R&D Investment and Financial Contracting in Spanish Manufacturing Firms

Ester Martínez-Ros and Josep A. Tribó[*]
Universidad Carlos III de Madrid [1]
October 2001

Abstract

This paper presents a model in which a firm with a degree of R&D specialization raises external funds to develop a two-period project that involves some non-verifiable returns (R&D-type of project). Taking into account a possible opportunistic behavior by the manager, we find out that the optimal firm's debt equity ratio is negatively related to the firm's degree of R&D specialization, its internal funds, and the output generated by the R&D project. Moreover, the expected R&D output of the firm is related negatively to the firm's leverage and positively to the firm's degree of R&D specialization as well as the amount of internal funds. The novelty of this work is to derive these results from strategic default consideration of the managers of firms specialized in R&D investments, as opposed to the standard collateral arguments concerning debt financing. This has a consequence of a lower growth of the firm's debt-equity ratio once we compare firms specialized on R&D investments with others non specialized in these activities. We confirm our main theoretical findings making use of a Spanish data set of manufacturing firms during the period 1990-94.

JEL: G32, O30, O31

---

[*] The authors wish to thank Sandro Brusco, Maite Martínez, Jaime Ortega and Marco Trombetta for their useful comments. This paper has been presented at the Workshop of Industrial Economics at Carlos III University, at the II Encuentro de Economía Aplicada in Zaragoza (Spain), at the I congress of Iberoamerican Academy of Management in Madrid and at the XVI Jornadas de Economía Industrial in Madrid. They also wish to thank the *Ministerio de Industria y Energía* for providing the data. Financial support provided by the projects *PB97-0185-C03-01* and *PB97-0089 (DGSIC)* is gratefully acknowledeged.

[1] Correspondence to: Josep A. Tribó. Departamento de Economía de la Empresa. Universidad Carlos III. C/ Madrid 126 (28903) Getafe: e-mail: joatribo@emp.uc3m.es

1. INTRODUCTION

Investments in R&D are particularly risky due to the high volatility of their returns and the intangibility of the assets involved. These assets cannot be offered as collateral due to their specificity and intangibility. As a result of this, R&D-intensive firms show a higher probability to suffer a credit rationing (Guiso, 1998) and a negative correlation between firm's leverage and their R&D investments takes place. This is confirmed in several empirical studies (Bradley *et al.*, 1984, Long and Malitz, 1985, and Board *et al.*, 1991).

The firms that are mainly devoted to develop R&D-intensive projects are a particular interesting case. They have serious problems to offer collateral to eventual debt lenders, and cannot attend a rigid payment scheme of their financial obligations given the volatility of their R&D project returns. A very low debt-equity ratio is expected for these firms. Himmelberg and Petersen (1994) show that small firms that invest significantly in R&D activities basically use internal funds to finance their projects, a fact that reduces their debt-equity ratio. These young and innovative firms also obtain funds from venture capitalists that recover their initial investments when these firms go public through an Initial Public Offering (Gompers and Lerner, 1999, Black and Gilson, 1998). Gaver and Gaver (1993) show that growth firms (which usually invest heavily in R&D projects) show a lower debt-equity ratio than non-growth ones.

Another line of research has studied how the markets react when R&D-intensive firms make a debt issue**.** Affleck-Graves and Spiess (1999) find out that the shares of small, young, and NASDAQ-listed firms, (that are basically firms in technological sectors**),** experience a long-run underperformance after issuing debt. However, concerning the market reaction to R&D investments, it seems that the firm's leverage is not so harmful. Zantout (1997) reports a positive relation between the leverage and the R&D induced abnormal stock returns. He explains these results in terms of the Debt-Monitoring Hypothesis, that is: debt is an efficient financial mechanism to monitor the managers' action in those firms with high agency costs (i.e. R&D-intensive firms)**.** Doukas and Switzer (1992) find out that R&D expenses announcements are associated with abnormal positive excess stock returns in concentrated markets. This result is not maintained when strategic considerations are introduced (Sundaran *et al.*, 1996).

It seems that the message that can be delivered from the existing literature is that a bad alternative to finance innovation is the use of debt instruments, (Hall, 1992), especially if the innovative firm is young and R&D specialized, (Goodacre and Tonks, 1995). This statement is mainly based on two facts. First, the rigidity imposed by debt contracts via fixed payments that are difficult to satisfy for non-diversified firms involved in R&D investments (usually generating highly volatile returns). Second, the intangibility and specificity of those assets linked to R&D investments, a feature that diminishes their collateral value. Cavanaugh and Garen (1997) prove that this second argument might not be true in the case of firms with powerful unions. We should say that, in general, firms specialized in more innovative sectors show a low level of unionization. Finally, some authors justify that R&D-intensive firms might not use debt to finance innovation by invoking tax reasons (De Angelo and Masulis, 1980). The R&D investments tax deductions decrease the relative value of the debt payments tax deductions**.** An exception to the previous lines of research is the paper of Anderson and Prezas (1999). In this paper the authors argue that the manager of a leveraged firm may decide to invest in R&D projects as a commitment device to implement high effort in other “real” projects. High effort is implemented in order to avoid a short-term bankruptcy that would eliminate all the potential rents that the R&D project could generate in the future. This results in a positive relationship between leverage and R&D investments.

This paper comprises both a theoretical and an empirical part. In the next section, we present a two-period theoretical model based on two main hypotheses: the existence of asymmetric information between the lender and the borrower **(**R&D returns are not verifiable), and the superior productivity that the R&D-specialized firms expect to obtain from their R&D investment**.** This last hypothesis is based on Rapoport (1971) among others, who finds out that in R&D-intensive sectors, like electronics, the R&D gestation lag needed to incorporate R&D expenditures in knowledge production is 2.5 times lower than in less R&D-intensive sectors like machinery. This knowledge production is embedded in the skills and capabilities of individuals and the organization (Teece 1981).

Our model’s framework is formally similar to Bolton and Scharfstein (1996), but we use it to address a completely different question. Their focus is on the optimal number of creditors needed to prevent the entrepreneur’s opportunistic behavior when project returns are non verifiable. We study the optimality of the debt contract as an instrument to finance firm’s R&D investments when there are problems of opportunistic behavior by the entrepreneur-manager due the non-verifiability of the R&D project returns.

