FINANCING R&D:

AN INFORMATIONAL ASYMMETRY APPROACH

by

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ABSTRACT

This paper will attempt to sketch an outline of Research and Development (R&D) characteristics and subsequent financing through a literature review. A substantial body of work already exist on the finance of R&D, but there is a need to characterize the state of knowledge on the subject. I will show that moral hazard and adverse selection, which are consistent hindrances to R&D expenditures, comes from informational asymmetry stemming from the uncertain nature of these innovations. I will show how these relate to the following different forms of finance: debt, internal and external equity, venture capital, employee stock options and trade credit.

INTRODUCTION

Research and Development (R&D) is usually a set of purposeful activities directed at making discoveries that are carried out by universities, corporations or government laboratories (see Barro and Sala-i-Martin, (2004)). R&D will traditionally take the form of an investment with an end goal of a technological improvement for profit or non-profit purposes. In multiple models of macroeconomic, R&D is an integral part of growth since it essentially embodies the process of innovation and the creation of value. This makes R&D a cornerstone of economic growth.

Finding the optimal institutional framework where R&D activities can thrive is of obvious significance. A large literature already exists on the optimal form of patent to maximize the social returns of R&D, which I will not look into. Instead, this paper focuses on the different ways of financing R&D. As it will be explained shortly, uncertainty and informational asymmetry are an integral part of R&D and forms of finance that can circumvent or mitigate this informational asymmetry are needed. I ask which of the following forms of finance, debt, internal equity, external equity, venture capital, employee stock option and trade credit, fits the R&D framework and is the most commonly used. I answer this question with a thorough literature review and combine all different forms of R&D finance which have traditionally been analyzed separately into one paper.

I contribute to this literature in three following ways. First, a modeling of manager's behavior under a promotion based reward system sheds some light as to the relative unsuccessfulness of corporate R&D relative to venture R&D. Second, I construct a general-limited partner model and prove that the contractual parameters of venture capital and it's early negative rates of returns can make the venture capitalist choose a number of projects to manage that is preferred by the external financiers. Third, I add an explanation of a financial nature to the literature for the use of ESO in R&D firms.

To the reader unfamiliar with the above categories of finance: debt financing is the loan from a lender to a borrower which is to be paid back in full (if possible) in addition to an extra payment generated by a predetermined interest rate. Internal equity is the financial slack of a corporation available for its immediate need while external equity is defined in the literature as the issuance of new shares to external investors. Venture capital is essentially the introduction of a third party between the external financier and the R&D firm to mitigate informational asymmetry and improve efficiency. Employee Stock Option (ESO) is the issuance of shares to employees as a form of wage. Trade credit is a form of finance where a supplier allows his client a delay in his payments of goods already purchased. An alternative way for a small R&D firm to get finance is by merging or being purchased by a larger firm but this is done so in order to tap into that firm's financial slack, which is just a special case of internal equity. Therefore, mergers and acquisitions will not be studied in this essay.

UNCERTAINTY AND INFORMATIONAL ASYMMETRY

Only with a thorough examination of the idiosyncratic aspects of R&D will we be able to understand what form of finance R&D firms use and for what reasons. The most important component of R&D for its financial structure is the implicit uncertainty of every new project. With no uncertainty, the R&D market as we know it would cease to exist. As Dasgupta and Stiglitz (1980) noted, in a patent system with free entry and no uncertainty, there would only be one firm engaged in research. Implied in the word uncertainty is the difficulty of computing a success probability. Indeed, the Financial Accounting Standards Board states that "the relationship between current research and development costs and the amount of resultant future benefits to an enterprise is so uncertain that capitalization of any research and development costs is not useful in assessing the earnings potential of the enterprise."[1] Kothrai, Laguerre and Leone (2002) find evidence strongly consistent with the hypothesis that R&D is much more uncertain than standard investment in properties, plants and equipments (PP&E). In fact, they compute a coefficient on R&D for explaining earnings variability of 0.067 while the coefficient for PP&E is only 0.021. "The lack of compelling evidence of future benefits to each firm"[2] is what makes some accountants expense R&D expenditures instead of capitalizing them. The recent unwillingness of both consumers and firms to answer survey questions about investments and the refusal of some governments of collecting adequate data can only thicken the veil of uncertainty regarding all form of industrial investments (see Griliches (1994)). Along the same lines, Levin, Klevorick, Nelson and Winter (1987) have also observed that firms do not feel fully protected by a patent and will often use secrecy concerning their R&D venture.

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[1] Financial Accounting Standards Board (1974), *Statement of Financial Accounting Standard No. 2*, paragraph 50
[2] Kothari, Laguerre and Leone (2002), p.358

Furthermore, "suppliers of capital often look to the achievement of definable milestones as a sign that some of the uncertainty has been resolved."[3] These milestones are almost non-existent for new R&D firms, which gives them little possibility to signal their credit worthiness to outside investors. We also know that the size of the firm can be a measure of equity risk (see Kothari, Shanken and Sloan (1995)). Indeed, "small firms are more likely to be singled-project or less diversified firms"[4]. Since new R&D firms tend to be small, this only makes future earnings for small and young firms even more uncertain.

Uncertainty can take on multiple forms, such as the competitor's response to the new product, the future pricing structure of the product, the potential market share that the R&D product will be able to capture and the size of that market. Uncertainty raises multiple questions which cannot be precisely answered since many different outcomes are possible. An attempt at transforming uncertainty into quantifiable risk can be made by assuming specific probability distribution for these outcomes (see Gompers and Lerner (2001)). While computing probabilities can be a tempting analytical method, these usually yield nothing more than subjective probabilities and can only 'structure' uncertainty and not reduce it[5]. Informational gaps between the two agents will arise because of the financier's possible lack of technical expertise and the R&D entrepreneur's daily contact with his specific market. Bridging these gaps might not be possible in an R&D context, since the information might be difficult to convey or because the R&D firm might not want to disclose private information that could potentially harm their fragile property rights.

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[3] Gompers and Lerner (2001), p.27

[4] Kothari, Laguerre and Leone (2002), p.362

[5] Sometimes, assuming a distribution for outcomes of R&D projects can be on based partially on objective probabilities and on subjective probabilities. Trying to quantify the odds of a new drug passing the first stages of government test can be a daunting task yielding only subjective probabilities, but it is know that a drug that has cleared the stage III of clinical trials has a 66% chance of obtaining approval. (see Gompers and Lerner (2001))

Consequently, this high level of uncertainty will create more informational asymmetry in R&D projects than in other, more certain, ventures. As it was noted by Aboody and Lev (2000), different contributing factors to the incertitude of future earnings can be categorized into three characteristics. First, many new R&D projects are simply unique. Most capital investments share common characteristics within an industry whereas a lot of R&D investments don't. This means external investors can derive little to no information regarding the firm's R&D by observing the value and productivity of rivals. Second, "there are no organized markets for R&D and hence no asset prices from which to derive information."[6] Compared to other commercial equipments and inputs which are traded and priced on a market, R&D projects do not yield information so easily through prices. Third, financial statements immediately expanse R&D investments, which gives no information on value or productivity to investors. Gompers (1995) and Gompers and Lerner (2001) add a fourth and fifth reasons for uncertain revenues: not only will R&D firms usually have very industry specific assets, which can potentially reduces revenues during liquidation, but these firms also possess a higher than average ratio of intangible assets to total asset than other sector, which further reduces potential revenues from liquidation. This level of informational asymmetry is indeed confirmed by the fact that investors demand more analyst coverage of R&D intensive firms (see Barth, Kasznik and McNichols (2001)).

