Financial Management

How Do Firm Characteristics Influence the Relationship between R&D and Firm Value?

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This paper focuses on how a firm's characteristics affect the market valuation of its research and development (R&D) spending. We derive a valuation model based on the capital market arbitrage condition. Using the generalized method of moments and data from the Eurozone countries to estimate this model yields interesting results. Several firm characteristics (size, firm growth, and market share) positively affect the relationship between firm value and R&D spending, while others (free cash flow, dependence on external finance, labor intensity, and capital intensity) exert a negative effect. Therefore, we conclude that the effectiveness of R&D spending depends on firm characteristics.

Over the last 10 years, the academic literature has provided evidence of the important role played by research and development (R&D) in economic growth (Jones, 1995; Bowns et al., 2003; Arnold, 2006). As a result, scholars have paid increasing attention to R&D spending, which is no longer considered a cost but rather a value-increasing investment in that R&D spending yields some supranormal profits.

In his seminal study, Griliches (1981) draws attention to the fact that R&D spending creates intangible capital for a firm and indicates that the market should capture this in the valuation of the firm. More recently, several empirical studies have analyzed the market reaction to announcements of R&D spending, and their results indicate that, in general, R&D investments increase the market value of firms. Chauvin and Hirschey (1993) investigate the market reaction to R&D expenditures using a large sample of Compustat firms. They find that R&D has a positive influence on the market value of the firms. This result is in accordance with Cockburn and Griliches (1988), who indicate that the market valuation of R&D investment is quite high. As in these earlier papers, Bae and Kim (2003) examine this relationship by comparing the effect of R&D investment on market value across US, German, and Japanese firms. Their findings confirm that R&D positively impacts firm value in these countries.

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However, there is some documentation in the literature to indicate that various firm characteristics may affect the magnitude of the market valuation of R&D investments. For example, Doukas and Switzer (1992) provide evidence that the rate of return for R&D announcements by US firms is greater for those firms operating in highly concentrated industries. Also using US data, Cannolly and Hirschey (2005) find support for size advantages in the valuation effects of R&D investments. Hall and Oriani (2006) suggest that the market response to R&D is favorable for firms with a lower level of ownership concentration in France, Germany, and Italy. In addition, as related in Booth et al. (2006), the stock market valuation of R&D spending is also affected by the financial environment. Results of a sample comprising G-7 countries, Finland, Sweden, and Switzerland support the notion that the relative size of the equity and private loan markets influences the way in which R&D is valued. Specifically, they document that the greater the portion of equity financing (or the lower the fraction of bank loan financing), the stronger the market valuation of R&D spending. Therefore, Booth et al. (2006) conclude that the institutional source of financing matters.

Building upon these early studies, the chief research question is how several firm characteristics moderate the relationship between R&D spending and firm value. A considerable body of research has identified the following firm characteristics as determinants of R&D expenditures: size, firm growth, free cash flow, market share, external finance dependence, labor intensity, and capital intensity. We go one step further by investigating whether or not certain firm characteristics, in addition to acting as determinants of R&D spending, also play an important role in moderating the relationship between R&D spending and firm value. Therefore, taking size, firm growth, free cash flow, market share, external finance dependence, labor intensity, and capital intensity as firm-specific characteristics that affect the firm's decision to undertake R&D investment, we pose several hypotheses that allow us to analyze how these characteristics influence the relationship between R&D and firm value.

Our paper makes a significant contribution to the literature in at least three ways. First, we derive a valuation model based on the capital market arbitrage condition. This model demonstrates that firm value is dependent upon residual income and R&D spending; therefore, it is a perfect tool for studying how firm characteristics affect the market valuation of R&D spending. As a result, the analytical derivation of a testable model is a quite important contribution in that our paper develops from a well-known equilibrium in the economic theory and is then tested by a robust econometric technique (panel data methodology). However, to allow a direct comparison of the results reported in earlier literature, we also perform robustness checks that address the effectiveness of the valuation model by using alternative dependent variables based on the market value of common equity and the market-to-book ratio (Chauvin and Hirschey, 1993; Bae and Kim, 2003).

Second, we offer new evidence regarding how several firm characteristics influence the relationship between R&D investments and firm value in a cross-country analysis. Specifically, we analyze the impact of the above-mentioned firm characteristics on the relationship between R&D and value in the Eurozone countries. As far as we know, this is the first time a study of these countries has been conducted, not only on the moderating effects we analyze here but also on the analysis of the effect of R&D on firm value.

The third contribution refers not only to the use of a robust econometric technique but also takes into account that R&D is linked to the strategy of the firm. We are able to consider this link in our study since panel data methodology allows us to incorporate the unobservable heterogeneity into the analysis through an individual effect. This effect captures characteristics related to the strategy of the firm, such as how the firm competes in the market, its propensity to innovate, and other unobservable characteristics. To control for endogeneity problems, the models have been estimated using the generalized method of moments (GMM), which embodies all the instrumental variable methods. Since the data quality requirements of this methodology are very high, we have extracted our data for all the Eurozone countries from an international database (Worldscope).

Our results reveal that the positive relationship between firm value and R&D spending is moderated by several firm characteristics. Specifically, size exerts a positive effect on this correlation due to economies of scale, easier access to capital markets, and R&D cost spreading. A positive effect is also found for firm growth in that a high rate of growth allows the firm to take greater advantage of the supranormal profits arising from R&D projects. In contrast, free cash flow negatively affects the market valuation of R&D. This result is consistent with Jensen's (1986) theory as firms with high levels of free cash flow could use these funds to undertake negative net present value (NPV) R&D projects. Interestingly, we find that market share, rather than firm value, affects the relationship between firm value and R&D spending. As a result, the supranormal profits are highly dependent upon the amount of R&D spending. Dependence on external financing negatively affects the market valuation of R&D spending due to the higher information asymmetry associated with R&D projects. Labor and capital intensity both negatively influence the impact of R&D spending on firm value, the former because the supranormal profits are likely to be diluted among employees and the latter because capital-intensive firms face greater financial constraints.

The remainder of the paper is organized as follows. In Section I, we derive the valuation model as a function of residual income and R&D spending. Section II explains the theoretical arguments behind our hypotheses. Section III describes our data set and the econometric method used to test our hypotheses. The results are discussed in Section IV, and the last section presents our conclusions.

I. Model

The development of our model for studying the relationship between R&D and firm value is based on the well-known capital market arbitrage condition (Blundell et al., 1992; Whited, 1992). According to this condition, the net after-tax return for shareholders in firm i during period t is obtained in two ways: 1) current dividends and 2) capital appreciation. Therefore, shareholders will maintain their shares as long as the return obtained is equal to their required after-tax return. This equilibrium can be expressed by the following equation:

$$r_{it} V_{it} = (E_t V_{i,t+1} - V_{it}) + E_t D_{i,t+1}, \tag{1}$$

where V_{it} is the value of equity of firm i at the end of period t, $D_{i,t+1}$ are the dividends paid by firm i at time $t+1$, r_{it} is the after-tax return required by shareholders, and E_t is the conditional expectation based on information known at moment t.

