FINANCIAL SOURCES OF R&D INVESTMENT

Ester Martínez-Ros and Josep A. Tribó*/**

Abstract

This paper explores how firms finance their R&D projects. There are several instruments that can be used, however, due to information asymmetries and the combination of tangible and intangible returns that R&D projects generate, debt-financing is the worst alternative. The novelty of this paper is that it combines aspects of the resource-based view with those of the agency theory. This, in terms of a firm's decision making, is to consider that a firm's R&D investment is, on the one hand, partly determined by its financing resources and, on the other hand, a major determinant of its financial structure. The theoretical hypotheses are supported in the empirical study that makes use of a data sample of Spanish manufacturing firms for the period 1991-99. The main implication for managers that can be extracted from our study is that the most powerful financing incentive mechanism to stimulate R&D effort is to follow a *deep pocket* policy of internal funds accumulation.

Keywords: R&D investment, financing instruments, resource-based view, agency theory.

** Departamento de Economía de la Empresa. Universidad Carlos III de Madrid. C/ Madrid 126, (28903) Getafe, Spain*
Phone: 34-91649321, FAX: 34-91649608, E-mail: joatribo@emp.uc3m.es
*** The authors wish to thank Sandro Brusco, Isabel Gutiérrez, 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 acknowledged.*

1. Introduction

An important issue in business strategy is how to manage knowledge in order to increase the competitive advantage of companies. On one hand, the traditional is that markets provide incentives as well as external information networks (Freeman, 1991) that drive a firm´s search for excellence. On the other hand, a more recent view looks to the firm´s fundamentals (resources and capabilities) and the evolution paths it has adopted or inherited (Teece, Pisano and Shuen, 1997) as the core of its competitive strategy. Those firms that have accumulated a higher stock of knowledge are more able to dominate the market (Tidd, Bessant and Pavitt, 1997). This knowledge is integrated into specific organization routines (Pavitt, 1984, Teece, 1986) and innovations that improve a firm´s productivity (Kamien and Schwartz, 1975) through better information exchange and communication among employees. Thus, given its importance, a central issue is to investigate the resources necessary to improve the innovation process.

In order to address this problem we should recognize that a firm´s investment in innovation is risky due to the uncertain returns (Fleming, 2001) and intangible assets involved (Santarelli, 1991). This has important implications for the combination of resources that stimulate these investments, and, in particular, those to finance them. This paper focuses on these latter resources, which in our opinion, management literature has not stressed enough the central role that they play in the innovation process. We adopt a two-track approach to investigate this issue. First, the resource-based view (Wernefelt, 1984; Prahalad and Hamel, 1990; Grant, 1991; Peteraf, 1993) sheds light on the design of a firm's financial instruments that stimulate R&D investments. Second, the agency theory approach (Jensen and Meckling, 1976; Hart, 1995) focuses on the role of financial contracts as a mechanism to soften the manager-lender conflicts that R&D investment returns generate. These conflicts are relevant in these kinds of investments because they involve high information asymmetries, a feature that raises substantially the associated financing cost; hence, the level of a firm's R&D investment may suffer.

It is not surprising that R&D-intensive firms experience credit rationing (Guiso, 1998). One of the reasons for this phenomenon is that lenders generally provide external capital through debt contracts. But, this type of financial instrument is particularly unsuitable to finance these activities (Bradley *et al.*,

1984; Long and Malitz, 1985; Hall, 1992; Board *et al.*, 1993; Chiao, 2002). Resource-based theory together with transaction cost theory point to different reasons. Firstly, the rigid payment schemes for these contracts are not adequately matched with volatile returns that characterize R&D-intensive projects (Santarelli, 1991). Secondly, collateral needs of debt contracts are difficult to fulfill in a context of a high proportion of intangible and specific assets (Williamson, 1988). Thirdly, debt is a financial contract that does not involve any ownership transference. This impedes the solution of hold up problems that typically appear in R&D investments (Kulti and Takalo, 2000). And finally, there are tax advantages linked to R&D investments. These tax deductions diminish the relative value of those deductions by interest debt payments (De Angelo and Masulis, 1980).

The main theoretical contribution of our paper is to move a step beyond the resource-based view and integrate aspects that rely on the agency theory in order to analyze the strategic problems of R&D financing**.** We introduce as a novelty, the timing of generation of intangible returns from R&D activities in comparison with other tangible returns as the driving mechanism for the potential conflicts linked to R&D investments. Our theory shows that entrepreneurs have compelling incentives to cheat lenders over the tangible (monetary) R&D returns. The focus is that once R&D-intensive projects have begun to produce cash-flow, the firm would have already assimilated the intangible returns (knowledge, in a broad sense), which cannot be transferred to the lenders. Thus, the entrepreneur bears a lower cost if he under-reports the cash-flow, and lenders liquidate the project as a consequence. In this context, debt contracts exacerbate this behavior as they increase the benefits of misreporting, because they oblige the firm to fixed cash-flow payments regardless of the returns generated. Thus, it is important to recognize in the mechanisms that provide the firm´s financing resources a role to soften entrepreneur-lender agency problems that emerge as an outcome of R&D investments. This, in terms of a firm's decision making, is to assume that a firm's R&D investment decision is, on the one hand, partly determined by its financing resources and, on the other hand, a major determinant of its financial structure. Thus, any correct methodology to estimate the firm levels of innovation should recognize the existence of an endogenous relationship with its financing resources. This is our main methodological contribution.

