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

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Abstract
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. The estimation of this model by using the Generalized Method of Moments and data from the eurozone countries yields interesting results. Several firm characteristics (namely, size, firm growth and market share) are found to positively affect the relationship between firm value and R&D spending, while others (specifically, free cash flow, dependence on external finance, labour intensity and capital intensity) exert a negative effect. Therefore, the effectiveness of the R&D spending depends on the firm characteristics.

Keywords: Research and development, valuation model, firm characteristics.

JEL classification: G30, O32

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1. Introduction

Over the last 10 years, the academic literature has provided evidence on the importance of the role played by research and development (hereafter R&D) in the economic growth (see, for instance; Jones, 1995; and, more recently, Bowns et al., 2003; Arnold, 2006). As a result, scholars have paid increasing attention to the R&D spending, which is not considered as a cost anymore, but rather as a value-increasing investment in that R&D spending yields some supra-normal profits.

Moreover, the seminal work by Griliches (1981) draws attention to the extent that R&D spending creates intangible capital for a firm, and indicates that the market should show it up in the valuation of the firm. More recently, several empirical studies analyze the market response to R&D spending, and their results indicate that, in general, R&D investments are positively valued by the market (see, for instance, Doukas and Switzer, 1992; Chauvin and Hirschey, 1993; Szewczyk et al., 1996; Chen and Ho, 1997; Chan et al., 2001; Bae and Kim, 2003; Eberhart et al., 2004; Cannolly and Hirschey, 2005). Furthermore, some of these papers indicate that the market response to the R&D spending depends on firm size. For instance, Cannolly and Hirschey (2005) find support for the size advantages to the valuation effects of R&D investments.

The stock market valuation of R&D spending is also affected by the financial environment, as shown by Booth et al. (2006). Their results support the notion that the relative size of the equity and private loan markets influence the way in which R&D is valued. Specifically, they document that the greater the portion of equity financing (or the lower the portion 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.

In this context, the aim of this paper is to analyse how several firm characteristics moderate the relationship between firm value and R&D spending. Our idea is that the market valuation of R&D spending is not only affected by the financial environment (see Booth et al., 2006), but also by some firm characteristics besides size (see Cannolly and Hirschey, 2005). Although there is no previous evidence on this point, there are some studies that has identified several firm characteristics (such as size, firm growth, free cash flow, market share, external finance dependence, labour intensity and capital intensity) as determinants of a firm's R&D (see, for instance, Blundell et al., 1999; Galende and Suárez, 1999; Del Monte and Papagni, 2003; Negassi, 2004). Therefore, in this paper we go a step forward in that we investigate whether or not certain firm characteristics, besides being themselves determinants of R&D spending, also play an important role in moderating the relationship between firm value and R&D spending. Accordingly, we pose several hypotheses that allow us to analyse how size, growth, free cash flow, market share, external finance dependence, labour intensity and capital intensity influence the positive relationship between R&D and firm value.

To achieve our goal, we first derive a valuation model based on the capital market arbitrage condition. This model shows that the firm value depends on the residual income and the R&D spending and, therefore, it is a perfect tool to study how firm characteristics affect the market valuation of R&D spending. In this way, our study relies on strong theoretical arguments for each firm characteristic and on the results from the estimation of the valuation model. The estimation is carried out by the Generalized Method of Moments, hence we use the panel data methodology that eliminates the individual heterogeneity and controls for endogeneity problems. Since the data quality requirements of this methodology are very high, we have extracted our data from an international database (Worldscope) and for all the eurozone countries[†].

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 relation due to economies of scale, easier access to capital markets and R&D cost spreading. A positive effect is also found regarding firm growth in that a high rate of growth allows the firm to take greater advantage of the supra-normal profits arising from R&D projects. In contrast, free cash flow negatively affects the market valuation of R&D spending, since 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 affects the relationship between firm value and R&D spending rather than firm value and, as a result, the supra-normal profits are highly dependent on the amount of R&D spending. The dependence of external financing negatively affects the market valuation of R&D spending because of the higher information asymmetry associated with R&D projects. Labour and capital intensity both negatively influence the impact of R&D spending on firm value; the first one because the supra-normal profits are diluted between employees, and the second one because capital intensive firms face greater financial constrains.

The remainder of the paper is organised as follows. In Section 2, we derive the valuation model depending on residual income and R&D spending, and explain the theoretical arguments behind our hypotheses. Section 3 describes our data set and the econometric method used to test our hypotheses. The results are discussed in Section 4, and the last section presents the conclusions.

[†] Note that the eurozone countries provide us with an ideal environment for our market share arguments.