Solving Equation (1) for V_{it} yields the following expression for the market value of equity:

$$V_{it} = E_t \sum_{j=1}^{\infty} \frac{D_{i,t+j}}{(1+r_{it})^j}. \tag{2}$$

The value of dividends may be calculated by using the following clean surplus relation (CSR):

$$BV_{it} = BV_{i,t-1} + \pi_{it} - D_{it}. \tag{3}$$

The CSR in Equation (3) proposes that the book value of equity in period t (BV_{it}) depends on the book value of equity at the beginning of the period ($BV_{i,t-1}$), the net income (π_{it}), and the dividends (D_{it}). Solving Equation (3) for dividends, we obtain

$$D_{it} = BV_{i,t-1} + \pi_{it} - BV_{it}. \tag{4}$$

Substituting Equation (4) into Equation (2) yields

$$V_{it} = E_t \sum_{j=1}^{\infty} \frac{(BV_{i,t+j-1} + \pi_{i,t+j} - BV_{i,t+j})}{(1 + r_{it})^j}. \tag{5}$$

Algebraic manipulation allows Equation (5) to be rewritten as[1]

$$V_{it} = BV_{it} + E_t \sum_{j=1}^{\infty} \frac{(\pi_{i,t+j} - rBV_{i,t+j-1})}{(1 + r)^j} - \frac{E_t(BV_{i,t+\infty})}{(1 + r)^{\infty}}. \tag{6}$$

Following Dechow, Hutton, and Sloan (1999) and Myers (1999), we assume that the last term in Equation (6) is zero. Also, in keeping with the economic literature, residual income is given as

$$RI_{i,t+j} = \pi_{i,t+j} - rBV_{i,t+j-1}. \tag{7}$$

Therefore, the firm market value can be expressed as

$$V_{it} = BV_{it} + E_t \sum_{j=1}^{\infty} \frac{RI_{i,t+j}}{(1 + r)^j}. \tag{8}$$

Consequently, attention should be paid to the second term in Equation (8). We assume that the expected residual income, conditional on information available at time, is dependent upon two factors. First, residual income could either display a trend (increasing or decreasing) or be constant. For instance, Green, Stark, and Thomas (1996) assume that the expected values of future residual income can be modeled as declining at rate δ. As a result, Equation (9) holds

$$\sum_{j=1}^{\infty} \frac{RI_{i,t+j}}{(1 + r)^j} \approx \frac{(1 - \delta)}{(r + \delta)} RI_{it}. \tag{9}$$

The other two possible outcomes refer to an increasing trend for the expected value of future residual incomes at rate δ and a constant value for future residual incomes. These yield the following equations, respectively:

$$\sum_{j=1}^{\infty} \frac{RI_{i,t+j}}{(1 + r)^j} \approx \frac{(1 + \delta)}{(r - \delta)} RI_{it}, \tag{10}$$

[1]Details will be provided by authors upon request.

$$\sum_{j=1}^{\infty} \frac{RI_{i,t+j}}{(1+r)^j} \approx \frac{(1+r)^n - 1}{r(1+r)^n} RI_{it}. \tag{11}$$

Second, Sougiannis (1994) argues that the impact of R&D on market value can be reflected indirectly through earnings. The idea is that the impact of past R&D expenditures on current market value can be captured by the investments undertaken by the firm, which yield earnings and, as a consequence, have a substantial impact on the current residual income. Furthermore, Sougiannis (1994) confirms that this effect is much larger than the direct effect of new R&D information conveyed directly by R&D measures. Therefore, past R&D expenditures likely play a role in explaining residual income, conditional on information available at time. The question is how many lags should be considered. According to Sougiannis (1994), lagged values of R&D rarely convey additional information when explaining market value once current residual income has been included as an explanatory variable in the valuation model. As a result, the best solution is to enter the current R&D spending into the valuation model, and use several lagged R&D values to estimate its current value using an instrumental variables method. In this paper, as explained in Section III.B, we use the GMM since this method embeds the other instrumental variables methods as special cases (Ogaki, 1993).

Taking into account the two factors mentioned above, the conditional expectation term in Equation (8) can be written as

$$E_t \sum_{j=1}^{\infty} \left[\frac{RI}{(1+r)^j} \right] = \beta_1 RI_{it} + \beta_2 RD_{it} + e_{it}, \tag{12}$$

where RD_{it} is R&D spending and e_{it} is a random error arising from the approximation process of the expectation term. β_1 and β_2 are the parameters of the model; the value of the former is dependent on the assumptions made in Equations (9), (10), and (11).

Substituting the expectation of the sum of the present residual income from Equation (12) into Equation (8) yields the following regression model:

$$V_{it} = BV_{it} + \beta_1 RI_{it} + \beta_2 RD_{it} + e_{it}. \tag{13}$$

As a method of controlling for size, all the variables in Equation (13) have been scaled by the replacement value of total assets.[2] Rearranging terms, we obtain the final model

$$\frac{V_{it} - BV_{it}}{K_{it}} = \beta_1 \frac{RI_{it}}{K_{it}} + \beta_2 \frac{RD_{it}}{K_{it}} + e_{it}. \tag{14}$$

In our model, the term on the left-hand side is the difference between the market and book value of equity. From a theoretical point of view, this difference captures the fluctuation of firm value when the explanatory variables change. In fact, our dependent variable is adjusted by the changes in market value that are due to the purchase of new assets. Therefore, by construction, our valuation model tells us that the residual income and R&D variables are positively related to firm value.

[2]Deflating by controlling for size is a common way to avoid heteroskedasticity problems in econometric models.

II. Hypotheses Development

In this section, we rely on the previous literature to derive our hypotheses regarding how several firm characteristics influence the market reaction to R&D effort.

A. Firm Size

Since Schumpeter (1961), scholars have widely studied the relationship between R&D and firm size. As described in Lee and Sung (2005), diverse results have been found in the empirical literature. Some studies find a linear and positive relationship, while others suggest that R&D and firm size are independent. The earliest studies of the correlation between firm size and R&D find a positive relationship that is interpreted as support for the Schumpeterian hypothesis.[3] Furthermore, Arvanitis (1997) observes that the positive relationship between R&D expenditures and firm size depends on the industry of the firm. However, Cohen, Levin, and Mowery (1987) investigate the Schumpeterian hypothesis and demonstrate that overall, firm size has a statistically insignificant effect on R&D intensity when either fixed industry effects or measured industry characteristics are taken into account. Recently, Lee and Sung (2005) find that the relationship between R&D and size is probably stronger for industries with greater technological opportunities. Note that this result is consistent with previous findings already reported by Cohen and Klepper (1996).

More important than the correlation between R&D and size is how size moderates the relationship between R&D and value. Cannolly and Hirschey (2005) find evidence supporting the importance of size advantages for the valuation effects of R&D spending. This is consistent with Chauvin and Hirschey (1993), who find that the R&D activity of larger firms appears to be relatively more effective than that of smaller ones, based on a market value perspective. Moreover, the advantages in technological competition (particularly the economies of scale in R&D, the easier access to capital markets, and the R&D cost spreading) are commonly attributed to large firms (Cohen and Klepper, 1996). Within this context, we use our valuation model to delve further in the analysis of the role played by firm size in moderating the relationship between R&D and value. Accordingly, we pose our first hypothesis:

> Hypothesis 1: The impact of R&D on firm value is greater for larger firms than for smaller firms.

B. Firm Growth

The economic literature assumes that R&D spending facilitates the success of the firm in the product market and that, as a result, R&D spending leads to a higher rate of growth. Ryan and Wiggins (2002) argue that a firm with high growth opportunities has more incentive to invest in R&D once a considerable percentage of its value stems from assets not yet in place. Moreover, R&D has been suggested as a proxy for a firm's investment opportunity (Becker-Blease and Paul, 2006; Billett, King, and Mauer, 2007) and growth (Yeh, Shu, and Guo, 2008; Poulsen and Stegemoller, 2008). However, Del Monte and Papagni (2003) summarize the results found by different studies over the last 20 years and come to the conclusion that a significant relationship between research intensity and firm growth has not always been found. Nevertheless, Del Monte and Papagni (2003) provide evidence revealing a positive relationship between R&D and the rate of growth. Furthermore, they argue that the variable proxying for innovation efforts (including

[3] See Cohen and Klepper (1996) for details about these papers.