The principal agent problem is another dynamic of R&D. The agency costs, defined as the monitoring expenditures by the principal, the bonding expenditures by the agent[7] and the residual loss (see Jensen and Meckling (1976)), will likely be very high in an innovation project due to its inherent riskiness, the many unforeseeable contingencies firms will face, the multiple

[6] Aboody and Lev (2000), p.2748

[7] Bonding costs occurs "in some situations, (where) it will pay the agent to expand resources (bonding costs) to guarantee that he will not take certain actions which would harm the principal". Jensens and Meckling (1976), p.308

stages of innovation required, its labor intensity and the difficulty of comparing it to other similar projects (see Holmstrom (1989)).

One of the traditional responses of the literature to the principal-agent problem is to write the 'optimal contract'. It is also widely known that, especially in the field of innovation, complete contracting is impossible to attain, and "once some aspects of performance are unverifiable, it is often optimal to leave other verifiable aspects of performance unspecified"[8] , which further exacerbates incomplete contracting. Since verifying performance and evaluating the worth of an R&D venture is so hard (some authors, like Zhang, Du and Tang (2006), have even suggested the introduction of random fuzzy theory in order to evaluate an R&D projects), incomplete contracting is inevitable in R&D. Therefore, not only is writing the 'optimal contract' not a solution to the principal-agent problem but using an incomplete contract to share the revenues of an R&D venture between a principal and an agent has also been shown by Tirole (1999) to create a welfare loss. Therefore, R&D firms will have to deal with these agency costs. This means every form of finance will have some form of agency costs. The question becomes what kind of financial structure will these technology driven firms use?

[8] Bernheim and Whinston (1998), p.902

DEBT

It is not unusual for start-up R&D firms, young R&D firms or R&D project managers to be overly optimistic about future revenues. It should be even expected of them: if the net present value of their project wasn't large and positive, why spend so much resources on it? On the other hand, financiers are usually deeply concerned about managing their losses occurring in the worst possible outcomes, which is poorly suited for R&D ventures. A debt contract has been proven to reduce this difference in expectations (see Neave (2009)). Intuitively, debt financing could therefore be considered as a very useful tool in coming up with an agreement between the R&D firm and the financier given their very different outlook on R&D expenditures. Table 1 shows how debt finance can bring the manager's and the financier's valuation closer together.

Table 1 - Different Subjective probabilities

	Firm Earnings	Subjective Probabilities of Manager	Subjective Probabilities of Financier
State 1	8	0.25	0
State 2	7	0.25	0.25
State 3	6	0.25	0.25
State 4	5	0.25	0.25
State 5	4	0	0.25

Source: Neave (2009), p.94

In order to illustrate this point, I assume risk neutrality and an interest rate of zero. It is obvious that the financier's valuation of the project is 5.5 while the manager's valuation is 6.5. If equity is used and 5 unit of capital are required, the financier would view this investment as being worth 91% (5/5.5) of the total firm. But 91% of the total shares would require an investment of 5.91 according to the subjective probabilities of the manager, which would yield a very high interest rate for the manager. If both agents were to use a debt contract with a promise to repay 5.5 in exchange for the investment 5 unit of capital, the financier would value this debt at 5 [(4 + 5 + 5.5 + 5.5)/4] versus a valuation of 5.38 for the manager [(5 + 5.5 + 5.5 +5.5)/4].[9]

We can see that debt financing "reduces the differences in their valuations more than equity"[10], and therefore brings down the expected and subjective costs of financing in the eyes of the R&D firm. Jensen (1986) also says that a debt contract would reduce the free cash flow available to managers which would in turn reduce managerial discretion and reduce agency costs. Both these advantages suggest that R&D firm would have a preference for debt financing. But Brown, Fazzari and Petersen (2009) find that debt financing is very unpopular in research and development, especially with younger firms. This is in fact due to the reluctance of banks and other intermediaries to apply a debt contract to such an uncertain venture.

Put in differently, "Banks -- as debt issuers -- also have an inherent bias toward prudence"[11]. This not only contradicts one of the required assumption for the above example (risk neutrality), but will push intermediaries to try and reshape the debt contract in order to give an incentive to the R&D firm to pick a safer project. However, "the high degree of uncertainty of future benefits from R&D expenditures and the generally negligible collateral value of R&D investments"[12] might make this task too difficult for traditional intermediaries. While banks might have greater monitoring capabilities than most financiers, key governance attributes such as control and adjustment capabilities will be hard to implement in traditional forms of debt contract. In the

[9] It is interesting to note that a degree of realism in constructing subjective probabilities is required in order for this reconciliation of valuation to work. If one were to used a Gilboa-Schmeidler model, which essentially forces the optimizing agent into absolute pessimism or optimism, debt contract would not be a better reconciliatory unit than external equity.

[10] Neave (2009), p.133

[11] Levine (2004), p31

[12] Kothari, Laguerre and Leone (2002), p.358

case of incomplete contracting, which is prevalent in technology ventures, "internal governance will normally be used to govern deals whose uncertainties are greater than those acceptable to intermediaries"[13]. This is where hierarchical governance would shine. We know venture capitalists or a kereitsu banking system will usually ask for a seat on the board of directors or at least some form of control in exchange for capital, but traditional banks will have limited control capabilities. Without this authority, intermediaries will not be able to deal with R&D informational asymmetry. Additionally, Petersen and Rajan (1995) also find that competitive banks cannot subtract rents from high risk projects.

Not only is posting collateral a problem for young R&D firms, especially start-ups R&D firms[14], but charging the appropriate interest rate will also aggravate adverse selection. Many unseen complications can arise during an R&D project and this unpredictable character makes the computation of subjective probabilities of failure and success a extremely hard task. However, Mansfield and al. (1977) do report a probability of financial success for R&D projects of only 27%, which is extremely low. Given this level of riskiness, financiers issuing debt will demand a high interest rate. Subsequently, this will attract riskier and even more uncertain projects. Based on Stiglitz and Weiss (1981), I construct the following profit function:

$$\prod(\hat{r},\hat{\theta}) \equiv \int_0^{\infty} \max[R-(\hat{r}+1)B;\ -C]\,dF(R,\hat{\theta}) = 0$$

where $\hat{\theta}$ is the type (riskiness) of project where profits are zero, $\prod$ is the profit function, $\hat{r}$ is the interest rate charged by the banks, R is the gross return of the project, B is the amount borrowed, C is the collateral posted and F is the probability distribution on the return of the project. The

[13] Johnson, Neave and Pazderka (2004), p.22

[14] Even older firms with intangible assets, like the pharmaceutical industry, will have problems posting collateral. See Fishman and Love (2005)

upper bound of potential revenue is infinity, which is simply a theoretical illustration of the unpredictable nature of the potential profits. It is assumed that the type of project is unobservable by the financier, since "the credibility gap between management and investors is likely to be most pronounced in the case of growth companies because management in such cases will often have far better information about the future profitability of undeveloped products"[15].

