R&D, Innovation, and the Signalling Properties of the firm's Financial Structure

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INDEX

1 Introduction

pag. 5

2 Debt contracts and firm financial structure

pag. 8

3 A principal-agent model of the financial structure of the innovating NTBF

pag. 10

4 A managerial model of the PELF's capital structure

pag. 19

5 Conclusions

pag. 28

References

pag. 29

Summary

pag. 31
1. INTRODUCTION*

This paper studies the influence that the types of investment a firm undertakes exert on its financial structure. In particular, it concerns R&D investment and presents a theoretical description of the signalling properties of the financial structure of innovating firms. An innovating firm is assumed to be one which engages in a (set of) specific action(s) in order to create new, patentable discoveries, and the innovative process is taken to be the result of an aggressive R&D strategy, aimed at developing drastic innovations.

It is assumed that the choice of financial structure provides Schumpeterian entrepreneurs and directors of large corporations with a strategic device for signalling their firms' expected future return stream and value to potential outside investors. This signalling mechanism, however, operates in reverse in start-up enterprises, for instance New Technology Based Firms (henceforth NTBFs), and Previously Established Large Firms (henceforth PELFs1). In fact, Schumpeterian entrepreneurs in NTBFs have access to specific technology but have to borrow funds in order to implement their investment decisions; and shareholding-directors in PELFs tend to increase their equity share when their corporations take innovative investment decisions (agency costs of alternative sources of funds being equal) to attract potential shareholders.

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1 Where "Previously" refers to the R&D project.
According to the above assumptions, the firm has better information than the market concerning the possible return stream generated by a specific R&D project, and it can thus use its finance structure as a signalling device to attract investors (Spence [1973], Leland and Pyle [1977]).

The paper draws on Transaction Costs Economics (henceforth TCE) and Agency Theory (henceforth AT), which offer many useful insights to modelling the relation between firm financial structure and innovation. In fact, both TCE and AT use an 'efficient contracting' framework; both are interested in the study of managerial discretion; and both maintain that a board of directors arises endogenously within large corporations as a control instrument (cf. Williamson [1988]). Among the differences between the two theories, the most interesting for the purposes of the present paper are that TCE takes the transaction as its elementary unit of analysis while AT uses the individual agent, and that TCE focuses on ex post, and AT on ex ante contractual relations (with respect to the process of production).

In the present paper, it is followed the TCE approach's assumption that there is a sharp distinction between firms which commit themselves to specific purpose investments, such as R&D, and firms committed to general purpose investments (cf. also Long and Malitz[1983]). Likewise, AT is employed for analysis of the roles played by the external financing of R&D activities and of the separation between ownership and control in innovating firms (cf. Hart [1988]). In fact, in such situation informational asymmetries arise between those who are in control of the R&D process and potential financiers (should these be external financiers or shareholders), and AT is a powerful tool of analysis when dealing with imperfect or incomplete information.
The above assumptions taken from TCE and AT provide the basis for the paper's principal arguments: that the Modigliani-Miller Irrelevance Theorem applies only to situations where general purpose investments are undertaken; that such theorem does not apply to the case of innovating firms, since the R&D process these undertake gives rise to informational asymmetries; that the firm's financial structure is a crucial variable in the presence of special purpose investment entailing asset specificity, such as R&D expenditures (Williamson [1985]); that in this situation the firm's financial structure displays important signalling properties; and that such a firm enters into financing contracts which can be represented as standard principal-agent relationships.

Section 2 reviews some features of the incomplete contract literature. Section 3 develops a principal-agent model of the relationship between an outside investor and an R&D-performing NTBF run by an entrepreneur wishing to undertake a specific purpose investment. Section 4 outlines a model of the relationship between aggressive R&D strategies and the issuing of new shares in PELFs.

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2 As it is already known, one of the crucial assumptions in the Modigliani-Miller Theorem is that the information structure is complete and perfect.
2. DEBT CONTRACTS AND FIRM FINANCIAL STRUCTURE

The special case of R&D programs considered in this paper is one in which innovating NTBFs can enter into long-term financing contracts only in order to fund their R&D blueprints. In fact, a) they cannot make use of retentions, since have just started up their business operations; b) they cannot resort to short-term finance\(^3\), since this only enables routine investment, which reaches maturity earlier than investment in an aggressive R&D strategy.