R&D) could be endogenous. This means that firms with a higher rate of growth will increase their size, and, according to the Schumpeterian (1961) hypothesis, will undertake more R&D projects. In this context, our study focuses on how a firm's growth affects the market valuation of its R&D spending. Our argument is that firms growing at a higher rate will make the most of the supranormal profits arising from the R&D projects. Consequently, the market will provide them with a better valuation than that of the remaining firms. This leads us to our second hypothesis:

Hypothesis 2: The impact of R&D on firm value is greater for firms with a higher rate of growth than for firms with a lower rate of growth.

C. Free Cash Flow

Another firm characteristic that may influence the relationship between R&D and firm value is free cash flow. Jensen (1986) defines a firm's free cash flow as the cash flow in excess of that required to fund all positive NPV projects when discounted at the relevant cost of capital. According to Jensen's (1986) theory, firms with a high level of free cash flow (HFCF firms) tend to use these funds in negative NPV projects. Several studies about investment find support for Jensen's (1986) theory (Del Brio, Perote, and Pindado, 2003a; Del Brio, Miguel, and Pindado, 2003b) in that firms with a low (high) free cash flow level are expected to experience positive (negative) market reaction to investment announcements. However, there are other studies (Szewczyk, Tsetsekos, and Zantout, 1996; Chen and Ho, 1997) that do not find enough evidence to support this theory, although this lack of support may be due to the fact that the variable used in these studies for proxying free cash flow is a measure of cash flow instead of free cash flow. In addition, except for Szewczyk, Tsetsekos, and Zantout (1996), the aforementioned studies focus on investments in fixed assets. Consequently, our study contributes to this strand of literature by analyzing whether or not the level of free cash flow affects the relationship between R&D spending and firm value by using a cross-country sample. According to Jensen's (1986) theory, the effect that HFCF firms' R&D projects have on their market value should be lower than that of low free cash flow firms (LFCF firms) in that the managers of LFCF firms are not encouraged to undertake negative NPV projects. Moreover, Fung (2009) investigates the relationship between innovativeness and executive pay-performance sensitivity. His findings also support the notion that a HFCF firm is more likely to invest in low NPV projects. Consequently, we arrive at our third hypothesis:

Hypothesis 3: The impact of R&D on firm value is greater for firms with LFCF levels than for ones with high free cash flow levels.

D. Market Share

The recent literature indicates that market share and R&D are complementary to each other in a firm's market valuation (Nagaoka, 2004). Blundell, Griffith, and Reenen (1999) investigate the relationship between innovation and market share and find that firms with high market share innovate more; hence, their market valuation is higher. To check the robustness of this result, they enter into their model the interaction between innovation stock and market share, finding a positive coefficient for the interaction term. Given that the R&D process is a wellspring of innovation (Booth et al., 2006), these findings report evidence of the importance of market share in moderating the relationship between R&D and firm value. In addition, Blundell, Griffith, and Reenen (1999) suggest that this positive influence plays a considerable role in creating barriers to entry that should be captured by firm value. In contrast, Chen, Ho, and Shih (2007) do not find evidence supporting the importance of market share. On the basis of these conflicting results, and in order to provide additional evidence on this matter, we pose our fourth hypothesis:

> Hypothesis 4: The impact of R&D on firm value is greater for firms with high market share than for those with low market share.

E. External Financial Dependence

The external finance dependence (EFD) is another firm characteristic that is expected to moderate the relationship between R&D and firm value. Following Rajan and Zingales' (1998) definition (see Section IV.A), external financial dependence captures the part of a firm's investments that cannot be financed by internal resources therefore requiring the firm to obtain external funds. Rajan and Zingales (1998) report that industries with EFD grow relatively faster in countries with developed financial markets. These authors also argue that the bank-based system has a comparative advantage in financing industries that are intensive in tangible assets. In addition, Franzen, Rodgers, and Simin (2007) point out that healthy firms with a high level of R&D spending are more likely to be misclassified as financially distressed, affecting investor willingness to provide external financing. Along with this misclassification may come the reduction of the market valuation of R&D activity given that intangible assets quickly lose their value in the presence of the cost of financial distress (Bhagat and Welch, 1995). Consequently, it would be more difficult to raise funds to undertake investments in intangible assets. Moreover, a traditional interpretation of the innovation-market power correlation is that failures in financial markets force firms to rely on their own retained earnings to finance their innovation (Blundell, Griffith, and Reenen, 1999). In this sense, Islam and Mozumdar (2007) find that a firm's investments are positively related to internal cash, supporting the assumption that internal and external funds are not perfect substitutes. Particularly for R&D, the availability of internal financial resources would be less costly considering that the extent of information asymmetry associated with R&D is larger than that associated with tangible assets due to the relative uniqueness of R&D (Aboody and Lev, 2000). Accordingly, we derive the following hypothesis:

> Hypothesis 5: The higher the dependence on external financing, the lower the impact that R&D has on firm value.

F. Labor Intensity

The relationship between human capital and R&D activities has received attention in empirical research. Scholars provide evidence supporting the hypothesis that qualified human capital increases the probability of R&D and innovation activities (Galende and Suárez, 1999; Negassi, 2004). In the same vein, Gustavsson and Poldahl (2003) indicate an elasticity of R&D related to a firm's wage-share to skilled labor. Furthermore, Beck and Levine (2002) focus on assessing whether R&D-intensive and labor-intensive industries grow faster depending on the orientation of the financial system (bank based vs. market based). However, they find no evidence supporting the idea that the orientation of the financial system favors labor-intensive industries. We go a step further by studying the moderating role of labor intensity in the effect of R&D on firm value. Our argument is that the effect of labor intensity on the relationship between firm value and R&D spending is negative since the supranormal profits of R&D spending are diluted among employees, especially when employees have been intensively involved in the firm's R&D projects. This argument is consistent with Ballot, Fakhfakh, and Taymaz (2006), who investigate how the return from investments is shared between firms and employees. They find that the part of return obtained by firms from intangible assets, such as R&D and training, is lower than that of tangible ones. As a result, our sixth hypothesis is as follows:

> Hypothesis 6: The higher the labor intensity, the lower the impact that R&D has on firm value.

G. Capital Intensity

Capital intensity is also related to R&D activities. Galende and Suárez (1999) find support for the hypothesis that capital intensity increases the probability of firms carrying out R&D activities. Alternatively, there is evidence to suggest that firms with a high level of investment in physical capital face more financial constraints (Fazzari, Hubbard, and Petersen, 1988; Hsiao and Tahmiscioglu, 1997). In their seminal paper, Fazzari, Hubbard, and Petersen, (1988) argue that under financing constraints, capital expenditures are more sensitive to internal funds. More recently, a considerable number of studies have examined investment-cash flow sensitivity (Love, 2003; Allayannis and Mozumdar, 2004; Almeida, Campello, and Weisbach, 2004; Agca and Mozumdar, 2008; Dasgupta and Sengupta 2007; Guariglia, 2008; Hovakimian, 2009). DeFond and Hung (2003) find that capital intensity is one of the firm characteristics for which market participants tend to demand cash flow information in order to assess firms with respect to solvency and liquidity. In addition, market imperfections such as agency problems and information asymmetries between insiders and investors give rise to a premium for external finance (Islam and Mozumdar, 2007). R&D activity will exacerbate the premium since the activity is inherently characterized by opaque information flows and managerial actions. Consequently, capital-intensive firms would face greater financing difficulties leading them to undertake fewer R&D projects. These projects could be poorly assessed by capital markets due to the higher cost of capital. As a result, our last hypothesis is as follows:

> Hypothesis 7: The impact that R&D has on firm value is lower for capital-intensive firms.

III. Data and Estimation Method

A. Data

To test the hypotheses posed in the previous section, we use data from Eurozone countries extracted from the international database Worldscope. Additionally, international data, such as the growth of capital goods prices, the interest rate of short-term debt, and the interest rate of long-term debt, was extracted from the *Main Economic Indicators* published by the Organization for Economic Cooperation and Development (OECD).

