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# Soft Budget Constraint and the Optimal Choices of Research and Development Projects Financing[1]

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Through analyzing the softness and hardness of budgeting constraints in research and development (R&D) investment under different institutions, we develop a theory of optimal R&D financing. Our theory not only provides a clear comparison of investment efficiency between centralized economies and market economies but also extends the analysis of soft budget constraint to firms in market economy. Based on this theory, we characterize optimal choices of R&D project financing in centralized and decentralized economies. Our results explain why some projects are financed internally by a large firm but others are cofinanced externally by several firms. We also explain what makes a centralized economy inefficient in R&D. *J. Comp. Econom.*, March 1998, **26**(1), pp. 62–79. Queen Mary and Westfield College, University of London, Mile End Road, London E1 4NS, United Kingdom, and Financial Markets Group, London School of Economics, Houghton Street, London WC2A 2AE, United Kingdom; and London School of Economics, Houghton Street, London WC2A 2AE, United Kingdom. © 1998 Academic Press

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## 1. INTRODUCTION

Since the term soft budget constraint was coined by Kornai (1980), it has been widely accepted as a basic concept for analyzing problems in centrally planned economies and transition economies, particularly those associated with state-owned firms. Although soft budget constraints are not restricted to state-owned firms, most theories of soft budget constraint compare state-owned firms with firms in decentralized economies, e.g., Dewatripont and Maskin (1995) and Qian and Xu (in press). This paper develops a coherent theory of soft budget constraints that applies to corporations in market economies and to state-owned firms in centralized economies.

It is well documented that, in a market economy, small companies contribute a disproportionate share of innovations, particularly in high-technology industries. A closely related, but unsettled question in economics is, should research and development (R&D) projects be financed internally or externally? The answer to this question is also relevant to our understanding of the centralized economy. Since, in a centralized economy, all the state-owned enterprises and financial resources are under the control of the government, this is equivalent to the case of no external financing.

Schumpeter argued that large corporations can do better than small firms in innovation because they are able to provide internal funds (Schumpeter, 1950). This idea has been well-received in the recent literature on information economics. Because of asymmetric information between a firm and its investor, both moral hazard and adverse selection problems exist. Therefore, it has been argued that external financing of R&D is less efficient then internal financing (Arrow, 1962; Kamien and Schwartz, 1978; Myers and Majluf, 1984; and Stiglitz and Weiss, 1981). Particularly, since a typical R&D project involves a large sunk cost due to the low liquidation value of the projects, the moral hazard and adverse selection problems accompanying external financing are more severe and harder to solve in R&D projects (Bernanke and Gertler, 1989; Calomiris and Hubbard, 1990; Hubbard and Kashyap, 1990).

According to this theory, as long as firms are not constrained by wealth, we should expect them to finance R&D projects internally. By similar reasoning, we might also expect a centralized economy to perform well in R&D. On the other hand, small firms in a market economy should be less efficient and more constrained from developing R&D projects because they have serious wealth constraints and their outside funding suffers from moral hazard and adverse selection problems. However, these theoretical expectations are obviously at odds with the facts. The stylized fact is that large firms in a market economy do not finance many R&D projects internally even when they are originated within the firm, nor do they purchase many R&D projects that are proposed by outside inventors, although they often finance those projects externally by joining with other firms and investors. Moreover, centralized economies are terribly inefficient in high technology R&D projects, such as R&D in computer, electronics, and biotechnology areas.

The basic puzzle is the following. If external financing is inefficient, why do large firms chose an inefficient way of financing R&D projects? If external financing is more efficient, why is it efficient when moral hazard and adverse selection problems are much more severe than with internal financing? A less direct but profound question is, if R&D in small firms enjoys an advantage in high-technology projects over large corporations, then why cannot large corporations mimic small firms in their high-technology R&D projects, particularly when they enjoy the benefit of not having binding financial constraints? If market economies enjoy an advantage in high-technology R&D projects over centrally planned economies, then why cannot centrally planned economies mimic market economies?

In this paper we answer these questions by developing a theory of soft budget constraints. We argue that a major characteristic of a typical R&D project is a high degree of uncertainty and such uncertainty can be resolved only after the project has been undertaken. Therefore, ex post selection is the most efficient screening mechanism for R&D projects. However, an ex post screening mechanism requires a commitment that a bad project be stopped even if refinancing is ex post profitable, which we show is possible only when there exists a conflict of interest among investors who have different information. When a project is financed internally, conflict of interest and asymmetric information among investors are avoided. Thus such a commitment device is associated only with external financing. Large corporations chose external financing to solve the commitment problem in R&D. However, no such choice is available to a centralized economy.

