Which Firms Can Get External Financing on Research and Development

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Abstract

This paper shows that firms with high initial capital and promising Research and Development (R&D) projects have a good probability to be financed by external funds. However, the financing decision made by outside investors might be hampered by the hidden information of R&D project’s quality. Monitoring is one way to attack this problem. By incorporating monitoring as a choice variable to outside investors, the model reveals the willingness to lend given that investors are equipped with certain degree of knowledge about the project’s quality. The optimal level of monitoring varies in responding to not only the amount borrowers invest in but also the completeness and accuracy of the information they have acquired.

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1 Introduction

Many studies on financing Research and Development point out at the very beginning of their reports that R&D activities are funded by internal finance rather than external finance. They make such theoretical predictions because of the spillover effects of knowledge and asymmetric information between inventors and investors. Spillover effect is first articulated by Arrow (1962), arguing that knowledge being non-rival reduces the return to the invention, and therefore such firms will be reluctant to invest, leading to the under-provision of R&D investment. As for the second reason, Myers and Majluf (1984) suggested that the inability of lenders to distinguish the quality of R&D projects, might also hinder the access of firms to equity markets. However, there are counter arguments against the internal only view. Levin et al. (1987) found that imitating a new technology could cost as much as 75% of the cost of the original invention. Hoshi et al. (1991) showed that in certain financial environments, such as firms with close ties with banks are able to obtain external finance. These arguments mitigate but not eliminate the superior position of internal finance. When it comes to empirical works, evidence suggested different results in the case of firms’ size, which countries or industries firms are in. For example, the work of Himmelberg and Petersen (1994) showed that small firms in the US high-tech industries rely on internal finance for funding R&D. In contrast, Hoshi et al. (1991) and Harhoff (1999) found that small firms in Germany and especially Japan get the funds from banks. Ballesteros and Rico (2001) found in Spain large firms’ R&D projects were cooperatively funded by public. Although past
literature favors the internal financing of R&D, the above observations raise the following question: what kinds of firms could get access to external finance? how can we extend the basic R&D models to account for the impacts by different countries, industries and firm size? Bougheas (2004) studied the case of different countries; he showed that financing R&D with bank loans might be feasible if banks are willing to monitor the investment activities of the borrowers, which is exactly what happened in Japan. In addition to account for monitoring issues differing across countries, in this model, I use variance of prior estimator on R&D return to represent the risk embedded in different industries, and initial assets firm have to proxy the size.

I begin this paper by describing several most important features of R&D projects. Then I summarize the theoretical issues related to the model set up. In the following up section, the model is presented and important properties are draw. Then, the paper discusses the intuition how the model results can offer potential explanation for the different country-wide financial arrangements, technology sensitiveness discrepancies in industries and variety in firm size.

## 2 R&D as Investment

From the viewpoints of investors, R&D project has several key characteristics that make it different from other tools of investment.

First and most importantly, in practice 50% or more of R&D spending is the wages and salaries of highly educated scientists and engineers. Their efforts
create an intangible asset, the firm’s knowledge base, from which profits in future years will be generated. The value of the project is embedded in the human capital of the firm’s employees, and is therefore lost if they leave or are fired. However, research activities are hard to evaluate in some sense. The researchers will exert full efforts on the R&D projects only if they are properly compensated. This fact has an important implication for the conduct of R&D investment. Investors tend to transfer part of their profits to the firm’s research group over time, in order to avoid shirking among knowledge workers. The inspiration scheme for researchers and the importance of intangible asset inputs are, thus, essential to study the financing of R&D projects.

