+ model

ARTICLE IN PRESS

Available online at www.sciencedirect.com

SCIENCE DIRECT®

ELSEVIER

International Journal of Industrial Organization
xx (2005) xxx–xxx

International Journal of Industrial Organization

www.elsevier.com/locate/econbase

Does the market value R&D investment by European firms? Evidence from a panel of manufacturing firms in France, Germany, and Italy ☆

Bronwyn H. Hall [a], Raffaele Oriani [b,*]

[a] University of California at Berkeley, NBER, and IFS London, UC Berkeley, Department of Economics 549 Evans Hall # 3880, Berkeley, CA 94720-3880, USA

[b] University of Bologna, Department of Management, Via Saragozza 8, 40126 Bologna, Italy

Received 3 May 2005; received in revised form 29 November 2005; accepted 1 December 2005

Abstract

Several studies based on US and UK data have used market value as an indicator of the firm's expected R&D performance. However, there have been no investigations for the continental countries in the European Union, in part because the analysis is complicated by data availability problems. In this paper we take a first step towards filling this gap using a newly constructed panel dataset of firms which are publicly traded in France, Germany, and Italy. Controlling for either permanent unobserved firm effects or sample selection due to the voluntary nature of R&D disclosure, we find that the relative shadow value of R&D in France and Germany is remarkably similar both to each other and to that in the US or the UK during the same period. In contrast, we find that R&D in publicly traded Italian firms is not valued by financial markets on average. However, when we control for the presence of a single large shareholder, we find that both French and Italian firms have high R&D valuations when no single

☆ We are grateful to the participants in the DRUID conference, Elsinore, June 2003, the EEA-ESEM conference, Stockholm, August 2003, the AiIG Conference, Bergamo, October 2003, and seminar participants at University of Bologna, European University Institute, Carnegie-Mellon University, and Economicum, Helsinki for comments. Thanks also to Jim Powell for advice on the sample selection model, Federico Munari for suggestions on the ownership data, Lucia Piscitello and Maurizio Sobrero for helpful comments on previous versions of this paper. Raffaele Oriani acknowledges the support by Andrea Generale and other colleagues at the Research Department of the Bank of Italy for the support received in creating the Italian sample.

* Corresponding author. Tel.: +39 051 2093956; fax: +39 051 2093949.

E-mail addresses: bhhall@econ.berkeley.edu (B.H. Hall), raffaele.oriani@unibo.it (R. Oriani).

doi:10.1016/j.ijindorg.2005.12.001

shareholder holds more than one third of the firm, but that R&D is essentially not valued at all in the remaining firms.

JEL classification: O30; G32; G12

Keywords: R&D; Market value; European companies; Control

1. Introduction

The question of how R&D investment affects the performance of the firm is of considerable interest to economists and other researchers. A number of empirical studies, beginning with the seminal contribution of Griliches (1981) and based on US firm-level data from the Compustat database, have used market value as an indicator of the firm's expected economic results from investing in R&D (among others, Hirschey, 1982; Jaffe, 1986; Cockburn and Griliches, 1988; Hall, 1993a,b).[1] These analyses generally show a positive relationship between R&D investments and the market value of the firm, even though the R&D coefficient is volatile between and even within studies.[2] Recent analyses in the same spirit conducted for the UK (Blundell et al., 1999; Toivanen et al., 2002) have also found a positive relationship between R&D investments and the market value of the firm. However, to our knowledge there have been no investigations into this subject for other countries in the European Union, including G8 economies such as France, Germany, and Italy. Lack of such studies is unfortunate because these countries are different in several important ways from Anglo-Saxon countries. First, a lower presence of professional investors and a relatively looser discipline exerted by public stock markets may lead firms in the continental European countries to have a higher propensity for long-term investments, due to the lack of pressure for quarterly results imposed by financial capital markets. Previous work has shown, for example, how financial constraints on firms' R&D and capital investments are looser in continental European countries than in the UK and the US (Hall et al., 1999; Mulkay et al., 2000; Bond et al., 2003a). These differences could have important implications for the market valuation of R&D investments, implying that we might obtain different results for French, German and Italian firms when compared to those available for UK and US firms.

Second, in France, Germany and Italy, which are characterized by a civil law system, the rights of minority shareholders and creditors are less protected than in the UK and the US, having a common law system (La Porta et al., 1998, 2000). In the former countries, therefore, external investors are more exposed to the risk of expropriation by controlling shareholders and ownership structures tend to be more concentrated than in the US and the UK (La Porta et al., 1999). The differences in legal regimes and ownership structures are particularly important for the market valuation of R&D investments, since, as demonstrated by Aboody and Lev (2000), these investments create higher information asymmetries that can favor expropriation by insiders more than other corporate investments. Accordingly, the presence of a controlling shareholder, jointly with a poor protection of minority shareholders, could negatively impact on the market value of R&D investments in continental European countries.

[1] The NBER R&D database based on Compustat is described in detail in Hall (1990).

[2] See Hall (2000) for a review and Oriani and Sobrero (2003) for a meta-analysis of the main results of these studies.

Third, the countries analyzed here have adopted significantly different mixes of government incentives for business R&D expenditures (see Hall and Van Reenen, 2000). Because public incentives can lower the hurdle rate for R&D investments (see Hall, 1996), we could expect some further differences in the expected rates of return on R&D among countries. This issue could be particularly relevant for Italy, where the empirical analysis of Parisi and Sembenelli (2001) shows a very high own R&D elasticity with respect to public expenditure.

Analysis using data on French, German, and Italian firms is however complicated by several specific problems that are closely related to the differences in capital market structure themselves. First, in these countries public disclosure of annual R&D expenditures is not required by the national accounting laws and regulations.[3] Therefore, not all the companies report the amount of R&D expenditures in their financial statements, creating problems in sample selection. Second, stock markets in European countries are smaller compared to those of the US and the UK and many firms are not publicly traded. This problem is particularly severe for Italy, whose industrial system is mainly based on Small and Medium-sized Enterprises (SMEs) that have credit relationships with financial intermediaries and where only very large companies are publicly traded at the Milan stock exchange (see Pagano et al., 1998). Third, many of the firms in these continental economies are part of a larger entity via interlocking ownership, so that the reported market value is established via trading in a minority subset of the shares of the company. These difficulties lead to smaller samples and limited data availability.

Nevertheless, in this paper we aim to explore some of the questions about the relationship between R&D and market value using the data that is available. For this purpose, we have created an original database including firm-level accounting and financial data for a panel of manufacturing firms that were publicly traded in France, Germany and Italy in the period from 1989 to 1998. This database was obtained by combining different national and international sources of information. Moreover, in order to analyze the differences between these three countries and the Anglo-Saxon countries, we also gathered data for comparable samples of manufacturing firms traded in the United Kingdom and the United States. Using these data we estimated the market value–R&D relationship using a variety of econometric methods, both ordinary least squares as well as methods that correct for the sample selection bias arising from the lack of R&D data for some of the firms. We also explored the use of models incorporating firm-specific effects, both fixed (correlated) and random (uncorrelated).

We report a number of interesting findings: first, there is no selection bias in the valuation equation induced by the fact that some firms choose not to report R&D for any of the countries. Second, although there seem to be "permanent" unobserved differences across firms that are correlated with R&D in the UK and US data, there are no such fixed effects in the data for our three countries of interest, and therefore no bias from this source in the cross section results. Finally and more substantively, we find that looking across all firms, R&D is valued similarly in France, Germany, and the US during this period, it is valued roughly twice as high in the UK, and not valued at all in Italy. But when we separate the firms into those with a major shareholder and those without, we obtain the interesting and suggestive result that R&D is valued highly, closer to the UK level, in French and Italian firms with no major shareholder. However, in firms with a major shareholder, consistent with the expectation of a lower R&D valuation for the countries with a lower legal protection, the market places zero value on the R&D.