In our model, there are many entrepreneurs in a market economy (or mangers in a centralized economy), each of whom has an idea for a project but no wealth to finance it. All the ideas are assumed to be of two types: a low-cost type that needs two periods to complete and is ex ante profitable and a high-cost type that needs three periods to complete and is ex ante unprofitable. We also assume that, before the project is started, nobody (including the entrepreneur or manager) knows its type. After working on the project for one period, the entrepreneur will know its type. After two periods of financing the project, the investors will know its type. Moreover, the first-period investment is completely sunk and the second-period investment is partly sunk.

The only feature that differentiates a centralized economy from a decentralized economy in our model is that, in the former system, there is only one investor, the state bank, or equivalently all financial resources are controlled by the government. We also assume that large firms or the state bank of a centralized economy are not constrained by wealth in financing R&D projects.

At the beginning of the game, an entrepreneur or a manager approaches large firms in the market economy or the state bank in the centralized economy, respectively, to get his project financed.

Given that the type of the R&D project is revealed to the entrepreneur or manager after one period and to the investors after two periods and that some of the earlier investments are sunk, the ability to turn down bad projects as early as possible is critical for efficiency. We demonstrate that, in the case of internal financing in a market economy or investment in a centrally planned economy, a high-cost project will always be continued due to the lack of commitment ex post. Consequently, anticipating refinance, the entrepreneur will always choose to hide the bad news and never terminate a high cost project. Therefore, the soft budget constraint always emerges in internal financing or in a centralized economy.

In contrast, if a R&D project is cofinanced externally by two investors and, if after two periods they realize that the project is a high cost one, each investor gets a different payoff from her own strategy in continuing or liquidating the project. Adopting the first investor's strategy yields a positive private value and some liquidation value but leaves the second investor with no private value; and vice verse. To focus on the interesting case, we suppose that both refinancing strategies are ex post profitable but only one strategy can be implemented. Therefore, if the two investors agree on a compensation transfer, one investor will take over the project completely and refinance it. Otherwise, it will be liquidated. We argue that such a conflict of interest between the two investors under asymmetric information will reduce the ex post efficiency of refinancing and the bargaining between the two investors may break down. As a result, an ex ante inefficient project may be liquidated if it is cofinanced; thus, we show that a hard budget constraint can emerge in external cofinancing.

Based on our results of soft or hard budget constraints under different institutions, we characterize the optimal choices of R&D financing in a decentralized economy and compare the efficiency between a centralized economy and a decentralized economy. Our results indicate that, when the uncertainties of the projects are high enough, external financing will dominate; otherwise, internal financing is more efficient. Thus our results predict that, when the uncertainty of a R&D project is not high, there is no difference between a centralized economy and a decentralized economy in which internal financing by large firm is more efficient. Examples consistent with our prediction are R&D in machine building and chemical industries in both economies. However, when uncertainty is very high, a centralized economy will be dominated by decentralized economies in which external financing is prevalent, such as venture capital financing. Good examples supporting our prediction are the R&D projects in high-technological industries, such as computers, electronics, and biotechnology.

Similar to Dewatripont and Maskin (1995) and Qian and Xu (in press), we emphasize the role of ex post inefficiency as a commitment device. Similar to Hart and Moore (1995) and Bolton and Scharfstein (1996), we consider conflicts of interest between multiple investors. A key difference between our model and the one of Dewatripont and Maskin and that of Qian and Xu is that investors are not constrained by liquidity or wealth to finance a project alone if they so choose. The ex post inefficiency in our model is related to the ex post different perspectives of the coinvestors or conflicts of interest over a high-cost project. This feature allows us to endogenize firms' decisions over R&D project financing. Unlike either Hart and Moore or Bolton and Scharfstein, we focus on the commitment problem and endogenize a renegotiation proof institution.

The paper is organized as follows. Section 2 sets up the basic model. Section 3 shows that external cofinancing hardens budget constraint in R&D refinancing. Section 4 compares the efficiency between centrally planned and market economies and discusses optimal strategies for a large firm financing R&D projects. Section 5 makes some concluding remarks.

## 2. BASIC MODEL

### *2.1. The Decentralized Economy vs the Centralized Economy*

In a decentralized economy, there are many entrepreneurs and many firms. Each entrepreneur has an idea for an innovation. However, no entrepreneur has wealth to finance the project. Each firm has its own R&D division and sufficient resources to finance at least one R&D project.[2] When an entrepreneur proposes a project to a large firm, the firm can either finance it internally, which includes buying a project if it was proposed from outside and hiring the entrepreneur as an employee, or cofinance the project with another firm.[3] In the case of external cofinance, the project becomes an entrepreneurial firm; the two investing firms and the entrepreneur share equally the outcome of the project.

If a project is financed internally, the firm will bear all the costs and recoup

[2] Large corporations run venture capital subsidiaries that are a major source of venture capital. Moreover, these venture capital subsidiaries of large firms have deep pockets and can get additional capital resources from the parent company if attractive opportunities develop (Schilit, 1991, p. 68).