Furthermore, rapid generation of intangible returns in comparison to tangible returns has interesting consequences in a dynamic context. Innovative firms improve their efficiency with time, and they can offer an increased real collateral guarantee to potential lenders [270]. This should lead to give rise to increased leverage. But, at the same time, efficiency improvements are translated into higher productivity in R&D activities (more intangible returns in a shorter time). This result will reduce leverage over time. To contrast empirically the relevance of this latter effect, directly linked to our theoretical contentions, we should observe a lower rate of growth in the leverage for those firms heavily involved in R&D activities, in contrast to their counterparts in less R&D-intensive sectors.

We use the database of Spanish manufacturing firms "Encuesta Sobre Estrategias Empresariales" for the 1991-99 period to carry out our empirical investigation. On one hand, we analyze how R&D expenses depend on the firm´s resources (including financial) as well as other features like its diversification. On the other hand, we recognize that the firm leverage is endogenous and depends on its R&D investment as well as other characteristics. The results confirm our hypotheses. Firstly, we prove that leverage has a negative impact on R&D investments, while internal funds have a strong positive impact. Secondly, leverage is also influenced inversely by a firm's R&D investments. And finally, the rate of growth of leverage is smaller for those firms that belong to R&D-intensive sectors.

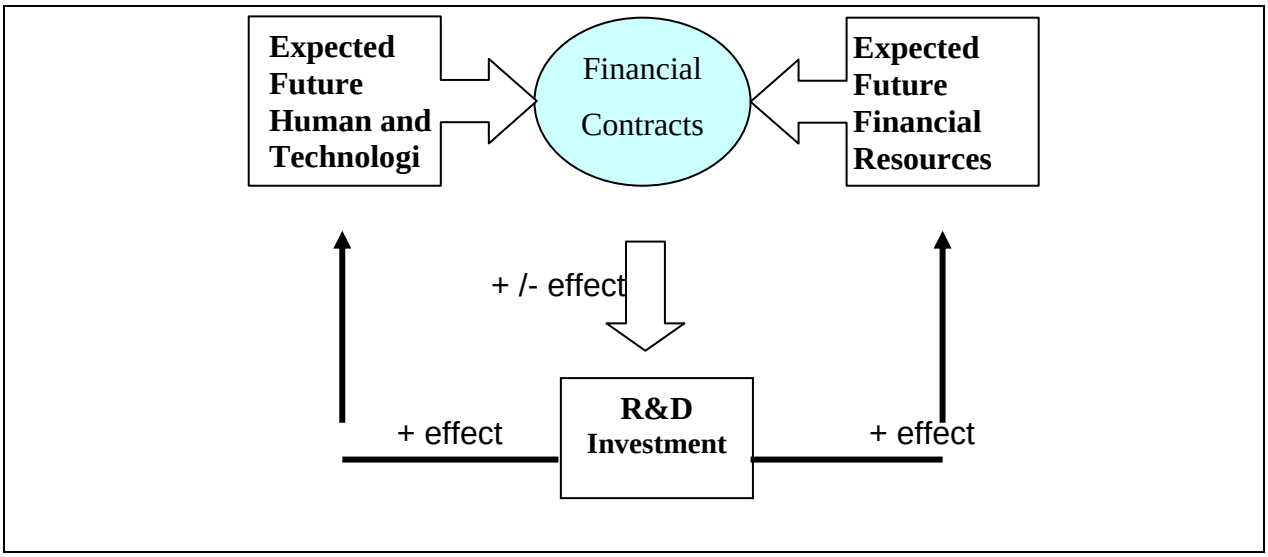
The rest of the paper is structured as follows: Section 2 defines the theoretical framework. In Section 3 the empirical analysis is carried out, while the results are presented in Section 4. The discussion is in Section 5. The paper concludes with some final remarks.

2. R&D activities and financing instruments

We can explain the strategy problems linked to R&D activities that confront firms by making use of two frameworks: the resource-based view to investigate the management of a firm's resources in order to undertake a successful innovation policy, and the agency cost theory to analyze the possible opportunistic behavior of entrepreneurs when choosing means of funding for innovation activities.

Galende and Suárez (1999) distinguish three types of resources to develop R&D activities: financial, physical and intangible resources. We focus on the financial endowments to develop our framework, and we recognize the determination jointly of the financial structure and the firm's R&D policy (Guerard and Bean, 1997). Our model complements the resource-based view to explain the firm's drivers of its R&D policy, with the agency theory to deal with the effect of its R&D investment on the conflicts of interest between entrepreneurs and lenders which can be ameliorated by making use of financial instruments. We think that this dual approach can provide a more complete insight into the relationship between financial structure (viewed as a resource and as an incentive mechanism to alleviate agency problems) and firm's strategic investments like R&D.

[270] We use the word debt-holder as equivalent to lender throughout the text.



External financial resources contribute to levels of innovation, but they are also the result of balancing the expected future conflicts that R&D activities generate. The obligations of the financial contracts that tie firms to lenders have a clear impact on investment and, specifically, on R&D investment. Financial structures with collateral requirements that demand rigid payments (debt) are not the best alternative to develop R&D projects that generate long-term volatile and mainly intangible returns. Lenders anticipate this feature and will push the cost of capital up and, consequently, R&D investment down. However, the description of this relationship does not complete the picture, because there is a feed back effect that moves in the other direction (from R&D investment to financial resources, see the scheme). The outcome of the innovation process affects human, technological and financial resources in the future. In the first place, much of these activities improve human capital because they involve some element of training. Next, by carrying out innovation in the production process and/or in the products, there is an improvement in technological resources. Thereafter, there is a tangible outcome (i.e. patents) that generates financial resources. The combination of these resources strongly influences the expected future collateral as well as the conflicts between managers and lenders. This determines the cost of raising external capital. Thus, a particular financial structure emerges to minimize the cost of capital that encompasses future agency conflicts between lenders and entrepreneurs derived from the resources that are the outcome of R&D investments.