[3] In many of these countries, such data is collected by government agencies or central banks, but it is kept confidential by the institutions and is not easily accessed, if available at all.

In the next section of the paper, we discuss theories of how the differences among continental European countries and Anglo-Saxon countries can affect the market valuation of firms' R&D investments, whereas the following section presents the valuation model we use, which is the familiar hedonic model pioneered by Griliches (1981), and its adaptation to our setting. Then we describe our new dataset and variables and present some descriptive statistics. The next section first presents our basic regression results, and then the various econometric investigations we undertook in order to verify the robustness of our results. We conclude with some discussion of our findings and suggestions for future research.

2. The market value of R&D in European countries

Whereas we have large evidence on the stock market valuation of R&D in the US and the UK, we are still lacking analyses for other important European countries, such as France, Germany and Italy. This is a severe shortcoming not only because of the economic importance of these countries, but also because their economies differ in some institutional structures such as capital markets, ownership patterns and law systems. With respect to capital markets, it is generally recognized that publicly traded firms in continental European countries receive weaker pressure on investment decisions (see for example Franks and Mayer, 1990; Black and Fraser, 2000). This could be for the good, in the case of profitable long-term investments that might not be undertaken by firms with short horizons, or the bad, if it implies that rate of return tests might not be imposed on these investments, or that projects might be continued too long when they have been demonstrated to be unsuccessful. Under the admittedly strong assumption of efficient capital markets, these differences should also imply market valuations of capital and R&D investments that may be either higher or lower on average than those in the US. Recent empirical literature seems to confirm that the UK stock market has a more short-term orientation than countries with different corporate governance regimes, such as Germany and Japan (Black and Fraser, 2000). Empirical evidence on the sensitivity of investments to cash flow or profitability shocks is consistent with this view. Bond et al. (2003a), estimating a set of investment equations, show that cash flows or profits have a higher and more significant effect on investments in the United Kingdom than in other European countries, such as Belgium, France and Germany. In the same spirit, Mulkay et al. (2000) find that cash flows or profits have a much larger impact on both R&D and investments in the US than in France.

Another issue relevant to the market value of R&D in the countries we analyze concerns ownership structures and law systems. Previous research has shown that in continental European countries several traded firms have a main shareholder (a family, another firm or the State) holding directly or indirectly more than 50% of the voting rights (see for example La Porta et al., 1999; Faccio and Lang, 2002). In these cases, agency problems are likely to arise between the controlling and the minority shareholders because the former are relatively protected from takeover threats and monitoring activities and have the opportunity to divert firms' profits from outside investors to their own benefit (Gomes, 2000; La Porta et al., 2000). This problem can be exacerbated by a weaker legal protection of minority shareholders. In a series of studies adopting a legal approach to financial markets, La Porta and colleagues (La Porta et al., 1998, 1999, 2000, 2002) have reported that civil law systems, such as those of France, Germany and Italy, grant on average less rights to minority shareholders than common law systems of Anglo-Saxon countries. In particular, in these countries minority shareholders are penalized in terms of voting rights against interferences by insiders and legal mechanisms against oppression by directors (La Porta et al., 1998). The French-origin legal regimes, including France and Italy, offer in this respect the weakest protection. The diffused presence of traded firms controlled by large shareholders, joint with a legal system offering a weak protection to external investors, can ultimately generate in these countries underpricing phenomena (La Porta et al., 2002). Our argument is that this underpricing should be related to R&D investments more strongly than to other corporate investments. In fact, R&D investments generate higher information asymmetries because of their uniqueness, non-tradability and limited disclosure (Hall, 2002). Empirically, Aboody and Lev (2000) have demonstrated that higher R&D intensity is associated with greater insider gains at the firm level. We can expect, therefore, that in the countries with a poorer investor protection, such as Germany and above all France and Italy, the R&D investments of firms with a controlling shareholder are undervalued by the stock market because, ceteris paribus, they expose minority investors, which have limited anti-director rights, to a greater risk of expropriation by insiders.

Finally, differences in the market valuation of R&D among countries could also result from different public incentive schemes, both subsidies and tax credits, adopted by the national governments. The problem is that State-funded R&D projects carry a lower risk for the firm than privately financed ones. Therefore, firms could be willing to accept the former projects even though their expected rate of return is lower than the threshold normally fixed for the latter. Previous empirical literature, although limited, has shown that the R&D performed through government funding yields lower returns than company-financed R&D (see Hall, 1996, for a review). This means that the overall market valuation of R&D in a firm may be lower when a greater share of its R&D investment is financed through public funds. Indeed, the countries investigated here have a varying mix of public incentives to industrial R&D (see Hall and Van Reenen, 2000; Parisi and Sembenelli, 2001). Moreover, the elasticity of R&D with respect to public incentives significantly changes across countries (see David et al., 2000 for a review), being particularly high in Italy (Parisi and Sembenelli, 2001).

3. R&D investments and market value: remarks on the estimation model

Several authors have tested the relationship of different types of innovation investment with firm-level performance measures based on the stock market. The studies analyzing in particular the relationship between knowledge stock and market value implicitly or explicitly assume that the stock market values the firm as a bundle of tangible and intangible assets (Griliches, 1981; Hall, 2000). The treatment here mainly follows Hall's (2000) survey. In equilibrium, the market valuation of any asset results from the interaction between firms' demand for investment and the market supply of capital for that specific asset (Hall, 1993b). Using this idea, it is possible to represent the market value V of firm i at time t as a function of its assets:

$$V_{it} = V(A_{it}, K_{it}, I_{it}) \tag{1}$$

where A_{it} is the book value of tangible assets, K_{it} is the replacement value of the firm's technological knowledge and I_{it} is the replacement value of the other intangible assets. If single assets are purely additive, it is possible to express the market value of the firm as a multiple of a weighted sum of its assets:

$$V_{it} = q_t(A_{it} + \gamma K_{it} + \lambda I_{it})^{\sigma} \tag{2}$$

where q_t is the average market valuation coefficient of a firm's total assets (reflecting the differential risk and monopoly position of the firms in the sample). When $\sigma = 1$, γ can be interpreted as the relative shadow value of knowledge capital to tangible assets and λ as the shadow value of the other intangible assets to tangible assets. The product $q_t\gamma$ is the absolute shadow value of the knowledge capital and reflects the investor expectations on the overall effect of K_{it} on the discounted value and present and future earnings of the corporation, while γ expresses the differential valuation of the knowledge capital relative to tangible assets. In principle both γ and λ should be allowed to vary over time, but due to the small sample sizes and relatively short time periods we consider here, we did not attempt this (see Hall, 2000, and Toivanen et al., 2002, for estimates of this kind using US and UK data, respectively).

The expression (2) can be interpreted as a version of the model that is known in literature as a hedonic pricing model, where the good being priced is the firm and the characteristics of the good are its assets, both tangible and intangible. As in the case of all hedonic models, the shadow prices are equilibrium outcomes in the market at a point in time, not structural parameters, so there is no reason to expect constancy over time or country unless adjustment costs are zero and international capital markets are perfect (Hall, 2000). Instead, these coefficients should be interpreted as a measure of the current average marginal shadow value of an additional currency unit spent on R&D.