2. Model and Hypotheses

The development of our model to study the relationship between R&D and firm value is based on the well-known capital market arbitrage condition (see, for instance, Whited, 1992, and Blundell et al., 1992). According to this condition, the net after-tax return for shareholders in the firm *i* during period *t* is obtained in two ways: current dividends and capital appreciation. Therefore, shareholders will maintain their shares as long as the return obtained equals 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 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 on information known at moment *t*.

Solving (1) forward for V_{it} yields the following expression for a firm's market value:

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

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:

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

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

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

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

Following Dechow et al. (1999) and Myers (1999), we assume that the last term in Equation (6) is zero. In addition, as usual in the economic literature, we consider that the residual income is:

$$RI_{i,t+j} = \pi_{i,t+j} - rBV_{i,t+j-1} \quad (7)$$

Therefore, the firm market value can be expressed as:

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

Consequently, the attention should be paid to the second term in Equation (8). We assume that the expected residual income conditional on date t information depends on two factors. First, the residual income could have either a trend (increasing or declining) or be constant. For instance, Green et al. (1996) assume that the expected values of future residual incomes can be modelled as declining at rate δ. As a result Equation (9) holds:

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

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

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

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

Second, Sougiannis (1994) argues that the impact of R&D on market value can be obtained 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) shows 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 should be a factor to explain the residual income conditional on date t information. The point is how many lags should be considered. According to Sougiannis (1994), lagged values of R&D rarely convey addition information in explaining market value, once current residual income has been included as an explanatory variable on 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 by an instrumental variables method. In this paper, as explained in Section

3.2, we use the Generalized Method of Moments, since this method embeds the other instrumental variables methods as special cases (see Ogaki, 1993).

Taking into account the two factors abovementioned, the conditional expectation term in Equation (8) could be written as:

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

where RD_{it} stands for the research and development 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 being dependent on the assumptions made in Equations (9), (10) or (11).

Substituting the expectation in Equation (12) into Equation (8) yields the following regression model:

$$V_{it} = BV_{it} + \beta_1 RI_{it} + \beta_2 RD_{it} + e_{it} \qquad (13)$$

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

$$\frac{V_{it} - BV_{it}}{K_{it}} = \beta_1 \frac{RI_{it}}{K_{it}} + \beta_2 \frac{RD_{it}}{K_{it}} + e_{it} \qquad (14)$$

Actually, the left hand side term in our model is the difference between 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.

In this paper, we focus on the market valuation of R&D spending. Therefore, the first outcome from our valuation model is that there is a positive relationship between firm value and R&D spending. This theoretical result is consistent with prior empirical studies (see, for instance, Chan et al., 2001; Booth et al., 2006), and it thus provides theoretical basis for our first hypothesis:

Hypothesis 1. The research and development spending positively affects firm value.

Since Schumpeter (1961), scholars have widely studied the relationship between R&D and firm size. As surveyed in Lee and Sung (2005), diverse results have been found by the empirical literature. Some studies find a linear

[§] Deflating by controlling for size is a usual way to avoid heteroscedasticity problems in econometric models.

and positive relationship, while others suggest that R&D and firm size are independent. The earliest studies of the relationship between firm size and R&D find a positive relation[**], which is interpreted as support for the Schumpeterian hypothesis. Furthermore, Arvanitis (1997) finds that the positive relationship between R&D expenditures and firm size depends on the firm industry. However, Cohen et al. (1987) investigate the Schumpeterian hypothesis and find 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 R&D-size relation is probably stronger for industries with high technological opportunity. Note that this result is consistent with previous findings already reported by Cohen and Klepper (1996).

More important than the relationship between R&D and size is how size moderates the relationship between R&D and value. Cannolly and Hirschey (2005) show findings supporting the importance of size advantages to the valuation effects of R&D spending. This result is consistent with Chauvin and Hirschey (1993), who find that 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, sometimes, the R&D cost spreading) are commonly attributed to large firms (see Cohen and Klepper, 1996). Within this context, we use our valuation model to go further in the analysis of the role played by firm size in moderating the relationship between R&D and value. Accordingly, we pose our second hypothesis:

Hypothesis 2. The impact of research and development on firm value is greater for larger than for smaller firms.

To test this hypothesis, we extend on the model in Equation (14) by interacting R&D with a dummy variable that distinguishes between large and small firms. The resultant model would be:

$$\frac{V_{it} - BV_{it}}{K_{it}} = \beta_1 \frac{RI_{it}}{K_{it}} + (\beta_2 + \alpha_1 DS_{it}) \left(\frac{RD}{K} \right)_{it} + e_{it} \qquad (15)$$

where DS_{it} is a dummy variable equal to 1 if the firm is larger than the sample mean, and 0 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 value zero); whereas $\beta_2+\alpha_1$ is the coefficient for large firms (since DS_{it} takes value one). In this last case, if both parameters are significant, a linear restriction test is needed in order to know

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

whether their sum ($\beta_2+\alpha_1$) is significantly different from zero. Hence the null hypothesis of no significance is $H_0: \beta_2+\alpha_1=0$.