Thus, an innovating NTBF is influenced in its choice of an optimal financial structure by this requirement to enter into a financial contract that specifies the terms of future finance. Otherwise, if the innovative investment project has not reached maturity by the time a short-term contract expires, problems will arise for both the firm and the outside investor. The former will be in an unfavourable bargaining position when renegotiating further loans, and the latter will run the risk of losing his or her funds should the firm go bankrupt before the investment project has reached maturity. This may provoke conflict between entrepreneur and outside financier as circumstances change to the advantage or detriment of one or other party to the contract. A sub-optimal solution to such conflict may be obtained by writing long-term contingent incomplete contracts (Hart and Holmström [1986]), which involve at least three different kinds of benefit.

Firstly, they provide a saving on transaction costs by establishing in advance what action is required of each party at different stages of the contractual relationship. The parties therefore do not have to negotiate

\(^3\) I.e. to a contract providing finance only in the foreseeable future.
further short-term contracts and they thus avoid the problems outlined above.

Secondly, long-term contracts enable the parties to avoid problems connected with informational asymmetries arising during their relationship which may affect their bargaining efficiency. This property is particularly significant in the cases considered in the present paper.

Thirdly, a long-term contract also performs a screening function: it may attract the outside financier by offering high future remuneration if the R&D program is successful. In this case, the outside financier and the owner of the firm sign a contract prescribing future shareholding involvement by the former in all those circumstances which give rise to a tangible outcome from research activity. Conversely, in the case of bankruptcy (which we can take to be the result of unsuccessful research activity) the outside financier decides whether to re-organize the business or to sell out.

From these premises it follows that a prospective outside financier grants unconventional loans and that he or she may wish to take a participatory role in the customer firm. This may take the form of output participation through shareholding or, in the case of failure, of full control over the firm.
3. A PRINCIPAL-AGENT MODEL OF THE FINANCIAL STRUCTURE OF THE INNOVATING NTBF

Let us consider an entrepreneur-technologist (or scientist) who, although he/she has access to a specific R&D program, needs long-term finance in order to implement his or her investment project (Arrow [1962]; Mayer [1988]). This entrepreneur will be unwilling to transfer a part of the control over his/her business to the outside financier if the project is successful but, conversely, will be willing to transfer full ownership and control should the firm go bankrupt. He/she does not issue equity, therefore, and there is no form of separation between ownership and control in the firm. Thus, we may assume a structure of preferences where ownership and control matter to the entrepreneur when the firm performs well (i.e. the R&D program is successful), whereas the outside financier can obtain ownership and control only when the firm performs badly and goes bankrupt (i.e. the R&D program is unsuccessful).

The outside financier is also assumed to be risk-neutral, and seeks all those investment opportunities which, at a given level of the rate of interest, offer the highest profitability. For the sake of simplicity, we may assume that profitability is positively correlated with the degree of innovativeness. Thus, a risk-neutral external financier is one who typically seeks innovative investment.

The above is a typical case where there are gains to specialization; it is therefore one where agency relationships between a risk-neutral

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4 In practice, the financing relation between the NTBF and the outside financier is seen as a mortgage deed. In this case, the structure of preferences is such that ownership and control matter to the outside financier when the firm goes bankrupt.
external financier and the innovating firm are likely to arise (Stoneman [1987], Ch. XIII; Holmström, [1989]). We also make the further two assumptions that tax incentives do not affect recourse to alternative sources of finance, and that both the entrepreneur and the external financier agree to a certain set of sharing rules as regards the outcome of the R&D effort.

The contract both parties agree to sign specifies in advance how the payoff is to be shared between the principal and the agent. This specification of the sharing rules is stated on the basis of a conflict of interests provoked by the agent’s disutility of effort (as stressed in principal-agent theory) and by the fact that the rate of interest charged by the principal to the agent should be higher than the market rate of interest, since the investment project has been assumed to be a special purpose one. The signalling device is implicit in the duration of the financing contract. By looking for long-term finance, the NTBF signals to potential outside financiers its willingness to undertake an aggressive R&D strategy and its confidence that, when the investment reaches maturity, the firm’s return stream will be significantly high.