Taking the natural logs of both the sides in Eq. (2), assuming constant returns to scale ($\sigma=1$), and subtracting log A_{it} from both sides, we obtain the following expression[4]:

$$\log(V_{it}/A_{it}) = \log q_t + \log(1 + \gamma K_{it}/A_{it} + \lambda I_{it}/A_{it}). \tag{3}$$

The ratio V/A is a proxy for average Tobin's q, the ratio of the market value of tangible assets to their physical value. The estimation of Eq. (3) allows one to assess the average impact of a euro or dollar invested in knowledge on the market value of a firm at a particular point in time. Hall and Kim (2000), Bloom and Van Reenen (2002), Hall et al. (2005) estimate Eq. (3) using non-linear least squares (NLLS). Other authors applying the same model have used the approximation log $(1+x) \approx x$, obtaining the equation below, which can be estimated by ordinary least squares (Griliches, 1981; Jaffe, 1986; Cockburn and Griliches, 1988; Hall, 1993a,b):

$$\log(V_{it}/A_{it}) = \log q_t + \gamma K_{it}/A_{it} + \lambda I_{it}/A_{it}. \tag{4}$$

In order to investigate the appropriateness of Eq. (3) or (4) for our model, we explored the use of semi-parametric estimation for the simple Tobin's q–R&D capital relationship by means of Kernel regression using data for the United States. The results of this exploration show that the relationship resembles a logistic curve, with zero and very small amounts of R&D capital (less than about 1% of tangible assets) having no effect on Tobin's q, a roughly linear relationship until $K/A=1$, and a flatter relationship thereafter. Above K/A value of 1%, the relationship is somewhat better described by Eq. (3) than Eq. (4), although we have explored the use of both specifications in this paper.[5]

The estimation of Eqs. (3) and (4) also raises two econometric problems, one due to our failure to observe R&D for many firms and one due to the possibility of left-out variables

[4] The assumption of constant returns to scale (homogeneity of degree one) in the value function has been confirmed repeatedly in the literature, at least for cross sections of firms.

[5] The lack of effect for small values of K/A implies that these levels are not "material" in the accounting sense, and we included them in the nonresponse category, which includes firms that do not perform R&D. There were only a few such observations in our panel. Full results of the Kernel regressions are available from the authors.

that are correlated with R&D. We first address the problem of *sample selection bias*, which, as discussed above, could be particularly severe for the countries we are analyzing because of the limited R&D and market data availability.[6] We investigate the potential for problems arising from this source in two ways: by checking the representativeness of our sample with respect to the whole manufacturing firms' population and then by estimating a probability model for the reporting of R&D and using the results to control for the bias. In particular, we adopt the censored regression model with a stochastic threshold described by Maddala (1983: Ch. 6) where our basic linear regression equation is jointly estimated with a Probit equation whose dependent variable is a dummy equal to one when R&D investment is reported.[7]

The second potential problem with our model is that the R&D–market value relationship may include *firm- and time-specific effects* that are correlated with the R&D stocks. Previous empirical analyses on R&D and market value have accounted for time effects by adding a full set of year dummies (Griliches, 1981; Hall, 1993a; Blundell et al., 1999) and we follow this practice, which amounts to measuring the log market value–assets ratio relative to the market as a whole. It is possible to control for unobserved firm-specific components using the fixed effects (within) or first-differenced estimators (see Toivanen et al., 2002, for an application to the questions under discussion). However, given the well-known problems of potential misspecification concerning these estimators (see Griliches and Hausman, 1986), also related to the fact that R&D is merely predetermined rather than endogenous[8], we estimate a random effects model along with the fixed effects model as has also been done in previous work (Munari and Oriani, 2005). In order to check the consistency of the random effects estimator, we use the Hausman (1978) specification test. In general, we find insignificant differences when heteroskedastic–consistent standard errors are used, largely because the first-differenced estimators are very imprecise. Therefore we cannot reject the random effects model in favor of the fixed effects model, at least for the continental economies, although this result might change if data on a greater number of firms become available.[9]

[6] Note that because R&D is an independent variable in our equation rather than a dependent variable, if the process generating observed R&D is not related to the disturbance in the market value equation, no bias in this equation will be introduced by selection, even if it generates a nonrandom sample of observed R&D; we will merely have fewer observations on R&D and those available may possibly span a smaller area in the space of independent variables, implying less precise estimates of the coefficients and a different approximation to any nonlinearity in the model. True selection bias will occur only when the disturbance in the "presence of R&D" equation is correlated with the disturbance in the valuation equation.

[7] Work in progress explores the semi-parametric treatment of this same model using US data, along the lines suggested by Das et al. (2003), incorporating also the potential endogeneity of the right hand side variables.

[8] The misspecification takes different forms depending on whether the within or differenced estimator is used. In the former case, it occurs because the means over time are subtracted from right and left hand side variables, and is attenuated as the number of time periods involved grows. In our case, the number of periods can be quite small, implying bias, and the procedure introduces substantial serial correlation in the errors within firm, so that the standard error estimates are also biased. In the case of first differenced estimation, the serial correlation is less of a concern (see the Durbin–Watson statistics in Table 6), but the coefficient estimates can still be biased if the lagged disturbance in the market value equation is correlated with the current R&D investment choice. Such bias is not reduced by increasing the number of observations per firm.

[9] The fact that first differenced estimators are so imprecise is probably due to the combination of the small sample size with the fact that R&D investment itself does not change quickly over time. The within firm variance of K/A in our sample is 10%, 19%, 5%, 4%, 8% of the total variance for France, Germany, Italy, the UK, and the US, respectively.

4. Data

4.1. Sample

Our sample consists of manufacturing companies publicly traded in France, Germany, Italy, the United Kingdom and the United States. For all the countries, the period of observations goes from 1989 to 1998. Firms have been classified into 22 different industries at the quasi-2-digit level using 1992 SIC codes, mainly according to the previous classification of Hall and Vopel (1996). For the European countries, we added the public utility industry (2-digit SIC = 49) because of its importance in R&D activities in these countries. All the accounting data of Italian firms have been gathered from *Centrale dei Bilanci*, a broad database including financial statements of about 40,000 Italian companies, which is available at the Research Department of Bank of Italy. The source for accounting figures in France, Germany and the United Kingdom is Datastream International, which covers more than 75% of the public companies from European countries. Market capitalization for all the European firms has been retrieved from Datastream International. For the US firms we used accounting and market data drawn from the COMPUSTAT database, described by Hall (1990). All the accounting data are consolidated at the corporate level, so that they are consistent with the stock market values. To increase the comparability of the samples, we removed very small firms from the UK and the US database.[10]

Our final dataset consists of an unbalanced panel of 2156 publicly traded firms, 127 from France, 283 from Germany, 86 from Italy, 592 from the United Kingdom and 1366 from the United States. The lower number of Italian firms in the sample is mainly due to the very small size of the Italian stock market as compared to the stock market of the other European countries. In Italy, in fact, only the very largest firms are publicly traded on the stock market (Pagano et al., 1998), whereas most firms are small- and medium-sized and rely on bank credit in order to finance their activities (see for example Angelini et al., 1998). Finally, we have collected industry-level data (ISIC 3rd revision) on the total output from the STAN database and on the R&D expenditures from the ANBERD database. The two databases are compatible and are both released and maintained by OECD.

4.2. R&D expenditures: accounting regimes, data sources and selection problems

One of the main problems we had to deal with in building the dataset is the accounting treatment of the R&D investments. One potential issue is the capitalization of R&D expenditures. In this respect, R&D capitalization regimes are very similar for all the selected countries. Annual R&D costs are normally expensed when they occur. Only applied research and development expenditures can be capitalized, and these only if particular conditions are satisfied.[11]

[10] The active venture capital/IPO market in the United Kingdom and above all in the United States, coupled with the R&D reporting requirement, means that there are many more smaller firms that do R&D and list on the stock market in these countries than in the others.