Economic literature assumes that R&D spending facilitates the success of the firm in the product market and, as a result, the R&D spending leads to a higher rate of growth. However, Del Monte and Papagni (2003) summarize the results found by different studies over the last 20 years. Based on the analysis of these studies, they 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 R&D) could be endogenous. This means that firms with higher rate of growth would increase their size and, according to the Schumpeterian hypothesis, they 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 supra-normal profits arising from the R&D projects and, consequently, the market will provide them with a better valuation than that of the remaining firms. Therefore, our third hypothesis would be as follows:

Hypothesis 3. The impact of research and development on firm value is greater for firms with higher rate of growth than for firms with lower rate of growth.

This hypothesis can be tested by substituting the dummy variable in Equation (15) by another dummy variable, DG_{it}, which takes value 1 for firms whose rate of growth is above the sample mean, and 0 otherwise.

Another firm characteristic that may influence the relationship between R&D and firm value is the 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 theory, firms with a high level of free cash flow (hereafter, HFCF firms) are prone to use these funds in negative NPV projects. Several studies on investment find support for Jensen's theory (see, for example, Del Brio et al., 2003a and 2003b) in that firms having low (high) free cash flow level are expected to experience positive (negative) market reaction to investment announcements. However, there are other studies (see, for instance, Szewczyk et al., 1996, and 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 their measure of free cash flow is a cash flow measure. In addition, except for Szewczyk et al. (1996), the abovementioned studies are focused on tangible assets investments. Consequently, our study contributes to this strand of literature by analyzing how the level of free cash flow affects the relationship between R&D spending and firm value. According to Jensen's theory, the effect of HFCF firms' R&D projects 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 so encouraged to undertake negative NPV projects. Consequently, our fourth hypothesis would be as follows:

Hypothesis 4. The impact of research and development on firm value is greater for firms with low free cash flow levels than for ones with high free cash flow levels.

We test this hypothesis by substituting the dummy variable in Equation (15) by another dummy variable, $DFCF_{it}$, which takes value 1 for firms with a level of free cash flow higher than the sample mean, and 0 otherwise. In order to avoid that an unsuitable measure of free cash flow enters any bias in our study, we follow Miguel and Pindado (2001) in the construction of the free cash flow variable. The idea is to build an index that takes high values when cash flow is high and investment opportunities low, and low values vice versa. Consequently, our measure of free cash flow is the result of the interaction between cash flow and the inverse of investment opportunities (see Appendix).

Recent literature has pointed out the influence of the relationship between market share and R&D spending on firm value. In fact, there is previous evidence suggesting that market share and R&D are complementary to each other in firms market valuation (see Nagaoka, 2004). Blundell et al. (1999) investigate the relationship between innovation and market share, and find that firms with high market share innovate more and, hence, their market valuation is higher. In order 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 (see Booth et al., 2006), these findings show evidence on the importance of market share in moderating the relationship between R&D and firm value. In addition, Blundell et al. (1999) suggest that such positive influence plays a considerable role in creating barriers to entry that, hence, should be captured by firm value. To provide additional evidence on this matter, we test the advantages of market share, and hence we pose our fifth hypothesis:

Hypothesis 5. The impact of research and development on firm value is greater for firms with high market share than for ones with low market share.

This hypothesis can be tested by substituting the dummy variable in Equation (15) by another dummy variable, DMS_{it}, which takes value 1 for firms whose market share level is larger than the sample mean, and 0 otherwise. Market share is calculated as described in the Appendix.

The external finance dependence (hereafter EFD) is another firm characteristic that is expected to moderate the relationship between R&D and firm value. We follow Rajan and Zingales (1998), and we define EFD as capital expenditures minus cash flow divided by capital expenditures. Therefore, the EFD measure captures the part of a firm's investments that cannot be financed by internal resources and, in consequence, that requires the firm to obtain external funds. Rajan and Zingales (1998) show 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 when financing the industries intensive in tangible assets. Consequently, it would be more difficult to raise funds to undertake investments in intangibles 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 (see Blundell et al, 1999). Therefore, in particular 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 (see Aboody and Lev, 2000). Accordingly, we derive the following hypothesis.

Hypothesis 6. The higher the external finance dependence, the lower the impact of research and development on firm value.

This hypothesis can be tested by substituting the dummy variable in Equation (15) by another dummy variable, $DEFD_{it}$, which takes value 1 for firms whose external finance dependence level is lager than the sample mean, and 0 otherwise.