Let $a$ denote a generic element among a given set of actions $A$ (e. g. alternative R&D programs) available to the agent. Let $x$ then denote a verifiable outcome (invention) or a monetary payoff (profit from invention) $x = x(a, \theta)$, resulting from the agent’s choice of some action $a$ and from a state of nature $\theta$, described by a distribution $G(\theta)$, where

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5 Although it is worth noting that the sources of the agency problem differ from those usually considered in standard principal-agent literature. In fact, in the situation that concerns us here, the agency problem is created by the risk-taking incentives implicit in the debt contract, whereas in standard principal-agent literature the agency problem arises because the principal has to induce a risk-averse agent to undertake a certain level of action.
$\theta$ can take a finite number of values $\theta_0, \ldots, \theta_n$. Each state of nature $\theta$ describes a technological regime, which the agent is supposed to know, embodying a series of technological trajectories (with $\theta = \{\sigma\}$) - which represent the direction of technical progress in specific fields - that lead to a number of alternative, although related, outcomes $x_0, \ldots, x_n$. A technological regime (Nelson and Winter [1977]; Dosi [1988], who introduced the similar concept of technological paradigm) is a general paradigm of scientific and technological knowledge which underlies the pattern of technological change. Thus, outcome $x$ depends not only on the agent's action, but also on a specific technological trajectory, since it represents one of the finite number of products made possible by a given technological trajectory $\sigma \in \theta$. Hence, outcome $x$ is obtained from a production process in which $\Omega$ is the subset of $A \cap \theta$, such that

$$A \cap \theta = \{x \mid x \in \Omega \subseteq A \text{ and } x \in \Omega \subseteq \theta\}$$ \hspace{1cm} (1)

where

$$A \cap \theta = \begin{cases} \emptyset \text{ with probability } p \\ \Omega \text{ with probability } 1 - p \end{cases}$$

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6 For example, in the present phase of industrial development at least three different regimes can be singled out. These relate, respectively, to 'information technologies', 'bio-technologies', 'new materials' (ceramics, composites, etc.).

7 In the sense that they all have similar technological features.
since the R&D process can be unsuccessful ($\emptyset$) or successful ($\Omega$). In practice, any possible value of $x$ reflects an action $a$ in the set of $A$ and a technological trajectory $\sigma$ in the set of $\Theta$. Thus, the following notation

$$\Omega = \{ x \mid P(x) \text{ is true} \}$$ (2)

denotes that $\Omega$ is the set of outcomes $x$ to which a certain property $P$ applies - i.e. those outcomes that can be achieved by undertaking an action $a \in A$ which makes it possible to exploit the potentialities of a technological trajectory $\sigma \in \Theta$.

The problem now is to determine how outcome $x$ can be shared optimally between the agent and the principal in a contractual relation whereby the principal makes a payment $y$ enabling the agent to develop his or her investment project from which a payoff $x$ is expected.

Let $y$ denote the compensation to the agent. Thus, the agent's utility function is $H(y, a)$ with $H_y \geq 0$, $H_a \leq 0$, and the principal's $U(x - y)$. The principal's utility function depends on the outcome of the inventive activity and the size of the payment $y$ made to the agent to obtain that particular outcome. It is independent of $\Theta$ - of which the principal is assumed to be uninformed - and such that $U' > 0$ and $U'' \leq 0$, since the principal's behavior is not risk-attracted. He or she is indifferent to the $a$ chosen by the agent and is interested only in the value of $x$.

If we assume that the principal does not monitor the agent's action, we can demonstrate that sharing rules are functions of $x$ alone. As in Holmström (1979), let $s(x)$ denote the agent's (NTBF's) share of $x$, and let $r(x) = x - s(x)$ denote the principal's (external financier's) share.