[11] These conditions are consistent with the prescription of GAAP accounting standards that allow some costs related to R&D activities to be appropriately capitalized and carried forward as assets only if they have alternative future uses. Moreover, according to IAS 38 principle .“. . . it follows from the recognition criteria that all expenditure on research should be recognized as an expense” (http://www.iasb.org.uk). See KPMG (1995), Lev and Sougiannis (1996) and Alexander and Archer (1998) for further information.

Table 1
Accounting regimes for R&D expenditures: summary

Country	Basic research capitalization	Applied research and development costs capitalization	Disclosure of annual R&D expenditures
France	Forbidden	Allowed under certain conditions	Not compulsory
Germany	Forbidden	Forbidden (they can be treated as special manufacturing costs if related to a specific order)	Not compulsory
Italy	Forbidden	Allowed under certain conditions	Not compulsory
United Kingdom	Forbidden	Allowed only for certain development costs	Compulsory (since 1989)
United States	Forbidden	Allowed under certain conditions	Compulsory (since 1972)

Source: KPMG (1995), Hall and Van Reenen (2000), Alexander and Archer (1998).

R&D disclosure represents instead a severe problem because, unlike in the United Kingdom and the United States, it is not compulsory in any of the country in the continental Europe we analyze. In fact, the accounting regulation of the European Union does not explicitly require the disclosure of R&D expenditures.[12] This situation makes it very difficult to obtain data on firm-level R&D investments and potentially creates sample selection bias due to the firms' opportunistic behavior in disclosure decisions (Belcher, 1996). A synopsis of the R&D accounting regimes in the countries we analyze is reported in Table 1.

Because of the difficulty of obtaining information on the firms' R&D investments in the analyzed countries, data on R&D expenditures have been obtained integrating Datastream International with two more databases: Worldscope and Global Vantage. In addition, for Italian firms only, we had access to several other sources to gather the information on firm-level R&D investments: Centrale dei Bilanci; the survey of Mediocredito Centrale, the previously State-owned investment bank, on the investments of Italian manufacturing firms[13]; SIM, the annual survey on the investments of Italian manufacturing firms performed by the Central Bank of Italy; R&S, an annual publication by Mediobanca, a main Italian merchant bank that reports information on the major Italian companies; AIRI, the Italian Association for Industrial Research; and information available on the corporate web sites.[14]

In the end we were able to gather R&D data for only some of the firms in the sample. Moreover, for most firms data were available only for selected years. The distribution of the firms and the observations with R&D data availability by country and industry is reported in Table 2. We have 51 firms and 308 observations for France, 79 firms and 339 observations for

[12] The accounting regulation of the European Union (Fourth Directive) does not require the disclosure of R&D expenditures. The only obligation is a general description of research and development activities must be included in the annual report (Fourth Directive, art. 46, 1978). This description does not imply a requirement to indicate the annual amount of R&D costs (see KPMG, 1995).

[13] This survey has been performed in 1992 (for the years 1989–1991), 1995 (for the years 1992–1994) and 1998 (for the years 1995–1997). Each survey refers to a sample of about 4500 companies.

[14] Mairesse and colleagues have built a database on the R&D and capital investments of French firms (SUSE datafiles at INSEE) that has been used for econometric analyses on firm productivity and investment decisions (e.g. Mulkay et al., 2000). However, these data are not suitable for market value analysis because they are gathered at plant level and their aggregation at corporate level would not be reliable. In addition, for confidentiality reasons they are not available for matching to external data by the name of the firm.

Table 2
Firms and observations by country and industry (R&D-doing firms only)

Industry	France			Germany			Italy			United Kingdom			United States		
	Firms	Observations	Observations (%)	Firms	Observations	Observations (%)	Firms	Observations	Observations (%)	Firms	Observations	Observations (%)	Firms	Observations	Observations (%)
Food and tobacco	5	31	10.1	0	0	0.0	3	23	9.6	18	119	5.9	23	174	2.5
Textiles and apparel	1	8	2.6	2	4	1.2	1	3	1.3	10	72	3.6	13	105	1.5
Wood and furniture	0	0	0.0	0	0	0.0	0	0	0.0	5	34	1.7	20	165	2.4
Paper and publishing	0	0	0.0	0	0	0.0	0	3	1.3	13	66	3.3	28	220	3.1
Chemicals	1	10	3.2	5	29	8.6	4	19	7.9	18	145	7.2	61	490	7.0
Pharmaceutical	3	15	4.9	4	19	5.6	3	19	7.9	12	64	3.2	49	379	5.4
Personal care	3	6	1.9	1	1	0.3	0	0	0.0	5	27	1.3	14	125	1.8
Oil	3	25	8.1	3	15	4.5	2	9	3.8	5	32	1.6	21	176	2.5
Rubber and plastics	1	7	2.3	3	11	3.3	2	15	6.3	5	31	1.5	24	196	2.8
Building materials	2	11	3.6	5	14	4.2	2	7	2.9	12	84	4.2	14	121	1.7
Primary metals	0	0	0.0	1	2	0.6	3	13	5.4	10	77	3.8	39	313	4.5
Refined metals	3	10	3.2	5	10	3.0	0	0	0.0	20	116	5.8	42	333	4.8
Machinery	6	18	5.8	20	84	24.9	7	39	16.3	41	241	12.0	86	711	10.2
Computer	1	9	2.9	4	14	4.2	2	16	6.7	8	64	3.2	76	568	8.1
Electrical	4	29	9.4	3	15	4.5	3	16	6.7	25	160	8.0	48	386	5.5
Electronics	5	23	7.5	6	31	9.2	2	15	6.3	46	309	15.4	186	1494	21.4
Motor vehicles and parts	3	30	9.7	4	16	4.7	1	6	2.5	6	50	2.5	36	293	4.2
Other transport, aerospace	2	6	1.9	0	0	0.0	1	4	1.7	9	63	3.1	16	133	1.9
Medical and optical instr.	4	33	10.7	9	43	12.8	3	25	10.5	10	81	4.0	60	459	6.6
Other manufacturing	3	29	9.4	3	25	7.4	1	10	4.2	12	67	3.3	19	154	2.2
Utilities	1	8	2.6	1	4	1.2	0	0	0.0	14	108	5.4	0	0	0.0
Reporting R&D in all years	22	208	67.5	10	100	29.7	26	182	76.2	110	838	41.7	866	6980	99.8
Reporting R&D in some years	29	100	32.5	69	237	70.3	14	57	23.8	195	1172	58.3	4	15	0.2
Total for R&D-doers	51	462		79	741		40	306		305	2571		870	7006	
Total non-R&D-doers	76	683		204	1947		46	379		287	2152		496	3886	
Total	127	1145		283	2688		86	685		592	4723		1366	10,892	

Germany, 40 firms and 239 observations for Italy, 304 firms and 2005 observations for the United Kingdom and 866 firms and 6995 observations in the United States. For many of the firms we have R&D during only some of the years; this is especially notable in Germany and the UK. The distribution reflects the different industrial structures of the countries. Nearly a quarter of the observations in the German sample (24.9%) are concentrated in the machinery industry. A substantial share of the observations in the United States (21.4%) is in the electronics industry, whereas the United Kingdom shows a more even distribution among industries.

The problems related to the size of the stock markets and to the R&D data availability raise some concerns about the ability of our sample to effectively represent the population of manufacturing firms in the three countries. Therefore, we tried to assess the coverage of the samples with respect to an aspect critical to our analysis, that is R&D investments. To this purpose, we have computed, as shown in Table 3, the ratio of the total R&D investments of the firms in our sample to the total R&D investments of all the manufacturing firms and utilities in the country. In spite of their small numbers, the firms in the sample cover a fair amount of the R&D reported by the population of manufacturing firms. In particular, in 1998 the R&D investment of the firms in our sample represent 50.6% of total business R&D of manufacturing firms and utilities in France, 63.6% in Germany, and 71.2% in Italy. These values are very similar to the ratio obtained for the US sample (57.8%), even though they are lower than the ratio obtained for the United Kingdom (92.2%). The conclusion is that even though reporting R&D is not required in continental Europe, in fact a fairly large share of major R&D-doers actually reports it. A second conclusion is that in continental Europe, as in the United States and United Kingdom, most industrial R&D is performed in large publicly traded firms.