The relationship between human capital and R&D activities has drawn attention from the empirical research. Galende and Suárez (1999) find evidence supporting the hypothesis that a high stock of qualified human capital increases the probability of R&D activities. In the same vein, Gustavsson and Poldahl (2003) show the importance of human capital for R&D spending. Furthermore, Beck and Levine (2002) focus on assessing whether R&D-intensive and labour-intensive industries grow faster depending on the orientation of the financial system (bank-based versus market-based). However, they do not find evidence supporting that the orientation of the financial system favours labour-intensive industries. We go a step forward in studying labour-intensive firms instead of industries. Our argument is that the effect of labour intensity on the relationship between firm value and R&D spending is negative, in that the supra-normal profits of R&D spending are diluted between employees, especially when employees have been hardly involved in the firm's R&D projects. As a result, our seventh hypothesis would be as follows:

Hypothesis 7. The higher the labour intensity, the lower the impact of research and development on firm value.

We test this hypothesis by substituting the dummy variable in Equation (15) by another dummy variable, DLI_{it}, which takes value 1 for firms whose labour intensity level is higher than the sample mean, and 0 otherwise. We defined the labour intensity as the ratio between the number of employees and sales revenue.

Capital intensity is also related to R&D activities (see Galende and Suárez, 1999). Hsiao and Tahmiscioglu (1997) find that capital intensive firms face more difficulties in financing investment projects. Consequently, capital intensive firms would face greater financial constrains, which may lead them to undertake less R&D projects, and these projects may be poorly assessed by capital markets because the cost of capital for capital intensive firms would be higher. Consequently, our last hypothesis is as follows:

Hypothesis 8. The impact of research and development on firm value is lower for capital intensive firms.

This hypothesis can be tested by substituting the dummy variable in Equation (15) by another dummy variable, DCI_{it}, which takes value 1 for firms whose capital intensity level is larger than the sample mean, and 0 otherwise. In this study, capital intensity is defined as the ratio between the replacement value of tangible assets and sales revenue.

3. Data and estimation method

3.1. Data

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

For each country we have constructed an unbalanced panel comprising companies for which information for a least six consecutive years from 1986 to 2003 was available[††]. This strong requirement is a necessary condition since we lost one-year data in the construction of some variables (see Appendix), we lost another year-data because of the estimation of the model in first differences, and

[††] Note that before this date there is no information available for research and development, which is the main topic of our research.

four consecutive year information is 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 Generalized Method of Moments (GMM), is based on this assumption.

As occurs in La Porta et al. (2000), we had to remove Luxembourg from our sample, since there are just a few companies listed in Luxembourg's stock exchange. We also had to remove all the countries (namely Finland and Portugal) for which samples with the abovementioned requirement could not be selected[‡‡]. As a result, our panel comprises Austria, Belgium, France, Germany, Greece, Ireland, Italy, the Netherlands and Spain. Table 1 provides the structure of the sample in terms of companies and number of observations per country. Note that the details of the data reported by the different tables of this paper are provided after removing the first-year data. These first-year data are only used to construct several variables, but not in the estimation of the models. Therefore, tables exclusively refer to the data used to estimate the models. Table 2 shows 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 comprises 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 when some companies are delisted, and consequently, dropped from the database. Finally, Table 3 provides the allocation of all companies to one of nine broad economic sector groups in accordance with the Economic Sector Code. Note that financial services companies have been excluded from our study due to their own specificity.

Using the information of the above described database we have constructed all the variables in our models following the procedure detailed in the Appendix. Our dependent variable is a measure of firm value, and the explanatory variables in the basic model are residual income and research and development. We have also estimated an extended version of the model including two control variables: market share and long term debt. The summary statistics (mean, standard deviation, maximum and minimum) are provided by Table 4. To analyse how certain firm characteristics moderate the relationship between firm value and research and development, we have used a set of dummy variables constructed as explained in the Appendix[§§]. The number of zeros and ones for each dummy variable is provided in Table 5.

3.2. Estimation method

[‡‡] Note that the information on research and development usually presents a lot of missing values in databases.

[§§] Note that both the basic and extended versions of the model have also been estimated by accounting for the interactions described in Section 2.

All the models specified in this paper have been estimated by using the panel data methodology. Two issues have been considered to make this choice. First, unlike cross-sectional analysis, panel data allow us to control for individual heterogeneity. This point is crucial in our study because the decision of undertaking R&D projects in a firm is very closely related to the firm specificity and, more importantly, the effect of research and development 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 modelling it as an individual effect, η_i, which is then eliminated by taking first differences of the variables. Consequently, the basic specification of our model would be as follows:

$$\frac{V_{it} - BV_{it}}{K_{it}} = \beta_1 \frac{RI_{it}}{K_{it}} + \beta_2 \frac{RD_{it}}{K_{it}} + \eta_i + d_t + c_i + v_{it} \qquad (16)$$

where the error term has several components, besides the abovementioned 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 standing for the country-specific effect, which are necessary in that our models are estimated using data of several countries; finally, v_{it} is the random disturbance.