To summarize, the scheme we propose links financial resources to R&D investments through the resource-based theories, and recognizes an endogeneity in the financial structure as a way of minimizing agency conflicts that R&D investment generates (agency theory).

The resource-based view highlights the firm's internal characteristics in order to explain why they pursue different strategies with different outcomes (Wernefelt, 1984; Prahalad and Hamel, 1990; Grant, 1991; Peteraf, 1993). Companies are heterogeneous and each one combines tangible and intangible resources as well as capabilities to develop different types of projects that generate different results. Within this setting, R&D projects represent a strategic (long-term) combination of resources and capabilities that leads, through a sequence of results, to a competitive advantage.

We argue that R&D intensive projects generate returns, which are in essence: a) uncertain; b) long-term; c) intangible. This facilitates firms to take advantage of in-deep project knowledge (information asymmetries) and behave opportunistically when they borrow funds externally. Lenders anticipate this behavior and require a high financing premium. Thus, a natural way to prevent these outcomes is to accumulate a large amount of funds carried over from the previous years in order to develop these kinds of projects (to follow a deep pocket policy). This configures the first hypothesis to be tested:

Hypothesis 1. *Firms are more likely to develop R&D projects when they have access to internal funds instead of external financing.*

We have argued that among the external financial resources, equity financing provides more incentives to invest in R&D-intensive projects than debt financing does (Hall, 1992, Long and Ravenscraft, 1993, Chiao, 2002). Uncertain returns of R&D-intensive projects, makes debt instruments particularly unsuitable, due to their rigid payment scheme. The obligation imposed by this financial resource is at odds with the investment outcome. Moreover, firms engaging in R&D projects face serious problems in offering collateral to lenders because of the intangible assets that are associated with innovation activities. This hinders the development of these kinds of projects, as debt obligations cannot be made contingent on future, mainly intangible, project returns. A high cost of capital will result for debt-financed R&D projects, which will, in turn, lead to an

underinvestment outcome. This is also reflected in the lower incentives for a debt-financed firm's employees to invest in acquiring specific human capital (hold-up problem). This is so because the threat of being dismissed without obtaining any return of their human capital investment if the project is liquidated is more likely. This feature will have important negative effects on a firm's innovation outcome as studies like Souitaris (2002) show using a sample of Greek firms. A way to prevent this hold-up problem is by using financial contracts that involve ownership transference like equity contracts (Kulti and Takalo, 2000). Thus, we expect a negative effect of debt financing on a firm´s R&D investments. This is the second hypothesis to test:

Hypothesis 2. *A company´s leverage has a negative impact on R&D investments*

Risk attitudes play a crucial role in the development of innovation activities. The degree of diversification, especially if it is unrelated, is an accepted proxy of a firm´s risk aversion. As innovation activities are considered risky investments, a negative relation between diversification and R&D investment is expected (Hoskisson and Hitt, 1988). However, diversified firms, generally have more tangible assets to offer as collateral to finance their R&D investments with debt. This would suggest a positive relation between diversification and R&D investments. Moreover, Anderson and Prezas (1999) highlight another effect, apart from collateral considerations, to justify the positive impact of diversification on R&D investments in leveraged firms. They explain that managers may decide to invest in R&D projects as an internal commitment device to ensure greater efforts in other projects (diversification). This effort is implemented in order to avoid a short-term bankruptcy that could eliminate all the profits that R&D projects might generate in the future. This would justify a positive impact of diversification on R&D investment through debt financial structure. The final outcome will be balanced by the previous three effects, (two positive and one negative). This leads us to suggest the following hypothesis:

Hypothesis 3. *There is a positive relationship between a firm's diversification and its R&D investments. And conversely, the more specialized a firm, the less incentives it has to invest in R&D.*

The returns from a firm's innovation activity can be classified as intangible and tangible. The first return is embedded in the skills and capabilities of individuals and the organization. It measures the benefits such as human and physical capital accumulation, which will become a firm's resources with an effect on eventual future investments. Some of these benefits are internalized within the firm, and the speed at which the organization assimilates them is an indicator of its management efficiency. The second return is cash-flow. Generally, these benefits emerge later and, in some cases, as the outcome of the human and technological resources developed within the R&D project. Interestingly enough, the sooner the intangible resources are generated in comparison with the cash-flow, the more incentives there are for an entrepreneur to cheat the lenders. The reason is that managerial misbehavior will not result in lenders appropriating the already generated intangible resources, because they are not transferable. In that case, project liquidation has low short-term costs, which is the root of an entrepreneur's opportunistic behavior. Our assumption is that there is agency problems because of tangible returns (cash-flow) are the final output (i.e patents) of intangible ones (Pearl, 2002) [271]. Thus, the optimal financial contract between the lenders and the firm has to tackle this agency problem. It has to balance two effects. The cost of an increase in the possibility of liquidation, which destroys value, as it precludes the firm from benefiting from future human and technological resources; versus the benefits of preventing the entrepreneur from "cheating" over cash-flow, which may raise the firm´s cost of capital and lead to an underinvestment outcome.