4.3. Variables

In Eqs. (3) and (4) our dependent variable is the natural log of the ratio between the firm's market value, V, and the total tangible assets, A. The total market value should be calculated as the sum of the market capitalization of the firm and the market value of its debt. However, the data on the market value of debt are often not available. Some of the studies on US samples have computed the market value of debt using data on the book value reported by the firm and observed prices in the corporate bond market (see for example Hall, 1990). This solution is not feasible for European samples because of the very limited development of corporate bond

Table 3
Total R&D for the sample and the population of manufacturing and utility firms in 1998

Country	Sample	All manufacturing and utility firms[+]	Sample as a share of population (%)
France[a]	7897	15,601	50.6
Germany[a]	18,180	28,577	63.6
Italy[a]	3631	5096	71.2
United Kingdom[b]	7753	8411	92.2
United States[c]	109,102	188,644	57.8

[+]Source: ANBERD database, OECD.
[a] Millions of euros.
[b] Millions of pounds sterling.
[c] 1997, millions of US dollars.

markets. Therefore, following previous analyses on UK data (Blundell et al., 1992, 1999), we have calculated the market value of the firm in all the European countries, including the United Kingdom, by simply adding the nominal value of outstanding debt to the market capitalization. For the United States we used the market value of long term debt, computed as described in Hall (1990). We removed observations from the sample when the ratio of market to book value was greater than 20 or the debt to assets ratio was greater than 5. This trimming affected the US and UK samples only.

Because R&D investments, as explained above, are not normally capitalized in the firm's balance sheet, we computed the R&D capital, K, as a perpetual inventory of the past and present annual R&D expenditures, R, with a constant depreciation rate, as described in detail by Griliches and Mairesse (1984) and Hall (1990). A constant annual depreciation (private obsolescence) rate of δ equal to 15% has been used and a constant annual R&D growth rate of g equal to 8% has been assumed to compute the R&D capital at the first year of firm R&D data availability. In order to check the validity of the assumptions on R&D depreciation and growth, we have recalculated the R&D capital for different values of g for France, Germany and Italy only. In particular, using the ANBERD database maintained by OECD, we have determined the annual growth rates of R&D expenditures by country and industry from 1979 to 1998. We have then calculated the first year R&D capital taking a g equal for any country and industry to the average growth rate of R&D investments in the previous five or ten years. Although we do not report the detailed results in this paper, we could observe that the different assumptions on g did not significantly modify the results.[15]

In order to analyze the effect of the presence of a controlling shareholder on the market value of R&D, we created a dummy variable (CONTROL) that is equal to unity when the main shareholder holds a control stake higher than 33%.[16] We used the database of Faccio and Lang (2002) that reports this information for all the publicly traded Western European firms in 1996 (these data were drawn from the official Stock Exchange ownership files). Slightly over half of the R&D-doing firms in the continental countries have such a majority shareholder.

Our regression equations also include other firm-specific variables, specifically the book value of other intangible assets and the logarithm of sales. We obtained I, a measure of other intangible assets, from the firm's balance sheet. This variable comprises capitalized costs (such as advertising, trademarks and licenses) and goodwill.[17] This variable will not generally include internal R&D costs among the capitalized costs because, as said above in this section, R&D investments can be capitalized in all the countries only if very specific conditions subsist. Goodwill, instead, often arises when an acquisition is made, as the difference between the price paid for a firm and the book value of its assets added to the balance sheet. It should represent the

[15] The full set of results is available from the authors.

[16] We explored the use of a number of other versions of CONTROL, two based on 40% and 50% cutoffs, and one where the largest 2 shareholdings summed to 50%. In general, the results were almost identical, with the exception of those for France, which suffered slightly from a small sample problem in the 33% to 50% range. Because we found that the 33% cutoff produced the most consistent set of results we have chosen to report those here. In addition, the well-known free-riding behavior of very small shareholders suggests that control in such firms can be achieved with substantially less than half the ownership.

[17] This accounting item is standardized across countries by Datastream. A check of the consistency of the definitions adopted by Datastream for France, Germany and the UK and Centrale dei Bilanci for Italy was made through the analysis of the user manuals.

market value of the off-balance sheet assets of the acquired firms. It may therefore include the value of the R&D investments done by an acquired firm, which for the same reasons explained above are not reported in its balance sheet. In a study specifically dealing with this question, Deng and Lev (1998) were able to separate acquired R&D from the goodwill for a selected sample of acquisitions, finding that investors placed a positive value on the former while highly discounting the latter. Our data do not allow us to separate the acquired R&D from goodwill, so that the variable I jointly controls for both of them. We included the total sales of the firm, S, in logarithmic form, in order to allow for nonconstant returns in the value function.[18] A full set of year dummies was added to the regressions to account for overall time-specific components due to macro-economic market effects.

Lack of R&D data for our firms can mean one of two things: either the firm did not do R&D or it did not report R&D. Because we are unable to distinguish these two reasons, we use a "reduced form" approach where a single Probit equation describes the probability of observing R&D. The dependent variable is a dummy variable (RDDUM) equal to 1 if R&D expenditures are reported and 0 otherwise. We include both firm- and industry-level independent variables in this equation. The industry-level R&D intensity, INDRD, was defined as the ratio between R&D expenditures from the ANBERD database and gross output from the STAN database for each industry in our sample. Although we experimented with the specification, we found that once we controlled for firm size using sales and the industry R&D intensity, other variables such as leverage and industry growth added little predictive power. Because the sample size is small and adding more variables led to misspecification (nonnormality) of the selection model, we preferred to use a parsimonious specification to predict the reporting of R&D.

4.4. Descriptive statistics

Table 4 shows descriptive statistics for observations with and without R&D data availability. We used a *two-tailed two sample t-test* to statistically compare the differences in the mean values of the variables between the two different groups. A striking difference appears in the mean values of total sales, S, and total assets, A between the two groups. The observations for which R&D expenditures are reported present much higher values for both the variables in all the countries (the differences are always significant at 1% level). This evidence suggests that R&D disclosure is strongly related to firm size. The ratio V/A is higher for the observations with R&D data in France, the United Kingdom and the United States, whereas it is lower in Germany, and the difference for Italy is not statistically significant. In addition, both in France and Germany the observations with R&D availability have higher mean values of the ratio I/A (the difference is significant at 1% level), whereas the opposite evidence is shown for Italy and the United States (where the difference is significant, respectively, at the 5% and the 1%). In the United Kingdom this difference is not statistically significant.

With respect to the industry variables, the observations with R&D data availability have higher mean values of INDRD (all the differences are significant at 1% level). This evidence suggests that there could be variation across industry in mean R&D performance and reporting

[18] The form of the value function in Eq. (2) suggests the use of assets (log A) to control for nonconstant returns. However, we prefer to use a different size variable (sales) for this purpose to avoid as much as possible the bias induced by common measurement error in the dependent (log V/A) and independent variables.

