Internal vs External Financing of R&D

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ABSTRACT. The empirical evidence suggests that while small firms in United States, United Kingdom and Canada rely on internal funds for financing R&D, similar firms in Japan, Germany and France have access to bank loans. In this paper, we analyze the financial decisions of small firms willing to invest in R&D. We find that their high ratio of intangible assets, along with the high risk nature of their investments, can explain their inability to raise debt in external capital markets. We also show that financing R&D with bank loans might be feasible, especially, if banks are willing to monitor the investment activities of their clients.

1. Introduction

For a long time economists have held the view that internal finance is the most important method available to small firms for funding their R&D. This is apparent in the methodology of early R&D models that assume that the rate of innovation depends on the availability of internal finance (e.g. Kamien and Schwartz (1978) and Spence (1979)). Developments in the economics of asymmetric information lent further support to the belief that liquidity constraints can limit the ability of small firms to invest in R&D. For example, Arrow (1962) was first to recognize that moral hazard, due to risk assessment problems, might prevent firms from accessing external financial markets to finance investments in inventive activities. Furthermore, the works of Leland and Pyle (1977) and Myers and Majluf (1984) suggest that high lemons' premia, because of the inability of investors to distinguish the quality of R&D projects, might also hinder the access of firms to equity markets. Moreover, projects that involve substantial investment in R&D lack tangible assets that can be used as collateral which, as demonstrated by Bester (1985), can mitigate incentive problems. Finally, another reason for the reliance of R&D firms on internal finance might be the cost of revealing the quality of their innovation to the market (Bhattacharya and Ritter, 1985).

The evidence, especially from small American manufacturing firms in high-tech industries that do not have access to the venture capital market, seems to be in accord with the theory.[1] For example, Hall (1992) finds that R&D intensive firms do not favor debt as a form of finance, Hao and Jaffe (1993) suggest that liquidity constraints affect R&D spending, Himmelberg and Petersen (1994) find a large, positive and statistically significant relationship between internal finance and R&D spending and Levenson and Willard (2000) find that liquidity constraints are tighter for smaller and younger firms. We should also mention the work of Levin et al. (1987) who argue that firms regard patents ineffective in protecting the returns of R&D investments which supports the Bhattacharya and Ritter (1985) hypothesis. In contrast, Hoshi et al. (1991) find that Japanese firms (including firms that belong to high-growth – high-tech industries) that have close ties with banks are able to obtain external finance.[2] The above evidence is consistent with the empirical results in Hall et al. (1998) suggesting that the stock of liquid assets causes R&D in United States but not in Japan. Their work also suggests that firms in United Kingdom and possibly Canada face the same constraints as those in the United States while firms in France and Germany operate in financial environments similar to the one in Japan.[3] The above observations raise the following question: can differences in financial institutions and corporate governance between

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countries account for differences in the ability of small manufacturing firms to finance innovative activities?

The purpose of this paper is twofold. Most of the theoretical results in the literature are direct applications of agency theory rather derivations from models of R&D.[4] Thus, our first goal is to present a simple model that captures these features that distinguish R&D from other types of investment. R&D projects are very risky and require a large investment in intangible assets that do not carry any liquidation value. Nevertheless, while the unavailability of collateral can account for the inability of American and British firms in high-tech industries to receive external finance, it does not explain why liquidity constraints are not equally important for Japanese, German and French firms that seem to have access to their banking system. Our second goal is to investigate whether our model can offer a potential explanation for the different financial arrangements that exist in these countries.

In the following section, we discuss issues related to our modelling choice. In Section 3, we present the model and derive the results. We conclude in the final section.

2. Theoretical issues

The model is an extension of the incomplete financing framework developed and analyzed in Aghion and Bolton (1992), Hart (1996), and Hart and Moore (1998). This environment provides a natural set-up for modelling the financial decisions of small R&D firms. Following Aghion and Tirole (1994),[5] we assume that the probability of success of the R&D project depends on the size of the firm's investment, therefore, in contrast to the rest of the incomplete financial contracts literature, is endogenous.[6] In addition, we distinguish between tangible (which, in case of bankruptcy, can be used as collateral) and intangible assets, and we assume that only the latter affect the return distribution of the project.[7] The last assumption intends to capture the high ratio of intangible to total assets that characterizes R&D investments.