Following standard agency theory, the hypothesis of imperfect information concerns states of nature in which the agent's action $a$ is
chosen when \( \theta \) is not known to the principal. In practice, the agent possesses a significant degree of knowledge concerning the technological regime which characterizes the period, even if he/she does not know in advance the exact features of the technological trajectory \( \sigma \in \theta \) when he/she chooses his/her action \( a \). Hence, he/she may be supposed to explore a new, previously unexploited technological trajectory within an active technological regime. In such a condition, Pareto-optimal sharing rules to the agent, \( s(x) \), are generated by solving the following program:

\[
\max_{s(x)} \sum_{i=0}^{n} U(x_i - s(x_i)) \tag{3}
\]

which explains the variation of the discrete variable \( x \). Accordingly, notation 3) can be substituted by notation 4), in which \( E \) denotes the expectational operator conditional on available information

\[
\max_{s(x),a} E\{U(x - s(x))\} \tag{4}
\]

subject to

\[
E\{H(s(x),a)\} \geq \bar{H} \tag{5}
\]

where \( \bar{H} \) denotes the minimum level of the agent's expected utility, and
\[ a \in \text{argmax}_{a^* \in A} \{ \mathbb{E}(H(s(x), a^*)) \} \] (6)

where 'argmax' denotes the set of arguments which maximize the principal's objective function. Solution 4), subject to 5) and 6), is a second best solution, where notation 4) denotes that the agent is guaranteed the minimum expected utility, and the agent's objective function 6) takes account of the fact that the principal can only observe the outcome \( x \) but not the action \( a \), since he or she does not monitor the agent's action. On the basis of the assumption that \( x = x(a, \theta) \), the program may be solved by taking the expectations in 4) and 5) relative to the distribution of \( \theta \) (see Harris and Raviv [1979]).

In this model, only informational asymmetries relating to the technological regime \( \theta \) persist. These allow adverse selection and, in terms of the TCE approach, opportunistic behavior on the agent side. To forestall the problems arising from adverse selection, the contract may be replaced by another one, independent of the agent's action \( a \).

Let us begin by considering two different contracts \( S_1 \) and \( S_2 \). The former is the standard contract as described above, where the sharing rules are a function of the agent's action \( a \), a particular outcome \( x \), and a state of nature \( \theta \); the latter is a contract where the agent's action does not affect the sharing rules. Thus, the problems of adverse selection are reduced, in the sense that they only depend on the informational asymmetries represented by the differing knowledge possessed by the agent and the principal of the technological regime \( \theta \). In contract \( S_2 \), the signalling argument is more clear cut than in contract \( S_1 \), since the outside investor has the guarantee that the NTBF will choose the action which, consistently with \( \theta \), enables achievement of outcome \( x \).
PROPOSITION 1. Assuming \((S_1; x, a, \theta)\) to be the general form of the contract between the NTBF and the outside financier considered here, there is a contract \((S_2; x, \theta)\) such that any contract which depends on \(x\), \(a\), and \(\theta\) can be dominated by one depending on \(x\) and \(\theta\) only.

Proof. As in Harris and Raviv [1979], let \(a_1 = a(S_1)\), and \(x \in \Omega\), with \(\Omega^*(\theta) = \Omega(a_1, \theta)\) and then define the contract independent of action \(a\) as

\[
S_2(x, \theta) = S_1(\Omega^*(\theta), a, \theta) - \Omega^*(\theta) + x
\]

Hence, with \(V^A\) denoting the agent's choice of the action maximizing his/her utility, and with \(a_2 = a(S_2)\), we obtain

\[
V^A(S_2, a_2) \geq V^A(S_2, a_1) \quad \text{by definition of } a_2
\]

\[
= V^A(S_1, a_1) \quad \text{by construction of } S_2
\]

In this case it is also true that

\[
\Omega(a_2, \theta) - S_2(\Omega(a_2, \theta), \theta) = \Omega(a_2, \theta) - S_1(\Omega^*(\theta), a_1, \theta) + \Omega^*(\theta) - \Omega(a_2, \theta)
\]

\[
= \Omega(a_1, \theta) - S_1(\Omega(a_1, \theta), a_1, \theta)
\]

Considering \(V^P\) as the action maximizing the principal's utility, we obtain

\[
V^P(S_2, a_2) = V^P(S_1, a_1)
\]
In this case, since the realizations of $\theta$ and $x$ are observable, $a$ is inferrable *ex post*. The existence of such a contract has been proved by Harris - Raviv [1979].