Table 4
Descriptive statistics for R&D and non-R&D reporting firms

Variable	France			Germany			Italy			UK			US		
	R&D		Non-R&D	R&D		Non-R&D	R&D		Non-R&D	R&D		Non-R&D	R&D		Non-R&D
$S^{\pm}$	1591	***	340	1518	***	175	975	***	225	218	***	59	472	***	283
$A^{\pm}$	956	***	204	868	***	101	822	***	223	208	***	60	268	***	154
V/A	1.75	***	1.43	1.02	***	1.42	1.07		1.11	1.38	***	1.06	2.75	***	2.11
I/A	0.246	***	0.126	0.066	***	0.043	0.072	**	0.098	0.065		0.060	0.130	***	0.150
D/A	0.421	***	0.376	0.244		0.253	0.412	*	0.377	0.209	*	0.196	0.976	***	0.920
INDRD	0.035	***	0.026	0.038	***	0.015	0.022	***	0.005	0.030	***	0.013	0.055	***	0.023
CONTROL	0.573	***	0.674	0.465	***	0.650	0.552	***	0.686	–		–	–		–
R/S	0.042		–	0.045		–	0.033		–	0.029		–	0.049		–
K/A	0.368		–	0.395		–	0.189		–	0.126		–	0.529		–
Observations	308		837	337		2351	239		446	2005		2689	6995		3897
Share of observations	26.9%		73.1%	12.5%		87.5%	34.9%		65.1%	42.7%		57.3%	64.2%		35.8%

$^{\pm}$Geometric mean; units are as reported (millions of for European firms; millions of $ for US firms).
t-tests with unequal variances for differences in the mean between R&D and non-R&D observations: ***$p<0.01$; **$p<0.05$; *$p<0.1$.

decisions, which is not surprising but will help us later in identifying our sample selection model.

For the observations for which R&D expenditures are reported, on average Italian and British firms have a significantly lower R&D intensity (respectively, 0.033 and 0.029 vs. 0.042 in France, 0.045 in Germany, and 0.049 in the United States). As a consequence, Italian and British firms also have lower stocks of R&D relative to their tangible assets (K/A, respectively, 0.189 and 0.126 vs. 0.368 in France, 0.395 in Germany, and 0.529 in the United States).

When we looked at the time patterns of the main variables defined above, we found some interesting features (not shown in this version of the paper).[19] The ratio V/A fluctuated over time and followed a similar pattern in all the countries analyzed. However, the US sample was characterized by higher values on average as compared to the other countries (especially Germany and Italy). The ratio of annual R&D expenditures to tangible assets, R/A, increased over time in the United States, was relatively steady in France and the United Kingdom, and decreased over time in Germany and Italy. Naturally, the trend of R/A was reflected in the dynamics of the ratio K/A. Finally, the ratio I/A increased significantly over time in all the countries, although the growth was steeper in France, the United Kingdom and the United States.

5. Results

In this section we discuss the results obtained by the estimation of the models reviewed in Section 3. Because the focus of this paper is on the hitherto unstudied R&D–market value relationship in France, Germany and Italy, we begin by reporting the results of OLS and NLLS regressions for these countries and comparing them to results for the United States and the United Kingdom. We then focus on the effect of control by a major shareholder on the market valuation of R&D. Finally, we explore the robustness of our results in two ways. We first investigate the presence of sample selection bias in our estimates, finding that it is negligible provided we control for differences in the ownership structures of continental firms versus those from the Anglo-Saxon economies. Based on this result, we turn our attention to the estimates that control for left-out firm effects.

5.1. Basic results

In Table 5 the results of the OLS estimation of Eq. (4) and the NLLS estimation of Eq. (3) are presented. The first set of five columns reports the basic equation for all five countries in our dataset estimated using ordinary least squares. The results show that in France and Germany R&D capital is positively valued by the stock market. The coefficients of K/A are positive (0.28 in France and 0.33 in Germany), statistically significant at the 1% level and have very similar values, similar also to those for the United States. However, they are considerably less than the equilibrium value of unity and are significantly lower than the coefficient estimated for the United Kingdom (0.88). Furthermore, they are lower than some of the coefficients obtained by similar analyses on the United States (e.g., Hall, 1993a,b) or the United Kingdom (e.g., Blundell et al., 1999) for earlier observation periods, although they are in agreement with results obtained by Hall (2000) using US data for the same period as here. The results for Italian firms are completely different from the others and imply that the valuation of R&D stock in these firms is not statistically different from zero.

[19] Detailed descriptive evidence on the time series is available from the authors.

Table 5
Basic market value regression with dependent variable = log (V/A)

Model	OLS					NLLS				
	US	UK	France	Germany	Italy	US	UK	France	Germany	Italy
K/A	0.33***	0.88***	0.28***	0.33***	0.01	0.80***	1.92***	0.41***	0.36***	−0.14
	(0.02)	(0.10)	(0.08)	(0.04)	(0.12)	(0.04)	(0.25)	(0.13)	(0.08)	(0.12)
Slope wrt K/A at averages						0.42	1.3	0.26	0.42	0.14
						(0.02)	(0.15)	(0.07)	(0.08)	(0.12)
Average slope wrt K/A						0.46	1.45	0.28	0.44	0.14
						(0.11)	(0.27)	(0.06)	(0.07)	(0.01)
I/A	0.60***	0.60***	0.87***	0.97***	1.09***	1.70***	1.15***	1.49***	1.09***	1.08***
	(0.04)	(0.08)	(0.13)	(0.15)	(0.23)	(0.09)	(0.19)	(0.32)	(0.19)	(0.27)
ln (S)	0.024***	0.07**	−0.02*	−0.06***	−0.06***	0.042***	0.008*	0.003	−0.025***	−0.010**
	(0.005)	(0.01)	(0.01)	(0.01)	(0.02)	(0.004)	(0.005)	(0.009)	(0.003)	(0.005)
Observations	6995	2005	308	337	239	6995	2010	308	337	239
Durbin–Watson	0.28	0.21	0.20	0.23	0.29	0.56	0.19	0.19	0.24	0.23
Adjusted R-squared	0.167	0.176	0.217	0.252	0.200	0.185	0.144	0.197	0.217	0.113

All equations include a complete set of year dummies.
***$p<0.01$; **$p<0.05$; *$p<0.1$; heteroskedastic–consistent standard errors in parentheses.

With respect to the other variables, in all the countries the intangible assets recorded on the balance sheet have a positive and significant coefficient, which is close to the unity for the three continental economies and somewhat lower for the United States and the United Kingdom. Finally, the coefficients of log sales suggest that there is a small decreasing returns size effect in all the continental economies and an increasing returns effect for the United States and the United Kingdom, although this is not very significant for France.

The next five columns in Table 5 report the results of the NLLS estimation of Eq. (3). Note that the slope coefficients are not directly comparable with the OLS estimates. In the former case the shadow value of the relevant variable is equal to its coefficient, whereas in the latter, the shadow value is the coefficient divided by the sum of one plus the capitals weighted by their coefficients:

$$\frac{\partial \log(V_{it}/A_{it})}{\partial \log(K_{it}/A_{it})} = \frac{\gamma}{1+\gamma(K_{it}/A_{it})+\gamma(I_{it}/A_{it})} \tag{5}$$

The results of computing the above expression at the variable means is shown below the coefficient estimates, and the results of averaging the estimated slope coefficient for each firm are shown below that. For the US, the UK and Germany, these values are typically somewhat higher than the OLS estimates and lower than the NLLS coefficient estimate, as we would expect if the linear model placed too much weight on large K/A values. For France, they are about the same, but for Italy they are slightly higher, although insignificantly so.

Similarly to R&D capital, the coefficients of I/A are positive, statistically significant, and higher in all of the countries except Italy, where the coefficient falls slightly. The scale coefficient is now insignificantly different from zero for France, Italy, and the UK, although still small and negative for Germany and it has increased for the US.