A second important feature of R&D investment is the degree of uncertainty associated with its output. This uncertainty tends to be greatest at the beginning of a research program or project, which implies that an optimal R&D strategy should have an exit-option character and should not really be analyzed in a completely static framework. R&D projects with small probabilities of great success in the future may be worth continuing even if they do not pass an expected rate of return evaluation. In this paper, the uncertainty is modeled as a simple well-specified normal distribution with a mean and variance; there is only a tiny probability that the return of the R&D project goes extreme.
3 Modeling Choice

This model is an extension of the corporate debt model in the framework of updating normal distributed information. Following Aghion and Tirole (1994), I assume that the probability of success of the R&D project depends on the size of the firm’s investment. However, instead of thinking a continuous investment size to choose for investors, the model introduces two types of investment, low type representing internal finance (investors choose not to invest) and high type representing external finance (investors choose to invest). Therefore, the investment size is exogenous like what they always did in the incomplete financial contracts literature. In addition, like Bougheas (2004), I distinguish between tangible (which can be liquidated and used as collateral in case of bankruptcy) and intangible assets, and I also assume that only the latter affect the return distribution of the project. This assumption intends to capture the high ratio of intangible to total assets that characterizes R&D investments. As I said in the beginning of the paragraph, the type of contract lenders offer is debt on the financial side of the model. The investors’ prior estimate of R&D return and incoming signals about the return will, crucially, affect the funding of the project. In countries where the management of loans is usually delegated to a single investor, say, a bank even if there are a large number of creditors (Hall et al., 1998), this investor has more incentive to monitor the process of R&D projects, accordingly a lower monitoring cost in the model. Investors could liquidate the tangible assets of the firm before the R&D project ends as a compensation to their investment of intangible assets. This option adds value to
the R&D projects, hence increases the probability of external financing.

4 The Model

4.1 Model Setup and Timing

The R&D investment matures during three periods; the model does not consider time discount factors.

1. At date 0, a risk neutral firm needs to raise funds for a research project. It has initial wealth $A$ that can be invested in the project. The project itself requires the use of tangible asset of value $K$ and intangible research efforts of value $E$. By assuming $A > K$, we convey the idea that firm can carry on the project by internal financing with research effort $E_{\text{internal}} = A - K$ or it can use the help of external finance to achieve a bigger $E > E_{\text{internal}}$. Basically, $E$ can take two values: the low value, $E_{\text{internal}}$, (internal financing) or the high value, $E$ (external financing). I.e., investors can only invest in a R&D project with amount $E$ or simply do not invest. If the project is successful, at each of the following dates 1&2, it will yield a monetary return $x$ that is unverifiable to outside investors until date 2. If the project fails, the return each period will be 0. Investors hold only a prior distribution about the return$^3$, $x$ is normal with mean $x_0$ and variance $\frac{1}{\tau_0}$ ($\tau_0$ is the precision of the distribution). Investors, nevertheless,

$^3$the return, $x$, can be below zero with small probabilities since there exists the hazard of imitation.
can observe the fact that the project is success or not instantly at date 1.
The probability of success, \( p(E) \), is increasing and strictly concave in the
investment in intangible assets, \( E \). We further assume that \( p(0) = 0 \) and
\[
\lim_{E \to -\infty} p(E) = 1.
\] The tangible asset is necessary for research but it is of
no use without any intangible investment and, in addition, the project’s
success cannot be guaranteed for any finite investment. The research team
could divert some parts of the intangible assets, \( B \), to its private benefits
by shirking. We need \( B < (K + E) - A \) to clarify that firm intends to
divert money to themself from outside investors’ share of the investment.
Based on all these, investors decide to finance the firm’s R&D project with
amount \( E \) or not.

2. At date 1, given the investment size \( E \) or \( E_{\text{internal}} \), the first realization of
return \( x \) occurs. In the case of external financing, investors do not know
its true value, but they may acquire a private signal \( y \) about the realized
earning. The probability \( q \) that the investors acquire this signal depends
on the intensity with which they monitor the firm’s R&D project. The
disutility of monitoring is \( d(q) \), where \( d(\cdot) \) is a strictly increasing and
convex function. The signal is distributed normally with a mean equal to
the true value, \( x \), and a variance equal to \( \frac{1}{\tau_1} \).