By the implicit function theorem, we see that increasing the interest rate will only attract riskier projects (a higher $\hat{\theta}$ means a riskier project):

$$\frac{d\hat{\theta}}{d\hat{r}} = \frac{B\int_{(1+\hat{r})B-C}^{\infty} dF(R,\hat{\theta})}{\frac{\partial\Pi}{\partial\hat{\theta}}} > 0$$

A debt contract will therefore face a downward spiral: the project is already risky and requires a higher than average interest rate, but this increased interest rate will attract the riskier R&D projects and "this fact may even further exacerbate the adverse selection problem.[16]" Furthermore, this high interest rates would subsequently create liquidity problems, with disastrous consequences for smaller firms (see Gompers (1995)).

Therefore, for all of the above reasons, "the structure of a debt contract is not well suited for R&D intensive firms with uncertain and volatile returns"[17]. The interest of the financiers and the R&D firm are simply not aligned.

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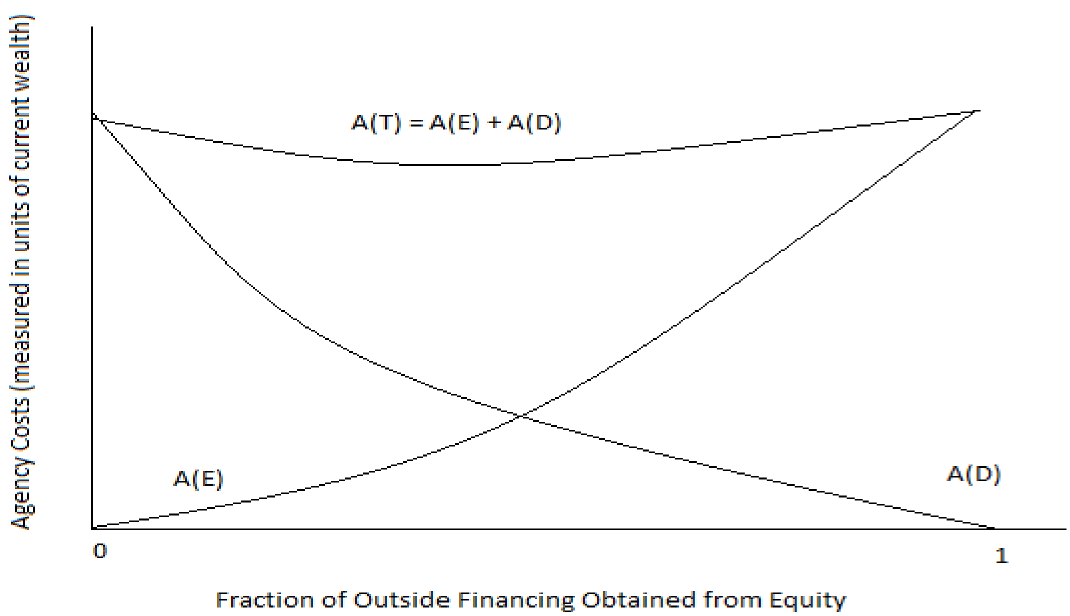
[15] Cornell and Shapiro (1988), p.12
[16] Mas-Colell, Whinston and Green, (1995), p.437
[17] Brown, Fazzari, and Petersen (2009), p.157

INTERNAL EQUITY

Since pure debt financing is inadequate for R&D firms, these high tech industries are left with very little choice but to turn to equity financing, both internal and external. While internal equity financing is usually measured with cash flow, external equity financing is issuing different forms of stock to external financiers to receive funds. Both achieve the same result but internal equity financing is typically easier to deal with and has little cost associated with it. Indeed, "a substantial wedge between the costs of internal and external equity financing"[18] is a fundamental structure of equity financing. Jensen and Meckling (1976) develop a model where the owner-manager will bear all the agency costs associated with external finance. Even with an 'optimal' financial structure, agency costs are still present. In graphic 1 below:

<u>Graphic 1 - Agency costs for external financing</u>



Source: Jensen and Meckling (1976), p.344

[18] Carpenter and Peterson (2002), p.F60

where, D is debt, E is external equity, A(E) is the agency costs associated with external equity, A(D) is the agency costs associated with debt and A(T) is the total agency costs, we see that no matter what financial structure the firm uses, there will always be agency costs associated with external financing. Therefore, this theory predicts that "the owner-manager, if he resorts to any outside funding, will have his entire wealth invested in the firm. The reason is that he can thereby avoid the agency costs which additional outside funding impose."[19] In other words, all internal equity will be used up before resorting to debt financing, which has almost been ruled out in the previous section, and various other forms of financing involving an external investor. "The conventional rationale for holding financial slack - cash, liquid assets, or unused borrowing power - is that the firm doesn't want to have to issue stock on short notice in order to pursue a valuable investment opportunity."[20] This way, any kind of firms, especially R&D firms, do not have to deal with agency costs or overpaying external investors for informational asymmetry. I use Nohria and Gulati (1996) definition of slack "as the pool of resources in an organization that is in excess of the minimum necessary to produce a given level of organizational output."[21] As they so beautifully stated, "slack provides a pool of resources that can ease adaption to the ebbs and flows of the innovation process."[22]

However, too much slack can kill discipline within an organization. Jensen (1986) define free cash flow as "cash flow in excess of that required to fund all projects that have positive net present values when discounted at the relevant cost of capital."[23] He also argues that there are tremendous agency costs in free cash flow because it is a reflection of managerial self-interest

[19] Jensen and Meckling (1976), p. 348
[20] Myers and Majluf (1984), p.194
[21] Nohria and Gulati (1996), p.1246
[22] Nohria and Gulati (1996), p.1249
[23] Jensen (1986), p.323

and organizational incompetence. Dividends payouts can reduce the level of free cash flow and "the fact that capital markets punish dividend cuts with large stock price reductions"[24] is consistent with this theory. This lack of discipline can also be embodied by less intense negotiations with suppliers, less severe deadlines and refusal to abandon bad pet-projects (see Cyert and March (1963)). And when a firm or a corporation decides to invest its cash flow in a R&D project, an important issue arises regarding the compensation of the managers of those internal R&D ventures. A vast literature, like Jensen (1993) and Sahlman (1990), examines how to realign the interests of the manager with those of the firm. I construct the following principal-agent model to compare effort induced by profit shares and effort induced by promotions.

Assuming the effort of the manager affects the success rate of the R&D project, assuming the success rate of the R&D project affects the chances of promotion, I build two density functions: F(w), which is the wage schedule density distribution with no promotion, and G(w), which is the wage schedule density distribution with a promotion. I assume G(w) first-order stochastically dominates F(w). Since the amount of effort affects the chances of promotion, I build a probability of being promoted equal to $\theta * e$, where e is effort and $\in \{0, 1\}$ and θ is the promotional structure of the firm and $\in [0, 1]$. The closer θ is to one, the more often a promotion will occur. In a setting where effort is being induced by promotions, the R&D manager will solve the following maximization problem:

$$\max_{e \in \{0,1\}} \int_0^T w * [\theta * e * g(w) + (1 - \theta * e) * f(w)] dw - c(e)$$

where c(e) is the cost function of effort. If, however, the firm decides to share a fraction $\alpha \in [0, 1]$ of its profits, Π, with the manager, the latter will solve this maximization problem:

[24] Jensen (1986), p.324

$$\max_{e\in\{0,1\}} \int_0^T \alpha * \prod * f(\prod|e) d\prod - c(e)$$

The inequality conditions for the manager to choose the high level of effort would be:

1) $$\int_0^T \theta * w * [g(w) - f(w)] dw \geq c(1) - c(0)$$

2) $$\int_0^T \alpha * \prod * [f(\prod|e=1) - f(\prod|e=0)] d\prod \geq c(1) - c(0)$$

We see that in both cases, the R&D manager is dealing with the same threshold. But to achieve these inequalities, the firm would need a promotion policy set of θ, which is the occurrence of being promoted, and of g(w) - f(w), which can be loosely interpreted as the wage increases after promotion, to be high enough. On the other hand, for inequality (2) to hold, a high enough $f(\prod|e=1) - f(\prod|e=0)$ and θ, which is the percentage of profits going to the manager, is needed. Since the R&D manager's effort is absolutely crucial to the success of the project, this difference is obviously high (see Johnson, Neave and Pazderka (2004)). This is a key feature of the profit sharing methodology: the manager's interests are naturally aligned with those of the firm/corporation. Both methods have their costs: promotions and wage increases for one, a loss of a fraction of the profits for the other. But only the method of giving a fraction of the profits to the R&D manager introduces an organic force to eliminate moral hazard. Unfortunately, most compensation for managers inside corporations still use the promotion method. This model suggests that while corporate R&D doesn't have to deal with external agency costs, wage schedules inside the firm do create some moral hazard. A compensation resembling that of the venture capitalist (see section below) usually eliminates this problem[25].

[25] The above was not a proof but merely an illustration of what factors determine the efforts chosen by the agent and how they do so.

Myers and Majluf (1984) have also noted that maintaining too much slack will prevent the firm from using external financing as a financial complement to internal equity because "an attempt to issue (stock) will send a strong pessimistic signal."[26]

But even detractors of slack have admitted its potential for R&D funding. The use of internal equity for R&D has in fact been calibrated by both Brown, Fazzari and Petersen (2009) (see table II below) and by Himmelberg and Petersen (1994). The latter authors even computed a cash flow elasticity for R&D of 0.67, all of which suggest internal equity is the principal determinant of investment for high-tech firms.

The idea "that R&D must be funded primarily by internal finance is (...) based on the existence of information asymmetries between firms and suppliers of external finance."[27] "The value of slack disappears if the firms can costlessly convey its special knowledge to all investors, new as well as old."[28] But since this cannot be, most notably because of the need to protect proprietary value, slack has value, and is the cheapest and most widely used form of finance available to the R&D firm. But what happens when internal equity has been dried up or never was available? Or in an even simpler case, what happens when outside financing is possible and not so expensive? External equity will simply be used as a financial complement to internal equity.

[26] Myers and Majluf (1984), p.195
[27] Himmelberg and Petersen (1994), p. 39
[28] Myers and Majluf (1984), p.195

EXTERNAL EQUITY

Different firms from different sectors have to deal with the same costs related to external equity financing, which are the usual underwriter spreads and administrative costs. These costs were computed by Lee, Lochhead, Ritter and Zhao (1996) to be approximately 13% for issues of seasoned equity of less than ten million dollars and 10% for issues between ten and twenty million dollars. Adding to these traditional costs, R&D firms have to deal with the above mentioned asymmetry of information. An ingenious way of computing this cost was done by Carpenter and Peterson (2002). First, he used as a base the hypothesis of Brealey and Myers (2000) that "most financial economists now interpret the stock price drop on equity issue announcements as an information effect and not a result of the additional supply"[29]. Then, by combining it with Asquith and Mullins (1986) empirical work, they conclude that the 31% drop in value following the issue of new equity is in fact an information effect. Given this discrepancy in cost, firms will therefore typically exhaust internal equity before turning to external equity.

While "the debt holder shares downside risk but not upside potential"[30], external investors holding stocks of the R&D firm share in upside returns, which is really what investors are looking for. Furthermore, "additional equity financing does not increase the probability of financial distress."[31] External equity also doesn't require R&D firms to post collateral, which is hard to come by in most high-tech industries. And since most managers in young R&D firms have a lot of 'love capital' invested in their ventures, their interests will be more aligned with

[29] Brealey and Myers (2000), p.423
[30] Johnson, Neave and Pazderka (2004), p.21
[31] Carpenter and Petersen (2002), F60

investors holding external equity whereas debt holders would have to worry about managers switching to riskier projects (see Carpenter and Petersen (2002)).

Table II suggests another dynamic: young firms have a much larger external equity to internal equity ratio than mature firms, respectively 0.486 versus 0.074. When a small firm makes its initial public offering (IPO), it issues for the first time equity to external investors and has now access to a much larger source of finance. This will typically lead to a dramatic increase in the size of the R&D firm. But once this is done, most firms will choose to refrain from issuing more equity because this might signal financial distress. This usually leads to a substantial drop in the value of pre-existing equity and could potentially lead to financial distress. A minority of firms continue to maintain some form of financing through external equity after IPO, but the majority of firms will typically exhaust internal equity before turning once more to external equity. An interesting phenomenon occurs for well-established firms reputed to be reliable: the informational asymmetry associated with debt contract improves, as is it shown by a ratio of 0.70 of secured debt to long term debt for young firms versus a ratio of 0.131 for older firms (see Carpenter and Petersen (2002)). And since internal equity will usually be more prevalent in size in mature firms due to the stability and the increased potential reserves of revenues implied by "old" age, mature firm will have access to much less restricted array of finance than young firms

Table II - Debt, Internal and External Equity

Variable and Statistic	Full Sample	Young Firms	Mature Firms	Difference (p-value)
Sum cash flow/net finance				
mean	0.686	0.659	0.916	0
median	0.731	0.692	0.957	0
SD	0.399	0.421	0.627	
90th percentile	1.139	1.11	1.357	
Sume new stock/net finance				
mean	0.289	0.32	0.068	0
median	0.219	0.247	0.027	0
SD	0.367	0.381	0.419	
90th percentile	0.807	0.85	0.484	
Sum new debt/net finance				
mean	0.021	0.015	0.019	0.82
median	0	-0.001	0	0.002
SD	0.182	0.194	0.382	
90th percentile	0.229	0.23	0.378	

Source: Brown, Fazzari, and Petersen (2009), p. 166-167

The last three sections can therefore be summed up in the following statement:"this discussion suggests that there is a financing hierarchy for R&D (...). When cash flow is exhausted and debt is not an option, firms must turn to new share issues."[32] But what happens when external equity is not available and not enough internal equity is available for the venture to be taken to the next stage? Enter venture capital.

[32] Brown, Fazzari, and Petersen (2009), p.158

VENTURE CAPITAL

Venture capital is "a professionally managed pool of capital that is invested in equity-linked securities of private venture at various stages in their development.[33]" It is essentially the introduction of a third party into the financier-entrepreneur relationship in order to mitigate informational asymmetry. A venture capital firm requires external investors, called limited partners, who have money to invest but snub all the informational asymmetry in high-technology industries. A syndication of limited partners will generally take place in order to make better investment decision (see Lerner (1994)), provide more capital stability (see Perez (1986)) and to spread risk among investors (see Wilson (1967)). This group of investors then comes into contact with a venture capitalist (general partner), whose ultimate function will be to act as an intermediary between the firm and the limited partners.