[3] In our model, an entrepreneur may or may have not worked for large firms before. In fact, some inventors are employees of large firms. They may choose to leave the firms and set up their own entrepreneurial firms with outside finance. In other situations, inventors are hired by large firms because these firms are interested in their ideas. Both possibilities are captured by our model. Many large firms have invested significant money, both internally and externally, in R&D projects.

all the returns. If a project is cofinanced, the two firms, A and B, that jointly finance the project will share all the costs equally between them but share the returns together with the entrepreneur before any new arrangement is agreed by both investors.[4]

In a centralized economy all financial resources are controlled by the state bank or the government. Thus, we regard the entire economy as one large firm and state-owned enterprises are considered to be plants or factories of the large firm. The central government has sufficient resources to finance R&D projects. Unlike a large firm in a market economy, when the government receives an investment proposal from a manager, it can finance it only internally because there are no other investors available in the economy. In our model, this is the only difference between a centralized economy and a decentralized economy.

## 2.2. *The Structure of the Game*

In our model, there are three time periods. Among all the projects proposed by entrepreneurs, $\lambda$ of them are high-cost types that take three periods to finish, require $I_1 + I_2 + I_3$ units of funds, and generate $V$ units of revenue, where $I_i$ is the investment in period $i$. Similarly, $1 - \lambda$ are the low-cost types that take two periods to finish, require $I_1 + I_2$ units of funds, and generate $\hat{V} > V$ units of revenue. We suppose that the ex ante expected return to the investors is more than the expected costs of cofinancing; i.e., $\lambda V + \frac{2}{3}(1 - \lambda)\hat{V} > I_1 + I_2 + \lambda I_3$. Thus, all projects are profitable to be financed ex ante.

At date 0, only the distribution of projects is known and this is common knowledge, although neither the investors nor the entrepreneurs in the market economy know each project's type. At the end of the first period, date 1, the entrepreneur observes the type of the project. If it is a high-cost one and he discontinues the project at date 1, he gets a low private benefit, $b_1 > 0$.

At the end of the second period, date 2, a low-cost project is finished; thus the type of project becomes public knowledge. If a project is a low-cost one and is completed at date 2, the entrepreneur gains a high private benefit $b_{\hat{V}}$. If the project is liquidated at date 2, the entrepreneur gets no private benefit. However, if the project is refinanced after date 2 and completed, the entrepreneur receives a positive private benefit, $b_V > b_1$ but $b_V < b_{\hat{V}}$ at date 3.

We assume that the first-period investment, $I_1$, is completely sunk and that the second-period investment, $I_2$, is partly sunk. Regardless of whether a project is financed internally or externally, if it is a high-cost one, it will not

[4] The share of costs and payoffs between the coinvestors and the entrepreneur can be endogenized in a more complicated way but it is obvious that, in the symmetric case, equal sharing should be the equilibrium result.

be completed. Thus it cannot generate any revenue at date 2 unless it is liquidated. Because the second-period investment, $I_2$, is partly sunk, the liquation value of the project will be below the second-period investment. When the investors are facing a decision of refinancing a high-cost project, they may have different perspectives about their private benefits in reorganizing the project and of the liquidation values corresponding to different strategies on the project.[5] The refinancing decision may be interpreted as reorganization, e.g., chapter 11 under the American bankruptcy procedure, or liquidation, e.g., chapter 7 under the American bankruptcy procedure.

In the case of liquidation, we suppose that the two investors are able to generate different liquidation values that are observable and verifiable.[6] If the project is handled by investor A, the liquidation value of the project will be low, $\underline{L}$; but if the project is handled by investor B, she will generate a high liquidation value at date 2, $\bar{L}$. We assume $0 < \underline{L} < \bar{L} < I_2$. The difference between the two investors' liquidation value, $\ell = \bar{L} - \underline{L}$, is a measure of the difference between the perspectives of the coinvestors. Obviously, it is in the coinvestors common interest to let investor B handle liquidation.

In the case that the project is refinanced, we suppose that each investor has her own reorganization approach that fits best her interests and differs from the other investor's best approach. For investor A, approach ''a'' yields a private value, $u_a$, in addition to an observable and verifiable value $V$, such that if the project is taken over by A, the refinance is ex post efficient; i.e., $V + u_a - I_3 > \underline{L}$. However, approach ''b'' makes no private value for her. Similarly, for investor B, approach ''a'' makes zero private value; but approach ''b'' makes a high private value, $u_b$, such that the project is ex post profitable if she has complete control over the project; i.e., $V + u_b - I_3 > \bar{L}$. We assume that $u_a$ is not observable by B and $u_b$ is not observable by A, but that both A and B know that $E[u_a] > E[u_b]$, where $E[.]$ is the expectations operator. For the sake of simplicity, we also assume that the private benefits, $u_a$ and $u_b$, are uniformly distributed. In the case of investor A, as we are interested in the case in which the soft budget constraint arises with internal financing, i.e., $V + u_a - I_3 > \underline{L}$, that is $u_a > \underline{L} + I_3 - V$. Thus, the uniform distribution should be $u_a \sim U(\underline{L} + I_3 - V, \bar{u}_a + \underline{L} + I_3 - V)$,

[5] There are many reasons that the two investors may have different ex post expectations over a project even though they have the same a priori expectations and even get the same information. One reason is that they have different joint distributions of the profitability between the R&D project and their own production such that their a posteriori expectations are different. For example, a computer company may have a different joint distribution of the profitability between its own production and a semiconductor project from that of a communication company.