The second issue we can deal with by using the panel data methodology is the endogeneity problem. The endogeneity problem is likely to arise since the dependent variable (firm value) may also explain research and development in that a higher value may encourage managers to undertake new R&D projects. Therefore, all models have been estimated by using instruments. To be exact, we have used all the right-hand-side variables in the models lagged twice and three times as instruments.

Finally, we have checked for the potential misspecification of the models. First, we use the Hansen J statistic of over-identifying restrictions in order to test the absence of correlation between the instruments and the error term. Tables 6 to 9 show 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 6 to 9 show that there is not 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 of the models. Third, our results in Tables 6 to 9 provide good results for the following three Wald tests: z_1 is a test of the joint significance of the reported coefficients; z_2 is a test of the joint significance of the time dummies; and z_3 is a test of the joint significance of the country dummies.

4. Results

In this section, we first summarize the main results obtained by estimating our basic model. Then, we comment on the findings from an extended model, which are totally consistent with those from the basic model.

4.1. Results from the basic model

Column I of Table 6 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 the important role played by R&D in increasing the value of the firm. Consequently, this last result is in accordance with financial literature (see, for instance, Chan et al., 2001; Booth et al., 2006) and supports Hypothesis 1.

This first result is the starting point for testing other interesting hypotheses about how several firm characteristics moderate the positive relationship between firm value and R&D. Column II of Table 6 shows notable results on the role played by size in the abovementioned relationship. Specifically, we obtain that the R&D coefficient for large firms ($\beta_1+\alpha_1$=7.3350+14.5066= 21.8416)[***] is greater than the coefficient for small firms (β_1=7.3350). This result supports Hypothesis 2 in that R&D spending has a greater impact on the firm value of large firms. This result is also consistent with the Schumpeterian hypothesis. Moreover, there are other factors that explain why R&D is more effective in large firms than in small ones, such as economies of scale, the easier access to capital market and the R&D cost spreading.

Regarding firm growth, our results provide a new view to economic literature. As shown in Column III of Table 6, the R&D coefficient for firms with a high rate of growth ($\beta_1+\alpha_1$=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 (β_1=12.961). Our third hypothesis is totally confirmed by this

[***] Note that the linear restriction test whose null hypothesis is $H_0:\beta_1+\alpha_1=0$ provides a result rejecting this null hypothesis, see the t value in Table 6.

result, and we provide new evidence going further on the relation between R&D spending and firm growth. Specifically, we show that a firm's growth positively affects the market valuation of its R&D spending. This higher valuation arises thanks to the greater advantage that firms with a higher rate of growth take from the supra-normal profits yielded by R&D projects.

Regarding the effect of free cash flow on the relationship between firm value and R&D spending, our results also provide interesting empirical evidence. As can be seen in column IV of Table 6, the R&D coefficient for HFCF firms ($\beta_1+\alpha_1$=22.4653-15.8905=6.5748)[†††] is lower than the coefficient for LFCF firms (β_1=22.4653). This result is consistent with our Hypothesis 4, and it can be interpreted as evidence supporting the free cash flow theory in that HFCF firms could use their free cash flow to undertake negative NPV R&D projects, which would be obviously rejected in the case of LFCF firms.

The results on how market share moderates the relationship between firm value and R&D spending are shown in Column I of Table 7. These results are in agreement with our Hypothesis 5, since they reveal that the R&D coefficient is higher for firms with high market share ($\beta_1+\alpha_1$=12.7357+10.2647=23.0004, see t value for its significance), than for firms with low market share (β_1=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 in that R&D spending yields some supra-normal profits for each euro sold; hence the overall benefits will be greater as the market share rises.

Since Rajan and Zingales (1998), the external finance dependence has played an important role in the recent development of economic theory. We also provide interesting results on how the external finance dependence affects the market valuation of R&D spending. Column II of Table 7 shows that the R&D coefficient is lower for firms with higher external finance dependence ($\beta_1+\alpha_1$=22.4936–12.9414=9.5522, which is statistically significant, see t value) than for those with lower external finance dependence (β_1=22.4936). This result supports our Hypothesis 6, and confirms that firms with higher dependence on external finance face an important handicap in order to undertake R&D projects. In fact, the higher information asymmetry associated with this kind of projects substantially increases the cost of external financing. As a result, part of the supra-normal profits yielded by the R&D projects are spent on paying the premium of external financing faced by firms highly dependent on external finance and, consequently, the market reaction to R&D spending is lower than for the remaining firms.

[†††] The t value resulting from the linear restriction test (see Table 6) tells us that this coefficient is significantly different from zero.