Two main results are obtained from our theoretical model. First, the optimal debt-equity ratio decreases with the intensity of R&D investment, the firm’s R&D specialization degree and the amount of internal resources. Second, the R&D specialization degree, and the amount of internal funds have a positive impact on the expected R&D project returns. However, leverage has a negative impact on R&D activities.

The novelty of our model is to provide a new theoretical background to analyze the problems of R&D financing. Previous models have focused mainly on the differences in collateral between R&D-specialized firms and other types of firms. We introduce in the model the differential in the R&D investment productivity of those R&D-specialized firms in comparison to that of other firms. We believe this is a relevant question because in a dynamic context each of these assumptions affects differently the evolution of the debt-equity ratio of R&D-intensive firms. As these firms improve their efficiency as time goes by, they can offer an increased real collateral guarantee to potential lenders. This should lead to a growing firms' debt-equity ratio. But, at the same time, efficiency improvements are translated into a higher productivity of the R&D investments (reductions of the R&D gestation lag). According to our model, this should lead to a decrease in the debt-equity ratio over time. To contrast empirically the arguments exposed, we should observe a lower rate of growth in the debt-equity ratio for those firms involved on R&D activities, in contrast to their counterparts in less R&D-intensive sectors. This conclusion contrasts to those in other studies like Vilasuso and Minkler (2001). They make use of the transaction and agency costs theories to neglect the strategic default consideration we focus upon.

We use the database of Spanish manufacturing firms “Encuesta Sobre Estrategias Empresariales" for the 1990-94 period to carry out our empirical investigation. On top of the work issue mentioned above, further questions are addressed. First, we analyze how the debt equity ratio depends on R&D investment and other characteristics of innovative firms. Second, we analyze how R&D expenses depend on internal and external capital as well as other firm’s characteristics like its degree of R&D specialization.

The results confirm our theory. First, firms that invest more in R&D and/or are specialized in these activities have lower debt-equity ratios. Second, in line with other works like Fortunato and Belfo (1999), we prove that the leverage has a negative impact on

R&D efforts, while the internal funds has a positive one. And finally, growth rate of the debt-equity ratio is smaller for those firms that belong to R&D-intensive sectors. These findings are consistent with the model.

The rest of the paper is structured as follows: Section 2 defines and solves the model. In Section 3 the empirical analysis is carried out, while the results are discussed in Section 4. The paper concludes with some final remarks.

2. THEORETICAL FRAMEWORK

We present a two-period model for a representative risk-neutral firm that borrows external funds, I_E, from a competitive credit market (with a zero discount rate) to finance a project. This requires a layout of I= I_E +d and d is the value of the firm's internal funds. A firm with a high d is said to have followed a deep-pocket policy. It has accumulated a big amount of funds in the previous years to develop the project.

The project lasts for two periods and involves some R&D investment. The returns of this project are of two types: a deterministic [2] non-liquid return *E*, and a cash-flow Y, this last received at the end of the first period with probability *p*. Both returns are non-verifiable. E measures the benefits generated by the R&D investment such as human and physical capital accumulation. A part bE is assimilated by the organization at the end of the first period, and the rest $(1-b)E$ accrues at the end of the second period**.** Thus**,** b measures the "speed" at which the organization assimilates the R&D investments.

We consider a contract {R, a }, where *R* is the payment promised by the firm to the lender [3] at the end of the first period, and a is the probability that the lender decides to liquidate the project conditional on the fact that the entrepreneur does not pay R [4]. In the event of liquidation, the debt-holder obtains a rent *L*. The contract cannot specify second-period payments, as *E* is not verifiable, Y is generated at the end of the first period, and the entrepreneur has no resources once the project has been undertaken. Thus, ex-post renegotiation between the debt-holder and the entrepreneur is not possible. Finally, note that the R&D returns the firm expects to assimilate are $E-(1-p)a(1-b)E$. These are

[2] A non-deterministic *E* would have not changed our main findings.
[3] We use the word debt-holder as equivalent to lender throughout the text.
[4] This kind of contract (à la Bolton Scharfstein) can be sustained *ex-post*, if the lender cares about reputation. This will prevent the implementation of an an ex –post liquidation policy non-consistent with the ex-ante probability a .

proportional to b [5]. This allows us to characterize the R&D-specialized firms, those with a high productivity in their R&D investment, with the parameter b.

Assumptions:

1/ L< I_E. This is to ensure that a successful project does not involve liquidation.

2/ $p(1-b)E+(1-p)L>I_E$. It ensures an interior solution for the optimal contract $(a<1)$. Note that the left hand side of this expression is the maximum rents the lender can obtain when there is a sure liquidation of a failed project $(a=1)$. If the project is succesful (with a probability p), the maximum returns the lender can receive from the entrepreneur are $(1-b)E$ (see equation (4) below). Otherwise, it will be a strategic default. If the project fails (this happens with a probability $1-p$), and there is a sure liquidation, the lender obtains *L*. Thus, to be viable a contract with $a<1$ in a competitive credit market (see equation (2) below), it is necessary and sufficient a higher LHS rents than the funds, I_E, the debt-holder lends to the entrepreneur.

3/ Y is high enough [6]. This is to avoid that the project cash-flow may be entirely exhausted by the debt payments which is an exceptional situation (see equation 3 below).

The optimal contract balances the cost of an increase in a, due to inefficient liquidation (see assumption 1 above), against the benefit of preventing the entrepreneur from "cheating" over cash-flow Y. In particular, it is the solution to the following problem:

$$Max._{\{0\le a\le 1,R\}}\,p \equiv p(Y-R+E)+(1-p)\left[1-a(1-b)\right]E \qquad (1)$$

$$\text{S.t. } pR+(1-p)aL-I_E=0 \qquad (2)$$

$$\text{S.t. } 0\le R\le Y \qquad (3)$$

$$\text{S.t. } Y-R+E\ge Y+abE+(1-a)E \Leftrightarrow R\le a(1-b)E \qquad (4)$$

Maximizing the entrepreneur's expected profits (p) is equivalent to maximizing social utility because of the debt-holder's zero-profit condition stated in equation (2). Equation (3) is the limited liability constraint. This expression does not include the returns *E* because as intangibles, they cannot be offered as a monetary counterpart. Finally (4) is a truth-telling constraint, which prevents the entrepreneur from simulating a null cash-flow when the project has really generated a cash-flow Y.