[6] Their different liquidation values are associated with their different natures of business, e.g., computer vs communication, and their different strategies in liquidation.

which has a density function of $1/\bar{u}_a$ in the above-defined domain. Similarly, in the case of investor B, we assume that $u_b \sim U(\bar{L} + I_3 - V, \bar{u}_b + \bar{L} + I_3 - V)$, which has a density function of $1/\bar{u}_b$ in the above-defined domain. In our later discussion, we focus on $u_a$ only; thus when there is no confusion, we replace $\bar{u}_a$ by $\bar{u}$.

We assume that reorganization approaches ''a'' and ''b'' cannot be implemented at the same time. To focus on the more interesting case, we assume that $V + u_a - I_3 > \frac{1}{2}(\bar{L} + \underline{L})$. Hence, it is always worthwhile for A to refinance the project alone after paying B's reservation value of the project, $\frac{1}{2}\bar{L}$. However, reorganization can happen only when the two investors agree upon the appropriate transfer from A to B or if A is able to buy out B's share of the project. We assume further that the bargaining game has only one round in which B makes a take-it-or-liquidate-it offer to A.[7] When the game is over, a project will be either reorganized or liquidated. Moreover, B's offer is in the form of the transfer price $T$. In calculating $T$, B certainly takes into account the unobservable private benefit of refinancing the project, $u_a$, and her own liquidation value, $\bar{L}$, in the sense that she wants to extract more financial transfer from A, the higher is $u_a$, and she shall ask for at least her share of $\bar{L}$, i.e., the least she can get if she is in charge, to allow investor A to take over the project completely.

To simplify our exposition, we assume that each coinvestor has an equal share in financing the project. This assumption seems ad hoc but, in a more complete theory, we can endogenize the optimal share for each investor and it will turn out to be one-half. Thus, in such a one-round bargaining game over how to compensate B under the asymmetric information on A's private value of the project, if a side payment can be agreed upon by both parties, the project may be refinanced by investor A alone. Otherwise, if bargaining breaks down, the project has to be liquidated as this is the default option for both investors and a hard budget constraint emerges.

## 3. COFINANCING HARDENS BUDGET CONSTRAINTS

In this section we show that internal financing will lead to a soft budget constraint while cofinancing may lead bargaining to break down in which case a hard budget constraint emerges. Given asymmetric information about

[7] Our bargaining captures the essence of the situation in that a multiround bargaining game under two-sided asymmetric information shall not lead to learning or revelation of the true information due to incentive considerations. Another reason is that, in our setting, A may have more expertise in reorganizing the firm, while B has more expertise in liquidation. In a more general theory, we show that allowing general bargaining games does not alter our results qualitatively (Huang and Xu, 1997).

the private value of the project, B's problem is to choose $T$ such that her expected return from the bargaining game is maximized. Hence,

$$\max_T T \Pr\left[V + u_a - T - I_3 \geq \frac{\underline{L}}{2}\right] + \frac{\bar{L}}{2}\left(1 - \Pr\left[V + u_a - T - I_3 \geq \frac{\underline{L}}{2}\right]\right)$$

$$\text{st} \qquad T \geq \frac{\bar{L}}{2}.$$

The first-order condition is

$$\Pr\left[V + u_a - T - I_3 \geq \frac{\underline{L}}{2}\right] - \left(T - \frac{\bar{L}}{2}\right) f\left(V + u_a - T - I_3 \geq \frac{\underline{L}}{2}\right) = 0, \quad (1)$$

where, $f(.)$ is the density function, and the second-order condition is

$$-2f\left(V + u_a - T - I_3 \geq \frac{\underline{L}}{2}\right) + \left(T - \frac{\bar{L}}{2}\right) f'\left(V + u_a - T - I_3 \geq \frac{\underline{L}}{2}\right) < 0. \quad (2)$$

This condition will always hold if $f'(.) \leq 0$, which is a strong sufficient condition.