If one wishes to solve all the problems arising from adverse selection, the importance of $\theta$ in establishing the sharing rules should decrease even further, thus also reducing the degree of technological determinism implicit in the contract$^8$. The problem arising over informational asymmetries relates to the role of $\theta$ in the establishing of sharing rules and compensation schemes for the agent. Such a problem can be solved in the way pointed out by Harris and Raviv [1979], and this enables us to consider a contract $S_3$ dominated by $x$ alone, which is superior to $S_1$ and $S_2$ in terms of signalling properties. In fact, by signing such a contract the NTBF guarantees that, although it possesses superior information, it will also act in the outside financier's interest.

**Proposition 2.** In the particular case where the NTBF is risk-neutral and the outside financier does not monitor the agent because of his/her limited knowledge of the technical features of the agent's action, any contract which depends on $x$, $a$, and $\theta$ will be dominated by a contract which depends only on $x$.

*Proof.* As in the proof of proposition 1, let $(S_1; x, a, \theta)$ be a generic contract with $a_1 = a(S_1)$, $x \in \Omega$, and $\Omega^* = \Omega(a_1, \theta)$, and define

$$c = E_\theta(\Omega(a, \theta) - S_1[\Omega(a_1, \theta), a_1, \theta])$$

and let $S_3$ be a contract such that $S_3(x) = x - c$.

The principal is indifferent as to the choice between $S_1$ and $S_3$. Hence the action maximizing his/her utility may be defined as

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$^8$ Since it is the technological regime that determines the features and the outcome of the contractual relation.
\[ V^p(S_3,a_3) = E_0 U[\Omega(a_3,\theta) - S_3(\Omega(a_3,\theta))] \\
= E_0 U(c) \quad \text{with} \quad S_3(x) = x - c \\
= U[E_0(\Omega(a_1,\theta) - S_1[\Omega(a_1,\theta),a_1,\theta])] \\
= E_0 U[T(a_1,\theta) - S_1[T(a_1,\theta),a_1,\theta]] \\
= V^p(S_1,a_1). \\
\]

In his/her turn, the agent solves the following problem to maximize his/her utility:

\[ V^a(S_3,a_3) \geq V^a(S_3,a_1) \text{ by definition of } a_3 \\
= E_0 U^a[T(a_1,\theta) - c, a_1] \\
= U^a[E_0(T(a_1,\theta) - c), a_1] \text{ by risk neutrality} \\
= U^a[E_0 S_1(T(a_1,\theta), a_1, \theta), a_1] \\
= V^a(S_1, a_1) \text{ by risk neutrality}. \]

In this case the optimal contract, which is a second-best solution, is written when the sharing rules are such that the principal's share is independent of the technological trajectory \( \theta \), ignoring incentive problems. This equilibrium solution overcomes the problems connected with informational asymmetries between principal and agent, and the principal's lack of knowledge of the features of the technological trajectory \( \theta \). The existence of this contract has been proved by Harris - Raviv [1979].
4. A MANAGERIAL MODEL OF THE PELF'S CAPITAL STRUCTURE

The centralized multidivisional form of corporate organization (CM-form) is characterized by head office involvement in operating decisions (Williamson [1975]). In this case the internal capital market is not an optimal mechanism for the reallocation of cash flow between competing claims. On the basis of this premise, this section considers a) the financial strategy of a CM-form PELF when it decides to implement an aggressive R&D strategy, and b) the signalling mechanism activated by its directors in order to raise the necessary funds in the external capital market.