On the financial side, the type of contract lenders offer is debt.[8] Their ability to renegotiate the contract will, crucially, affect the funding of the project. According to Hall et al. (1998), a key difference between Japan and the United States is that in the former, even if there are a large number of creditors, the management of loans is usually delegated to a single bank. Moreover, Hoshi et al. (1991) contrasting Japanese firms affiliated with big industrial groups with unaffiliated firms observe that the latter tend to spread their borrowing around a pattern similar to that of United States corporations which depend on the bond market. As Gorton and Kahn (2000) argue, a distinguishing feature of bank loans relative to bonds is that the former are usually held by a single creditor. Therefore, banks have more bargaining power, relative to bondholders when they renegotiate the terms of a loan.[9] In most of the incomplete contacting literature[10] it is assumed that the borrower has all the bargaining power when a contract is renegotiated. A notable exception is the paper by Bolton and Scharfstein (1990) where the authors argue that for firms requiring capital to finance R&D it is more appropriate to assume that the investor has the bargaining power. In this paper, we analyze both cases. We find that when the lenders have the bargaining power (bank lending), liquidity constraints might not prevent firms from financing R&D. On the contrary, when the borrowers have the bargaining power (bond market), liquidity shortage will cause underinvestment in R&D. The above predictions seem to be supported by the empirical evidence from American and Japanese firms.[11]

Hoshi et al. (1991) and Hall et al. (1998) further suggest that the delegation of loan management to a single bank gives also incentives to the latter to monitor the investment activities of their clients. In our model, when the lender has the bargaining power, such a monitoring role can be important in preventing the investor to divert the funds away from their intended purpose.

3. The model

There are three dates. At date 0, a risk-neutral firm needs to raise funds for a research project. The project requires the use of a tangible asset of value K. An additional investment, E, is needed to carry out the research. If the project is successful, at each of the following two dates (1 and 2) will yield an unverifiable monetary return, x, otherwise, the return each period will be 0. The

probability of success of the project, $p(E)$, is increasing and strictly concave in the investment in intangible assets, E. We further assume that $p(0) = 0$ and $\lim_{E\to\infty} p(E) = 1$; i.e. the tangible asset is necessary for research, however, it is of no use without any additional investment and, in addition, the project's success can not be guaranteed for any finite investment. At date 1, the tangible asset can be liquidated and its liquidation value, L, satisfies the following constraint:

$$L < \min(k, x). \tag{1}$$

Notice that $L < x$ implies that liquidation is inefficient when the project is successful. At date 2, the asset has zero liquidation value.

If the firm is not financially constrained, it will choose the first best level of investment, E^*, defined as:[12]

$$E^* \equiv \arg\max_{E\in R^+}\{2p(E)x + (1 - p(E))L - E - K\}. \tag{2}$$

The F.O.C. implies that:

$$(2x - L)p'(E^*) = 1. \tag{3}$$

At the optimum, we assume that expected profits, given by the expression in brackets in (2), are positive.

3.1. *External finance*

Suppose that the firm is financially constrained. We would like to know how the terms of financing vary with the firm's initial wealth, W; thus, we assume that $W \in [0, K]$, and derive the optimal contract for any initial wealth in this interval. Potentially the firm can get the funds from a risk-neutral investor.[13] Because the monetary returns, x, are non-verifiable the financial contract will be incomplete.[14] Any repayment cannot be made contingent on the success of the project. Throughout the paper, we assume that all transfers of funds between the two parties are contractible; i.e. amount borrowed, repayment, R, liquidation proceeds, and wealth participation, $W_p \leq W$. In this subsection, we also assume that the use of funds is verifiable. The distinction between transfer and use of fund is important. While the size of the loan can be included in the contract, it might not be possible for the investor to verify that the funds were used for their intended purpose. In the following subsection, we will examine the case where the investor cannot verify that E was spent on research.[15]