For each country, we construct an unbalanced panel comprising companies for which information is available for at least six consecutive years from 1986 to 2003.[4] This strong requirement is a necessary condition since we lose one year of data in the construction of some variables (see the appendices), we lose another year of data due to the estimation of the model in first differences, and four consecutive years of information are required in order to test for second-order serial correlation, as Arellano and Bond (1991) point out. We need to test for the second-order serial correlation because our estimation method, the GMM, is based on this assumption.

As occurs in La Porta et al. (2000), we had to remove Luxembourg from our sample as there are only a few companies listed in Luxembourg's stock exchange. We also had to remove all the

[4]Note that before this date there is no information available for R&D, which is the main topic of our research.

Table I. Structure of the Samples by Country

Data were extracted for companies where information was available for at least six consecutive years from 1986 to 2003. After removing the first year data only used to construct several variables (see the appendices), the resultant samples comprise 83 companies (722 observations) for Germany, 76 companies (683 observations) for France, 2 companies (17 observations) for Spain, 18 companies (174 observations) for the Netherlands, 7 companies (70 observations) for Belgium, 28 companies (240 observations) for Ireland, 10 companies (78 observations) for Greece, 9 companies (83 observations) for Austria, and 38 companies (320 observations) for Italy.

Country	Number of Companies	Percentage of Companies	Number of Observations	Percentage of Observations
Germany	83	30.63	722	30.25
France	76	28.04	683	28.61
Spain	2	0.74	17	0.71
Netherlands	18	6.64	174	7.29
Belgium	7	2.58	70	2.93
Ireland	28	10.33	240	10.05
Greece	10	3.70	78	3.27
Austria	9	3.32	83	3.48
Italy	38	14.02	320	13.41
Total	271	100.00	2,387	100.00

countries (namely, Finland and Portugal) for which samples with the above requirement could not be selected.[5] As a result, our panel comprised Austria, Belgium, France, Germany, Greece, Ireland, Italy, the Netherlands, and Spain. Table I provides the structure of the sample in terms of companies and number of observations per country. Note that the data reported in the tables in this paper is provided after removing the first-year data. These first-year data are used only to construct several variables but not to estimate the models. Therefore, tables refer exclusively to the data used to estimate the models. Table II illustrates the structure of the resultant unbalanced panel used in the estimation according to the number of annual observations per company. To be exact, our unbalanced panel comprised 271 companies and 2,387 observations. Using an unbalanced panel for a long period (16 years) is the best way to solve the survival bias caused by companies delisting, and, consequently, being dropped from the database.

Using the information from the database described above, we construct all of the variables in our models following the procedure detailed in the appendices. Our dependent variable is a measure of firm value, and the explanatory variables in the basic model are residual income and R&D. We have also estimated an extended version of the model including two control variables: 1) market share and 2) long-term debt. The summary statistics (mean, standard deviation, maximum, and minimum) are provided in Table III. To analyze how certain firm characteristics moderate the relationship between firm value and R&D, we use a set of dummy variables constructed as explained in the appendices.[6] The number of zeros and ones for each dummy variable is provided in Table IV.

[5]Note that the information on R&D usually presents many missing values in databases.

[6]Note that both the basic and extended versions of the model have also been estimated by accounting for the interactions described in Section I.

Table II. Structure of the Panel

Data were extracted for companies where information was available for at least six consecutive years from 1986 to 2003. After removing the first year data used only to construct several variables (see the appendices), the resultant unbalanced panel comprises 271 companies (2,387 observations).

No. of Annual Observations per Company	Number of Companies	Percentage of Companies	Number of Observations	Percentage of Observations
16	2	0.74	32	1.34
15	5	1.84	75	3.14
14	28	10.33	392	16.42
13	10	3.70	130	5.45
12	16	5.90	192	8.04
11	17	6.27	187	7.83
10	22	8.12	220	9.22
9	26	9.60	234	9.80
8	34	12.54	272	11.40
7	27	9.96	189	7.92
6	44	16.24	264	11.06
5	40	14.76	200	8.38
Total	271	100.00	2,387	100.00

Table III. Summary Statistics

$((MV-BV)/K)_{it}$ stands for the difference between market and book value of equity scaled by the replacement value of total assets. $(RI/K)_{it}$ is residual income scaled by the replacement value of total assets. $(R\&D/K)_{it}$ is research and development scaled by the replacement value of total assets. MS_{it} is market share and $(LTD/K)_{it}$ is long-term debt scaled by replacement value of total assets. See the appendices for details regarding the definitions of these variables.

Variable	Mean	Standard Deviation	Minimum	Maximum
$((MV-BV)/K)_{it}$	0.6191	1.0738	−0.4323	20.7136
$(RI/K)_{it}$	0.0202	0.0553	−0.7848	0.2638
$(R\&D/K)_{it}$	0.0300	0.0350	0.0000	0.4132
MS_{it}	0.0015	0.0036	4.21e-07	0.0416
$(LTD/K)_{it}$	0.0535	0.0449	0.0000	0.2662

B. Estimation Method

All the models specified in this paper have been estimated using the panel data methodology. Specifically, the estimation is carried out by the GMM. Two issues have been considered in making this choice. First, unlike cross-sectional analysis, panel data allow us to control for individual heterogeneity. This point is crucial in our study as the decision to undertake R&D projects in a firm is very closely related to firm specificity and, more importantly, the effect of R&D on firm value is strongly linked to the specificity of each firm. Therefore, to eliminate the risk of obtaining biased results, we have controlled for this heterogeneity by modeling it as an individual effect, η_i, which is then eliminated by taking the first differences of the variables. Consequently, the basic specification of our model is as follows:

$$\frac{V_{it}-BV_{it}}{K_{it}} = \beta_1 \frac{RI_{it}}{K_{it}} + \beta_2 \frac{RD_{it}}{K_{it}} + \eta_i + d_t + c_i + v_{it}, \tag{15}$$

Table IV. Dummy Variables

DS_{it} denotes a size dummy, DGR_{it} is a growth dummy, $DFCF_{it}$ denotes a free cash flow dummy, DMS_{it} is a market share dummy, $DEFD_{it}$ is an external finance dependence dummy, DLI_{it} is a labor intensity dummy, and DCI_{it} is a capital intensity dummy. See appendices for details regarding the definitions of these variables.

Dummy Variable	Number of Zeros	Percentage of Zeros	Number of Ones	Percentages of Ones
DS_{it}	1,112	46.59	1,275	53.41
DGR_{it}	1,493	62.55	894	37.45
$DFCF_{itt}$	434	18.18	1,953	81.82
DMS_{it}	1,770	74.15	617	25.85
$DEFD_{it}$	1,545	64.73	842	35.27
DLI_{it}	1,470	61.58	917	38.42
DCI_{it}	1,326	55.55	1,061	44.45

where the error term has several components besides the above-mentioned individual or firm-specific effect (η_i); d_t measures the time-specific effect by the corresponding time dummy variables, so that we can control for the effects of macroeconomic variables on firm value; c_i are country dummy variables representing the country-specific effect, which are necessary as our models are estimated using data from several countries; and finally, v_{it} is the random disturbance.

The second issue we deal with by using panel data methodology is the endogeneity dilemma. The endogeneity problem is likely to arise given that the dependent variable (firm value) may also explain R&D since a higher value may encourage managers to undertake new R&D projects. Therefore, all models have been estimated using instruments. Specifically, we have used all the right-hand-side variables in the models, lagged two and three times, as instruments in the difference equations and just once in the level equations since we use the system GMM developed by Blundell and Bond (1998).