3. At the very end of date 1 and before the beginning of date 2, if the investors
do acquire the signal, they update their estimate of the return to the R&D
project. \( x' = \frac{\tau_0 x + \tau_1 y}{\tau_0 + \tau_1} \) and \( \tau' = \tau_0 + \tau_1 \). Based on this posterior estimate,
the investors make the decision whether or not to liquidate the tangible
assets at the value of $L$, satisfying $L < \min (k + E - A, x_0)$. If the project is not successful at date 1, there is no value to liquidate. Notice that this implies that liquidation is inefficient when the project is successful in expectation and no liquidation value left when the project failed. Further, if the investors do not acquire the signal, they will rely solely on the prior estimate of $x$, we assume they do not liquidate in this case. At date 2, the asset has zero liquidation value.

4. At date 2, the second realization of return that is equal to the first one occurs if the project is successful at first place. Investors now observe the true value of $x$. Then investors decide how to divide the profits $2x$ to parts given to the firm, $R^I_f$ (where the upper script $I \in \{S, F\}$, $S$ and $F$ denotes the benefit that is given to firm’s research team if the project is successful and failed, respectively) and the rest, $2x - R^S_f$, kept as investment payoff to themselves.

### 4.2 Internal Finance

If the firm finance the R&D project by its own, then the expected payoff is:

$$R_{\text{internal}} = p(E_{\text{internal}})2x,$$

where $E_{\text{internal}} = A - K$. This is true if the following incentive constraint is satisfied:

$$p(E_{\text{internal}})2x \geq p(E_{\text{internal}} - B)2x + B.$$

Intuitively, the benefit from shirking should be low enough that firm chooses not to shirk when it runs the R&D project by its own money. And cost is sunk and does not appear in the payoff expression.
4.3 External Finance

If I use $R_f^t$ to denote the payoff to the firm by outside investors given that the project succeeds, $I = S$, or fails, $I = F$, I can write down the incentive constraint that investors keep in mind to prevent firm’s research team from shirking as the following:

$$p(E)R_f^S + (1 - p(E)) \times 0 \geq p(E - B)R_f^F + (1 - p(E - B)) \times 0 + B,$$

i.e., the expected benefits of working hard is greater or at least equal to the benefits of shirking. A sufficient condition for an optimal contract would be $R_f^F = 0$, thus this equation is reduced to:

$$(p(E) - p(E - B)) R_f^S \geq B \Rightarrow R_f^S \geq \frac{B}{(p(E) - p(E - B))}.$$ 

Firm will get at most $R_f^S (E, B) = \frac{B}{(p(E) - p(E - B))}$ when firm finance it own R&D project by outside funding. Note that $\frac{\partial R_f^S (E, B)}{\partial E} > 0$ but $\frac{\partial R_f^S (E, B)}{\partial B}$ is ambiguous for there are two effects when the private benefit is high, one makes shirking enjoyable for firm and another makes the probability of success under shirking low, not favorable to firms. In order to make the external financing attractive to firms, I assume that $\frac{B}{(p(E) - p(E - B))} > p(E_{\text{internal}})2x$. Therefore, external finance is welcomed by firms for the reason that outsider’s participation increases the odds to succeed, hence increases firm’s payoff, especially firms with low initial intangible assets $E_{\text{internal}}$. One problem is that the investors would be worried about the fact that firms with low initial assets prevail in the market. One can easily assume away this problem by making the required intangible assets $E$ big enough to induce high initial-asset firms to seek outside funding in the market. This ensures that the lemon market
problem does not occur here. However, it is the outside investors’ decision to invest or not. Basically, they are willing to lend money to firm’s R&D project if the net expected income they can earn is positive. I normalize the return of all the other financial market tools to be zero, the opportunity cost of investing in R&D is thus 0.