We now move on to the analysis of the effect of labour intensity on the relationship between firm value and R&D spending. As shown in Column III of the Table 7, the R&D coefficient is lower for labour intensive firms ($\beta_1+\alpha_1$=19.2024–7.9051=11.2973, which is statistically significant, see t value) than for the remaining firms (β_1=19.2024). Consequently, in agreement with Hypothesis 7, the market valuation of R&D spending is lower for labour intensive firms, since the supra-normal profits from R&D projects are diluted between employees.

Finally, we also provide results on how capital intensity affects the market valuation of R&D spending. Specifically, column IV of Table 7 reveals that the R&D coefficient is lower for capital intensive firms ($\beta_1+\alpha_1$=23.2176 – 11.4951=11.7225, statistically significant, see t value) than for the remaining firms (β_1=23.2176). This evidence supports our last hypothesis, and shows that capital intensive firms face greater financial constrains and, as a result, the market valuation of their R&D projects is lower.

4.2. Results from the extended model

Green et al. (1996) derive a valuation model for R&D also based on the residual income. Apart from other differences in the derivation process, they include some control variables. Therefore, we extend on our basic model by means of 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[‡‡‡]. Consequently, our extended model would be 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, also accounting for the interactions described in Section 2, are presented in Tables 8 and 9. The main characteristic of these results is that they are in total agreement with those for the basic model discussed in the previous section. specifically, the coefficients for residual income and R&D variables show always the expected positive sign. In addition, the role played by firm characteristics in moderating the relationship between firm value and R&D spending is exactly the same than that found in the basic model. Overall, this evidence provides an excellent robustness check of our results.

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

Furthermore, the two control variables also throw light on the role played by some firm characteristics[§§§]. 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 the coefficient of the market share variable is not significant. Consequently, this result strongly supports our approach in explaining the role of certain firm characteristics in that some of them (such as market share), despite non-significant in explaining value, play an important role in moderating the relationship between firm value and R&D spending.

5. 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. By using this model we interact several firm characteristics with R&D in order to investigate the role played by these characteristics in the market valuation of R&D spending.

Our results reveal a positive relationship between firm value and R&D spending. Furthermore, this relation is moderated by several firm characteristics. Particularly, 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 affects positively the relationship between firm value and R&D spending because firms with a high rate of growth make the most of their supra-normal profits arising from the R&D projects. On the contrary, free cash flow has a negative effect on the abovementioned relation in that firms with high free cash flow could be tempted to use the free cash flow to undertake negative net present value R&D projects. Regarding market share, we find a positive effect on the relationship between firm value and R&D spending, rather than on firm value, which means that the supra-normal profits are highly dependent on the amount of R&D spending. The dependence of external finance 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 projects. Labour intensity also has a negative effect on the market valuation of R&D spending, since the supra-normal profits from R&D projects are diluted between employees. There is also a negative effect of capital intensity on the relationship between firm value and R&D spending because of the greater financial constrains faced by capital intensive firms.

[§§§] The Wald test of the joint significance of the control variables provides positive results (see z_4 in Tables 8 and 9).

Finally, this study provides interesting ideas in order to make decisions at the firm level and get a more effective R&D spending, in that the 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. Doing so, both types of decision makers would substantially increase the effectiveness of the R&D spending, which would benefit the whole society.

Appendix

In this Appendix we present the definition and calculation of the variables used in our analysis, when necessary. Except for the items we point out that come from the *Main Economic Indicators* published by the Organization for Economic Cooperation and Development (OECD), the remaining items used in the construction of the have been extracted from Worldscope.

Firm value

This variable is a derivation of our valuation model. As a result, our dependent variable is computed as follows:

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

where V_{it} is the market value of common stock 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. On the other hand $\delta_{it}=D_{it}/BF_{it}$ 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*.

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 by using the Capital Asset Pricing Model (CAPM):

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

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}) was computed by using the market price of all the companies listed in each country regardless of whether or not they provide research and development information. The sample used for computing the market return comprises 3,147 companies and 21,072 observations[****]. The company's beta (β_i) was also computed by using the market price and the same sample abovementioned to compute the market return item.

Research and development

This variable (RD_{it}) was 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.

Market share

This variable is computed as follows:

$$MS_{it} = \frac{NS_{it}}{\sum_{i=1}^{n} NS_{it}}$$

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. To compute the net sales of the industry, we have used the sample comprising 3,147 companies and 21,072 observations.

Long term debt

[****] The distribution of this sample across countries and industries will be provided by authors upon request.

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

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

where $BVLTD_{it}$ is the book value of the long term debt, i_l is the rate of interest of the long term debt reported in the *Main Economic Indicators* and l_{it} is the average cost of long term debt that is defined as $l_{it}=(IPLTD_{it}/BVLTD_{it})$, where $IPLTD_{it}$ is the interest payable on the long term debt, which has been 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 is the rate of interest of the short term debt, also reported in the *Main Economic Indicators*, and $BVSTD_{it}$ is the book value of the short term debt.