[5] In the equilibrium we will see that $a>0$.

The solution of the previous problem is given by [7]:

$$R = \frac{I_E(1-b)E}{p(1-b)E+(1-p)L} \equiv \overline{Y} \text{ and } a = \frac{\overline{Y}}{(1-b)E} \qquad (5)$$

At this stage, we compute two variables that will be estimated in the empirical part. First, the expected R&D output, $\mathrm{E}\{E\} \equiv \overline{E}$. Second, the firm's debt-equity $DE = \dfrac{R}{p}$ where p are firm's profits [8].

Concerning the first measure, we obtain the following expression:

$$\overline{E} = pE + (1-p)(bE + (1-a)(1-b)E) = E - (1-p)a(1-b)E$$

And by (5) this expression can be rewritten as:

$$\overline{E} = E - (1-p)\overline{Y} \quad \textit{with} \quad \overline{Y} = \frac{(I-d)(1-b)E}{p(1-b)E+(1-p)L} \qquad (6)$$

To determine the debt-equity ratio, we use the expression of firm's profits $p = p(Y-R+E)+(1-p)[1-a(1-b)]E$, to obtain:

$$DE = \frac{1}{K-1} \quad \textit{with} \quad K \equiv \frac{pY+E}{\overline{Y}} \qquad (7)$$

In the empirical part, we estimate (6) and (7). The following comparative statics results yield the relationship between $\overline{E}$ and DE [9] with the structural parameters of the model [10].

Result:

The expected R&D output that the project generates ($\overline{E}$) increases with the firm's internal funds d, the firm's R&D specialization degree, b, and decreases with the firm's indebtness, R.

The debt-equity ratio is negatively correlated with the internal funds, d, the degree of specialization in innovation, b, as well as with the R&D project returns E. In this last case, this is only true for high E values **(** $E > \overline{E} \equiv \sqrt{\dfrac{(1-p)LY}{1-b}}$ **).**

---

[6] In particular $Y > \overline{Y} \equiv \dfrac{(I-d)(1-b)E}{p(1-b)E+(1-p)L}$.

[7] Proof in the Appendix

[8] We are computing the "market value" of equity. That is, the profits expected to be obtained by making use of the initial internal funds, d, and the external funds I_E.

[9] An alternative measure of the debt-equity ratio, like $DE = \dfrac{R}{p+R}$ would lead to the same comparative statics results as those we find.

[10] Proof in the Appendix.

From the previous theoretical result, we extract a set of hypotheses to be tested. They can be classified in two types (see 1 and 2):

1. *Hypotheses concerning the debt-equity ratio*

First, with regard to the debt-equity ratio, we have made a comparative statics analysis over three structural parameters (*E*, b *, d)* that defines three different hypotheses:

The measure of the firm's R&D specialization degree, b , is negatively related with firm's debt-equity ratio. Note that the higher b , the higher the entrepreneur's incentives to cheat over the project's cash-flow. To prevent this behavior the lender decreases the entrepreneur's costs of telling the truth, (by reducing debt payments *R*). Therefore, we expect to obtain:

Hypothesis 1. *Debt-equity ratio should be lower in those firms specialized in R&D activities than in those other firms that are not specialized in these investments.*

We have also found a negative relationship between the firm's debt-equity ratio and the returns of their R&D investments (*E*), when these are high enough. Yet as E grows, firm's profits and the required debt payments *R* grow as well. But, Y bounds the latter, due to the entrepreneur limited liability condition. This fact ensures that for high values of E (when the last condition is exhausted) the firm's debt-equity ratio decreases with *E*. This is explained in the second hypothesis:

Hypothesis 2. *The debt-equity ratio must be lower in those firms that are involved in projects with a high R&D returns.*

Finally, we have obtained a decreasing relationship between the debt-equity ratio and the amount of internal funds (*d*). Note that, the lower the required external funds I_E , (the higher the amount of internal funds), the lower the debt payments (*R*), and, the lower the entrepreneur's incentives to behave opportunistically. As a result, the lender decreases the probability to liquidate the project (a), which would be inefficient. The final result is an increase in profits. This feature and the mentioned decrease in *R*, ensure a decrease in the debt-equity ratio. This configures our third hypothesis:

Hypothesis 3. *The debt-equity ratio will be lower in those firms that have a high amount of internal funds to finance their R&D investments (firms that have implemented a deep-pocket policy).*

2. *Hypothesis concerning the determinants of R&D expected output*

We have found that the R&D expected output, generated by the project, satisfies the following relationships:

Hypothesis 4 *For those firms that make R&D investments, their R&D expected real returns increase with the firm's internal funds (implementation of a deep-pocket policy), and with the firm's R&D specialization degree. On the other hand, they decrease with the firm's leverage.*

3 EMPIRICAL ANALYSIS

3.1. Data

The data used comes from the "Encuesta Sobre Estrategias Empresariales" (*ESEE*) database provided by the Spanish Ministry of Industry. Our sample covers the period 1990-1994. The information collected in the *ESEE* is representative of the Spanish manufacturing sector and accounts for differences in firms' size [11]. The *ESEE* surveys approximately *2500* firms each year and contains information on sales, employment structure, technological behavior, foreign activities as well as accounting information. The sample that we use has been reduced to *732* firms due to consistency problems or due to failures in some important variables. The sample constitutes a complete panel since we have available continuous information of all firms during the period.

The initial descriptive statistics (see Table 1) show that, on average, the debt-equity ratio (DEQUITY) constructed as total debt over total equity is lower in industries with high-tech opportunities (HIGH=1) than in industries with medium or low technological

[11] See the empirical appendix for more details about the sectors that compose our database.

opportunities (HIGH=0) [12], although this difference is not significant. Moreover, this lower value of the debt-equity ratio is basically concentrated in the last year of our sample (1994). This pattern also works in the last year for the short-term debt-equity ratio (STDEQUITY) constructed as a short-term debt (less than one year) over total equity.

PUT TABLE 1 HERE

To characterize in more detail the type of industries we are dealing with, we provide descriptive statistics of some variables in the following table.

PUT TABLE 2 HERE

In high-tech industries, firms develop both more product innovations and process innovations. The different figures of both innovation types indicate that technological activity does not constitute a homogeneous activity. In all sectors, process innovation is higher than product innovation. But, the ratio of process to product innovation is lower in HIGH sectors than in the other sectors.