Debt, in contrast to equity, is a financial instrument that promotes managerial cheating related to the cash-flow generated by the firm´s innovation activity. The former instrument holds the firm to a rigid payment scheme coupled with an explicit thread of liquidation. This is in contrast to equity where there is no such liquidation, nor a compulsory payment scheme. As a result, the cost of capital under a debt-financing scheme will be higher than under an equity-financing one. This is because lenders will internalize the potential agency problems that each financing instrument promotes. In short, firms will avoid debt instruments as a means of financing their R&D investments. Along these lines, Rothwell (1992) describes different internal factors that affect the speed to market of a firm's innovation. One of these factors, flexibility, may be reduced if a firm is subject to a rigid debt repayment scheme. Thus, more indebted firms will show a longer period of generating cash-flows from their innovations. This, according to our model, will increase the aforementioned entrepreneur's opportunistic behavior of masking the real tangible returns. By avoiding the use of debt as a financial instrument we can get rid of this inefficiency.

There is another line of research that makes use of the market mechanism that supports the negative effect of innovation on leverage. These articles investigate how the markets react when R&D-intensive firms issue debt. Affleck-Graves and Spiess (1999) find that shares in small, young, and NASDAQ-listed firms, that are basically firms in technological sectors, experience a long-run underperformance after issuing debt. To summarize, debt instruments seem to be a bad alternative to finance innovation, (Hall, 1992). This is our fourth hypothesis:

Hypothesis 4. *Leverage must be lower in those firms that invest in R&D.*

[271] Venture Capital financing provides a good example (Gompers and Lerner, 1999). In the initial stages, start-up firms mainly produce intangible assets, while in the later stages, returns are more tangible.

In firms specialized in R&D investments the agency problem described previously is particularly important. This statement is based mainly on these firms' efficiency in generating non-monetary returns from their R&D activities and internalizing them in the short-term. This is confirmed by Rapoport (1971) among others, who finds 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. As we have already mentioned, the rapid time schedule in generating intangible assets provides an incentive to an entrepreneur to behave opportunistically. Within this setting, the use of debt instruments can exacerbate agency problems. Thus, the degree of specialization in R&D investment should show a decreasing relationship with leverage (Goodacre and Tonks, 1995). Consistently with this idea, Gaver and Gaver (1993) show that growth firms (generally R&D specialized) have a lower debt level than non-growth ones. This is our last hypothesis:

Hypothesis 5. *Leverage should be lower in those firms specialized in R&D activities than in those that are not specialized in these investments.*

3. Empirical analysis

3.1. Data

We use a database called "Encuesta Sobre Estrategias Empresariales" (ESEE) which includes information of the Spanish manufacturing industry and covers the period 1991-1999. The ESEE surveys approximately 3000 firms each year and accounts for differences in their size [272]. It contains information on sales, employment structure, technological behavior, and foreign activities as well as accounting information. After controlling for consistency problems and failures in some important variables we employ a sample of 3195 firms by year. The sample contains an incomplete panel for 9 consecutive years and 18 sectors, where there are 1360 of firms that invest in R&D (42.57% of the total).

3.2 Variables Definition

We use as dependent variables to test hypotheses 1, 2 and 3, the RD EFFORT constructed as the ratio of R&D expenditure to sales. The question of measurement of R&D activity 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 of the returns (tangible and intangible) that R&D activities generate. This measure fits better with the arguments presented in the theoretical discussion, where it is essential to incorporate in the measurement those intangible returns. These could have been missed with a variable of R&D output, which basically accounts for tangible outcomes.

Explanatory variables:

DEBT: It is the ratio of DEBT to total assets [273].

HIGH: 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 sum of R&D expenses plus technology payments (i.e. patent royalties). Second, the Total Technological Effort Index (TTEI) 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 higher 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.

SPECIALIZATION: It is an inverted measure of the degree of a firm diversification. It is defined as the complement to a diversification index such that:

SPECIALIZATION =1-DIVERSIFICATION = $\sum_i Q_i^2 \Big/ 100\sum_i Q$, where Q_i is the percentage of firm's sales in product i with i=1,.., 10 (we focus on the 10 main products) [274]. The diversification variable is basically an estimator of the degree of a firm's diversification. Note that, a firm focused on one activity (Q=100 and i=1) would have a zero value of DIVERSIFICATION (value of SPECIALIZATION equals one), and a firm equally diversified in ten activities would have a diversification value of 0.9 (0.1 of SPECIALIZATION). We will also use an interaction of specialization with the variable HIGH (HISPECIALIZATION) to control for those firms specialized in R&D activities.

INTERNAL FUNDS: It is a way of measuring the implementation of a deep-pocket policy. It is computed as the ratio of internal funds to total assets. In the estimations, we are going to use this variable lagged by one-period to better fit with the idea of a cash-flow

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

[273] We take this variable in intensive terms to avoid spurious size effects.

[274] As there are only 18 sectors, this measure is more related to an unrelated diversification than to a related one. Unrelated diversification fits better with the theoretical contentions that lead to hypothesis 3.

accumulation in the past to finance, among other things, a firm´s R&D activities.