The solution for the optimal contract will depend on the bargaining power of the two parties in their *ex ante* negotiations at date 0 and in any *ex post* renegotiation at date 1. We assume, along with the rest of the literature, that the firm has all the bargaining power at date 0 which captures the highly competitive nature of financial markets. In contrast, because the bargaining power at date 1 will depend on institutional characteristics (i.e. the number of creditors and their ability to delegate) which are important for our study, we will analyze the case where the firm has all the bargaining power separately from the one where the investor does.

We begin the analysis of the optimal contract at date 2. We observe that at the last date the firm will not make any payment to the investor because the project is finished and the assets are worthless. Because the return of the project is nonverifiable the firm will default. On the contrary, it is possible to get the firm to make a payment at date 1 by transferring the project's control rights to the investor when the firm defaults. At this time, the project (if successful) is still valuable to the firm.

We consider the following contract. At date 0, the firm borrows $K + E - W_p$ and promises to repay R at date 1. If the firm makes the payment it keeps control of the project. If the firm defaults then the investor has the right to liquidate the assets. However, it is still possible that the two parties might choose to renegotiate. The outcome of the renegotiation will depend on the bargaining power of the two parties.

3.1.1. *Firm (bonds)*

As Gorton and Kahn (2000) argue bonds are held by dispersed creditors who lack any bargaining power. In United States, while most corporations have access to the bond market, small R&D firms rely more on internal finance for funding their investments. We will demonstrate that what prevents them from raising funds by issuing bonds is their lack of tangible assets.

When the firm has all the bargaining power, the maximum payment that the investor can receive at date 1 is L. If the contract specifies a higher repay-

ment ($R > L$) and the project is successful, the firm will default and in the ensuing renegotiation it will force the payment down to L. Therefore, at date 0, the investor will never lend more than L. Because $L < K$, financing is not feasible when the firm's wealth is too low. We begin our analysis by finding the minimum level of wealth, $\underline{W}_f$, that is necessary for the project to go ahead. Let E_f denote the level of investment in intangible assets when the firm has all the bargaining power. When the amount borrowed is set equal to L, $\underline{W}_f$ must satisfy:

$$\underline{W}_f = K + \underline{E}_f - L \tag{4}$$

where $\underline{E}_f$ denotes the minimum level of investment that is necessary for the project to break-even. In addition to (4), $\underline{E}_f$ and $\underline{W}_f$ must also satisfy:

$$p(\underline{E}_f)\,(2x - L) - \underline{W}_f = 0 \tag{5}$$

i.e. the firm breaks-even given that the investor's participation constraint is satisfied. The payment, R, is set equal to L, because if $R < L$, the investor will not provide the funds. In summary, if $W < \underline{W}_f$, then $E_f = 0$ and the project will not be financed. Our next step, is to find the optimal level of investment when $W > \underline{W}_f$. The following optimization problem gives the solution:

Problem 1:

$$\max_{R,E,W_p} p(E)\,(2x - R) - W_p \tag{6}$$

subject to:

$$p(E)R + (1 - p(E))L - K - E + W_p \tag{7}$$

$$L - R \geq 0 \tag{8}$$

$$\mathrm{W} - W_p \geq 0 \tag{9}$$

where: (6) represents the firm's expected profit, (7) is the investor's participation constraint, (8) and (9) show the renegotiation and wealth participation constraint, respectively. Let λ_1, λ_2, and λ_3 denote the multipliers associated with constraints (7), (8), and (9), correspondingly. The F.O.C.s of problem 1 are:

$$-p(E) + \lambda_1 p(E) - \lambda_2 = 0 \tag{10}$$

$$p'(E)(2x - R) + \lambda_1(p'(E)(R - L) - 1) = 0 \tag{11}$$

$$-1 + \lambda_1 + \lambda_3 = 0. \tag{12}$$

We need to consider two cases:

Case 1: $\lambda_1 > 0$, $\lambda_2 > 0$, $\lambda_3 > 0$.