But a venture capitalist is not just third party who reduces the uncertainty and informational asymmetry of R&D ventures. He is an experienced business man who will contribute to making the due diligence of investments and confirming all material facts with regards to a sale or investment. He will help evaluate the firm and provide expert advice, most notably with the pricing of the product. A venture capitalist will usually have an extensive network of clients in order to generate demand, suppliers in order to lower the costs of inputs, financiers in order to help with the planning and implementation of the road show, executives like a vice-president of marketing or sales and researchers in order to help with the R&D activities of the firm. His management skills will help make the firm operational or reach the next stage of production, doing markets tests or expanding to industrial products (see Bottazi and Da Rin (2002)). He will

[33] Sahlman (1990), p.473

help with possible mergers, acquisitions and Initial Public Offering (IPO) (see Schmidt (2003)) and provide advice on market timing skills. A venture capitalist will on average spend one hundred hours in direct contact with each portfolio company, visit them nineteen times per year (see Gorman and Sahlman (1989)) and, when required, will help facilitate the regulatory approval process of the product (see Kortum and Lerner (2000)). All of the above are reasons why venture capital backed firms consistently outperform other firms. Better road shows and better success rates are only some empirical measures of venture capital's performance amongst others.

In order to see whether or not a venture capitalist really does help with road shows, we need a measure of how successful a road show was. Bharat and Kini (2000) use the discrepancy between the offer price investors paid and the initial filing range estimated by investment bankers. They note that 22.06% venture capital backed firm will have an IPO price above filing range while only 12.69% of non-venture capital firm have an IPO price above filing range.

Gompers, Kovner, Lerner and Scharfstein (2010) have noted that previously successful entrepreneurs have a 30% success rate versus a 21-22%% rate for inexperienced entrepreneurs. Gompers, Kovner, Lerner and Scharfstein (2010) interpret this discrepancy as being due not only to managerial skills but to market timing skills (entering the market at an optimal time)[34]. The latter could be viewed as blind luck. But since market timing skill is done consistently by the same successful entrepreneurs, it is not just luck and this skill does seem to be possessed by venture capital firms. First time and failed entrepreneurs, who lack this market timing skill, have

[34] While the usual the traditional component of market timing skill might be entering the market at appropriate macroeconomic times, competition can also be an integral factor of optimal market timing. An interesting example is that of Netscape Communications, which was backed by a venture capital firm called Kleiner Perkins Caufield & Byers (see Gompers and Lerner (2001), p.22)

a better success rate when backed by venture capital firm than those who don't: 20.9% versus 14.3% for first-time entrepreneurs, and 25.9% versus 17.7% for failed entrepreneurs.

The introduction of a venture capitalist to mitigate this effect is not without consequences: there are now two different relationships and two different sets of informational asymmetry; however, breaking down the informational asymmetry into two sets makes each set easier to deal with separately.

Managing a venture capital fund is not without its costs and requires substantial efforts, notably the cost of screening opportunities, recruiting key personnel, obtaining regulatory approval of the products (see Kortum and Lerner (2000)) and most importantly, the opportunity cost of micro-managing and visiting the firms (see Gompers (1995)). The general partner, or venture capitalist, owns approximately 30% of the venture fund (see Amit, Brander and Zott (1998)) so this aligns his interest with those of the limited partners (external investors) as the previous model suggested. They will both want to maximize the returns on the portfolio, but will disagree as to the risk parameters of the portfolio. "The venture capitalist's equity participation may be thought of as an option that entitles the venture-capital management firm to (his share) of the increase in value of the underlying fund.[35]" Since the venture capitalist's pay is essentially a contingency claim on value, he will have an incentive to increase the risk of the portfolio. To mitigate this moral hazard, venture capital contracts will usually contain a mandatory distribution policy specifying what to do with the proceeds from the sale of assets in the portfolio (see Sahlman (1990)). Furthermore, all firms surveyed by Sahlman (1990) provided limited partners with periodic reports.

[35] Sahlman (1990), p.496

There are also scale and scope economies and learning effects for venture capital (see Sahlman (1990)) so a venture capitalist has a big incentive to manage multiple companies at the same time and increase the size of the portfolio. But certain situations can arise in which it is in the interest of the venture capitalists to increase the size of the firm, even though it would lower returns to the limited partners because of diseconomies of scale in the investment-return-generating process. Mohindra (2011) notes that the dissipation of managerial talent and hierarchy are the principal causes to diseconomies of scale in investments, and Lopez-de-Silanes (2011) empirically finds that as the number of projects held by a single manager increases, the rate of returns decreases. But with the limited life of venture capital funds and the fact that limited partners phase in the remainder of their investments over time, "the ability to withdraw funding support is the ultimate tool for aligning the interests of the agent and principal"[36]: it prevents the venture capitalist from benefiting from scale or scope economies and from learning effects.

To further illustrate the disciplinary effect of the ability to withdraw and the staging of investments, I construct the following bargaining model. For the sake of expositional purposes, I first assume that the limited partner must invest all the required capital at the beginning of the venture capital fund and cannot 'walk away' from his commitments (this assumption will be relaxed shortly). The first bargaining model will have two periods:

-t=1; both players, the limited and the general partners, realized both their beliefs α_{GP} and α_{LP} regarding the ability of the venture capital: information is complete. It is assumed that the limited partner's assessment of the general partner's ability is more objective and closer to the truth than the general partner's assessment, which is assumed to be inflated (see Bernardo and Welch

[36] Sahlman (1990), p.501

(2001))[37]. However, the limited partner is uncertain regarding the exactness of his assessment. So he will construct an error term:

$$\varepsilon = (\alpha_{GP} - \alpha_{LP})/2$$

from which he will construct an 'acceptable interval' to estimate the ability of the general partner, $[\alpha_{LP} - \varepsilon; \alpha_{LP} + \varepsilon]$.

-t=2; the general partner makes a take-it-or-leave-it offer to the limited partner of α'. The limited partner only accepts if the offered α' is within $[\alpha_{LP} - \varepsilon; \alpha_{LP} + \varepsilon]$. With a backwards induction method, the general partner will offer $\alpha_{LP} + \varepsilon$ which is the closest acceptable offer to his α_{GP}.

With this agreed upon assessment of the general partner's ability, both players will solve the following optimization problem (based on Berk and Green (2004)):

$$\max_{q} \prod = [\, q_t \, \alpha'_t + \Delta_t \, q_t - C(q_t) \,]^{38}$$

where $\prod$ is profits, q is the number projects simultaneously managed by the general partner, α'_t is the agreed upon value of the general partner ability also contains a profit component which is related to ability),

Δ_t is an error term regarding the returns on one project and is normally distributed with a mean of zero and a variance of σ^2 and C(q) is the cost function of managing q number of projects[39].

[37] This assumption is made for qualitative and not quantitative purposes.
[38] This function represents the profits from the venture capital fund and will be shared by both players.
[39] For reasons that will be obvious soon enough, I assume the following. For the profit function $\prod(q, ...)$ for some number $\Psi \in R$, given than q_t* represent the profit maximizing q, $\prod(q^* - \Psi, ...) = \prod(q^* + \Psi, ...)$, that is straying from the optimal q* with too many projects reduces profits by the same amount as straying away from q* with too little projects.

The derivatives $C'(q) > 0$ and $C''(q) > 0$ represent the weakening of information gathering activities as the number of projects managed by the same general partner increases. The first order condition:

$$\alpha'_t + \Delta_t - C'(q_t) = 0$$

suggests that if α' decreases, the number of projects managed by the general partner should also decrease.