Control variables:

- Tangible resources:

EMPLOYMENT: It is measured using the total number of employees at the end of the year and it is constructed in logs to keep within the scale. It controls by size and it is also an indirect proxy of physical resources. Related to employment there are authors, as Cavanaugh and Garen (1997), who suggest the inclusion of the firm's level of unionization as a variable to interact with the R&D effort to explain the leverage. We have argued before that R&D investment is a mechanism to curb union power in leveraged firms. However, we have not included this variable because wages in Spain are fixed through collective industry agreements. Thus, we take indirectly into consideration such an effect by introducing industrial dummy variables in our estimations.

TANGIBILITY is the ratio of tangible assets to the sum of tangible and intangible assets. With this variable we try to reflect the availability of collateral in the firm, which is one of the driving determinants of the firm leverage. Also, this variable represents a physical resource that may have an influence on its R&D investment.

CAPITAL EXPENDITURES: It is constructed as the ratio of firm´s investment to total assets. We include as investment: Hardware and software acquisitions, physical capital investment, portfolio investment, and investment in distribution.

STOCK: It is a dummy that equals 1 when the firm is listed in the stock market. This variable represents a first approximation to the existence of alternative financing resources to those provided internally or through debt contracts.

- Intangible resources:

AGE is the firm's age. This is a natural proxy of its reputation, which is a synthesis of intangible resources behind a brand name. This variable also reflects the availability of different financing channels and it is also a measure of the firm's bargaining power with regard to lenders.

HUMAN CAPITAL: It is the ratio of qualified employees (with a university degree) to the total number of employees.

- Other controls:

FOREIGN CAPITAL: It is a dummy that is equal to 1 when there is more than 50% of foreign capital in the firm's ownership, and 0 on the contrary. This is a proxy of managerial control, as foreign shareholders are less likely to collude with the management. Thus, it is inversely related to the existence of agency problems.

3.3. Methodology

We test the strategy decision to assign financial resources to innovate by recognizing the existence of an endogenous relationship that conditions a firm capital structure due to, among other things, the R&D investment policy. We suspect this is the case, as we have already mentioned, because the resources that generate R&D investments may generate some agency problem that can be ameliorated by making use of financial instruments.

According to hypotheses 1, 2 and 3, the estimation strategy of the R&D effort has the following specification:

$$\text{RD EFFORT} = \begin{cases} \alpha_1 \text{DEBT} + \alpha_2 \text{SPECIALIZATION} + \alpha_3 \text{INTERNAL FUNDS} + \\ \alpha_4 \text{EMPLOYMENT} + \alpha_5 \text{CAPITAL EXPENDITURES} + \\ + \alpha_6 \text{STOCK} + \alpha_7 \text{AGE} + \alpha_8 \text{HUMAN CAPITAL} + \alpha_9 \text{FOREIGN CAPITAL} + \eta_i + \varepsilon_{it} \end{cases} \quad (1)$$

The error term ε_{it} follows a normal distribution with 0 mean and σ^2 variance. Variable η_i accounts for the possible existence of fixed effects.

Two features that we would like to highlight:

1. There is a high percentage of firms that do not make R&D efforts (57,43%). This feature generates a non-continuous equation. We use the Tobit model to estimate it, where the latent dependent variable (the effort) follows this observability rule:

$$RD\,EFFORT^*_{it} = \begin{cases} RD\,EFFORT_{it} & if \quad RD\,EFFORT^*_{it} > 0 \\ 0 & Otherwise \end{cases}$$

2. To obtain consistent estimators, as the financial structure is an endogenous variable, we use an instrument to overcome the problems of correlation between the error term and the leverage. Hence, we estimate an auxiliary equation for the firm leverage (DEBT). The comparative static results linked to that equation give us some insight into the R&D investment determinants of firm capital structure, which will allow testing of hypotheses 4 and 5. 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, we use the "within method" to obtain consistent estimators of the determinants of a firm leverage. In particular, the specification we propose is the following.

$$\text{DEBT} = \begin{cases} \beta_1 \text{HIGH} + \beta_2 \text{HISPECIALIZATION} + \beta_3 \text{ EMPLOYMENT} + \\ + \beta_4 \text{ TANGIBILITY} + \beta_5 \text{STOCK} + \beta_6 \text{AGE} + \eta_I + \varepsilon'_{it} \end{cases} \quad (2)$$

The error term ε'_{it} follows a normal distribution with 0 mean and σ^2 variance. Variable η_i accounts for the possible existence of fixed effects.

It is important to stress that, consistent with our theoretical discussion, we have not considered a simultaneous equation model between R&D effort and financial structure. Our model relies on the resource-based framework to explain the determinants of R&D efforts, and applies agency theory in a complementary way to justify the adjustment in a firm financial structure by anticipating the future conflicts that R&D efforts may generate. This logic leads us to estimate a resource-to-investment equation and use an auxiliary leverage state equation to instrument the financial resources (equation 2).

4. Results

In Table 1, we present the estimation of the "auxiliary" equation for a firm leverage, which tests hypotheses 4

and 5. From this equation we are going to obtain the instrument of DEBT variable to estimate firm R&D investment. In the first row, we have conducted simple cross-section estimation without taking into consideration the panel structure of the data. In the second, we take advantage of the panel structure to control for the existence of fixed effects, which is confirmed by the Hausman Test.

INSERT TABLE 1 HERE

This table shows the importance of controlling for fixed effects, as the results change dramatically when it is implemented this control (last row). Firstly, competing in an R&D-intensive sector has a negative impact on the firm´s leverage, as is predicted by hypothesis 4. As for R&D specialization, it also has a negative impact on leverage. This confirms Hypothesis 5. Control variables show that, unsurprisingly, asset tangibility, eventually offered as collateral, favors debt financing. Bigger firms use more debt as they have more collateral. Also, younger [275] firms are more leveraged because have limited internal funds and have no access to alternative financing channels like capital markets. These results are consistent with Acs and Isberg (1991).