3.2. Variable Definition and Descriptive Statistics

To undertake our analysis, in Table 3 we define the set of variables of interest, as well as their differences in mean values once we compare R&D intensity sectors with non-R&D intensity sectors. At this point it is important to address the question of the measurement of the R&D activity. This has been broadly discussed in the literature (Griliches, 1979, 1988). R&D inputs or R&D outputs are used as a measure of R&D depending on the availability of the data and the issue to be studied. In our approach we use the ratio of R&D expenditures to sales, because it is a better measure out of all the returns the R&D investments generate, the intangible capital for the firm included. This measure fits better with the spirit of the theoretical model, where the project output, E, is related to non-verifiable returns linked to intangible capital. Moreover, the impact of these returns on the present value of R&D projects should, therefore, be reflected in the firm's market valuation. And, the way to finance innovation activities will be affected by such fact.

[12] The classification of sectors as high and non-high technology sectors is based on exogenous measures. See point 2 in the empirical appendix for details.

Finally, with R&D expenditures we may eventually capture the effect of announcements of the firm's R&D spending (Johnson and Pazderka, 1993) and the impact to use different financing tools (Zantout, 1997). A second question concerns the debt-equity ratio. In the theoretical part we computed what is defined as the market value of the debt-equity ratio. Unfortunately, in our database only 5.5% of firms are listed in the stock market. This feature has lead to use the book value of the debt-equity ratio. It is remarkable that the difference between book and market values is lower for short-term horizons. This has persuaded us to also incorporate an analysis of the short-term debt-equity ratio (STDEQUITY).

PUT TABLE 3 HERE

We can make some comments to the definition of several variables.

First, variable DIVERSIFIC = $1 - \sum_i Q_i^2 \Big/ 100 \sum_i Q_i$, where Q_i is the percentage of firm's sales in product i. This is basically an estimator of the degree of firm's diversification. Note that, a firm focused on one activity (Q=100 and i=1) would have a zero value of DIVERSIFIC, and a firm equally diversified in ten activities would have a value of 0.9. Variable HISPECIAL is higher for those firms on a R&D-intensive sector (HIGH=1) which are consolidated (RECENT=0) and which are specialized (low DIVERSIFIC). Thus, this is a complete measure of what we define as R&D-specialized firms. Finally, INTFUNDS is a way to measure the implementation of a *deep-pocket* policy. In the estimations, we are going to use this variable one-period lagged (INTFUNDS1), to better fit with the idea of a cash-flow accumulation in the past to finance, among other things, the firm's R&D investments.

Table 3 clearly shows that the degree of R&D intensity of the sector influences the realization of firm's R&D expenditures (EFFORT). However, such effect is small when we take into account the capital structure of a firm. The debt-equity ratio is practically the same in both types of sectors. Concerning the long-term debt to total debt ratio (DEBTLENGTH), we can see that firms in R&D-intensive sectors have a significantly lower debt length (0.153) than firms in non-R&D intensive sectors (0.181). This is consistent with the idea of the theoretical model that lenders might want to discipline the managers of firms in innovative sectors (where there is a wide scope for opportunistic behavior) by reducing the length of the debt. Moreover, these “innovative” firms accumulate more internal resources, which can simply be explained because they are significantly bigger and use less external equity financing (lower value of STOCK variable). Finally, note that although firms in high-tech industries are not significantly older, they are bigger in terms of employment and more diversified, which are clear signs that they have experienced a high growth.

3.3. Methodology

We test the extent to which the decision to assign resources to innovate determines the capital structure of a firm. We suspect that the effort made on R&D is endogenous to the firm’s financing decisions. Doukas and Switzer (1992), among others, show that R&D efforts are associated with abnormal positive excess stock returns when firms can enjoy quasi-monopolistic rents (compete in concentrated markets). R&D effort constitutes a managerial decision that is partially determined by the firm’s total budget, which depends on the firm’s financing policy. Besides, Himmelberg and Petersen (1994) emphasize the importance of controlling for unobserved fixed effects when one explains the capital structure of firms that devote resources to innovation. Under such evidence, our purpose is to estimate the firm’s debt-equity ratio, as well as the short-term debt-equity ratio and control for the unobserved fixed effects and the endogeneity of the technological effort. Apart from the book and market value accounting considerations we made before over these ratios, the reason why we also analyze the short-term debt-equity ratio is that in our theoretical model all debt is short-term debt. Thus, to conduct a specific analysis of this financial ratio might be quite interesting. We use the “within method” to obtain consistent estimators of the determinants of both financial ratios. The equations we estimate follow expression (6) of the theoretical model:

$$\begin{Bmatrix} DEQUITY \\ STDEQUITY \end{Bmatrix}_{it} = b_1 EFFORT^{*}_{it} + b_2 HISPECIAL_{it} + b_3 HINTFUNDS1_{it} + b_4 STOCK_{it} + b_5 EMPLOY_{it} + y_t + h_i + e_{it} \tag{8}$$

Where the error term e_{it} is a normal distribution with 0 mean and σ^2 variance.

We include the effort on R&D (EFFORT), the degree of experience in a High-tech industry (HISPECIAL) and the amount of internal funds accumulated in *period t-1* for those firms in R&D-intensive sectors (HINTFUNDS1). We expect all with a negative impact ($b_1 < 0, b_2 < 0,\ b_3 < 0$) on both financial ratios (DEQUITY and STDEQUITY). We have also included a variable (STOCK), to account for the impact of equity financing on the firm's financial structure. The other variables like firm's size (EMPLOY), and temporal dummies (ψ) act as controls. Cavanaugh and Garen (1997) suggest the inclusion of the firm's level of unionization as a variable to interact with the R&D effort to explain the debt-equity ratio. We have not considered this variable. This is because in Spain wages are fixed through collective industry agreements. Thus, by introducing industrial dummy variables in our estimations, as we do, we take, indirectly, into consideration this effect.