From (1), we have

$$T^* = \frac{\bar{L}}{2} + \frac{\Pr\left[V + u_a - T^* - \mathrm{I}_3 \geq \frac{\underline{L}}{2}\right]}{f\left(V + u_a - T^* - \mathrm{I}_3 \geq \frac{\underline{L}}{2}\right)}. \quad (3)$$

Given $u_a \sim U(\underline{L} + I_3 - V, \bar{u} + \underline{L} + I_3 - V)$, then $f(.) = 1/\bar{u}$, and

$$\Pr\left[V + u_a - T - I_3 \geq \frac{\underline{L}}{2}\right] = \Pr\left[u_a \geq T + I_3 + \frac{\underline{L}}{2} - V\right]$$

$$= \int_{T+I_3+\underline{L}/2-V}^{\bar{u}+\underline{L}+I_3-V} \frac{1}{\bar{u}}\, du = \frac{1}{\bar{u}}\left(\bar{u} - T + \frac{\underline{L}}{2}\right).$$

Substituting the above result into (1), we have the optimal strategy of investor B, i.e., the optimal offer that she will make, $T^*$, equal to

$$T^* = \frac{1}{2}\left(\bar{u} + \frac{\bar{L} + \underline{L}}{2}\right).$$

Using the optimal offer $T^*$, the probability of bargaining being successful is given by

$$1 - p = \Pr\left[V + u_a - T^* - I_3 \geq \frac{\underline{L}}{2}\right]$$
$$= \frac{1}{\bar{u}}\left(\bar{u} - T^* + \frac{\bar{L}}{2}\right) = \frac{1}{4\bar{u}}\,[2\bar{u} - (\bar{L} - \underline{L})].$$

Hence, with probability $p = 1/4\bar{u}[2\bar{u} + (\bar{L} - \underline{L})]$, bargaining breaks down and a hard budget constraint is obtained.

In contrast, in the case of internal financing or investment in centralized economies, at date 2 when the firm or the government discovers that a project is a high-cost type, it can always choose the appropriate reorganization approach, be it ‘‘a’’ or ‘‘b’’, that generates a high enough expected return, including the observable value $V$ and the unobservable private value $u$, such that $V + u > I_3 + L$. Thus a high-cost project will always be refinanced at date 2 by a large firm in a market economy or by the government in the centralized economy. Therefore, internal financing or government financing in a centralized economy always leads to a soft budget constraint.

To summarize, we have the following proposition.

PROPOSITION 1. *Ex post, at date* 2, *when the type of the project is recognized by investor*(*s*) *or government:*

(*i*) *with a centralized economy or internal finance in a decentralized economy, the high-cost project is always refinanced;*

(*ii*) *with external finance in a decentralized economy, there is a positive probability* $p$, $1/2 < p = 1/4\bar{u}[2\bar{u} + (\bar{L} - \underline{L})] < 1$, *such that the high-cost project will be liquidated rather than refinanced.*

From Proposition 1, if $\bar{L} - \underline{L} = \ell = 0$, then $p = \frac{1}{2}$; moreover, if $\bar{L} - \underline{L} = \ell > 0$, then $p > \frac{1}{2}$. Hence, the higher is $\ell$, i.e., the difference between $\bar{L}$ and $\underline{L}$, the more likely it is that bargaining breaks down.

PROPOSITION 2. *The higher is the difference in gross liquidation value* $\bar{L} - \underline{L} = \ell > 0$, *the more likely that a cofinanced high-cost project will be liquidated; i.e.,* $\partial p/\partial \ell > 0$. *In particular, we have the following results.*

(*i*) *If there is no disagreement between the two investors about the liquidation value, i.e.,* $\bar{L} - \underline{L} = 0$, *bargaining will be successful half of the time; i.e. with external cofinancing there is a* 50% *possibility that a bad project will be liquidated. However, internal financing is always subject to soft budget constraint.*

(*ii*) *If the difference between the two investors is large enough, i.e.,* $\bar{L} - \underline{L} = 2\bar{u}$, *then bargaining always fails.*

In the case of external finance, the fact that ex post there is a probability $p$ of a high-cost project being liquidated at date 2 affects the entrepreneur's ex ante incentives. At date 1, he makes a decision on whether to terminate the project immediately or to continue it that may be liquidated later. If he terminates, his private benefit is $b_1 > 0$. If he continues, there is a probability $(1 - p)$ that the project will be refinanced after date 2 and thus will be finished providing a benefit of $b_V > b_1$. However, there is also a probability $p$ that the project will be liquidated at date 2 and generate no private benefit. Thus, his expected private benefit from continuing the project at date 1 is $(1 - p)b_V$ and his decision is based on maximizing the expected payoff. The entrepreneur's optimal decision at date 1 is to terminate if $b_1 \geq (1 - p)b_V$ and to continue if $b_1 < (1 - p)b_V$. Obviously, the higher the probability that a high-cost project is liquidated at date 2, the more likely it is that an entrepreneur will terminate the project at date 1.