This solution corresponds to medium wealth levels, i.e. $\underline{W}_f < W < K + E^* - L$. The contract sets $L = R$, so that the investor's participation constraint is binding. In addition, the firm chooses $W_p = W$. However, because the total funds are not sufficient, the first-best level of investment is not attained, i.e. $\underline{E}_f < E_f < E^*$.

Case 2: $\lambda_1 = 1$, $\lambda_2 = 0$, $\lambda_3 = 0$.

In this case, $W \geq K + E^* - L$. When $\lambda_1 = 1$, (11) requires that:

$$p'(E_f)\,(2x - L) = 1. \tag{13}$$

As a consequence, $E_f = E^*$, i.e. the first-best level of investment is attained.

The following proposition summarizes the above results:

Proposition 1. *Suppose that the firm has all the bargaining power in any ex post renegotiation, then*:

(*a*) *if* $W < \underline{W}_f$ *then* $E_f = 0$ *and* $W_p = 0$,
(*b*) if $\underline{W}_f \leq W < K + E^* - L$ *then* $\underline{E}_f \leq E_f < E^*$ *and* $W_p = W$, *and*
(*c*) *if* $K + E^* - L \leq W$ *then* $E_f = E^*$ *and* $W_p \leq W$.

For low levels of wealth we have an underinvestment result. In fact, the problem of underinvestment when the firm has the bargaining power is severe. This is not surprising given the similarities of the model with the "hold-up problem" literature (e.g. Grout (1984)). The maximum amount that the investor is willing to lend is equal to the liquidation value of the project. This is because payoffs are nonverifiable and the investor has no control over the date 2 payoff. Therefore, any investment in intangible assets is financed by the firm. As in Shleifer and Vishny (1992), it is the illiquidity of assets that limits the level of debt that the firm can raise.

3.1.2. *Investor (banks)*

One advantage of banks over bondholders is that they have sufficient bargaining power to renegotiate (Gorton and Kahn (2000)). In our model, this power allows them to extract a higher repayment at date 1 and, consequently, are willing to lend more at date 2. The analysis is very similar to the one where the firm has the bargaining power and

to avoid repetition we will only demonstrate that, as long as the payoffs are sufficiently high, the first-best level of investment can be achieved even if the firm's initial wealth is zero.

In this case, the repayment, R, cannot exceed x. If $x > R$ the firm will default at date 1 even if the project is successful. Loosing control of the project means that the firm gives up the date 2 payoff. Therefore, if $R > x$ the firm rationally defaults. However, because $L < x$, renegotiation will take place setting $R = x$. As a result, when the project is successful, as long as $R < x$ the firm will never default.[16]

Then, a sufficient condition for the first-best level of investment to be achieved is that $x > K + E^*$. In this case, even if initial wealth is equal to zero, the ability of the investor to extract a large repayment at date 1, implies that the size of the loan is sufficiently high so that there is no underinvestment. It is also interesting to note that, because $x > L$, the minimum level of wealth needed for the project to go ahead is less than the one where the firm has the bargaining power. Therefore, because of the ability of banks to renegotiate loans, liquidity constraints do not necessarily prevent firms from investing in R&D.

3.2. *Monitoring*

An additional advantage that banks have over bondholders is their ability to monitor their client activities. In contrast, bondholders' incentives to monitor, because of the free-rider problem, are low. In this section, we assume that E is non-contractible. However, the investor by monitoring the firm can verify that the latter does not misuse the funds intended to be spent on intangibles.

Without monitoring the contract has to be designed in a way that offers the firm the incentive to use the funds for their intended purpose. When the firm has the bargaining power we know that the maximum amount that the investor will lend is $L < K$ and, consequently, the repayment of the loan does not depend on the investor's ability to verify the investment in intangible assets. Therefore, when the firm has the bargaining power there is no need for the investor to monitor.