Finally, Table 2 shows the main results of the paper, those corresponding to the determinants of R&D effort. In the first row, we conduct a Tobit specification without taking into consideration the endogeneity problem linked to the financial structure. The second row shows a Tobit estimation, making use of the predicted instrument obtained in the leverage estimation.

INSERT TABLE 2 HERE

Results show a negative relation between leverage and R&D investment once leverage endogeneity is taken into consideration. This fully supports Hypothesis 2. Hypothesis 1 is also confirmed as those firms that follow a deep pocket policy invest more in R&D. Concerning the diversification issue, the results also back hypothesis 3, as it is described a negative impact of specialization on R&D efforts [276]. Control variables show that bigger and younger firms [277] with high capital expenditures and more human capital make more R&D efforts. Finally, the external capital, which is a proxy of low probability of manager-ownership collusion, has a negative impact on these activities. The idea is that R&D investments are associated with high possibilities of managerial divestures due to the high information asymmetries associated. These actions will be more difficult to implement under a foreign ownership scheme. This is confirmed in other studies like Martínez-Ros (2000).

5. Discussion

From previous results, it is worth emphasizing the relevance in allowing for an endogenous determination of a firm leverage once its R&D effort is analyzed. To treat the problem in that way, as mentioned in the theoretical part, we are recognizing the dual nature of leverage. It is a financial resource that may contribute to R&D investment, but it is also a mechanism to deal with agency problems that emerge form the combination of tangible and intangible resources that R&D-intensive projects generate. In Table 2, when we do not tackle the endogeneity problem, and the leverage is only treated as a resource, a non-significant relation with a firm´s R&D effort is obtained. Interestingly, once leverage is instrumented taking into account the endogeneity problem, the sign becomes the negative, which is fully consistent with our hypothesis 2.

A second comment is the positive effect on the firm´s R&D efforts to implement a deep-pocket policy of internal funds accumulation. This strategy has a direct positive effect on these efforts as it gives the firm financial flexibility high enough to carry innovation activities (Teece and Pisano, 1994) and to deal with the long-term uncertain returns of R&D investments. Also, there is an indirect effect that moves in the same direction. With internal funds accumulation, there is less need of debt financing that hinders R&D investments. Hence the relevance to stress this strategy for those firms interested in developing a vigorous innovation policy.

A final important comment, which is an extension of the theory presented, concerns the dynamic evolution of leverage. We may argue that those firms that belong to R&D-intensive sectors are acquiring a superior expertise as time goes by, and, according to our theoretical discussion, this implies higher manager incentives to behave opportunistically. Thus, hypothesis 4 predicts a negative impact on the firm's leverage. 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 whether the growth of leverage for R&D-intensive firms is positive or negative. In contrast, firms in less R&D-intensive sectors only show the second effect of this increased efficiency (an improvements in their resources and reputation). In this case, only the positive contribution prevails. Therefore, we expect a smaller growth rate in the leverage of those firms that belong to an R&D-intensive sector in comparison to those firms that do not. This is shown in the next table:

INSERT TABLE 3 HERE

[275] We have conducted a test to confirm the non-existence of multicollinearity between AGE and EMPLOYMENT.

[276] In terms of the diversification variable, the relation with a firm´s R&D effort is positive, as expected.

[277] Pavitt *et al.* (1987) shows a U-shaped relationship between size and innovation. Small and R&D-specialized firms (eventually young firms), as well as big and diversified ones innovate more than their counterparts.

Table 3 shows a mean analysis to test whether period-t leverage and that of period t-1 were equal or not for firms in an R&D-intensive sector and for firms in a non R&D-intensive sector. Additionally, in panel B, we compare leverage in period t with that in period t-2. Results show that when firms belong to R&D-intensive sectors, the difference between leverage and past leverage is significantly negative, while this difference is not significant or positive (panel B) for non R&D-intensive firms. This broadly confirms our hypotheses. Note that, just by making use of standard collateral arguments we cannot explain the different patterns in the temporal variation of leverage. Thus, the introduction of agency costs considerations on behalf of the managers of R&D-intensive firms can explain this different behavior.

6. Conclusions

In this paper we have presented a theory that recognizes the importance of treating financial resources for the implementation of R&D efforts not only as factors that condition these efforts, but also as mechanisms that can ameliorate agency problems that might emerge from the outcome of these efforts. R&D projects generate intangible and tangible returns. And, the former are the intermediate outcome of the process that leads to the latter. Thus, firms can benefit in the short-term (especially if they are specialist) from those intangible resources generated before the monetary returns from these R&D investments emerge. This gives the entrepreneur incentives to mislead the external lenders over the tangible returns generated as the firm has already benefited from the intangible ones. Moreover, debt financing can exacerbate this problem. In this case the entrepreneur will benefit from misleading lenders as the result to avoid fulfilling debt financial obligations. And, the threat of project liquidation associated with debt contracts is not very helpful, as lenders cannot appropriate the already internalized intangible resources within the firm. At the end, lenders anticipate this problem and demand high interest rates for the capital provided under debt instruments. This feature allows us to predict negative impact of a firm's leverage on its R&D investments.