Finally, we check for the potential misspecification of the models. First, we use the Hansen J statistic of overidentifying restrictions in order to test the absence of correlation between the instruments and the error term. Tables V-VII demonstrate that the instruments used are valid. Second, we use the m_2 statistic, developed by Arellano and Bond (1991), in order to test for the lack of second-order serial correlation in the first-difference residuals. Tables V-VII indicate that there is no second-order serial correlation (m_2) in our models. Note that although there is first-order serial correlation (m_1), this is caused by the first-difference transformation of the model, and consequently, it does not represent a specification problem with the models. Third, our results in Tables V-VII provide good results for the following three Wald tests: 1) z_1 is a test of the joint significance of the reported coefficients, 2) z_2 is a test of the joint significance of the time dummies, and 3) z_3 is a test of the joint significance of the country dummies.

IV. Results

In this section, we first summarize the main results obtained by estimating our basic model. We then comment on the findings from the robustness checks, which are completely consistent with those from the basic model.

Table V. Results of the Basic Model

The regressions are performed using the panel described in Tables I-III. The rest of the information needed to read this table is as follows: 1) heteroskedasticity-consistent asymptotic standard error in parentheses; 2) t is the t-statistic for the linear restriction test under the null hypothesis H0: $\beta_2 + \alpha_1 = 0$; 3) z_1 is a Wald test of the joint significance of the reported coefficients asymptotically distributed as χ^2 under the null of no relationship with degrees of freedom in parentheses; 4) z_2 is a Wald test of the joint significance of the time dummy variables asymptotically distributed as χ^2 under the null of no relationship with degrees of freedom in parentheses; 5) z_3 is a Wald test of the joint significance of the country dummy variables asymptotically distributed as χ^2 under the null of no relationship with degrees of freedom in parentheses; 6) m_i is a serial correlation test of order i using residuals in first differences asymptotically distributed as $N(0,1)$ under the null of no serial correlation; and 7) Hansen is a test of the overidentifying restrictions asymptotically distributed as χ^2 under the null of no relationship between the instruments and the error term with degrees of freedom in parentheses.

Panel A. Results for Hypotheses 1, 2, and 3

	(1)	**(2)**	**(3)**	**(4)**
$(RI/K)_{it}$	11.0025***	11.6254***	9.6344***	12.4897***
	(0.2886)	(0.2171)	(0.2591)	(0.9209)
$(R\&D/K)_{it}$	14.8585***	7.3350***	12.1961***	22.4653***
	(0.4367)	(0.3152)	(0.2089)	(0.1351)
$DS_{it}(R\&D/K)_{it}$		14.5066***		
		(0.2558)		
$DGR_{it}(R\&D/K)_{it}$			13.7147***	
			(0.1495)	
$DFCF_{it}(R\&D/K)_{it}$				−15.8905***
				(0.8444)
t		131.94	127.78	42.35
z_1	961.62 (2)	16800.65 (3)	10141.03 (3)	21580.58 (3)
z_2	52.16 (16)	628.79 (16)	624.99 (16)	682.60 (16)
z_3	54.11 (8)	76.33 (8)	148.75 (8)	157.88 (8)
m_1	−3.22	−2.24	−3.30	−2.38
m_2	−0.87	0.58	−0.82	0.95
Hansen	134.03 (122)	104.80 (139)	101.02 (139)	101.71 (139)

Panel B. Results for Hypotheses 4, 5, 6, and 7

	(1)	**(2)**	**(3)**	**(4)**
$(RI/K)_{it}$	10.2722***	8.12318***	10.1172***	9.7657***
	(0.1869)	(0.2068)	(0.1486)	(0.1680)
$(R\&D/K)_{it}$	12.7357***	22.4936***	19.2024***	23.2176***
	(0.3052)	(0.2475)	(0.1388)	(0.1776)
$DMS_{it}(R\&D/K)_{it}$	10.2647***			
	(0.4091)			
$DEFD_{it}(R\&D/K)_{it}$		−12.94138***		
		(0.3291)		
$DLI_{it}(R\&D/K)_{it}$			−7.9051***	
			(0.1067)	

(*Continued*)

Table V. Results of the Basic Model (*Continued*)

Panel B. Results for Hypotheses 4, 5, 6, and 7 (Continued)

	(1)	(2)	(3)	(4)
$DCI_{it}(R\&D/K)_{it}$				−11.4951***
				(0.1048)
t	40.20	27.17	58.75	77.92
z_1	1085.88 (3)	10727.40 (3)	13995.65 (3)	14246.17 (3)
z_2	130.48 (16)	492.27 (16)	193.13 (16)	474.54 (16)
z_3	306.59 (8)	125.92 (8)	50.53 (8)	105.69 (8)
m_1	−3.10	−2.55	−2.03	−2.42
m_2	−0.95	0.75	0.27	0.20
Hansen	174.06 (139)	101.88 (139)	105.51 (139)	108.56 (139)

***Significant at the 0.01 level.

A. Results from the Basic Model

We start our analysis by verifying the effectiveness of our valuation model to capture the market reaction to R&D investment. This variable (RD_{it}) is extracted from Worldscope and represents all direct and indirect costs related to the creation and development of new processes, techniques, applications, and products with commercial possibilities. As seen in Panel A, Column (1) of Table V, which reports the results from the basic model based on the capital market arbitrage condition, the coefficient for the residual income variable is positive as predicted by our valuation model. In addition, the coefficient for the R&D variable is positive confirming that the role played by R&D in increasing the value of the firm is important.

To test our hypotheses, we interact the R&D variable with several dummy variables related to each firm characteristic. Taking size as an example, the basic model in Equation (14) can be written as follows:

$$\frac{V_{it} - BV_{it}}{K_{it}} = \beta_1 \frac{RI_{it}}{K_{it}} + (\beta_2 + \alpha_1 DS_{it}) \left(\frac{RD}{K}\right)_{it} + e_{it}, \tag{16}$$

where DS_{it} is a dummy variable equal to one if the firm is larger than the sample mean and zero otherwise. Firm size is measured as the natural logarithm of the replacement value of total assets. According to this model, the coefficient of R&D for small firms is β_2 (since DS_{it} takes the value zero), and $\beta_2 + \alpha_1$ is the coefficient for large firms (since DS_{it} takes the value one). In this last case, if both parameters are significant, a linear restriction test is needed to determine whether their sum ($\beta_2 + \alpha_1$) is significantly different from zero. Hence, the null hypothesis of no significance is H_0: $\beta_2 + \alpha_1 = 0$. The results are presented in Panel A, Column (2) of Table V. We find that the R&D coefficient for large firms ($\beta_2 + \alpha_1 = 7.3350 + 14.5066 = 21.8416$) is greater than the coefficient for small firms ($\beta_2 = 7.3350$).[7] This result supports Hypothesis 1 since R&D spending has a greater impact on the firm value of large firms. This

[7]Note that the linear restriction test with null hypothesis H0: $\beta 2 + \alpha 1 = 0$ provides a result rejecting this null hypothesis (see the *t*-value in Table V.)

Table VI. Robustness Check: Results of the Extended Model

The regressions are performed using the panel described in Tables I-III. The rest of the information needed to read this table is as follows: 1) heteroskedasticity-consistent asymptotic standard error in parentheses; 2) t is the t-statistic for the linear restriction test under the null hypothesis H0: $\beta_2 + \alpha_1 = 0$; 3) z_1 is a Wald test of the joint significance of the reported coefficients asymptotically distributed as χ^2 under the null of no relationship with degrees of freedom in parentheses; 4) z_2 is a Wald test of the joint significance of the time dummy variables asymptotically distributed as χ^2 under the null of no relationship with degrees of freedom in parentheses; 5) z_3 is a Wald test of the joint significance of the country dummy variables asymptotically distributed as χ^2 under the null of no relationship with degrees of freedom in parentheses; 6) m_i is a serial correlation test of order i using residuals in first differences asymptotically distributed as $N(0,1)$ under the null of no serial correlation; 7) Hansen is a test of the overidentifying restrictions asymptotically distributed as χ^2 under the null of no relationship between the instruments and the error term with degrees of freedom in parentheses.