Now, consider the case when the investor has the bargaining power. Also, for simplicity, consider the case when the firm's initial wealth is zero. Because E is non-contractible, we need to make sure that the firm's expected payoff is higher than E. Put differently, the contract must offer the incentive to the firm to invest in R&D rather than misusing the funds. Then, we need to add the following incentive compatibility constraint:

$$p(E)\ (2x - R) \geq E.$$

It is clear, that if the additional constraint binds then there will be underinvestment in R&D.

Therefore, in our model there are strong incentives for banks, but not for bondholders, to monitor their clients. The reason is that the bondholders' investment is relatively low and it is protected by the liquidation value of the project.

4. Conclusion

The empirical evidence suggests that many small firms in United States, United Kingdom and to a lesser extent Canada do not have access to external capital markets and rely on internal finance for funding R&D. In contrast, small firms in Germany, France and especially Japan get the funds from banks which, in the cae of Japan, they also monitor the investment activities of their clients. In this paper, we have presented a simple extention of the incomplete financial contracting framework that allowed us to examine the financial decisions of small R&D firms. The results suggest that the above differences can be accounted by the ability of banks to renegotiate the terms of loan contracts. In addition, we have argued that, because R&D requires investment in intangible assets, banks have strong incentives to monitor the use of the funds.

We have made no attempt to account for the coexistence of different institutional arrangements. A possible interesting extension of the model would be to integrate it with that of Aghion and Tirole (1994) who examine the organization of R&D activity in an incomplete contracting framework. Potentially, this line of research could help us to understand a) the interaction of managerial and financial decisions of firms investing in R&D, and b) the role of financial institutions in promoting technological innovation.

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Notes

[1] Venture capital finance is only available to new small pure reseach firms, however, it is expensive (Sahlman (1990)). Despite its relative growth during the mid-1990s, the venture capital industry committed only $6.2 billion of new funds in comparison with $184 billion spent in R&D in 1996 (Berlin (1998)).

[2] These are firms affiliated with industrial groups (known as *keiretsu*) that provide most of their financing and monitor their activities.

[3] Winker (1999) finds that small firms in Germany face tight financial constraints.

[4] Of course, the exceptions are the models by Kamien and Schwartz (1978) and Spence (1979). However, these models assume that R&D is financed internally rather than providing an explanation for the inability of firms to access external markets.

[5] Aghion and Tirole (1994) use the incomplete contracting framework to investigate how the allocation of property rights affects both the intensity and the size of innovations.

[6] As a consequence, in our model, the size of the investment is also endogenous.

[7] Acs and Isberg (1996) analyze the role of asset specificity for a firm's financial structure following the transactions cost approach.

[8] Hart and Moore (1998) have proved that, in a simmilar setting, debt is optimal.

[9] See Dianond (1991) for a model where bonds and bank loans coexist.

[10] See for example, Aghion and Bolton (1992), Gertner, Scharfstein, and Stein (1994), Hart (1996), and Hart and Moore (1998).

[11] In the present paper, we are interested to understand how different institutional arrangements affect the financing of R&D. See the concluding comments in Hoshi, Kashyap, and Scharfstein (1991) for some speculation on the origin of these arrangements.

[12] For simplicity, we assume no discounting and that the interest rate is zero.

[13] Irrespective of the number of creditors, we will refer to them as the "investor".

[14] In our model, the payoffs of both periods depend on the success of the innovation process. Therefore, it is natural to assume that they are positively correlated. However, perfect correlation creates a problem because any payment made in the first period signals that the second period return is positive. We can avoid this difficulty by letting the two returns be highly, but not perfectly, correlated. Then the firm can always claim that the second period payoff is equal to zero. For a similar point see footnote 9, page 103 in Hart (1996).

[15] Of course, there is no such concern for the amount K spent on the tangible asset.

[16] The only change that we need to make in problem 1 in order to examine the case where the investor has the bargaining power is to replace the renegotiation constraint (8) with:

$$x - R \geq 0.$$

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