Size dummy

This dummy variable, DS_{it}, is equal to 1 if the firm size is larger than the sample mean, and 0 otherwise. The firm size is calculated as the natural logarithm of the replacement value of total assets.

Growth dummy

This dummy variable, DGR_{it}, takes value 1 for firms whose rate of growth is lager than the sample mean, and 0 otherwise. The rate of growth for each firm is calculated as follows:

$$GR_{it} = \frac{NS_{it} - NS_{i,t-1}}{NS_{i,t-1}}$$

where NS_{it} denotes the net sales.

Free cash flow dummy

This dummy variable, $DFCF_{it}$ takes value 1 for firms whose free cash flow level is higher than the sample mean, and 0 otherwise. The free cash flow index is calculated following Miguel and Pindado (2001):

$$FCF_{it} = CF_{it}\left(\frac{1}{Q_{it}}\right)$$

We compute a firm's cash flow as $CF_{it} = NIAPD_{it} - DEP_{it}$, where $NIAPD_{it}$ denotes net income after preferred dividends, and DEP_{it} stands for the book depreciation expense.

Tobin's q is calculated as follows:

$$Q_{it} = \frac{V_{it} + PS_{it} + MVLTD_{it} + BVSTD_{it}}{K_{it}}$$

where PS_{it} is the value of the firm's outstanding preferred stock.

Market share dummy

This dummy variable, DMS_{it}, takes value 1 for firms whose market share level is lager than the sample mean, and 0 otherwise.

External finance dependence dummy

This dummy variable, $DEFD_{it}$, takes value 1 for firms whose external finance dependence level is lager than the sample mean, and 0 otherwise. The external finance dependence is calculated as follows:

$$EFD_{it} = \frac{I_{it} - CF_{it}}{K_{it}}$$

where I_{it} denotes investment, calculated according to the proposal by Lewellen and Badrinath (1997):

$$I_{it}=NF_{it}-NF_{it-1}+BD_{it}$$

where[††††] NF_{it} denotes net fixed assets and BD_{it} is the book depreciation expense.

Labour intensity dummy

This dummy variable, DLI_{it}, takes value 1 for firms whose labour intensity level is higher than the sample mean, and 0 otherwise. The labour intensity is calculated as follows.

$$LI_{it} = \frac{NE_{it}}{NS_{it}}$$

where NE_{it} denotes the number of employees.

Capital intensity dummy

[††††] The details on the derivation process of this formula will be provided by authors upon request.

This dummy variable, $DC_{it,}$ takes value 1 for firms whose capital intensity level is larger than the sample mean, and 0 otherwise. The capital intensity is calculated as follows:

$$CI_{it} = \frac{RF_{it}}{NS_{it}}$$

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Table 1

Structure of the samples by country

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

Data of companies for which the information is available for at least six consecutive years between 1986 and 2003 were extracted. After removing the first year data only used to construct several variables (see Appendix), 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.

Table 2

Structure of the panel

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

Data of companies for which the information is available for at least six consecutive years between 1986 and 2003 were extracted. After removing the first year data only used to construct several variables (see Appendix), the resultant unbalanced panel comprises 271 companies (2,387 observations).

Table 3

Sample distribution by economic sector classification

Economic sector	Number of companies	Percentage of companies	Number of observations	Percentage of observations
Basic Materials	43	15.88	394	16.51
Consumer – Cyclical	39	14.39	327	13.70
Consumer – Non Cyclical	48	17.71	402	16.84
Health Care	33	12.18	330	13.82
Energy	7	2.58	80	3.35
Capital Goods	64	23.62	519	21.74
Technology	25	9.22	251	10.52
Utilities	12	4.42	84	3.52
Total	271	100.00	2,387	100.00

All companies in our panels have been allocated to one of nine broad economic industry groups in accordance with the Economic Sector Code, excluding Financial Services.

Table 4

Summary statistics

Variable	Mean	Standard deviation	Minimum	Maximum
$(MV\text{-}BV)/K)_{it}$	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

$(MV\text{-}BV)/K)_{it}$ 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 Appendix for details on the definitions of these variables.

Table 5

Dummy 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

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 labour intensity dummy and DCI_{it} is a capital intensity dummy. See Appendix for details on the definitions of these variables.