Panel A. Results for Hypotheses 1, 2, and 3

	(1)	(2)	(3)	(4)
$(RI/K)_{it}$	10.0110***	9.8028***	9.9920***	11.6941***
	(0.1206)	(0.3687)	(0.2840)	(0.2529)
$(R\&D/K)_{it}$	14.7337***	7.2297***	11.9983***	22.9706***
	(0.1894)	(0.4693)	(0.2829)	(0.2541)
MS_{it}	1.4050	−3.2543	−2.5640	2.3925
	(1.9730)	(4.4929)	(5.3124)	(3.7596)
$(LTD_{it}/K)_{it}$	1.5270***	4.0269***	3.9690***	2.1794***
	(0.1775)	(0.4407)	(0.4462)	(0.3318)
$DS_{it}(R\&D/K)_{it}$		15.7089***		
		(0.2849)		
$DGR_{it}(R\&D/K)_{it}$			11.4697***	
			(0.1363)	
$DFCF_{it}(R\&D/K)_{it}$				−16.7261***
				(0.1192)
t		61.02	108.61	21.18
z_1	3525.52 (4)	3001.95 (5)	9091.80 (5)	9617.32 (5)
z_2	501.14 (16)	373.53 (16)	281.75 (16)	224.94 (16)
z_3	202.39 (8)	115.04 (8)	94.25 (8)	39.82 (8)
z_4	38.21 (2)	44.50 (2)	40.47 (2)	24.62 (2)
m_1	−2.99	−1.90	−3.01	−2.29
m_2	−0.90	0.61	−0.65	0.96
Hansen	216.39 (208)	99.88 (208)	102.44 (208)	99.76 (208)

Panel B. Results for Hypotheses 4, 5, 6, and 7

	(1)	(2)	(3)	(4)
$(RI/K)_{it}$	9.5559***	7.5429***	8.9114***	9.0097***
	(0.6504)	(0.2939)	(0.2616)	(4.2329)
$(R\&D/K)_{it}$	12.7598***	21.9724***	20.3908***	22.3864***
	(0.1346)	(0.2346)	(0.2415)	(0.2726)
MS_{it}	0.2939	0.7860	−7.3866	−3.7571
	(0.6406)	(4.0164)	(4.0267)	(4.2329)

(*Continued*)

Table VI. Robustness Check: Results of the Extended Model (*Continued*)

Panel B. Results for Hypotheses 4, 5, 6, and 7 (Continued)

	(1)	(2)	(3)	(4)
$(LTD_{it}/K)_{it}$	2.1563***	4.2457***	4.3628***	2.3187***
	(0.9785)	(0.4693)	(0.3570)	(0.3287)
$DMS_{it}(R\&D/K)_{it}$	9.4015***			
	(0.1333)			
$DEFD_{it}(R\&D/K)_{it}$		−10.5011***		
		(0.3846)		
$DLI_{it}(R\&D/K)_{it}$			−10.1333***	
			(0.1826)	
$DCI_{it}(R\&D/K)_{it}$				−10.7438***
				(0.1397)
t	99.05	29.76	37.10	39.71
z_1	4625.05 (5)	4214.38 (5)	7641.76 (5)	5021.96 (5)
z_2	4235.45 (16)	341.38 (16)	245.02 (16)	103.88 (16)
z_3	1884.85 (8)	82.82 (8)	121.54 (8)	84.67 (8)
z_4	243.67 (2)	41.32 (2)	81.90 (2)	24.89 (2)
m_1	−2.95	−2.27	−1.82	−2.23
m_2	−0.94	0.68	0.20	0.22
Hansen	252.72 (208)	102.49 (208)	97.44 (208)	105.85 (208)

***Significant at the 0.01 level.

result is also consistent with the Schumpeterian (1961) hypothesis. There are also other factors that explain why R&D is more effective in large firms than in small ones such as economies of scale, easier access to capital markets, and R&D cost spreading.

We test Hypothesis 2, related to growth, by substituting the dummy variable in Equation (16) with another dummy variable, (DG_{it}), which takes value one for firms whose rate of sales growth is above the sample mean and zero otherwise. Our results provide a new view for the economic literature. As illustrated in Panel A, Column (3) of Table V, the R&D coefficient for firms with a high rate of growth ($\beta_2 + \alpha_1 = 12.1961 + 13.7147 = 25.9108$; see t-value for its statistical significance) is greater than the R&D coefficient for firms with a low rate of growth ($\beta_2 = 12.961$). Our second hypothesis is confirmed by this result, and we provide new evidence regarding the role played by firm growth in moderating the relationship between R&D and firm value. Specifically, we confirm that a firm's growth positively affects the market valuation of its R&D spending. This higher valuation occurs due to the greater advantage that firms with a higher rate of growth take from the supranormal profits yielded by R&D projects.

To test the free cash flow hypothesis, we change the dummy variable in Equation (16) to another dummy variable, $DFCF_{it}$, which takes the value one for firms with a level of free cash flow higher than the sample mean and zero otherwise. To avoid entering a bias in our study due to an unsuitable measure of free cash flow, we follow Miguel and Pindado (2001) in the construction of the free cash flow variable as the interaction of cash flow and the inverse of investment opportunities (proxied by Tobin's q). We use Jensen's (1986) definition of free cash flow as cash flow that is not consumed by investment opportunities; thus, we rely on the above defined index that takes on a higher value when cash flow is high and investment opportunities are low indicating that the firm suffers from severe free cash flow problems, and vice versa if the level of cash flow is low

Table VII. Robustness Check: Using Market-to-Book Ratio as Dependent Variable

The regressions are performed using the panel described in Tables I-III. The market-to-book ratio as measured by $MB_{it} = (TA_{it} + V_{it} - BV_{it})/TA_{it}$, where TA_{it} is the book value of total assets, V_{it} is the market value of equity, and BV_{it} is the book value of common equity. The rest of the information needed to read this table is as follows: 1) heteroskedasticity-consistent asymptotic standard error in parentheses; 2) t is the t-statistic for the linear restriction test under the null hypothesis H0: $\beta_2 + \alpha_1 = 0$; 3) z_1 is a Wald test of the joint significance of the reported coefficients asymptotically distributed as χ^2 under the null of no relationship with degrees of freedom in parentheses; 4) z_2 is a Wald test of the joint significance of the time dummy variables asymptotically distributed as χ^2 under the null of no relationship with degrees of freedom in parentheses; 5) z_3 is a Wald test of the joint significance of the country dummy variables asymptotically distributed as χ^2 under the null of no relationship with degrees of freedom in parentheses; 6) m_i is a serial correlation test of order i using residuals in first differences asymptotically distributed as $N(0,1)$ under the null of no serial correlation; 7) Hansen is a test of the overidentifying restrictions asymptotically distributed as χ^2 under the null of no relationship between the instruments and the error term with degrees of freedom in parentheses.