4.3.1 Liquidation Decision for Investors

At date 0, if they believe that they will acquire the signal \( y \), the investors form an expectation of their pledgeable income:

\[
p(E)2x' - p(E)R_j^S \Rightarrow p(E)2x' - p(E) \left( \frac{B}{p(E) - p(E - B)} \right).
\]

The risk neutral investors would liquidate the project if this pledgeable income is smaller than the liquidation value \( L \), equivalently, if the updated estimate of return, \( x' \), satisfies the following condition

\[
p(E)2x' - p(E) \left( \frac{B}{p(E) - p(E - B)} \right) \leq L
\]

\[
\Rightarrow x' \leq \frac{1}{2} \left( \frac{L}{p(E)} + \frac{B}{(p(E) - p(E - B))} \right) \equiv \hat{x} \leq x_0.
\]

The latter inequality, \( \hat{x} \leq x_0 \), is satisfied because I assume that if the investors do not observe the signal, then based on the prior, they will not get their money out of the project.

**Proposition 1** The lower bound for the investors to continue a R&D project is decreasing with the intangible assets \( E \). Firms that can get outside funds (a higher \( E \)) have a lower probability of R&D program being suspended than their counterparts who financed R&D projects by their own.
4.3.2 Updating Beliefs

When the signal is obtained by the investors, the posterior estimates are $x' = \frac{\tau_0 x_0 + \tau_1 y}{\tau_0 + \tau_1}$ and $\tau' = \tau_0 + \tau_1$. Now, the investors have a more precise estimate of the return of the R&D project than they would have before the signal arrived. That is, $\tau' > \tau_0$, there is less uncertainty about the return of the R&D project.

The distribution of the signal $y$ given the true value of the return, $x$, is normal with mean $x$ and variance $\frac{1}{\tau_1}$. Further, the distribution of $y$ given the prior estimate, $x_0$, is normal with mean $x_0$ and variance $\frac{1}{\tau_1} + \frac{1}{\tau_0} \equiv \frac{1}{\nu}$. By learning this, I can restate the liquidation condition above as

$$\frac{\tau_0 x_0 + \tau_1 y}{\tau_0 + \tau_1} \leq \hat{x} \Rightarrow y \leq \frac{\tau_0}{\tau_1} (\hat{x} - x_0) + \hat{x} \equiv \hat{y}.$$ 

On the opposite, the probability that the investors continue the project given they evaluate is $prob (x' > \hat{x}) = prob (y \geq \hat{y})$. Since we know that $y|x_0 \sim N (x_0, \frac{1}{\nu})$ and $f (y|x_0) = \sqrt{\frac{\nu}{2\pi}} e^{-(V/2)\left(y-x_0\right)^2}$, the probability can be written as $\Phi \left( -\left(\frac{\tau_0}{\tau_1} + 1\right) (\hat{x} - x_0) \sqrt{V} \right)$. For notation simplicity, it is denoted as $\Phi$, and correspondingly, $\phi \left( \left(\frac{\tau_0}{\tau_1} + 1\right) (\hat{x} - x_0) \sqrt{V} \right)$ is denoted as $\phi$, where $\Phi (\cdot)$ is the distribution of a standard normal random variable, and $\phi (\cdot)$ is its corresponding density function.

4.3.3 Expected Pledgeable Income for Investors

At date 0, after the investors decide the amount to lend to the firm $E$ and the monitoring intensity $q$, the investors take the expectation (ex ante) of their profits in the end of the R&D project.
\[
I = \int_{-\infty}^{+\infty} \max \left\{ p(E) \left( \frac{2x_0 + \tau_1 y}{\tau_0 + \tau_1} - \frac{B}{(p(E) - p(E - B))} \right), L \right\} f(y|x_0) \, dy + \\
(1 - q) \left( 2x_0 - \frac{B}{(p(E) - p(E - B))} \right) - d(q).
\]

the return to investors if they acquire the signal

the return if do not acquire the signal

cost of signal

After manipulating with the integration, I show that \( I \) can be written as well as:

\[
q \left[ p(E) \left( 2x_0 - \frac{B}{(p(E) - p(E - B))} \right) \Phi + L (1 - \Phi) + \frac{\sqrt{V}}{\tau_0} \phi \right] + ...
\]

\[
... (1 - q) \left( 2x_0 - \frac{B}{(p(E) - p(E - B))} \right) - d(q).
\]

The R&D project is financed by external funds if and only if the above equation is greater or equal to the amount outside investors lend to the firm at date 0, \((K + E) - A\).