5.2. Corporate control and the market value of R&D

Table 6 shows the result of our investigations into the impact of large shareholder control on the market value of R&D in the continental European countries. We included the dummy variable CONTROL in the market value equation both by itself and interacted with K/A. The results for both OLS and NLLS estimation are shown in Table 6 for our three continental countries. In the case of Germany, the variable makes little difference to the OLS results, although it does appear that R&D is slightly less valued in firms with a majority shareholder. In the NLLS results for Germany, having a majority shareholder reduces the valuation of R&D substantially. For France and Italy, the results are very striking, whether we look at OLS or NLLS. R&D capital in firms without a majority shareholder is valued the same way as it is in the other countries (or even slightly higher), whereas R&D capital in firms that have a single shareholder with a more than 33% share is essentially not valued at all, although control itself is positively valued. The sum of the two K/A coefficients for these firms is 0.16 (0.10) for France and -0.09 (-0.06) for Italy. The differences between the two types of firms are quite significant. These results are consistent with our expectations. In all the continental countries, characterized by a civil law system, the presence of a major shareholder reduces the market valuation of R&D, supposedly because of the accrued risk of expropriation by the major shareholder. In particular, the greatest undervaluation of R&D occurs in the firms controlled by a major shareholder in those countries that according to the study of La Porta et al. (1998) offer the weakest protection to outside investors, which are France and Italy. In the next section we

Table 6
Market value regression with control for ownership structure

Model	OLS			NLLS		
	France	Germany	Italy	France	Germany	Italy
K/A	0.56***	0.38***	0.71***	0.66***	0.56***	0.94***
	(0.13)	(0.03)	(0.27)	(0.22)	(0.10)	(0.30)
$K/A*D$ (control)	−0.40**	−0.12	−0.82***	−0.56**	−0.37***	−1.00***
	(0.17)	(0.10)	(0.30	(0.27)	(0.12)	(0.31)
I/A	0.69***	0.94***	1.18***	1.24***	0.99***	1.10***
	(0.14)	(0.15)	(0.21)	(0.29)	(0.18)	(0.24)
ln (S)	0.02	−0.06***	−0.06***	0.004	−0.026***	−0.019***
	(0.02)	(0.01)	(0.02)	(0.008)	(0.004)	(0.005)
D (control>33%)	0.46***	−0.03	0.23***	0.42***	0.11	0.32***
	(0.10)	(0.07)	(0.07)	(0.09)	(0.07)	(0.07)
Test for control variables	13.1***	3.04**	5.25***	27.2***	11.2***	19.0***
(p-value)#	(0.000)	(0.049)	(0.006)	(0.000)	(0.004)	(0.000)
Observations	308	337	239	308	337	239
Durbin–Watson	0.22	0.24	0.31	0.21	0.23	0.30
Adjusted R-squared	0.276	0.260	0.221	0.269	0.247	0.188

All equations include a complete set of year dummies.
***$p<0.01$; **$p<0.05$; *$p<0.1$; heteroskedastic–consistent standard errors in parentheses.
#The test is an F-statistic in columns 1 to 3, and a chi-squared in columns 4 to 6.

explore this result further, hypothesizing that the reporting of R&D itself may be determined by the nature of the ownership structure of the firm.

Another interesting result evident in this table is that control provides a significant premium in France and Italy, where the stand-alone coefficient of CONTROL is, respectively, 0.46 and 0.33. A possible explanation of this result is provided by those studies highlighting the benefits deriving from the presence of block ownership. For example, Allen and Phillips (2000) show that the stock prices of target firms increase when corporate block purchases by nonfinancial corporations are announced, suggesting potential benefits from alliances between the target firm and the new corporate owner, alleviation of financial constraints, and more effective board monitoring. Apparently in R&D-intensive firms, these benefits to outside investors can be outweighed by the difficulty of monitoring investment in intangible assets such as R&D.

5.3. Robustness checks: sample selection and panel estimation[20]

In order to check the robustness of our results to the potential selection bias related to R&D disclosure, we estimated a sample selection model where, as described above, Eq. (4) is jointly estimated with a Probit model for the probability of reporting R&D. Although we adopt maximum likelihood for estimation because it is more efficient, we used the Heckman estimator to test for the validity of the normality assumption, by including two additional terms in the regression above: the product of the inverse Mills' ratio with its associated probability p that R&D is observed and with p-squared (see Lee, 1982; Newey, 1988; Das et al., 2003). This test showed that although the US sample violates the normality assumption, the samples for all the other countries do not.

[20] In this section, for the sake of simplicity we just report the main results of the sample selection and the panel models. Tables with the full set of results are available from the authors or in NBER Working Paper No. 10408.

Turning to the results, our predictor variables had a fair amount of explanatory power in the expected directions, with size and industry R&D intensity being positive for performing and reporting R&D.[21] We also included CONTROL in this regression, on the grounds that reporting R&D might be affected by being part of a larger entity. Other things equal, we found that having a majority shareholder reduces the probability of reporting R&D slightly in Germany and Italy, but has no effect in France. For all the countries, the correlation of the error terms in the two equations was not significantly different from zero, which implies that there is no bias arising from sample selection in the estimates of Tables 5 and 6. This result was confirmed by the coefficient estimates, which are almost identical to those in Table 6. Thus the conclusion from our sample selection estimation was that although we observe R&D for only a subset of the R&D-doing firms in the French, German, and Italian economies, we are still able to estimate the valuation–R&D equation consistently.

We also checked how our results were robust to firm-specific effects through the first differences and the fixed (within) and random effects estimation of Eq. (4) for all the countries. For France, Germany, and Italy, we included the CONTROL variables in the model; in the case of the model with fixed effects, only the interaction term is identified, since CONTROL is the same in every year within firm. Estimating model (4) with the first differences of the variables decreased the precision of the estimates considerably in France and Italy, and somewhat in the UK. Overall, the R&D capital coefficients were insignificantly different from zero, but with large standard errors. In contrast, the German and US results were similar to those obtained in levels. When we estimated fixed and random effects specifications we find that there are significant permanent differences across firms in all the samples but that these differences do not appear to be correlated with the regressors for the continental firms. The data did reject a random effects model in favor of fixed effects for the US and UK firms. Note that this contrast may simply be due to sample size. When conventional standard errors rather than robust estimates are used, random effects are rejected in favor of fixed effects for Germany and Italy as well. This implies that the average value–R&D relationship varies across firms with differing R&D intensities in a "permanent" way.

These results were confirmed by the coefficient estimates of the within and the random effects estimators. Thus controlling for firm effects makes little difference to the estimates (other than increasing the standard errors). The puzzle was the UK, where R&D was valued very highly in the cross section, but zero within firm. Firms in that country can have permanently higher market value due to their R&D strategies, but changing those strategies has little impact. Our tentative conclusion from this investigation into the presence of firm fixed effects in the valuation relation was that permanent differences across firms in market value do not seem to be related to R&D investments for firms in the continental economies. For Germany, we have some confidence in this conclusion, but for the other two countries, the sample sizes are probably too small to produce a definitive test.

6. Discussion and conclusions

In this paper we have addressed questions related to the market valuation of R&D investments in the European countries through a comparison with the Anglo-Saxon countries

[21] Using industry R&D intensity to control for individual firm reporting of R&D may raise some concerns, but the industries in question are rather broadly defined and the R&D intensity figure comes from a separate data source (the OECD STAN and ANBERD databases, whose data is largely drawn from confidential surveys by the National Statistical Offices in the relevant countries). Thus any individual firm in our sample is unlikely to have much impact on the industry-level numbers reported for R&D.

(United Kingdom and United States). To our knowledge, this is the first in-depth empirical analysis of the valuation of firms' R&D expenditure by the stock market in European countries other than the United Kingdom, such as France, Germany and Italy. We believe that such an investigation is important for several reasons: the relevance of these economies, the specificity of their capital markets, corporate governance regimes and law systems as compared to Anglo-Saxon countries, and the differences in the schemes of the public incentives to private R&D.