Other results that configure our hypotheses to test are: Firstly, the degree of diversification and the amount of available internal funds have a positive impact on a firm's innovation investments. Secondly, sector innovation and the degree of a firm´s R&D specialization have a negative impact on its leverage. Lastly, the rate of growth of a firm's leverage should be lower in innovative firms than in non-innovative ones.

We test these results by making use of a Spanish database of manufacturing firms. The outcome of this empirical estimation basically confirms our theoretical hypotheses. The availability of internal funds (implementation of a deep-pocket policy) positively influences a firm´s R&D activities. But, the leverage as well as the specialization has a clear negative impact on R&D efforts. Moreover, firms that operate in R&D-intensive sectors and/or that are specialized on innovation show a lower leverage than their counterparts. Finally, what is interesting in our model, is that we have observed that, on average, the growth of a firm´s leverage is lower for firms in R&D-intensive sectors when compared with their counterparts in less innovative sectors. This is relevant, because neglecting the agency considerations mentioned in our theory, and using just standard collateral arguments, we should not find a different pattern in the leverage growth rate of those firms in R&D-intensive sectors in comparison with those others in non-R&D intensive sectors.

Implications for managers. In short, the main implication for a manager that can be extracted from our model is that the most powerful financing incentive mechanism to stimulate R&D effort is to follow a deep pocket policy of internal funds accumulation and avoid raising capital with debt instruments. This is to adopt a long-term view to anticipate in good time the financing necessary to implement a particular innovation policy. Note that these kinds of investments, as we have stressed throughout the paper are long-term. Consequently, the manager must apply the same long-term view.

References

1. Acs, Z. J. and Isberg C., (1991). Innovation, firm size and corporate finance. An initial inquiry. Economics letters 35, 323-26.
2. Affleck-Graves, J., and Spiess, D., (1999). The Long-run Performance of Stock Returns Following Debt Offerings. Journal of Financial Economics 54, 45-73.
3. Anderson, M. H. and Prezas, A. P. (1999). Intangible Investment, Debt Financing and Managerial Incentives. Journal of Business Economics 51, 3-19.
4. Board, J., Delargy, P.J.R., Tonks, I., (1993). R&D intensity and firm finance: A US-UK comparison in New technologies and the firm, Peter Swan (ed.): Routledge, 321-42.
5. Bradley, M., Jarrell, G., Kim, E. Han, (1984). On the Existence of an Optimal Capital Structure. Journal of Finance 39, 857-78.
6. Cavanaugh, J. K., and Garen, J., (1997). Asset Specificity, Unionization and the Firm's Use of Debt. Managerial and Decision Economics 18, 255-69.
7. Chiao, C., (2002). Relationship between debt, R&D and physical investment, evidence from US firm-level data. Applied financial economics 12, 105-21.
8. De Angelo, H. and Masulis, R. W., (1980). Optimal Capital Structure under Corporate and Personal Taxation. Journal of Financial Economics, 8(1), 3-29.
9. Fleming, L., (2001) Recombinant uncertainty in technological search. Management Science 47(1), 117-132.
10. Freeman, C (1991). Networks of Innovators: A Synthesis of Research Issues. Research Policy 20 (5), 499-15.
11. Galende, J. and Suárez, I., (1999) A Resource-based Analysis of the Factors Determining a Firm's R&D Activities. Research Policy 28, 891-905.
12. Gaver, J., and 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.
13. Gompers, P. and Lerner, J., (1999). The Venture Capital Cycle: Mit Press.
14. Goodacre, A., and 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.
15. Grant, R. M., (1991). The Resource-based Theory of Competitive Advantage: Implication for Strategy Formulation. California Management Review 33,114-135
16. Griliches, Z., (1979). Issues in Assessing the Contribution of Research and Development to Productivity Growth. Bell Journal of Economics 10(1), 92-116.
17. Griliches, Z., (1988). Research Expenditures and Growth Accounting. In the Technology, Education, and Productivity: Oxford and New York: Blackwell, 244-67.
18. Guerard, J. J. and Bean, A. S. (1997). R&D Management and Corporate Financial Policy: John Wiley & Sons.
19. Guiso, L., (1998). High-Tech Firms and Credit Rationing. Journal of Economic Behavior and Organization 35, 39-59.
20. 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.
21. Hart, O., (1995). Firms, Contracts, and Financial Structure, Clarendon Lectures in Economics: Oxford and New York, Oxford University Press.
22. Himmelberg, C. P. and 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.
23. Hoskisson, R. E., and Hitt, M. A., (1988). Strategic Control and Relative R&D Investment in Large Multiproduct Firms. Strategic Management Journal 9, 605-621.
24. Jensen, M. and Meckling, W., (1976). Theory of Firm: Managerial Behavior, Agency Cost and Capital Structure. Journal of Financial Economics 3, 305-360.
25. Kamien, M. and Schwartz, N., (1975). Market Structure and Innovation: A Survey. Journal of Economic Literature (March), 1-37.
26. Kulti, k. and Takalo, T., (2000). Incomplete contracting in an R&D project: The Micronas case. R&D Management 30 (1), 67-76.
27. Long, M. and Malitz, I., (1985). The Investment-Financing Nexus: Some Empirical Evidence. Midland Corporate Finance Journal 3, 53-9.
28. Long, W. and Ravenscraft, D. J. (1993). LBOs, Debt and R&D Intensity. Strategic Management Journal 14, 119-135.
29. Martínez-Ros, E., (2000). Explaining the decisions to carry out product and process innovations: the Spanish case. The Journal of High Technology Management Research 10(2), 223-242.
30. Pavitt, K., (1984). Sectoral Patterns of Technical Change: Towards a Taxonomy and a Theory. Research Policy 13 (6), 343-373.
31. Pavitt, K., Robson, M., Townsend, J., (1987). The size distribution of innovating firms in the UK: 1945-1983. Journal of Industrial Economics 35 (3).
32. Pearl, J. (2002) Intangible investments, tangible results. MIT Sloan Management Review 43(1), 13-14.
33. Peteraf, M. A. (1993). The Cornerstones of Competitive Advantage: A Resource-based View. Strategic Management Journal 14 (3), 179-91.
34. Prahalad, C. K., and Hamel, G., (1990). The Core Competence of the Corporation. Harvard Business Review 90(3), 79-91
35. Rapoport, H., (1971). The Anatomy of the Product-innovation Process: Cost and Time. In Research and Innovation in the Modern Corporation, Mansfield: Norton : New York, 110-35.
36. Rothwell, R., (1992). Successful industrial innovation: Critical factors for the 1990s. R&D management 22 (3), 221-238.
37. Santarelli, E., (1991). Asset specificity, R&D financing, and the signalling properties of the firm's financial structure. Economics of Innovation and new technology 1, 279-94.
38. Segura et al., (1989). La Industria Española en la Crisis 1970/1984: Alianza Editorial, Madrid.
39. Souitaris, V. (2002). Firm-specific competencies determining technological innovation. A survey in Greece. R&D management 32 (1), 61-77.
40. Teece, D., (1986). Profiting from Technological Innovation. Research policy 15 (6), 285-306.
41. Teece, D. J. and Pisano, G. (1994). The Dynamic Capabilities of Firms: An Introduction. Industrial and Corporate Change 3, 537-56.
42. Teece, D. J., Pisano, G., Shuen, A. (1997). Dynamic Capabilities and Strategic Management. Strategic Management Journal 18 (7), 509-533.
43. Tidd, J., Bessant, J. and Pavitt, K., (1997). Integrating Technological, Market and Organizational Change: John Wiley & Sons Ltd, 3-20.
44. Wakelin, K., (1998). Innovation and Export Behavior at the Firm Level. Research Policy 26, 829-841.
45. Williamson, O.E. (1988). Corporate finance and corporate governance. Journal of Finance 43, 567-591.
46. Wernefelt, B., (1984). A Resource-based View of the Firm. Strategic Management Journal 5, 171-180.