To obtain consistent estimators, as the effort is an endogenous variable, we use an instrument to overcome the problems of correlation between the error term and the effort. Hence, we estimate an auxiliary equation for the effort on R&D. Equation (7) of the theoretical model and the comparative statics results linked to that equation, give us some avenues of the determinants of this R&D effort. Recall that, although in the theoretical part we refer to R&D output (including non-verifiable intangible assets), we estimate this magnitude through firm's R&D effort (R&D expenditures to sales), because in this way we account for returns linked to intangible non-verifiable capital. The equation to estimate is:

$$\begin{aligned} EFFORT_{it} &= d_1 HISPECIAL_{it} + d_2 \begin{Bmatrix} HIDEBT \\ HISTDEBT \end{Bmatrix}_{tt} + d_3 INTFUNDS1_{it} + \\ & d_4 STOCK_{it} + d_5 EMPLOY_{it} + y_t + h_i + n_{it} \end{aligned} \tag{9}$$

Where the error term ν_{it} is a normal distribution with 0 mean and σ^2 variance.

According to hypothesis 4, equation (9) includes, as explanatory, the following variables. First, the degree of specialization of the firm's R&D (HISPECIAL). Second, the leverage in case of R&D-intensive firms (HIDEBT). As an alternative, we also consider the short-term leverage (HISTDEBT) [13]. And third, the total internal funds in the period before to that of implementing the R&D effort (INTFUNDS1) as a way to control for the definition of a *deep-pocket* policy. We expect $d_1 > 0, d_2 < 0, d_3 > 0$. Equation (9) also includes control variables: Firm's size (EMPLOY), and whether the firm is listed in the

[13] We are going to use this variable to estimate the instrument (R&D effort) to be applied in the estimation of the STDEQUITY equation (8).

stock market (STOCK). We expect that the possibility to raise additional funds, through the stock market, should facilitate firms' investment, and, in particular, R&D investment.

Finally, equation (9) has another particularity. There is a high percentage of firms (62%) that do not make R&D efforts. This fact generates a non-continuous equation. We use the Tobit model to estimate it, where the latent dependent variable (the effort) follows the observability rule:

$$Effort^{*}{}_{it} = \begin{Bmatrix} Effort_{it} & if \quad Effort^{*}{}_{it} > 0 \\ 0 & Otherwise \end{Bmatrix}$$

4. RESULTS AND DISCUSSION

In Table 4, we present the results for the debt-equity ratio in addition to the short-term debt-equity ratio, which test hypotheses 1, 2, and 3. Table 5 shows the results corresponding to the R&D effort auxiliary equation to test hypothesis 4. We conduct the estimation of the principal equation (8) by assuming that there are firm specific and non-time variant effects which are correlated with some explanatory variables. This is justified by the correlation among such variables (0.57 for debt-equity ratio and 0.56 for the short-term debt-equity ratio) which indicates that we must control for the unobserved effects. Otherwise, we would obtain inconsistent estimates in the debt structure specification. Finally, a c^{2} test is conducted in all equations to reject the null hypothesis of a zero value of each set of regressors.

PUT TABLE 4 HERE

Table 4 shows that specialized firm working in a R&D-intensive sector have a lower debt-equity ratio than their counterparts. This is especially true for the short-term debt-equity ratio (99% significant). This confirms hypothesis 1. Moreover, the investment in R&D seems to have a strong negative effect on both financial ratios. Firms, which carry out some innovation activity, reduce the share of leverage, especially short-term, in the financing of that activity (a feature that it is confirmed in Table 5). This result supports Hypothesis 2. The amount of internal funds stimulates the total leverage. This positive sign contradicts what we expected, and might be justified because in our model only one project is financed. Thus, the decrease in the cost of capital for those firms with a high amount of internal funds leads directly to a decrease in the debt-equity ratio. But, by introducing the possibility to finance more projects, we might eventually expect that those firms with a high amount of internal funds might demand a lot of external capital to finance various projects. As a result the firm's leverage might increase**.** Finally, the size of the firm has a positive, and significant, impact on the short-term firm's debt-equity ratio, which is quite intuitive since these firms have higher collateral to offer to obtain debt.

The second part of the analysis corresponds to the estimation of the auxiliary equation of R&D effort.

PUT TABLE 5 HERE

Table 5 shows the following results. First, in line with hypothesis 4, the higher the leverage a firm in a R&D-intensive sector, the lower its R&D effort. This is also true for the short-term leverage. This result illustrates the theoretical outcome of Anderson and Prezas (1999). They suggest that in some sectors a positive relationship between R&D effort and firm's leverage could be found. We can state that for R&D-intensive sectors this positive relationship is not observed. Second, to have implemented a *deep-pocket* policy (INTFUNDS1) has a positive impact on firm's R&D efforts. Third, to be a specialist firm within a R&D-intensive sector, as we define it, have a positive, but non-significant, effect on the R&D investments. And Fourth, R&D effort is marginally dominant in firms that are listed in the Stock market, and in large firms in comparison to their counterparts.

Related to the results presented above, we can just speculate, as our theoretical model is static, over the dynamic evolution of the debt-equity ratio. We may argue that those firms that belong to R&D-intensive sectors are acquiring a superior expertise as time goes by, and, as in our model, this implies higher incentives to behave opportunistically. According to our results this has a negative impact on the firm's debt-equity ratio. On the other hand, these firms have also accumulated resources and reputation, as they become more efficient with time. This fact smoothes collateral requirements and facilitates debt financing. The interaction of both effects does not allow us to define an unambiguous sign in the growth of the debt-equity ratio for R&D-intensive firms. In contrast, with firms in less R&D-intensive sectors, the effect of the firm's growing efficiency is just the second one, that is, an increased resources and reputation. Therefore, we expect a smaller growth rate in the debt-equity ratio in those firms that belong to a R&D-intensive sector in comparison to those firms that do not.

Table 6 looks at this question by conducting a mean analysis to test whether period-t debt equity ratio (DEQUITY) and that of period t-1 (DEQUITY1) were equal or not for firms in a HIGH sector and for firms in a non-HIGH sector. We do the same for the short-term debt-equity ratio (STDEQUITY)

PUT TABLE 6 HERE

These results show that only when HIGH=0, the difference between DEQUITY and DEQUITY1 as well as STDEQUITY and STDEQUITY1 is significantly positive. This basically confirms our theory. Note that, just by making use of standard collateral arguments we cannot explain the different pattern in the temporal variation of both firm's financial ratios for HIGH and non-HIGH sectors found it. Thus, the introduction of our strategic default considerations on behalf of the managers of R&D-intensive firms can be a possible explanation of this different behavior. This result contrasts with Vilasuso and Minkler (2001). They argue that the firm's debt-equity ratio converges to an optimal level. Thus, firms with highly specific assets (i.e. R&D-intensive firms) show, at their early stages of evolution, a low debt-equity ratio that increases, due to agency cost considerations, to a higher optimal level. On the other hand, for those other firms with no specific assets, the reverse is true. As a conclusion, a higher growth in the debt-equity ratio should be observed when we compare the former firms with the latter. We should mention that they use arguments based on the higher transaction costs of firms with specific assets and the superior agency costs of mainly debt-financed or mainly equity-financed firms. The introduction of the strategic default consideration we focus on reverses their result.