Panel A. Results for Hypotheses 1, 2, and 3

	(1)	(2)	(3)	(4)
$(RI/K)_{it}$	8.5711***	11.6086***	8.8507***	12.5011***
	(0.1852)	(0.2283)	(0.1978)	(0.1386)
$(R\&D/K)_{it}$	22.2913***	5.8411***	12.4670***	24.1447***
	(0.2269)	(0.4558)	(0.2728)	(0.2170)
$DS_{it}(R\&D/K)_{it}$		17.1546***		
		(0.3626)		
$DGR_{it}(R\&D/K)_{it}$			13.7870***	
			(0.2031)	
$DFCF_{it}(R\&D/K)_{it}$				−18.8499***
				(0.1479)
t	140.12	129.95	95.47	21.88
z_1	9851.23 (2)	7094.60 (3)	4964.44 (3)	16133.40 (3)
z_2	512.93 (15)	598.45 (16)	311.50 (15)	967.48 (15)
z_3	108.74 (5)	60.63 (5)	41.94 (5)	89.10 (5)
m_1	−1.96	−2.28	−3.21	−2.40
m_2	0.34	0.49	−1.17	0.95
Hansen	98.31 (105)	102.99 (139)	100.96 (139)	102.24 (139)

Panel B. Results for Hypotheses 4, 5, 6, and 7

	(1)	(2)	(3)	(4)
$(RI/K)_{it}$	9.1190*	6.5839*	9.2353*	9.2221*
	(0.2202)	(0.26043)	(0.1772)	(0.2012)
$(R\&D/K)_{it}$	11.8197*	24.05622*	20.8207*	24.3732*
	(0.3332)	(0.3184)	(0.2471)	(0.2318)
$DMS_{it}(R\&D/K)_{it}$	9.7531*			
	(0.4467)			
$DEFD_{it}(R\&D/K)_{it}$		−14.94205*		
		(0.5191)		

(*Continued*)

Table VII. Robustness Check: Using Market-to-Book Ratio as Dependent Variable (*Continued*)

Panel B. Results for Hypotheses 4, 5, 6, and 7 (*Continued*)				
	(1)	**(2)**	**(3)**	**(4)**
$DLI_{it}(R\&D/K)_{it}$			−11.1941*	
			(0.2337)	
$DCI_{it}(R\&D/K)_{it}$				−11.6714*
				(0.1895)
t	33.91	20.13	24.82	57.67
z_1	671.11 (3)	4639.94 (3)	8691.84 (3)	6528.57 (3)
z_2	98.67 (16)	236.93 (15)	573.62 (15)	319.81 (16)
z_3	142.23 (5)	68.12 (5)	58.00 (5)	40.87 (5)
m_1	−2.78	−2.48	−2.00	−2.33
m_2	−1.05	0.58	−0.28	0.11
Hansen	182. (161)	101.07 (139)	105.46 (139)	103.94 (139)

***Significant at the 0.01 level.

and the level of investment opportunities is high. Our results also provide interesting empirical evidence. As can be seen in Panel A, Column (4) of Table V, the R&D coefficient for HFCF firms ($\beta_2 + \alpha_1 = 22.4653–15.8905 = 6.5748$) is lower than the coefficient for LFCF firms ($\beta_2 = 22.4653$).[8] This result is consistent with our Hypothesis 3. It can be interpreted as evidence supporting the free cash flow theory as HFCF firms could use their free cash flow to undertake negative NPV R&D projects, which would obviously be rejected in the case of LFCF firms.

We test Hypothesis 4 related to market share by substituting the dummy variable in Equation (16) with another dummy variable, DMS_{it}, which takes the value one for firms whose market share level is larger than the sample mean and zero otherwise. Market share is calculated as $MS_{it} = \frac{NS_{it}}{\sum_{i=1}^{n} NS_{it}}$, where NS_{it} denotes the net sales of firm i, and $\sum_{i=1}^{n} NS_{it}$ stands for the total net sales of its industry.[9] The results are illustrated in Panel B, Column (1) of Table V. They are in agreement with our Hypothesis 4 as they reveal that the R&D coefficient is higher for firms with high market share ($\beta_2 + \alpha_1 = 12.7357 + 10.2647 = 23.0004$; see t-value for its significance) than for firms with low market share ($\beta_2 = 12.7357$). Consequently, our results confirm that the higher the market share of the firm, the more effective the R&D spending and, therefore, the higher the market valuation. Actually, there is a simple reason for this fact. R&D spending yields some supranormal profits for each dollar sold; hence, the overall benefits will be greater as the market share rises.

To test Hypothesis 5, we substitute the dummy variable in Equation (16) with another dummy variable, $DEFD_{it}$, which takes the value one for firms whose EFD level is larger than the sample mean and zero otherwise. We follow Rajan and Zingales (1998) and define external financial dependence as $EFD_{it} = \frac{CE_{it} - CF_{it}}{CE_{it}}$, where CE_{it} and CF_{it} represent capital expenditures and cash flow, respectively. Since Rajan and Zingales (1998), dependence on external financing has played an important role in the development of economic theory. We also provide interesting

[8]The t-value resulting from the linear restriction test (see Table V) tells us that this coefficient is significantly different from zero.

[9]To compute the net sales of the industry, we use a sample composed of 4,086 companies and 31,355 observations.

results regarding how the dependence on external financing affects the market valuation of R&D spending. Panel B, Column (2) of Table V reports that the R&D coefficient is lower for firms with higher EFD ($\beta_2 + \alpha_1 = 22.4936 - 12.9414 = 9.5522$, which is statistically significant; see *t* value) than for those firms with lower EFD ($\beta_2 = 22.4936$). This result supports our Hypothesis 5 and confirms that firms with higher dependence on external financing face an important handicap in undertaking R&D projects. In fact, higher information asymmetry associated with this kind of project substantially increases the cost of external financing (Van Ness, Van Ness, and Warr, 2001). As a result, part of the supranormal profits yielded by the R&D projects are spent on the premium of external financing faced by firms highly dependent on external financing and, consequently, the market reaction to R&D spending is lower than it is for the remaining firms.

We now move on to the analysis of the effect of labor intensity on the relationship between firm value and R&D spending. We test this hypothesis by substituting the dummy variable in Equation (16) with another dummy variable, DLI_{it}, which takes the value one for firms whose labor intensity level is higher than the sample mean and zero otherwise. We define labor intensity as the ratio between the number of employees and sales revenue. As shown in Panel B, Column (3) of Table V, the R&D coefficient is lower for labor-intensive firms ($\beta_2 + \alpha_1 = 19.2024 - 7.9051 = 11.2973$, which is statistically significant; see *t*-value) than for the remaining firms ($\beta_2 = 19.2024$). Consequently, in agreement with Hypothesis 6, the market valuation of R&D spending is lower for labor-intensive firms as the supranormal profits from R&D projects are diluted among employees.

Finally, we test Hypothesis 7 related to capital intensity by substituting the dummy variable in Equation (16) with another dummy variable, DCI_{it}, which takes the value one for firms whose capital intensity level is larger than the sample mean and zero otherwise. In this study, capital intensity is defined as the ratio between the replacement value of tangible assets and sales revenue. Panel B, Column (4) of Table V reveals that the R&D coefficient is lower for capital-intensive firms ($\beta_2 + \alpha_1 = 23.2176 - 11.4951 = 11.7225$, which is statistically significant; see *t*-value) than for the remaining firms ($\beta_2 = 23.2176$). This evidence supports our last hypothesis and demonstrates that capital-intensive firms face greater financial constraints, and as a result, the market valuation of their R&D projects is lower.

B. Robustness Checks

1. Extended Model

Green, Stark, and Thomas (1996) derive a valuation model for R&D that is also based on residual income. Apart from other differences in the derivation process, they include some control variables. Therefore, we extend our basic model by using two control variables as a robustness check for our results. Specifically, we enter into the model market share and long-term debt as control variables.[10] Consequently, our extended model is as follows:

$$\frac{V_{it} - BV_{it}}{K_{it}} = \beta_1 \frac{RI_{it}}{K_{it}} + \beta_2 \frac{RD_{it}}{K_{it}} + \beta_3 MS_{it} + \beta_4 \frac{LTB_{it}}{K_{it}} + e_{it}. \quad (17)$$

The results for this extended model are presented in Table VI. The main characteristic of these results is that they are in total agreement with those of the basic model discussed in the previous section. Specifically, the role played by firm characteristics in moderating the relationship between

[10]The first variable is defined as a firm's sales divided by the sales of its industry, while the second variable is the long-term debt scaled by replacement value of total assets (see appendices for details).

firm value and R&D spending is exactly the same as that found in the basic model. Overall, this evidence provides an excellent robustness check of our results.