**Proposition 2** The project is more likely to get external finance if the firm has:

(i) A higher initial wealth, \( A \);

(ii) A promising R&D project with higher prior estimate of return, \( x_0 \) or higher precision \( \tau_0 \);

(iii) A lower monitoring cost function \( d(q) \).

Intuitively, investors will first consider to financing the R&D projects operated by large firms who boast of their high initial wealth. In practice, firm size sometimes can be interpreted as "cash" size. However, a small firm might as well get financed if the industry it belongs to has a good reputation of earning high returns on R&D projects. For example, Information Technology Industry
in the last decade shows how R&D can make millionaires while in other fields you may find out that it is difficult to persuade investors to risk their money.

Finally, those firms born in countries where monitoring R&D projects is a regulation or routine to bank representatives are also among the types that are highly possible to receive external financing.

4.3.4 Optimal Monitoring

Investors choose $q$ to maximize the expected pledgeable income $I$, i.e., $\max_{\{q\}} I$

The expression for $I$ is concave in $q$, so the first order condition is sufficient as well as necessary to provide us with global maximum.

The first order condition with respect to $q$ is

$$p(E) \left( 2x_0 - \frac{B}{(p(E) - p(E - B))} \right) \Phi + L (1 - \Phi) + ...$$

$$... \frac{\sqrt{V}}{\tau_0} \phi - p(E) \left( 2x_0 - \frac{B}{(p(E) - p(E - B))} \right) \Phi = d'(q)$$

$$\Rightarrow \frac{\sqrt{V}}{\tau_0} \phi + \left[ L - p(E) \left( 2x_0 - \frac{B}{(p(E) - p(E - B))} \right) \right] (1 - \Phi) = d'(q).$$

Define $q^*$ to be the solution to the above equation. To keep the analysis straightforward, I consider only interior solutions (i.e., $q^* \in (0, 1)$). Corner solutions are a relatively simple extension. Properties of $q^*$ are:

**Proposition 3** Given the investment amount, the intensity with which the investors monitor the firm’s research team, $q^*$, is:

(i) increasing with the private benefit from shirking, $B$, and the liquidation value, $L$;

(ii) decreasing with their prior estimate of the R&D project return $x_0$, and the
corresponding precision, \( \tau_0 \);

(iii) increasing with the precision of the signal, \( \tau_1 \).

Intuitively, first point, research team is less likely to work hard if they can get more private benefit from shirking, so the investors monitor more intense in this case. High liquidation value raises the value of the project; hence make it worthy of being monitored intensely. Secondly, the more valuable the investors believes the R&D project to be, the less valuable is option to liquidate, so the investors monitor less. Similarly, the option is less valuable when less uncertainty there is in its prior estimate. However, in the third point, the option to liquidate is more valuable the greater is the precision of the signal, the investors monitor more intensely when the signal is more informative.

5 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 case of Japan, they also monitor the investment activities of their clients. In this paper, we have presented a simple extension of corporate debt framework with incomplete information that allowed us to examine the financial decisions of outside funding providers. The results suggest that the above differences can be accounted by the cost of evaluating the true value of R&D project return. In
addition, we have argued that, because acquiring the signal is important to help making the liquidation decision, investors have strong incentives to monitor. The model has also made attempt to account for R&D project performance in different industries. In summary, large firms, firms belonging to traditional industries or bank-holding-share firms have a good chance of getting external finance. On the contrary, small, high-risk industry and independent firms will have to count on themselves.

A possible interesting extension of the model would be to let the investment amount be endogenous as that of Bougheas (2004) who examines the continuous investment size choice of R&D activity in an incomplete contracting framework. Potentially, this paper helps us to understand (i) the interaction of outside investors and firms in financial decisions on R&D investment, and (ii) the role of monitoring regulations in promoting technological innovation. Furthermore, patent can play a role in future studies as it always does in the area of technological breakthrough economics. Firm as a player in this model is more like a passive agent awaiting the judgment of outside investors. Models, in which firms can signal their R&D ability to investors would be interesting as well.

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