If an entrepreneur decides to terminate the project at date 1, he takes his private benefit and the game is over. If the entrepreneur decides to continue the project at date 1, however, the investors cannot tell whether or not he has hidden some information from them, since they do not know the relevant information at that point of time with certainty nor do they know his private benefits. With the knowledge of the distribution of $b_V$ and $b_1$, they can only infer the probability $1 - q$ that an entrepreneur will terminate a bad project himself at date 1. However, it is clear that the higher the probability is that a bad project will be liquidated by the investors, the more likely it is that the entrepreneur will terminate it when his private information is revealed to him.

In the case of internal finance, an entrepreneur can foresee that a high-cost project will always be continued and refinanced by the large firm at date 2. Thus, he will never choose to terminate any high-cost project because by hiding the information on the type of the project that he privately observes at date 1 and continuing the project he will always receive a higher private benefit $b_V$ $(b_V > b_1)$.

PROPOSITION 3. *When the type of the project is recognized by the entrepreneur at date* 1 (*interim*)*:*

(*i*) *With internal finance, the high-cost project is always continued.*

(*ii*) *With external finance, there is a positive probability* $(1 - q)$, *where* $0 < (1 - q) < 1$, *that the high-cost project will be terminated by the entrepreneur. Moreover, q is decreasing in the probability of liquidating a high-cost project, p, i.e.,* $\partial q/\partial p < 0$; *decreasing in the private value of terminating a high-cost* *project at date* 1, $b_1$, *i.e.*, $\partial q/\partial b_1 < 0$; *and increasing in the private value of completing a high-cost project*, $b_V$, *i.e.*, $\partial q/\partial b_V > 0$.

Thus, we have shown that the properties of the financial constraint have expectational effects on entrepreneurs' behavior. When a project is cofinanced by two investors, once the entrepreneur knows that he is working with a high-cost project at date 1, he may choose to terminate it to avoid more losses if the probability of liquidation at date 2 is high enough. However, if a project is internally financed, the entrepreneur will hide the information that he discovered at date 1. In this case, all high-cost projects will be continued after date 1 by the entrepreneur and will be refinanced by the firm at date 2.

## 4. THE EFFICIENCY OF DIFFERENT INSTITUTIONS

Our basic result is that, if an R&D project is financed internally by a large corporation or financed by the government in a centralized economy, all high-cost projects will be refinanced ex post. For any project proposed randomly from the project pool, there is a probability $(1 - \lambda)$ that a project is a low-cost one with an expected return $\hat{V}$ and a probability of $\lambda$ that a project is a high-cost one with an expected return $V$. Therefore, the expected profit of internal or government financing is

$$\pi^i = -I_1 + (1 - \lambda)(\hat{V} - I_2) + \lambda(V - I_2 - I_3).$$

However, if a project is cofinanced externally by two firms, high-cost types of projects may be liquidated by investors at date 2 with probability $p$. The positive probability of liquidating a high-cost project is a threat to the entrepreneur who has worked on this project. Anticipating this, high-cost projects may be dropped by entrepreneurs at date 1 with a probability of $(1 - q)$ and, even if an entrepreneur continues the project with probability $q$, it still may be liquidated at date 2 with probability $p$. Therefore, a high-cost project has a probability $q(1 - p)$ of being refinanced by one of the coinvestors at date 2. Comparing this situation to internal financing in which a high-cost project will be refinanced for certain, the budget constraint is hard when a project is cofinanced externally.

If a high-cost project is refinanced externally, there will be only one investor in the refinancing stage. The refinancing investor will gain all the benefits of the project. Then, we can calculate the expected profit of external financing as follows:[8]

[8] In most of our analysis, we assume that in the case of external financing the investing firms (investors) must share the returns of low-cost project with the entrepreneur but not the high-cost project because, in the latter case, the original firm would be reorganized and there would be only one investor. This assumption is quite realistic but we point out that this is not a theoretically critical assumption in our model (see Huang and Xu, 1997).

$$\pi^o = -I_1 + (1-\lambda)\left(\frac{2}{3}\hat{V} - I_2\right) + \lambda[(1-p)q(V - I_2 - I_3) - pqI_2].$$

With options of financing a project internally or externally, a large firm's R&D financing strategy and efficiency are affected by the uncertainty of the project type, λ, and the degree of hardness of budget constraints in the case of external cofinancing. The latter is related to the probability that a high-cost project will be liquidated at date 2, *p*, and to the probability that an entrepreneur will terminate a high-cost project at date 1, $(1 - q)$. Notice that the difference between the profit from internal financing and the profit from external cofinancing is

$$\pi^i - \pi^o = \frac{1}{3}(1-\lambda)\hat{V} + \lambda[(1 - q + pq)(V - I_3) - (1-q)I_2]. \qquad (4)$$

From (4), if an entrepreneur never terminates a high-cost project at date 1, i.e., $q = 1$, internal financing will always be more efficient than external financing regardless of the uncertainty of the project type. An equivalent statement regarding centralized and decentralized economies is that, if an entrepreneur never terminates a high-cost project at date 1, i.e., $q = 1$, a centralized economy will always be more efficient than a decentralized one regardless of the uncertainty of the project type. After paying the second-period investment, it is always ex post efficient to refinance a high-cost project.