Proposition 1: *Assuming α_{GP} is closer to the real value of α than α_{LP}, the ability of the limited partner to stage the remainder of his investment and to 'walk out' on the portfolio is either Pareto improving or simply improves the expected payoff of the limited partner (based on his beliefs).*

Proof: The above bargaining model will now have a third period:

-t=3; The limited partner reviews the performance of the venture capital fund and reviews his assessment of the general partner's ability. If the number of firms he manages is too high with regards to the limited partner's revised assessment of his ability, the limited partner will 'walk out' on his commitment and the R&D firms managed by the general partner will run out of liquidity and will go bankrupt, leaving nothing for the general partner.

The longer a portfolio lasts, the more information the limited partner will have about the real value of α. Therefore, the 'acceptable interval' will shrink. If the initial returns are negative, the interval shrinks to $[\alpha_{LP} - \varepsilon; \alpha_{LP}]$. If the returns are positive, it shrinks to $[\alpha_{LP}; \alpha_{LP} + \varepsilon]$. Since R&D ventures are highly uncertain activities, returns tend to be lower in the first years (see

Sahlman (1990)). The general partner will know this and will set up his venture capital fund in order to resist to these shocks[40]. He will once again use a backward induction method to solve this bargaining problem but this time, he will make take-it-or-leave-it offer of α_{LP} which is the closest value to α_{GP} he can get without having the limited partner walk out on his commitment.

Say α^* is the real ability of the general partner. If $\alpha^* \in [\alpha_{LP}; \alpha_{LP} + \varepsilon/2]$, then this is Pareto improving since profits will be higher. If $\alpha^* \in [\alpha_{LP} + \varepsilon/2; \alpha_{LP} + \varepsilon]$, this isn't Pareto improving but the limited partner imposes his subjective assessment of the general partner's abilities. For the limited partner, being right or wrong will depend on how his 'acceptable interval' is constructed and how close α^* really is to α_{LP}. But the goal of this model was to show that whether he is right or wrong, the limited partner with this form of contract is more dominant in imposing his preferences in the general-limited partner relationship.

Another way of dealing with potential moral hazard is to directly forbid certain types of actions in the contract. The contracts are usually designed to forbid any self-dealing and, although harder to implement, requires the venture capitalist to commit a certain percentage of their effort to managing the fund (see Salhman (1990)).

Another merit of syndication of investors is that it can prevent the venture capitalist from exploiting informational asymmetry. Since "the performance data are often difficult for outsiders to confirm"[41], the venture capitalist can try to increase or decrease his share of the fund during good or bad times. To prevent this, the venture capitalist must maintain a constant share of the portfolio. When new revenues are needed, additional investors must be brought into the venture

[40] It is assumed here that the general partner will want an absolute protection from these shocks. He will therefore assume that all his successful projects will have negative returns in the earlier years.
[41] Lerner (1994), p.18

fund. So later stage syndication along with the obligation of maintaining a constant share of the portfolio for the venture capitalist reduces the possibility of moral hazard.

Now, as to the venture capitalist and R&D manager relationship, both have different information and different goals, leading to informational asymmetry. Since continuous monitoring is costly and almost impossible, the venture capitalist needs other forms of solutions. One of the most common way of dealing with this problem is staged capital infusion: funding will be made progressively over time, usually in a round system, and will typically grow over time. Johnson, Neave and Pazderka (2004) give the following table illustrating the different rounds of financing:

Table III - The Different Rounds of Financing

Type	**Stage and Financing Purpose**
Seed Finance	Allow the entrepreneur to verify the feasibility and economic potential of the project
Start-up Finance	Makes the firms operational, i.e. the funds are used to hire employees and executives, develop a prototype, conduct market tests, etc.
Expansion Finance	Assists the firm in reching industrial-scale production, upgrading production facilities and additional hiring
Later Stage Financing	Helps the firm become a market leader and develop its earning potential, thus preparing the firm for an IPO or trade sale
Bridge Financing	May be extended by specialized financial intermediaries after the IPO in order to increase the equity base. At this stage, the venture capitalists often sell a part of their original investment.

Source: Johnson, Neave and Pazderka (2004), p, 16

Of course, staging capital infusion doesn't have to follow the above five categories. The adequate number of financing rounds will be chosen by the venture capitalist, who will make his decision based on a variety of reasons (current performance, potential, etc.) The shorter the duration of each round is, the bigger the reduction in agency costs. A higher the number of rounds of financing gives the same results (see Gompers (1995)). Additionally, stage financing allows the venture capitalist to draw new information about the company at each stage (see Cornelli and Yosha (2003)). Lerner (2004) also notes that venture capital fund of three rounds or more of financing will have almost twice the amount of limited partners, suggesting that staged capital infusion goes hand in hand with syndication of investors. R&D managers and entrepreneurs may continue running NPV projects because of high personal benefits. Stage financing would allow the venture capitalist to cut off bad projects earlier.

By staging capital infusion, this makes the projects dependent on venture capitalists, giving them the power to abandon the project, not to R&D managers. Combining this with the usual non-compete restrictions and vesting clauses, the R&D manager's array of actions that could potentially harm the venture capitalist and his limited partners greatly diminishes. Most notably, the possibilities of hold-up are reduced. Kaplan and Stromberg (2003) note that 41% of venture capital firms they surveyed will buy back the share if an entrepreneur leaves at some pre-determined low values. Seven out of ten firms will have some form of non-compete clauses, suggesting that these behaviour restricting tools are widely used.

There is little cost for the R&D manager for misusing funds. To realign the interests of their agents with his interest, the venture capitalist can penalize R&D managers for misusing capital by issuing new stock to acquire new capital which dilutes the R&D manager's stock equity. But the most widely used tool to combat moral hazard in venture capital is convertible securities, which are essentially bonds (or debt contracts) which can be converted into the company's common stock or preferred stock (equity). One of the things convertible securities will prevent is 'window dressing', where the R&D managers artificially inflate his numbers to pass a financing round (see Schmidt (2003) and Cornelli and Yosha (2003)). 'Window dressing' makes it easier to identify high value projects, so the venture capitalist subsequently convert his shares for these projects, leaving less potential profits for the entrepreneurs. On that same note, Green argues that because the venture capitalist will convert his securities in good states, these convertible securities therefore reduce risk-taking by the R&D managers by reducing his payoffs during high payoff states. Another feature of convertible securities is that, under certain conditions, they will provide the appropriate incentives for both the venture capitalist and R&D manager to provide the adequate effort (see Schmidt (2003)). Convertible securities will make the venture capitalist invest efficiently at and beyond a threshold point. This creates a kink in the R&D manager's payoff and induces him to provide an optimal amount of effort into the venture.

But the venture capitalist is not alone in wanting to shield himself from possible deleterious actions from the other party. The R&D manager also wants some form of protection from the investors. Besides using a mandatory conversion rate at the IPO in order to avoid a shakedown for more shares from the venture capitalist, the R&D manager will want to protect himself from possible shares dilution by the use of a debt contract. At the same time, the venture capitalist needs the possibility to convert this debt into equity to profit from efficiency improvements, so convertible securities is the right match for both parties. Berglof (1994) shows that co-sale and take-me-along clauses are dominated by convertible securities. The debt feature of convertible securities even allows the venture capitalist to control cash-flow and liquidation rights in bad state, allowing him to implement the necessary improvements he sees fit to make[42]. All these reasons explain why Kaplan and Stromberg (2003) noted that 204 of the 213 (almost 96%) of the

[42] Hellmann and Puri (2002) note that both support and control actions from the venture capitalist provide value to the project. This suggest that when the venture capitalist wants to make some key changes to the company, he is on average right. Whether or not the manager agrees with this is irrelevant.

financing rounds of the firms they surveyed use convertible securities. Specific terms of convertible securities include the conversion price, the liquidation preferences, the dividend rate, the payment terms and the voting rights in case of conversion (see Sahlman (1990)).