In their study of the relationship between rates of R&D and the level of borrowing, Long and Malitz [1983] discovered that such a relationship is negative in the case of large US corporations. Therefore, the assumptions made for NTBFs are in effect reversed: the issue of new common shares is taken to be the optimal financial strategy for innovating PELFs. However, the conclusions are no different from those obtained when NTBFs are examined, since the issue of new common shares enables incumbent and new shareholders to act as risk sharers and to bear any current losses (which take, for example, the form of a non-payment of dividends while the innovative project is still in its early stages) in the expectation of future rewards - for example higher dividends and/or an increase in the face value of shares.

According to Jensen and Meckling [1976], when 100 per cent of equity is held by those not controlling the firm, its managers tend to slack. This tendency diminishes, however, when managers hold a share of total equity, because the greater their claim on the firm, the stronger
is their incentive to reduce slack. We may assume in this situation that a board of directors emerges endogenously which controls internal information concerning the firm's structure that stockholders do not possess (Myers and Majiluf [1984]; Myers [1989]).

Figure 1 - Value of the firm and level of the directors' stock options (including the case when they increase their equity share)

The directors' performance is therefore closely related to the firm's performance, and stock options (which are taken as representative of a range of pecuniary and non-pecuniary benefits), by improving the directors' performance, indirectly benefit the firm. In fact, in managerial
firms the relationship between directors' shareholdings and firm's performance is usually positive\(^9\).

For analytical simplicity - since this section of the paper focuses on the agency relationship between directors and shareholders - we assume that directors' decisions are fully accepted and implemented by R&D managers, i.e. that no agency relationship exists between the central R&D function and the directors.

Let \( K = \{k_1, k_2, \ldots, k_n\} \) be the vector of all the firm's factors and activities that give its directors stock options; \( C(K) \) the cost of providing these items; \( P(K) \) the total value to the firm of \( K; B(K) = P(K) - C(K) \) the net benefit to the firm of \( K \) assumed not to affect the equilibrium wages of the directors. The optimal levels of the factors and activities \( K \) are then defined by \( K^* \), so that

\[
\frac{\delta B (K^*)}{\delta k^*} = \frac{\delta P (K^*)}{\delta k^*} - \frac{\delta C(K^*)}{\delta k^*} = 0 \quad (10)
\]

Hence, for any vector \( KX^* \), \( F = B (K) > 0 \) measures the cost to the firm of providing the increment \( K - K^* \) of the factors and activities which generate utility to the board of directors. Let \( F \) then denote the current value of directors stock options; line \( VF \) in figure 1 thus represents the constraint which directors face when deciding how much benefits to extract from the firm.

In figure 2 (which is based on Jensen and Meckling's figure 1, p. 316), 0\( \bar{V} \) measures the firm's value when the directors receive a zero

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\(^9\) Even if it can be curvilinear, as shown by Lawriwsky [1984].
amount of non-pecuniary income; $\bar{V}$ is the maximum market value of the firm's cash flow when the level of directors' benefits is $OV = 0$ for a given money wage\textsuperscript{10}. The system of indifference curves $U_1, U_2, U_3, \ldots, U_n$ represent the preferences by directors for wealth and stock options. They are convex because the rate of substitution between stock options and wealth is a decreasing function of the level of benefits. Consequently, when the board of directors owns 100 per cent of the equity, the firm's value is $V^*$ at the point (D) at which the indifference curve $U_2$ is tangent to $\bar{V}F$, and the amount of stock options is $F^*$. If the stockholding-directors decide to resign as stockholders (i.e. to sell all the equity they own), but to stay on as directors, and, moreover, if the new owner convinces past owners to accept the same level of $F^*$, then $V^*$ is the price the new owner will pay to buy the total equity.

Significant here is the situation in which the directors sell a fraction of the firm to an outsider, i.e. when they sell a share $1 - m$, (with $0 < m < 1$), and retain a share $m$ for themselves. In this case, if the outsider is confident that the directors will not change their level of stock options, he or she will be satisfied to pay $(1 - m)V^*$ to buy the fraction $(1 - m)$ of total equity. If this is the sum actually paid by the buyer, and assuming that the directors can choose the level of stock options they wish, their budget constraint will be $V^*P_1$, as shown in figure 1.

