991), "Changing Perspectives on the Firm Size Problem," in Z. Acs and D. Audretsch (eds.) *Innovation and Technological Change*, NY: Harvester Wheatsheaf.

[39] Scherer, F. M. (1992), "Schumpeter and Plausible Capitalism," *Journal of Economic Literature*, XXX(3):1416-1433.

[40] Schilit, W. Keith. (1991) *Dream Makers and Deal Breakers: Inside the Venture Capital Industry*, London: Prentice Hall.

[41] Schumpeter, J. (1934), *The Theory of Economic Development*, Cambridge (Mass.): Harvard University Press.

[42] Schumpeter, J. (1950) *Capitalism, Socialism and Democracy*, New York: Harper.

[43] Stiglitz, Joseph E., and Andrew Weiss (1981), "Credit Rationing in Markets with Imperfect Information," *American Economic Review*, 71.

[44] U.S. Bankruptcy Court for the Western District of Michigan, Southern Division (1997), "Case No. 96-83767, Chapter 11 -Filed: 6/3/96, Converted to Chapter 7: 7/30/96," 216 Bankr. 784; 1997 Bankr. LEXIS 2111.

[45] Weiss, Lawrence A. and Karen H. Wruck (1998) "Information problems, conflicts of interest, and asset stripping: Chapter 11's failure in the case of Eastern Airlines," *Journal of Financial Economics,* 48:55-97, 1998.