Furthermore, the two control variables also shed light on the role played by certain firm characteristics.[11] The coefficient of the long-term debt variable is always positive, revealing the benefits resulting from the fact that interest payments are tax deductible while, consistent with Chen, Ho, and Shih (2007), the coefficient of the market share variable is not significant. Consequently, we find strong support for our approach to explaining the role of certain firm characteristics. This is because some of them, despite being insignificant in explaining value (such as market share), play an important role in moderating the relationship between firm value and R&D spending.

2. Alternative Measure of Dependent Variable

Our second robustness check is intended to provide a comparison of our results regarding the value relevance of the R&D investment to those reported in earlier studies. With this purpose in mind, we have reestimated all our models by using an alternative dependent variable that allows us a direct comparison with previous evidence on the effect of R&D on firm valuation. Specifically, we have constructed an alternative dependent variable following Lie (2001) and Chang, Dasgupta, and Hilary (2006), the market-to-book ratio. This variable is computed as $MB_{it} = (TA_{it} + V_{it} - BV_{it})/TA_{it}$, where TA_{it} is the book value of total assets, V_{it} is the market value of equity, and BV_{it} is the book value of common equity. The results of the reestimation of our models using this alternative dependent variable are provided in Table VII. Confirming the results of prior studies that use this measure (Bae and Kim, 2003), we find that the market positively assesses R&D investment.

As we have already pointed out, this positive relationship is the starting point to test our hypotheses. As demonstrated in Table VII, the reestimation of our models totally confirms our previous evidence. That is, there is a strong link between some firm characteristics and the market reaction to R&D efforts. Again, firm size, growth, and market share advantages make R&D valuation greater. Alternatively, free cash flow, labor and capital intensity, and dependence on external financing negatively influence the market response to R&D spending.

Finally, we also check our previous results by using the market value of common equity (V_{it}) as the dependent variable (Chauvin and Hirschey, 1993). Once again, the results confirm the positive relationship between a firm's R&D spending and its market value found in previous research. Moreover, this last test corroborates that several firm characteristics (namely, size, firm growth, and market share) positively affect this relation, while others (specifically, free cash flow, dependence on external finance, labor intensity, and capital intensity) exert a negative effect.[12]

V. Conclusions

This paper focuses on how firm characteristics moderate the relationship between firm value and R&D spending. Taking the capital market arbitrage condition as our starting point, we derive a valuation model in which firm value depends on residual income and R&D spending. We then interact R&D with several firm characteristics in order to investigate the role played by these characteristics in the market valuation of R&D spending.

[11]The Wald test of the joint significance of the control variables provides positive results (see z_4 in Table VI).

[12]Estimation results will be provided by authors upon request.

Our results reveal that the relationship between firm value and R&D is moderated by several firm characteristics. In particular, size increases the market valuation of a firm's R&D spending since size provides economies of scale, easier access to capital markets, and R&D cost spreading. Firm growth also positively affects the correlation between firm value and R&D spending as firms with a high rate of growth make the most of their supranormal profits arising from R&D projects. Regarding market share, we find a positive effect on the association between firm value and R&D spending, rather than on firm value as has been widely documented in previous research. This means that the supranormal profits of R&D investment are highly dependent on the amount of R&D spending. Alternatively, free cash flow has a negative effect on the above-mentioned relation as firms with high free cash flow could be tempted to use the free cash flow to undertake negative NPV R&D projects. The dependence on external financing is a handicap negatively assessed by the market when firms undertake R&D projects due to the higher information asymmetry associated with this kind of project. Labor intensity also has a negative effect on the market valuation of R&D spending since the supranormal profits from R&D projects are diluted among employees. Capital intensity also has a negative effect on the relationship between firm value and R&D spending due to the greater financial constraints faced by capital-intensive firms.

Finally, this study provides interesting ideas to be taken into account when making decisions at the firm level and in order to attain more effective R&D spending as R&D intensity strongly depends on the characteristics of the firm. Apart from the effect of the financial environment, there are several firm characteristics that also moderate the market valuation of R&D spending. Therefore, the financial environment should be taken into account by the policy decision maker, whereas firm characteristics should be accounted for by shareholders and managers. In doing so, both types of decision makers would substantially increase the effectiveness of R&D spending, benefiting the rest of society. ■

Appendix A: Firm Value

This variable is a derivation of our valuation model. According to Equation (14), our dependent variable is computed as follows:

$$\frac{V_{it} - BV_{it}}{K_{it}},$$

where V_{it} is the market value of equity and BV_{it} is its book value. K_{it} stands for the replacement value of total assets computed as follows:

$$K_{it} = RF_{it} + (TA_{it} - BF_{it}),$$

where RF_{it} is the replacement value of tangible fixed assets, TA_{it} is the book value of total assets, and BF_{it} is the book value of tangible fixed assets. The latter two have been obtained from the firm's balance sheet and the first one has been calculated according to the proposals by Perfect and Wiles (1994)

$$RF_{it} = RF_{it-1}\left[\frac{1+\phi_t}{1+\delta_{it}}\right] + I_{it},$$

for $t > t_0$ and $RF_{it0} = BF_{it0}$, where t_0 is the first year of the chosen period, in our case 1986. Alternatively, $\delta_{it} = D_{it}/BF_{it}$ and $\phi_t = (GCGP_t - GCGP_{t-1})/GCGP_{t-1}$, where $GCGP_t$ is the growth of capital goods prices extracted from the *Main Economic Indicators*.

Appendix B: Residual Income

As expressed in Equation (7), this variable is defined as

$$RI_{it} = \pi_{it} - \kappa_{it} BV_{i,t-1},$$

where π_{it} stands for the net income and K_{it} denotes the cost of capital. For each firm and time period, the cost of capital has been calculated using the capital asset pricing model

$$\kappa_{it} = rf_{it} + (E(rm_{it}) - rf_{it})\beta_{it},$$

where rf_{it} is the risk free rate extracted from the *Main Economic Indicators* for each country and time period. The market return (rm_{it}) is computed using the market price of all the companies listed in each country regardless of whether or not they provide R&D information. The sample used for computing the market return comprises 4,086 companies and 31,355 observations.[13] The company's beta (β_i) is also computed using the market price and the same sample mentioned above to compute the market return item.

Appendix C: Long-Term Debt

The market value of long-term debt, $MVLTD_{it}$, is obtained from the following formula:

$$MVLTD_{it} = \left[\frac{1 + l_{it}}{1 + i_t}\right] BVLTD_{it},$$

where $BVLTD_{it}$ is the book value of the long-term debt, i_l is the interest rate of the long-term debt reported in the *Main Economic Indicators*, and l_{it} is the average cost of long-term debt. The cost of long-term debt is defined as $l_{it} = (IPLTD_{it}/BVLTD_{it})$, where $IPLTD_{it}$ is the interest payable on the long-term debt obtained by distributing the interest payable between the short- and long-term debt, depending on the interest rates. That is

$$IPLTD_{it} = \frac{i_l\, BVLTD_{it}}{i_s\, BVSTD_{it} + i_l\, BVLTD_{it}} IP_{it},$$

where IP_{it} is the interest payable, i_s stands for the interest rate on the short-term debt also reported in the *Main Economic Indicators*, and $BVSTD_{it}$ is the book value of the short-term debt.

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[13] The distribution of this sample across countries will be provided by the authors upon request.

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