Consider a certain company which seeks to achieve a sales maximization goal (according to Baumol [1959]), and assume that directors hold $m\%$ of the company's shares and are willing to undertake an aggressive R&D project ($I_{RD}$) in the belief that it may place the

\textsuperscript{10} Jensen and Meckling's model assumes that the manager's money wage represents the current market value of his contract.
company in a better competitive position, increase its market share and enable them to obtain additional stock options. The board of directors can sell a fraction of the firm (i.e. issue an amount \( m \) of voting shares) to outside investors or to incumbent shareholders in order to collect the funds necessary to start the R&D project. The underlying assumption is that when directors hold a significant shareholding in the firm, they improve their performance (see Morck, Shleifer and Vishny [1988]).

The problem may be treated in a two period model where decisions taken in the first period affect the second period return-stream. We may assume that the total value of the shares issued by the PELF are represented by the sum of the shares \( m \) issued at different times \( m_1, \ldots, m_n \) and that

\[
\sum_{i=1}^{n} m_i = M_n
\]

represents the total value of equities at time \( n \). When starting \( I_{RD} \), at time \( n + 1 \) the PELF issues new shares, so that the value of total shares is raised from \( M_n \) to \( M_{n+1} \) and may be represented by the following sum

\[
\sum_{i=1}^{n+1} m_i = M_{n+1}.
\]

Accordingly, if things go as planned the directors receive (as in Ross [1977]) the following remuneration in period 2 (in terms of stock options)
\[ F = (1 + r)\gamma_1 V_1 + \gamma_2 \begin{cases} V_2 \text{ if } V_2 \geq M_{n+1} \\ V_2 - L \text{ if } V_2 < M_{n+1} \end{cases} \] (11)

where \( V_1 \) and \( V_2 \) denote, respectively, firm value in period 1 and period 2, \( L \) is the penalty to the board of directors if the firm goes bankrupt in period 2 after having carried out \( I_{RD} \), \( r \) is the rate of interest, \( \gamma_1 \) and \( \gamma_2 \) are non-negative constants. The value of such constants differ from period 1 to period 2. In fact, in the model we are dealing with logical time, and in such a perspective the distance between period 1 and period 2 may be assumed to be long enough to determine a change in the constants.

Directors maximize the objective function \( F \), so that their main goal is to implement \( I_{RD} \) and maximize - by maximizing the firm's total sales - the value of their stock options. Accordingly, notation (11) represents a signalling device, in the sense that \( M_{n+1} \) signals the firm type to outsiders and incumbent shareholders. In practice, the greater the difference between \( M_n \) and \( M_{n+1} \) in period 2, the more clearly will outside investors and shareholders perceive that the firm is undertaking an innovative investment able to improve the firm's future return stream and value.

Let \( A^* \) and \( B^* \) represent two different PELFs, with the former engaged in aggressive research programs and the latter pursuing adaptive and imitative investment strategies, and let \( a \) and \( b \) denote the respective total return. Assuming \( M^* \) as the critical level of financing, taking \( F^* \) as the level of directors' non-pecuniary benefits when they own 100% of the equity and \( F \) as the actual level, the result will be \( b \leq F^* < a \) if \( F > F^* \) - in which case the market will perceive the PELF as a
type A* firm - and F ≤ F* if the market perceives the PELF as a type B* firm. Corporation A* will sell its newly issued shares at a face value such that F^A ≤ a. Consequently firm value in period 1 will be

\[ V_1 = V_1(F^A) = a/(1+r) \]

with \( r \) denoting the interest rate, while firm B* will choose a face value such that F^B ≤ b, and hence

\[ V_1 = V_1(F^B) = b/(1+r). \]

At this point, the non-pecuniary benefits \( F \) of firm A*’s directors are

\[ F^A(M^A_{n+1}) = \begin{cases} 
(\gamma_1 + \gamma_2) & \text{if } F^* < F^A \leq a \\
\text{and} & \\
\gamma_1 b + \gamma_2 a & \text{if } F^A \leq F^* 
\end{cases} \]  

(12)

while those of firm B* are

\[ F^B(M^B_{n+1}) = \begin{cases} 
\gamma_1 a + \gamma_2(b - L) & \text{if } F^B > F^* \\
\text{and} & \\
\gamma_1 b + \gamma_2 b & \text{if } F^B \leq b \leq F^* 
\end{cases} \]  

(13)

The directors may resort to a particular strategy in order to spread confidence in the market concerning expected returns on I_{RD}; they attract investors by increasing their total shareholdings, in this way
signalling their confidence in the research project which is about to begin.