Empirical Appendix

Our database is composed by 18 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 recognized 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

Table 1. Debt and R&D Intensity

Dependent variable	DEBT (Cross-Section) [1, 2]	DEBT (Panel data with fixed effects) [1, 2]
HIGH	0.020 (1.02)	-0.212 ** (1.83)
HISPECIALIZATION	-0.022 (1.46)	-0.045 ** (2.26)
EMPLOYMENT	-0.007 *** (4.20)	0.028 *** (5.28)
TANGIBILITY	0.113 *** (7.42)	0.033 *** (2.50)
STOCK	-0.026 (1.23)	-0.009 (0.69)
AGE	-0.001 *** (11.97)	-0.004 *** (5.01)
Number of observations	11,652	11,652
Log(likelihood)	771.922	9927.06
LR test [χ^2]	865.94 (0.000)	168.112 (0.000)
Hausman Test		98.23 (0.000)

[1] T-statistics in parenthesis.
[2] It includes temporal and industry dummy variables
*** 99% signif. ** 95% signif. * 90 % signif.

Table 2. Determinants of R&D effort

Dependent variable	R&D Effort (Tobit [1, 2, 3])	R&D effort (Tobit [1, 2, 3] Instrumental variables)
DEBT	-0.341 (0.570)	
PREDICTED DEBT		-43.614*** (4.22)
SPECIALIZATION	-0.721*** (2.55)	-1.33*** (4.11)
INTERNAL FUNDS (-1) [4]	0.459 (0.79)	0.671** (2.04)
EMPLOYMENT	1.025*** (15.41)	2.20*** (7.56)
CAPITAL EXPENDITURES	4.025*** (3.81)	4.20*** (3.97)
STOCK	-0.406 (1.10)	-0.790** (2.09)
AGE	0.005* (1.56)	-0.164*** (4.06)
HUMAN CAPITAL	11.790*** (9.80)	11.329*** (9.50)
FOREIGN CAPITAL	-0.741*** (3.92)	-0.707*** (3.79)
Number of observations	3,307	3,259
Log (likelihood)	1641.468	1661.902
LR test [χ^2]	1023.01 (0.000)	1026.03 (0.000)

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

Table 3. DEBT Variation in HIGH and non-HIGH Sectors

		PANEL A	
Variables	DEBT	DEBT1 [1]	Test of Means [2]
In High intensive sectors	0.558 (0.226)	0.563 (0.225)	-1.786 (0.074)
In non-High intensive	0.577 (0.241)	0.576 (0.243)	0.934 (0.350)
		PANEL B	
Variables	DEBT	DEBT2 [3]	Test of Means [2]
In High intensive sectors	0.551 (0.222)	0.560 (0.224)	-2.547 (0.011)
In non-High intensive sectors	0.573 (0.236)	0.569 (0.242)	1.950 (0.051)

[1] One-period lagged DEBT variable.
[2] T-statistics in parenthesis.
[3] Two-period lagged DEBT variable.