As far as using contractual contingencies to restrict the manager's behavior, even though contracts are inherently incomplete, which is shown by cash flow and control rights being key features of contracts (see Kaplan and Stromberg (2003)), contingencies are still being used. On average, venture capitalist have about 50% of cash flow rights while managers have between 24.3% to 31.1% of cash flow rights. 40.8% of financing rounds have some form of contingencies on founder remaining with the firm and 27.7% have contingencies on default of dividend or redemption payment (see Kaplan and Stromberg (2003)).

A further reduction in informational asymmetry in both relationships is due to the fact that, as Amit, Brander and Zott (1998) noted, venture capitalists will specialize in industries with informational asymmetry. So when it is time to exit and pull their money out of these firms, venture capitalists will have a hard time selling shares to uninformed investors. To mitigate this effect, venture capitalist will try to build a solid reputation by consistently offering quality shares. The same goes for his relationship with the R&D manager: if he abuses his power, the venture capitalist will create an adverse selection problem (see Sahlman (1990)) and viable entrepreneurs will seek funding from other venture capitalists. Thus, to keep this reputation intact, a disciplinary force is created which keeps venture capitalists from moral hazard and questionable behavior.

But a caveat should be noted here: while venture capital is the best form of external finance to deal with the informational asymmetry of young R&D firms, it is very expensive. In fact, R&D

managers and entrepreneurs are growing increasingly concerned about the high percentage of ownership venture capitalist are asking from their companies. In other words, venture capital is a very efficient way of getting finance for R&D but it is very expensive.

A logical epilogue of this section on venture capital would be to review the usefulness of public funding of R&D. First, any public program will have a goal. Public R&D will seek to fund and spur innovation. Because of limited resources and the high risk of failures, these government programs will have to screen investment opportunities. If the screening method is done in order to maximize profits, the bureaucrats working for the government will never be able to compete with the highly efficient and highly paid venture capitalists, so public expenditures on R&D will end up financing the scraps of venture capital with detrimental consequences to taxpayers money. Furthermore, public R&D expenditures might increase the price of funding R&D for private financiers and reduce the number of firms who might be financially viable. A useful alternative highlighted by Lerner (2002) is to focus on "technologies which are not currently popular among venture investors"[43]. In other words, to focus on technologies which are not financially viable in the hope that these technologies may one day be useful in the innovation process. A second interesting alternative would be to "provide follow-on capital to firms already funded by venture capitalists during periods when venture inflows are falling."[44] But even this alternative has its flaw since venture inflow might be falling for bad macroeconomic reasons and as it was noted above, market timing skills is an essential component of success. While there is certainly a vast literature defending the use of public R&D (see Walsh, Niosi and Mustar (1995), Giesecke (2000) and Hoffman, Parejo, Bessant and Perren (1998) amongst other), the above reasoning suggest a very limited role for government in R&D.

[43] Lerner (2002), p. F81
[44] Lerner (2002), p. F81-F82

EMPLOYEE STOCK OPTION

Employee Stock Option (ESO) is a form of finance where the firm essentially turns its employees into small equity financiers: each employee is underpaid by some margin which is made up for through stock options. But ESO does not have the same informational asymmetry and characteristics as external equity. Since the employee is involved in the firm and possibly in R&D project, he is not an inactive external financier. The relation of the employee holding ESO cannot be analysed in the traditional principal-agent model since he is in some ways both the general and the agent. The ESO contract can reduce informational asymmetry regarding the productivity of the employee.(see of the papers). At the same time, since ESO contribution to the overall finance of the firms tends to be small, other external financiers will be needed. For those others external financiers, ESO can be a way to realign the managers/employees interest with their own. In fact, small R&D companies whose employees have a lot of ESO can signal motivation to a venture capitalist or external financier, further aiding in the financing process.

However, the literature is divided on the contribution of ESO contracts to R&D. One part will say firms with high expenditures on R&D will typically use more ESO than firms with low R&D expenditures. Clinch (1991) reports that 93% of high R&D companies use ESO contracts versus only 76% for low R&D companies use ESO. This suggest than ESO should be positively correlated with R&D and Clinch (1991) interprets this with "motivation-based concerns (moral hazards), information-based concerns (adverse selection), and tax issues."[45] This however doesn't help to explain why employees who aren't related to R&D activities get ESO. In the context of

[45] Clinch (1991), p.59

this paper, I offer the explanation that it is simply to generate a little more financial slack which, as explained above, is the best form of finance for R&D.

On the other side of the spectrum are the authors who believe ESO is in fact detrimental to R&D. Bens, Nagar and Wong (2002) computed that if the value of options exercised by the top five executives increases by $52 million, R&D expenditures will actually decrease by approximately $34 million. The main reason for this negative correlation is that when an employee exercises his stock options, he is forcing the company to repurchase stock in order to avoid dilution. To do this, firms will tap into existing financial slack, which would have gone into positive net present value R&D projects. The only way to avoid this is to make sure ESO are issued when the firms needs slack and are exercised when R&D projects have come to maturity and the firm has the sufficient slack.

However, Bens, Nagar and Wong have used a dataset containing only publicly traded firms, which indicates a sign of maturity. And Clinch (1991) have realized most high R&D companies tend to be young. A compromise between both side of the literature can be made here. For younger cash-flow hungry R&D firms, ESO contracts are a good way to get the required financial slack. But when a firm has reached a certain age, ESO contracts can potentially harm R&D ventures by the timing of employee's repurchase.

TRADE CREDIT

Trade credit is defined as a form of finance that arises when a supplier allows his client a delay in his payments of goods already purchased. Simply put, "if payment is made after delivery, the seller is extending credit to the buyer."[46] Also known as mercantile credit, trade credit is so widely used that in the 1990s it "represented approximately 2.5 times the combined value of all new public debt and primary equity issues during a given year."[47] Some R&D firms will use it, some won't. It all depends on whether or not the characteristics of the firm fit the trade credit framework.

Quite a few explanations have been given for the raison d'être of trade credit. Possibly the most important explanation is that "suppliers may be better specialized than financial institutions in evaluating and controlling the credit risk of their buyers."[48] This is, of course, a natural consequence of day-to-day trading, which allows the supplier to collect quality information which normal financial intermediaries couldn't do (see McMillan and Woodruff (2000) and Love and Zaidi (2010)). Another explanation is given by Brennan, Maksimovic and Zezhner (1988) who make the case that trade credit is one way for firms to circumvent the Robinson-Patman Act and practice some form of price discrimination. They argue that if the cash demand is more elastic than credit demand, offering credit to potential buyers could raise demand and profits. According to Long, Malitz and Ravid (1993), trade credit is also a form of guarantee for product quality: payment would be due only when the customer has inspected the inputs. In fact, the Uniform Commercial Code (UCC) states that an inspection of the goods is a prerequisite of the

[46] Ng, Smith and Smith (1999), p.1110
[47] Ng, Smith and Smith (1999), p.1109
[48] Petersen and Rajan (1997), p.662

payment unless it is agreed otherwise[49]. Furthermore, there is the substitution hypothesis which states that during liquidity shock or financial distress, traditional financiers will stop lending and firms will turn to trade credit. An interesting study was done by Blasio (2005) who came to the conclusion that firms with high proportion of intangible assets, like high technology firms or R&D expenditures, showed evidence supporting the substitution hypothesis. Regardless of the reasons, trade credit exists and is accessible to R&D firms.