Table 6

Results of the basic model (I)

	I	II	III	IV
$(RI/K)_{it}$	11.0025* (0.2886)	11.6254* (0.2171)	9.6344* (0.2591)	12.4897* (0.9209)
$(R\&D/K)_{it}$	14.8585* (0.4367)	7.3350* (0.3152)	12.1961* (0.2089)	22.4653* (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)

Notes: The regressions are performed by using the panel described in Tables 1 to 3. The rest of the information needed to read this table is: i) Heteroskedasticity consistent asymptotic standard error in parentheses; ii) * indicates significance at the 1% level; iii) t is the t-statistic for the linear restriction test under the null hypothesis H_0:$\beta_2+\alpha_1=0$; iv) 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, degrees of freedom in parentheses; v) 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; degrees of freedom in parentheses; vi) 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; degrees of freedom in parentheses; vii) 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; viii) Hansen is a test of the over-identifying restrictions, asymptotically distributed as χ^2 under the null, degrees of freedom in parentheses.

Table 7

Results of the basic model (II)

	I	II	III	IV
$(RI/K)_{it}$	10.2722* (0.1869)	8.12318* (0.2068)	10.1172* (0.1486)	9.7657* (0.1680)
$(R\&D/K)_{it}$	12.7357* (0.3052)	22.4936* (0.2475)	19.2024* (0.1388)	23.2176* (0.1776)
$DMS_{it}(R\&D/K)_{it}$	10.2647* (0.4091)			
$DEFD_{it}(R\&D/K)_{it}$		-12.94138* (0.3291)		
$DLI_{it}(R\&D/K)_{it}$			-11.4951* (0.1048)	
$DCI_{it}(R\&D/K)_{it}$				-7.9051* (0.1067)
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)

Notes: The regressions are performed by using the panel described in Tables 1 to 3. The rest of the information needed to read this table is: i) Heteroskedasticity consistent asymptotic standard error in parentheses; ii) * indicates significance at the 1% level; iii) *t* is the t-statistic for the linear restriction test under the null hypothesis H_0:$\beta_2+\alpha_1=0$; iv) 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, degrees of freedom in parentheses; v) 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; degrees of freedom in parentheses; vi) 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; degrees of freedom in parentheses; vii) 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; viii) Hansen is a test of the over-identifying restrictions, asymptotically distributed as χ^2 under the null, degrees of freedom in parentheses.

Table 8

Results of the extended model (I)

	I	II	III	IV
$(RI/K)_{it}$	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)

Notes: The regressions are performed by using the panel described in Tables 1 to 3. The rest of the information needed to read this table is: i) Heteroskedasticity consistent asymptotic standard error in parentheses; ii) * indicates significance at the 1% level; iii) *t* is the t-statistic for the linear restriction test under the null hypothesis $H_0:\beta_2+\alpha_1=0$; iv) 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, degrees of freedom in parentheses; v) 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; degrees of freedom in parentheses; vi) 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; degrees of freedom in parentheses; vii) z_4 is a Wald test of the joint significance of the control variables, asymptotically distributed as χ^2 under the null of no relationship; degrees of freedom in parentheses; viii) 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; ix) Hansen is a test of the over-identifying restrictions, asymptotically distributed as χ^2 under the null, degrees of freedom in parentheses.

Table 9

Results of the extended model (II)

	I	II	III	IV
$(RI/K)_{it}$	9.5559^{*} (0.6504)	7.5429^{*} (0.2939)	8.9114^{*} (0.2616)	9.0097^{*} (4.2329)
$(R\&D/K)_{it}$	12.7598^{*} (0.1346)	21.9724^{*} (0.2346)	20.3908^{*} (0.2415)	22.3864^{*} (0.2726)
MS_{it}	0.2939 (0.6406)	0.7860 (4.0164)	-7.3866 (4.0267)	-3.7571 (4.2329)
$(LTD_{it}/K)_{it}$	2.1563^{*} (0.9785)	4.2457^{*} (0.4693)	4.3628^{*} (0.3570)	2.3187^{*} (0.3287)
$DMS_{it}(R\&D/K)_{it}$	9.4015^{*} (0.1333)			
$DEFD_{it}(R\&D/K)_{it}$		-10.5011^{*} (0.3846)		
$DLI_{it}(R\&D/K)_{it}$			-10.7438^{*} (0.1397)	
$DCI_{it}(R\&D/K)_{it}$				-10.1333^{*} (0.1826)
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)

Notes: The regressions are performed by using the panel described in Tables 1 to 3. The rest of the information needed to read this table is: i) Heteroskedasticity consistent asymptotic standard error in parentheses; ii) * indicates significance at the 1% level; iii) t is the t-statistic for the linear restriction test under the null hypothesis $H_0: \beta_2+\alpha_1=0$; iv) 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, degrees of freedom in parentheses; v) 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; degrees of freedom in parentheses; vi) 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; degrees of freedom in parentheses; vii) z_4 is a Wald test of the joint significance of the control variables, asymptotically distributed as χ^2 under the null of no relationship; degrees of freedom in parentheses; viii) 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; ix) Hansen is a test of the over-identifying restrictions, asymptotically distributed as χ^2 under the null, degrees of freedom in parentheses.