5. CONCLUDING REMARKS

In this paper we present a model that analyzes financing tools to prevent managers of firms involved in R&D activities from behaving in an opportunistic way. This allows us to obtain several results. First, the amount of project returns on R&D investments, the degree of specialization on R&D activities and the amount of available internal funds have a negative impact on the firm's debt-equity ratio. And second, the average returns of the firm's R&D intensive projects are positively explained in terms of its R&D specialization degree and its amount of internal funds. But, for those firms that invest in R&D projects a negative relationship between their R&D output and their leverage is hypothesized.

In the second part of the paper we conduct an empirical study on the debt-equity ratio as well as the short-term debt-equity ratio of Spanish manufacturing firms in connection with their R&D investments, their R&D specialization degree and their policy of internal funds accumulation. Additionally, we investigate the financing determinants of R&D investments and how the financing structure (debt-equity ratio) of firms on R&D-intensive sectors might evolve in time in comparison to other firms in less R&D-intensive sectors. The results we find confirm our theoretical hypotheses. Moreover, there is no basic difference when we focus on the short-term debt-equity ratio instead of the debt-equity ratio. Firms that make high efforts on R&D investments and/or are specialized in these activities show a lower debt-equity ratio than their counterparts. It is also confirmed that the amount of firm's internal funds (implementation of a *deep-pocket* policy) positively influences its R&D investments. But, the leverage of firms in R&D-intensive sectors has a clear negative impact on their R&D effort. Finally, what is interesting for our model, we have observed that, on average, the growth of the debt-equity ratio is lower for firms in R&D-intensive sectors in comparison to their counterparts in less innovative sectors. This is relevant because neglecting the strategic considerations we have dealt with in our model, and just using standard collateral arguments over asset specificity, we could not have appreciated a different pattern in the temporal evolution of firm's debt-equity ratio between R&D-intensive and non-R&D intensive sectors. On the negative side, our hypothesis connected with the relevance to implement a *deep-pocket policy* as a way to explain the financial structure of those firms in R&D intensive sectors is not confirmed. Probably, this is a direct consequence of considering a static model with only one project to be financed instead of a dynamic one, where the effects of accumulating funds in the past to finance more than one project could be dealt with.

This work can be extended in several ways. First, we could use market data as a way to validate our hypotheses (Affleck-Graves and Spiess, 1999). In this sense, we should find in those firms that are listed in the stock market, a positive stock reaction to public announcement of increases in their R&D investments in two cases. First, when the firms are highly-specialized with a low leverage. And second, when they have followed a *deep-pocket policy* in the years previous to that announcement. A second extension of our model is to develop a dynamic framework to prove theoretically the result over a lower growth in the debt-equity ratio for those R&D-specialized firms in comparison to their counterparts. This is left for future research.

Theoretical Appendix

To determine the optimal contract, we use equation (4) to get $a \geq \frac{R}{(1-b)E}$ (A.1)

As $Y \geq \overline{Y}$ (by assumption 3), the limited liability constraint $R \leq Y$ is not binding for the optimal R. Thus, given that the entrepreneur profits, p, are decreasing in a (see (1)), we can ensure from (A.1) that $a = \frac{R}{(1-b)E}$, and (4) is exhausted with equality.

Substituting this value of a into the debt-holder's zero-profit condition (2), we find:

$$R(p(1-b)E+(1-p)L) - I_E(1-b)E = 0 \Rightarrow R = I_E(1-b)E \Big/ p(1-b)E+(1-p)L \quad \text{(A.2)}$$

And, from (A.2), we get that $a = \frac{\overline{Y}}{(1-b)E}$ with $\overline{Y} = \frac{I_E(1-b)E}{p(1-b)E+(1-p)L}$ (A.3)

To prove the result of the text, we inspect those non-trivial derivatives:

a/ Concerning $E\{E\} \equiv \overline{E} = E-(1-p)a(1-b)E$, given in (9), we compute:

$$\partial_b \overline{E} = -(1-p)\partial_b \overline{Y} = -\partial_b\{\frac{I_E}{p+(\frac{(1-p)L}{(1-b)E})}\} > 0 \quad \text{(A.4)}$$

$$\partial_R \overline{E} < 0 \quad (as\ R = a(1-b)E \Rightarrow \overline{E} = E-R)$$

b/ For the debt-equity ratio (*DE*) given by (7), we have:

$\partial_d DE = -\partial_{I_E} DE < 0$, where we have used $\partial_{I_E}\overline{Y} > 0$ and $\partial_{\overline{Y}} DE > 0$

$\partial_b DE = (\partial_{\overline{Y}} DE)(\partial_b \overline{Y}) < 0$ (Where $\partial_{\overline{Y}} DE > 0$ and $\partial_b \overline{Y} < 0$ by (A.4))

To compute $\partial_E DE$, we first compute $\partial_E \overline{Y}$

$$\partial_E \overline{Y} = \partial_E\{\frac{I_E}{p+(\frac{(1-p)L}{(1-b)E})}\} = \frac{I_E(\frac{(1-p)L}{(1-b)E^2})}{(p+(\frac{(1-p)L}{(1-b)E}))^2} = (\frac{\overline{Y}}{E})(\frac{F}{P+F})\ with\ F = \frac{(1-p)L}{(1-b)E} \quad \text{(A.5)}$$

From (A.5), we can compute:

$$\partial_E DE = \partial_E\{\frac{1}{\frac{pY+E}{\overline{Y}}-1}\} = -\frac{1}{\overline{Y}^2}(\frac{\overline{Y}-(pY+E)(\partial_E \overline{Y})}{(\frac{pY+E}{\overline{Y}}-1)^2}) = -\frac{1}{\overline{Y}(\frac{pY+E}{\overline{Y}}-1)^2}(1-\frac{(pY+E)}{E}\frac{F}{p+F})$$

Thus, we can ensure that

$$\partial_E DE \lessgtr 0 \Leftrightarrow \frac{1+pY/E}{1+p/F} \lessgtr 1 \Leftrightarrow \frac{Y}{E} \lessgtr \frac{1}{F} = \frac{(1-b)E}{(1-p)L} \Leftrightarrow E \gtrless \sqrt{\frac{(1-p)LY}{1-b}} \equiv \overline{\overline{E}} \quad \text{(A.6)}$$

Empirical Appendix

1/ Our database is composed by sectors based on a classification, CNAE, that has a correspondence with the NACE-CLIO classification. NACE is a general industrial classification of economic activities within the European Community and CLIO is the Classification and Nomenclature of Input-Output table. Both classifications are officially recognised by the Accounting Economic System.