However, if entrepreneurs always terminate high-cost projects once they discover the type and the uncertainty of the project type is not very low, i.e., when λ is larger than a threshold level $\lambda^* = \hat{V}/[\hat{V} + 3(I_2 + I_3 - V)]$, external financing will be more efficient. Therefore,

$$\begin{cases} \pi^i > \pi^o, & \text{if } q = 1 \\ \pi^i < \pi^o, & \text{if } q = 0, \text{ and } \lambda > \lambda^*. \end{cases}$$

The above discussion provides an important insight. Given the asymmetric information developed in the first-period between the entrepreneur and the investor(s), a hard budget constraint is appropriate only if an entrepreneur terminates a high-cost project at date 1, i.e., if the cost of the second-period investment is saved. Similar to Aghion *et al.* (1992), we conclude that, once a high-cost project is already at date 2, liquidation is less efficient than reorganization. However, we show a result different from theirs; if liquidation can deter entrepreneurs from hiding private information, the institution that commits to liquidate high-cost projects is more efficient.

PROPOSITION 4. *Without the deterrence effect, liquidation alone is less efficient than reorganization. However, with deterrence effect, the institution that commits liquidation is more efficient.*

Given the above proposition, we might conjecture that, everything being equal, the harder the budget constraint, the more efficient external finance will be. Indeed, it is easy to check that, in our model, the higher the probability that an entrepreneur terminates a high-cost project at date 1, i.e., the smaller $q$, the more efficient is external financing relative to internal financing, i.e., the larger the difference between $\pi^i$ and $\pi^o$. That is,

$$\frac{\partial}{\partial q}\{\pi^i - \pi^o\} = \lambda[p(V - I_3) + (I_2 + I_3 - V)] > 0.$$

Thus, we have the following proposition to summarize the optimal strategies of a large firm for financing R&D projects with a given degree of uncertainty of project type and the corresponding hardness of budget constraints under external financing.

PROPOSITION 5. *When the uncertainty of the project type is significant, that is, for any* $\lambda \in (\lambda^*, 1)$, *where* $\lambda^* = \hat{V}/[\hat{V} + 3(I_2 + I_3 - V)] \in (0, 1)$, *there exists a critical degree of hardness of the budget constraint for external financing measured by the probability that the entrepreneur terminates a high-cost project at date* 1, $q_\lambda = [I_2 + I_3 - V - [(1 - \lambda)/\lambda]\,\hat{V}]/[I_2 + I_3 - V + p(V - I_3)] \in (0, 1)$, *such that,*

(*i*) *if budget constraint is not hard enough, that is,* $q > q_\lambda$, *internal financing is more efficient, while*
(*ii*) *if budget constraint is hard enough, that is,* $q < q_\lambda$, *external financing dominates.*

Moreover, it is intuitive that if there is no uncertainty concerning project type; that is, if all the projects are low-cost ones, internal financing will be more efficient. However, if almost all the projects are high-cost ones, and as long as entrepreneurs have a not-too-low probability to terminate a high-cost project at date 1, external financing will be more efficient. Specifically,

$$\begin{cases} \pi^i > \pi^o, & \text{if } \lambda = 0 \\ \pi^i < \pi^o, & \text{if } \lambda \to 1 \text{ and } q < q^*, \end{cases}$$

where $q^* = [I_2 + I_3 - V]/[I_2 + I_3 - V + p(V - I_3)] \in (q_\lambda, 1)$. Furthermore, if the budget constraint is reasonably hard, that is, when $q < q^*$, the advantage of external financing over internal financing will increase when the uncertainty of the project type increases. Specifically,

$$\frac{\partial}{\partial \lambda}\{\pi^i - \pi^o\} < 0, \qquad \text{if } q < q^*.$$

Therefore, as long as the probability that entrepreneurs will terminate high-cost projects at date 1 is not too low, the efficiency of external financing over internal financing will increase with the uncertainty of the project type. Therefore, we have the following optimal strategies of R&D project financing for a firm facing different degrees of uncertainty.