It should be noted that trade credit is not the optimal form of finance to deal with the informational asymmetry and uncertainty associated with R&D. First, trade credit is far from being free of informational asymmetry. The possibility that the seller delivers inferior goods or doesn't respect the contract and the possibility of the buyer defaulting are typical issues with trade credit. Second, trade credit typically deals with quantifiable risk to be dealt with an appropriate interest rate, not uncertainty. Smith (1987) observes an implicit rate of 348 percent for women's clothing, which are traditionally riskier than men's clothing, who benefit from a zero financing cost for thirty days. Whether or not this is a popular way of getting finance depends on the idiosyncratic characteristics of the supplier-R&D firm relationship. Third, McMillan and Woodruff (2000) find that, since receiving a bank loan is a direct measure of credit worthiness, firms that currently receive credit from banks will receive more trade credit than those who don't by 26%. Unfortunately, as it was stated above, R&D firms use very little debt, so using a bank loan as a signal of credit worthiness will be difficult.

But one aspect where trade credit fits R&D is that it is "forward looking because [it] depends on the future value of the relationship between supplier and [R&D firm]"[50], which is well suited for

[49] See sections 2-513(1) and (4), 2-310(b), 2-321(3), 2-512(2) and 2-513(3) (a) in the UCC
[50] Cunat (2007), p.494

the possible future potential of research and development, but the past is far from being irrelevant. In fact, Cunat (2007), McMillan and Woodruff (2000) and Ng, Smith and Smith (1999) have empirically shown that the older a supplier-R&D firm relationship is, the more trade credit will be available. Ng, Smith and Smith (1999) revealed the results from a survey where 72.5% of firms reported to occasionally doing nothing if a longstanding customer pays within the net period and takes an unearned discount. McMillan and Woodruff (2000) find that the use of trade credit increases by 7% during the first year and by 14% during the second year. Cunat's (2007) finding are in table III below, which confirms the same trend:

Table IV - The ratio of trade credit to total debt versus the age of the relationship

Dependent variable	Trade credit/total debt
Age spline (0-1)	0.0560 (2.96)***
Age spline (1-2)	0.0105 (1.66)*
Age spline (2-3)	0.0108 (2.12)**
Age spline (3-4)	0.0205 (4.23)***
Age spline (4-5)	-0.0019 (0.39)
Age spline (5-6)	0.0030 (0.62)
Age spline (6-7)	0.0055 (1.16)
Age spline (7-8)	0.0011 (0.24)

*, **, *** respectively mean statistically significant at 10, 5 and 1% levels
Source: Cunat (2007), p.522

Ng, Smith and Smith (1999) interpret this discount to longstanding customers as a perception that these firms are less costly to serve or that losing their business would be a great loss to the supplier. As for younger R&D firms or start-ups, Gosh and Ray (1996) point out that when no information flow is available, the supplier can lend little credit and gradually raise the amount lent in order to screen good firms from bad ones.

Fishman and Love (2003) and Cunat (2007) both state that if the supplier-firm relationship involves large amount of sunk costs, the supplier will be willing to accord more trade credit. Tailor-made product and learning by doing are essential parts of research and development and are indeed sunk costs, so these aspects of the supplier-R&D firm relationship will augment the use of trade credit.

An advantage supplier have over traditional intermediaries is the ease of resell of collateral in the case of default. In fact, in a regression of accounts payable over assets, Fishman and Love (2003) find statistically significant positive coefficient, further calibrating this idea. But not every R&D industry will generate the required collateral. In fact, Ng, Smith and Smith (1999) and Fishman and Love (2003) both report that the use of trade credit varies at the industry level, which fits the above idea since different industries generate different levels of collateral. Fishman and Love (2003) find that accounts payable over total assets are at 11.8%, 10.5% and 11.2% for petroleum refineries, transportation equipment and motor vehicles respectively. On one hand, those three industries all have substantial equipment and capital to be posted as collateral, and the last two have very heavy R&D expenditures (see Brown, Fazzari and Petersen (2009)). Another R&D heavy industry is of course the pharmaceutical/drug industry, which, on the other hand, has very little collateral to be posted. Fishman and Love (2003) find an accounts payable to total assets of only 5.5% for the drug industry. An interesting fact is that six of the seven industries that accounted for almost all the R&D 1990s boom generally used Net 30 terms, meaning that payment is due in 30 days and if this is not done, the buyer is in default. Two part terms, generally offering a discount for prompt payment, are generally not offered to these industries.

Most R&D firms have access to trade credit, but will use it with caution since it is expensive: Cunat (2007) finds that supplier will typically charge an insurance premium, because they foresee a need for future extra credit that they will have to supply, and a default premium, because trade credit sometimes arises when banks have refused to lend. Firms will typically exhaust equity and venture capital before turning to trade credit or simply use it to solve temporary cash flow problems.

CONCLUSION

At the beginning of this project, I set out to inquire about the different ways R&D ventures can achieve adequate funding. I quickly realized that informational asymmetry was pervasive in this field and that the high level of uncertainty in the returns of these projects was an immense hindrance in the funding of R&D. An extensive literature was written on the relationship of specific types of finance and R&D, but very little work besides Brown, Fazzari and Petersen (2009) had been done comparing multiple forms of finance and their efficiency with regards to funding high technology projects. By combining most of the papers examining the relationship between specific forms of finance and R&D, I was able to paint a complete and concise picture of how to finance research and development.

I found that debt financing is a very poor financial tool for aligning the interests of managers and financiers. Internal equity is the best form of finance since it doesn't require the use of an external financier. However, in a corporate R&D setting, compensation systems should be based on sharing parts of the profits between the R&D managers and the corporation to properly induce the highest level of effort from the manager. External equity is a good way for older and mature firms to obtain additional finance since these firms can use their established reputations to mitigate the uncertainties external financiers might have concerning their R&D ventures. Lacking this reputation, small R&D firms will have to turn to venture capital. The addition of a third party will reduce informational asymmetry between managers and financiers and will enhance the success rate of R&D projects. ESO are a minor way of getting finance but fit the R&D framework and its informational asymmetry while trade credit will typically be used by some R&D firms to solve temporary cash flow problems.

I now realize that the financial structure of the market, most specifically, the venture capital market, is constructed to seek and fund the best R&D projects and firms. Any attempt to organize public funding of the best R&D projects will meet an extreme level of competition by private financiers and will be doomed to failure, assuming well-developed financial markets exist.

For quite some time, scholars have focused only on specific forms of finance. More work similar to this essay would be required to merge all these different financial forms in one exhaustive theory. Most of the literature is also very descriptive and is encumbered by a lack of available data. The best empirical work are based on small surveys and data gathered and offered by private firms. A national and public set of data on R&D activities, project and firms would be of immense help in separating the empirically proven theories from the farfetched. Methodology enhancement would also be beneficial to the overall literature: the use of models should become a standard analytical tool in a setting with multiple agents frustrated by informational asymmetry.

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