Correspondence of the sample CNAE codes
With NACE-CLIO codes

	CNAE	NACE-CLIO
Chemical, plastic, rubber and metal products	1, 2, 3, 4	22, 24, 25, 31
Electric and electronic material	6, 7	33, 34, 35, 39
Machinery, motors and vehicles	5, 8, 9	32, 36, 37, 38
Food and beverages	10, 11, 12	41, 42
Leather, wooden and paper	3, 14, 15, 16, 17, 18	43, 44, 45, 46, 47, 48, 49

2/ The criteria we have chosen to distinguish between HIGH, and NON-HIGH (MEDIUM and LOW) sectors is based on two measures extracted from Segura et al. (1989). First, the Autonomy Technology Index (ATI), which is the ratio of R&D expenses to the R&D expenses plus the technological payments. Second, the Total Technological Effort Index (TTEI) which is the ratio of the R&D expenses plus the technological payments to the added value.

- HIGH sectors are those where the AIT and the TTEI are higher than the mean for all sectors. This includes the chemical sector, electric and electronic material, office machines, computers, optical products, and transformation of plastic and rubber materials.
- MEDIUM sectors are those where the AIT or the TTEI, but not both, are lower than the mean for all sectors. This includes production and transformation of metal products, machinery, motors, vehicles and paper.
- LOW sectors are those where the AIT and the TTEI are lower than the mean for all sectors. This includes the food, beverages, tobacco, wood and leather sectors.

References

Affleck-Graves, J., and Spiess, D. 1999. The Long-run Performance of Stock Returns Following Debt Offerings. *Journal of Financial Economics* **54**: 45-73.

Anderson, M. H., Prezas, A. P. 1999. Intangible Investment, Debt Financing and Managerial Incentives. *Journal of Business Economics* **51**: 3-19.

Black, B. S., Gilson, R. J. 1998. Venture Capital and the Structure of Capital Markets: Banks versus Stock Markets. *Journal of Financial Economics* **47**: 243-277.

Board, J., Delargy, P.J.R., Tonks, I. 1990. Firm Financing and R&D Intensity: A Post-SSAP 13 US-UK Comparison. *Mimeo.*

Bolton, P., Scharfstein, D. 1996. Optimal Debt Structure and the Number of Creditors. *Journal of Political Economy* **104 (1)**: 1-25.

Bradley, M., Jarrell, G., Kim, E. Han 1984. On the Existence of an Optimal Capital Structure. *Journal of Finance* **39**: 857-78.

Cavanaugh, J. K., Garen, J. 1997. Asset Specificity, Unionization and the Firm's Use of Debt. *Managerial and Decision Economics* **18**: 255-69.

De Angelo, H., Masulis, R. W. 1980. Optimal Capital Structure under Corporate and Personal Taxation. *Journal of Financial Economics,* **8(1)**: 3-29.

Doukas, J., Switzer, L. 1992. The Stock Market's Valuation of R&D Spending and Market Concentration. *Journal of Business Economics* **44**: 95-114.

Fortunato, A., Belfo, F. P. 1999. R&D and Capital Structure: A Simulation Approach. *Manuscript, University of Coimbra.*

Gaver, J., Gaver, K. M. 1993. Additional Evidence on the Association between the Investment Opportunity Set and Corporate Financing, Dividend, and Compensation Policies. *Journal of Accounting and Economics* **16(1-3)**: 125-60.

Gompers, P., Lerner, J. 1999. The venture capital cycle, MIT Press: Cambridge and London.

Goodacre, A., Tonks, I. 1995. Finance and Technological Change. In the *Handbook of the Economics of Innovation and Technological Change*, P. Stoneman (ed). Oxford: Blackwell Publishers; 298-342.

Griliches, Z. 1979. Issues in Assessing the Contribution of Research and Development to Productivity Growth. *Bell Journal of Economics* **10(1)**: 92-116.

Griliches, Z. 1988. Research Expenditures and Growth Accounting. In the *Technology, Education, and Productivity.* Oxford and New York: Blackwell; 244-67.

Guiso, L. 1998. High-Tech Firms and Credit Rationing. *Journal of Economic Behavior and Organization* **35**: 39-59.

Hall, B. 1992. Investment and Research and Development at the Firm Level: Does the Source of Financing Matter? *National Bureau of Economic Research. WP 4096.*

Himmelberg, C. P., Petersen, B. C. 1994. R&D and Internal Finance: A Panel Study of Small Firms in High-Tech Industries. *Review of Economics and Statistics* **76(1)**: 38-51.

Johnson, L. D., Pazderka, B. 1993. Firm Value and Investment in R&D. *Managerial and Decision Economics* **14(1)**: 15-24.

Long, M., Malitz, I. 1985. The Investment-Financing Nexus: Some Empirical Evidence. *Midland Corporate Finance Journal* **3**: 53-9.

Rapoport, H. 1971. The Anatomy of the Product-innovation Process: Cost and Time. In *Research and Innovation in the Modern Corporation,* Mansfield (ed). Norton : New York; 110-35.

Segura et al. 1989. La Industria Española en la Crisis 1970/1984. Alianza Editorial: Madrid

Sundaran, A.K., John T.A., John, K. (1996). An Empirical Analysis of Strategic Competition and Firm Values. The Case of R&D Competition. *Journal of Financial Economics* **40**: 459-486.

Teece, D. 1981. The market for Know-how and the Efficient International Transfer of Technology. *The Annals of the Academy of Political Social Science* **458**: 81-96.