Let \( m_{n+1} \) be the additional equity issued when the firm is planning to undertake an R&D project. Only an amount \( i \) of the new equity \( m_{n+1} \) such that \( 0 < i < m_{n+1} \) will be sold to incumbent and/or new shareholders, while an amount \( (m_{n+1} - i) \) will be bought by its directors. This is a typical game of reputation, where a closed loop strategy is available to the participants. In fact, the directors decide to buy an amount \( (m_{n+1} - i) \) of shares when they discover that the potential outside investors are not interested in the new shares, and the outside investors decide to buy the amount \( i \) of new shares on the basis of information which has become available after the beginning of play, i.e. when the directors bought an amount \( (m_{n+1} - i) \) of voting shares. The equilibrium concept referred to in the game is a Nash equilibrium.

**Proposition 3.** Incumbent and potential shareholders lack confidence that the undertaking of an aggressive R&D strategy will be beneficial to the firm. In this case directors increase their equity share to spread confidence among shareholders over the firm’s investment strategy.

*Proof.* Let \( V^* \) be the face value of voting shares and

\[
\sum_{i=1}^{n+1} m_i = M_{n+1} V^ *
\]

the total value of firm equity. If the issue of new voting shares is linked with an R&D project, by buying a considerable amount of new shares, the stockholding-directors signal to outsiders their confidence in
the results of the new project. This will enable them to change their level of stock options in period 2, when extraordinary profits are achieved. In this situation the outsider and/or the incumbent shareholder will be ready to pay $(m_{n+1} - \lambda)V^*$ to buy the fraction of new common shares $(m_{n+1} - \lambda)$.

In period 2, an increase in firm value takes place, which causes an upward shift in the directors' budget constraint from line $V_1P_1$ to line $V_3P_3$, as shown in figure 2. In this way, the directors are compensated for the additional expenditures they have been forced to make in order to attract incumbent shareholders and/or outside investors to the new project.
5. CONCLUSIONS

This paper has employed standard static agency models to analyze the signalling properties of the firm's financial structure when aggressive R&D strategies are adopted. R&D investment has been considered to be a typical case of asset specificity a' la Williamson, one able to affect the firm's choice of its financial structure. This has made it possible to describe in formal models the financial strategies of both innovating small firms (NTBFs) and large corporations (PELFs). These models provide better understanding of the behavior of both Schumpeterian entrepreneurs and corporate directors, and they also enable the analyst to employ qualitative data from the firm when investigating the set of processes and decisions involved in the undertaking of R&D projects. Regarding the financing of aggressive R&D carried out by NTBFs, the paper's major conclusions relate to two kinds of optimal contract, which allow R&D financing contracts to be developed where the sharing rules are independent of the agent's action, and of both the agent's action and the state of nature, respectively. Regarding PELFs undertaking aggressive R&D, the paper has pointed out that directors increase their equity share as a signalling device to attract new and incumbent shareholders.
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Summary
Innovating firms use their finance structure as a signalling device to attract outside investors. This argument is developed in standard static principal-agent models dealing with New Technology Based Firms (NTBFs) and large firms undertaking an aggressive R&D strategy. In the case of NTBFs, the signalling device is implicit in two kinds of optimal financing contracts, which render the sharing rules independent of the agent's action and of both the agent's action and the state of nature (technological regime). Regarding innovating large firms, it is argued that directors use their equity share to signal the firm's expected return stream and value to outside investors.
QUADERNI GIA' PUBBLICATI DAL DIPARTIMENTO DI ECONOMIA


N. 7 - Geminello ALVI, "Due scritti eterodossi sulla scienza scienza in economia e la sua storia", maggio 1985.