PROPOSITION 6. *If the probability that an entrepreneur tries to hide the information of a high-cost type project is not too high, that is, for any* $q \in (0, q^*)$, *where* $q^* = [I_2 + I_3 - V]/[I_2 + I_3 - V + p(V - I_3)]$, *there is a critical level of uncertainty of the projects,* $\lambda_q = \hat{V}/\{\hat{V} + 3[(1 - q)(I_2 + I_3 - V) - pq(V - I_3)]\} \in (\lambda^*, 1)$, *such that*

(*i*) *if uncertainty is low, that is,* $\lambda < \lambda_q$, *internal financing is more efficient than the external cofinancing; while*

(*ii*) *if uncertainty is high, that is,* $\lambda > \lambda_q$, *external financing dominates.*

The above two propositions characterize large firms' strategies for financing different types of R&D projects. The best strategy for financing projects with high uncertainty may be external cofinancing as long as the two investing firms are different. In reality, most high-technological R&D projects, such as those in computer, software, and biotechnology areas, are indeed characterized by high uncertainty. Moreover, large proportions of the assets in these projects are usually specific, e.g., project-specific biological or chemical solutions may account for a large part of the assets in a particular biotechnology company, so that these solutions may be useless for other companies. Consequently, the values of the assets may differ significantly for different ways of reorganizing or liquidation.

When the conflict of interest between the potential investing firms is reasonably small, e.g., the potential investing firms are alike or the project is similar enough to potential investing firms that they may not have much disagreement in a reorganization approach when a liquidation or reorganization decision is to be made, the probability of liquidating a high-cost project at date 2 will be very low. In this case, there will be more cost and less benefit associated with cofinancing a project than internal financing. Thus, it is better under these conditions for a large firm to finance R&D projects internally even in the presence of high uncertainty of project type.

These results have important implications for centralized economies. In those industries, such as machine building, chemical, steel, and other heavy industries, for which R&D projects are less uncertain, the optimal financing strategy for a large corporation in a decentralized economy is to finance the projects internally. Because in a centralized economy R&D projects are always financed internally, our model predicts that there is no difference in efficiency between a decentralized economy and a centralized economy. In reality, centralized economies did not perform worse than decentralized economies in R&D in heavy industries. In particular, some of them, such as the former Soviet Union and China, have achieved outstanding performance in R&D projects in space and nuclear industries.[9]

In high-technological industries, such as computer, electronics, and biotech, where R&D projects can be very uncertain,[10] the optimal strategy for a large corporation in a decentralized economy is to cofinance the projects externally. However, with no other investors in a centralized economy, the option of cofinancing a project externally is not available. This implies significant inefficiencies in R&D projects in these areas due to the lack of an ex post screening mechanism in a centralized economy. In fact, the most striking examples supporting our implication are the unsuccessfully attempts by the Soviet government to catch up with the West in computers and electronics given their strategic and military importance.

## 5. CONCLUDING REMARKS

This paper attempts to develop a new foundation for the concept of the soft budget constraint coined by Kornai and to extend the analysis of soft budget constraints in market economies. A basic puzzle in a market economy is how small firms with binding financial constraints can do better than large firms that have less binding financial constraints in their R&D. An answer to this question is important to our understanding of the paradoxical phenomena that centralized economies can compete and even outperform decentralized economies in R&D projects having low uncertainty, such as those in heavy industry, but fail to catch up with the latter in R&D projects having high uncertainty, such as those in high-technological industries.

The essence of our theory is that soft budget constraint is the key to explaining these puzzles. While external cofinancing serves as a commitment device to harden budget constraints, such a device does not exist either for a monopoly state bank in a centralized system or for internal financing by large corporations in decentralized economies. The basic intuition is the following. We argue that good things do not always go together; the attractive features of a large company (or the state bank), i.e., no binding financial constraints in R&D and no serious conflict of interest in financial decisions, are precisely the reasons that prevent large companies from committing to efficient ex post selection of projects. Indeed, large corporations have a ten-

[9] The scientific principles in space technology and nuclear technology were well-developed before those applications. Thus, the uncertainties involved were reduced greatly.

[10] Most basic scientific principles of computers and integrated circuits were developed in parallel to the R&D projects in those fields. This makes the uncertainty of those projects very high.

dency to maintain the stability of their R&D organizations. Moreover, R&D budgeting is not usually based on individual projects; rather companies smooth revenue across projects (Mansfield, 1968, p. 62, and Reeves, 1958). The lack of an effective ex post screening mechanism in large corporations makes them tend to choose safer innovative projects through purchasing or self developing. This explains why large companies devote more attention to perfection related or cost reduction related innovation but less to new product related innovation (Scherer, 1991, 1992). It also explains why corporate executives tend to restrict their R&D activities in less uncertain and less novel projects (Jewkes *et al.*, 1969; Nelson *et al.*, 1967).

Our results have important implications for government-run venture capital institutions in a market economy and for restructuring the financial sector and the enterprises in transition economies. To preserve the commitment device of a decentralized system, these government-run institutions should not sponsor R&D projects alone. On restructuring the financial sector and the enterprises in transition economies, hardening budget constraints in the state sector is critical. The key question is how to harden the budget constraint in these economies. Our theory suggests that budget constraints for highly uncertain projects can be hardened only when they are cofinanced by two or more independent investors. However, this requires many independent investors in the economy. Thus, the development of private banking, other financial institutions, and independent government funding agents appears a key.

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