Vilasuso, J., Minkler A. 2001. Agency Costs, Asset Specificity, and the Capital Structure of the Firm. *Journal of Economic Behavior and Organization* **44**: 55-69.

Zantout, Z. 1997. A Test of the Debt-Monitoring Hypothesis: The Case of Corporate R&D Expenditures. *Financial Review* **32(1)**: 21-48.

Table 1. Evolution of the debt-equity ratio and the short-term debt-equity ratio

	DEQUITY HIGH=1 [1]	DEQUITY HIGH=0	Test of means [2]	STDEQUITY HIGH=1	STDEQUITY HIGH=0	Test of means [2]
1990	1.97	2.03	0.24 (0.81)	1.57	1.53	0.16 (0.87)
1991	2.39	2.54	0.38 (0.70)	1.99	1.95	0.13 (0.90)
1992	2.99	2.32	1.57 (0.12)	2.35	1.78	1.48 (0.14)
1993	2.76	2.64	0.29 (0.77)	2.21	2.02	0.56 (0.57)
1994	2.16	2.90	1.66 (0.09)	1.79	2.26	1.28 (0.20)
Mean	2.45	2.49	0.19 (0.85)	1.98	1.91	0.48 (0.63)

[1] For the definition of the variables, see Table 3.
[2] p-value in parenthesis

Table 2. Descriptive statistics R&D output

	HIGH=1 [1, 2]	**High=0** [1, 2]
Product innovation	0.375	0.261
	(0.484)	(0.439)
Process innovation	0.407	0.347
	(0.491)	(0.476)
Number of observations	895	2765

[1] HIGH is a dummy variable equals to 1 if a firm is in a R&D-intensive sector (see the Empirical Appendix for details)
[2] Standard deviation in parenthesis

Table 3. The measurement of variables

	Definition	HIGH=1 [1, 2]	HIGH=0 [1]	Test of Means [3, 4]
EFFORT	R&D expenditures to sales ratio.	0.017 (0.097)	0.004 (0,018)	6.496 (0.000)
DEQUITY	Ratio of total debt over firm's equity.	2.456 (5.080)	2.488 (4.331)	0.187 (0.851)
STDEQUITY	Ratio of short-term debt [5] over firm's equity	1.985 (4.753)	1.914 (3.45)	0.481 (0.631)
DEBTLENGTH	Ratio of long-term debt to total debt	0.152 (0.214)	0.181 (0.236)	3.106 (0.002)
HIDEBT	The product of HIGH and the log of total debt	13.534 (2.289)	0	
HISTDEBT	The product of HIGH and the log of short-term debt	13.266 (2.446)	0	
RECENT	Dummy equals to 1 if the firm is younger than five years.	0.089 (0.285)	0.095 (0.294)	
DIVERSIFIC	It is a measure of the firm's diversification (see the text for details)	0.286 (0.269)	0.206 (0.238)	8.496 (0.000)
SPECIAL	Product of (1-RECENT) and (1-DIVERSIFIC).	0.647 (0.328)	0.717 (0.325)	
HISPECIAL	Product of HIGH and SPECIAL	0.647 (0.328)	0	
STOCK	Dummy equals to 1 if the firm is listed in the Stock Market.	0.040 (0.197)	0.060 (0.238)	
INTFUNDS	The log of firm's internal resources	13.342 (2.181)	12.593 (2.552)	7.895 (0.000)
HINTFUNDS	Product of HIGH and INTFUNDS	13.342 (2.181)	0	
EMPLOY	Log of total employment.	4.917 (1.552)	4.556 (1.668)	5.720 (0.000)

[1] Means and (standard deviation).
[2] HIGH is a dummy variable equals to 1 if a firm is in a R&D-intensive sector (see the Empirical Appendix)
[3] p-value in parenthesis
[4] We only test the difference of means for those non-dummy variables. Dummy variables do not satisfy the normality hypothesis to conduct a test of mean differences.
[5] Short-term debt has a maturity of less than one year.

Table 4. Debt-equity and R&D intensity

Dependent variable	STDEQUITY [1, 2]	DEQUITY [1, 2]
EFFORT	-93.445*** (2.293)	-115.394* (1.808)
HISPECIAL	-1.362*** (2.560)	-1.303** (1.941)
HINTFUNDS1 [3]	0.509 (1.408)	0.908** (2.007)
STOCK	0.550 (0.713)	1.159 (1.198)
EMPLOY	0.936*** (2.347)	0.837 (1.470)
Log(likelihood)	-6888.30	-6279.77
LR test [c^2 (17)]	35.15 (0.01)	38.34 (0.00)

[1] T-statistics in parenthesis.
[2] It includes temporal and sectorial dummy variables
[3] HINTFUNDS1 is a one-period lagged HINTFUNDS
*** 99% signif. ** 95% signif. * 90 % signif.

Table 5. The R&D financing regimes

Dependent variable	R&D effort [1, 2, 3]	R&D effort [1, 2, 3]
HISPECIAL	0.349 (0.649)	0.383 (0.713)
HIDEBT		-0.232*** (2.797)
HISTDEBT	-0.240*** (3.054)	
INTFUNDS1 [4]	0.233*** (2.758)	0.228*** (2.701)
STOCK	0.446 (1.327)	0.446 (1.324)
EMPLOY	0.741*** (6.067)	0.746*** (6.049)
Log (likelihood)	1361.11	1361.85
LR test [c^2 (20)]	630.49 (0.00)	631.96 (0.00)

[1] All the coefficients are multiplied by 100
[2] T-statistics in parenthesis.
[3] It includes temporal and sectorial dummy variables
[4] INTFUNDS1 is a one-period lagged INTFUNDS
*** 99% signif. ** 95% signif. * 90 % signif.

Table 6: Descriptive Statistics of the variation of DEQUITY and STDEQUITY

	DEQUITY	DEQUITY1 [1]	Test of means [3]
HIGH=1	2.579	2.538	0.338 (0.735)
HIGH=0	2.605	2.308	2.942 (0.003)
	STDEQUITY	**STDEQUITY1 [2]**	**Test of means**
HIGH=1	2.090	2.039	0.477 (0.633)
HIGH=0	2.009	1.822	3.188 (0.001)

[1] DEQUITY1 is a one-period lagged DEQUITY
[2] STDEQUITY1 is a one-period lagged STDEQUITY
[3] p-value in parenthesis