In our analysis we dealt with two main difficulties limiting data availability in the analyzed countries: the fact that R&D disclosure is not compulsory, drastically reducing the number of observations for which R&D is reported; and the small size of the stock markets, as compared to the United Kingdom and the United States, restricting the number of publicly traded firms that could be included in the sample. Starting from the existing models on R&D and market value reviewed in Section 3, we tried to correct the potential biases arising from the problems discussed above, by applying two estimation methods that have not been widely used in R&D valuation analysis: sample selection and panel techniques.

The results we obtained exhibit several features that may be interesting to both researchers and policy-makers. German and French samples show a statistically significant and robust positive evaluation of the R&D capital by the stock market. The UK sample shows a substantially greater valuation of the R&D investments in the cross section. From the perspective of the financial investors, this means that a currency unit spent in R&D by a company in the United Kingdom has on average an impact whose magnitude is nearly three times bigger than in France and Germany. The fact that Bond et al. (2003b) find much higher productivity of R&D in the UK than in Germany confirms that our result is probably real. However, when we correct for fixed effects, the valuation of the R&D capital in the countries is very similar. Moreover, all the estimated coefficients of the R&D capital are considerably less than unity, and are significantly smaller than the coefficients reported by previous studies on the US and the UK, suggesting in line with previous contributions (Hall, 1993a,b, 2000; Oriani and Sobrero, 2003) that the market valuation of R&D expenditures has decreased in all the countries over time.

If we assume the financial markets are efficient, a coefficient of the firms' R&D capital lower than unity in the analyzed countries suggests that firms disclosing R&D expenditure are investing a non-optimal amount of resources in R&D. In particular, they may be investing too much, because the assets they are creating are worth less than they paid for them. Alternatively, the low valuation could imply that the private depreciation rate we used (15%) is too low, and that the value of R&D depreciates considerably faster.[22] Indeed, our data for the continental European countries is insufficient to investigate this question in a detailed manner. Other explanations can be advanced for the low valuation of R&D investments. It is possible that lack of an R&D disclosure obligation in continental European countries has a negative effect on R&D evaluation, exacerbating the information asymmetries between firms and investors that critically concern R&D investments. Seaton and Walker (1996) have shown that the introduction of the requirement to disclose corporate R&D investments somewhat reduced the financial constraints faced by British traded firms for innovation.

Low values for R&D investment could also result from public incentives to business R&D, both subsidies and tax credits. Previous empirical literature has shown that the R&D performed through government funding yields lower returns than company-financed R&D (see Hall, 1996, for a review), as indeed is the usual intent when designing such programs. This theme is

[22] A "back of the envelope" computation suggests a depreciation rate of about 50% per year. The shadow value is roughly 0.35, which is the ratio of $(g+\delta)$=(0.08+0.15) to (0.08+0.55).

particularly relevant in the case of Italy, since the empirical analysis of Parisi and Sembenelli (2001) shows for this country a very high R&D elasticity to public incentives as compared to other countries. The lower valuation of R&D in this country could at least in part due to a higher share of publicly financed R&D. Accordingly, it would be interesting to investigate the nature and the characteristics of the publicly funded firms' R&D investments in the analyzed countries.

Another interesting finding is that in Germany and above all France and Italy, for firms without large shareholders stock markets place a higher value on R&D spending. Based on the arguments of La Porta and colleagues (1998, 2000), this result could be explained by the expropriation risk suffered by outside investors. In other words, in countries offering weak legal protection to financial investors, such as France and Italy, the controlling shareholders can appropriate minority shareholders' profits exploiting the information asymmetries created by R&D investments, consistently with the evidence on R&D and insider gains presented by Aboody and Lev (2000). For this reason, in these countries stock markets should penalize more R&D-intensive firms controlled by a major shareholder.

These results support then the idea that legal regimes and ownership structures matter in stock market evaluation of firms' R&D investments. While previous literature on R&D financing has primarily advocated policy measures to reduce the information asymmetries inherent to R&D investments, the evidence presented here suggests that legal and corporate governance arrangements can be at least equally important. Stronger investor protection could reduce the reinforcing effect of R&D investments on potential insider expropriation and consequently increase R&D valuation by financial markets. Also corporate governance amendments strengthening or weakening the rights of minority investors at the firm level can be relevant in this respect. For example, Meulbroek et al. (1990) have documented how the introduction of takeover impediments weakening the rights of outside investors had a negative impact on firms' R&D investments in the US. A more recent study by Gompers et al. (2003) has shown that governance provisions strengthening shareholder rights are associated with higher firm market value. With specific respect to our research question, these provisions could mediate the effect of corporate control on the market valuation of R&D investments. Although our database did not allow us to explore this issue, we believe that it represents a very interesting question for future research.

This study, which has analyzed the valuation of R&D for firms in previously unstudied European countries and provided in this respect new and sometimes puzzling evidence, can stimulate the actual debate on R&D financing in the European Union. Even though the evidence concerns a limited number of countries, it represents a first step into a deeper investigation of the interactions between firms, markets and institutions in contexts where the corporate governance regime and the financial markets are significantly different from that of the United States or the United Kingdom.

References

Aboody, D., Lev, B., 2000. Information asymmetry, R&D, and insider gains. Journal of Finance 55, 2747–2766.

Alexander, D., Archer, S., 1998. European Accounting Guide. Harcourt Brace, San Diego.

Allen, J.W., Phillips, G.M., 2000. Corporate equity ownership, strategic alliances, and product market relationships. Journal of Finance 55, 2791–2815.

Angelini, P., Di Salvo, R., Ferri, G., 1998. Availability and cost of credit for small businesses: customer relationships and credit cooperatives. Journal of Banking and Finance 22, 925–954.

Belcher, A., 1996. R&D disclosure: theory and practice. In: Belcher, A., Hassard, J., Procter, S. (Eds.), R&D Decisions: Strategy, Policy and Disclosure. Routledge, London.

Black, A.J., Fraser, P., 2000. International comparisons on stock market short-termism: how different is the UK experience? Manchester School 68, 38–50 (supplement).

Bloom, N., Van Reenen, J., 2002. Patents, real options and firm performance. Economic Journal 112, 97–116.

Blundell, R., Bond, S., Devereux, M., Schiantarelli, F., 1992. Investment and Tobin's *Q*. Journal of Econometrics 51, 233–257.

Blundell, R., Griffith, R., Van Reenen, J., 1999. Market share, market value and innovation in a panel of British manufacturing firms. Review of Economic Studies 66, 529–554.

Bond, S., Elston, J., Mairesse, J., Mulkay, B., 2003a. Financial factors and investment in Belgium, France, Germany and the UK: a comparison using company panel data. Review of Economics and Statistics 85, 153–177.

Bond S., Harhoff D., Van Reenen J. 2003b. Corporate R&D and productivity in Germany and the United Kingdom. CEP Discussion Paper 595, London School of Economics, London.

Cockburn, I., Griliches, Z., 1988. Industry effects and appropriability measures in the stock market's valuation of R&D and patents. American Economic Review 78, 419–423.

Das, M., Newey, W.K., Vella, F., 2003. Nonparametric estimation of sample selection models. Review of Economic Studies 70, 33–58.

David, P.A., Hall, B.H., Toole, A.A., 2000. Is public R&D a complement or substitute for private R&D? A review of the econometric evidence. Research Policy 29, 497–529.

Deng Z., Lev B. 1998. The valuation of acquired R&D. Working Paper, New York University, New York.

Faccio, M., Lang, L.P.H., 2002. The ultimate ownership of Western European corporations. Journal of Financial Economics 65, 365–414.

Franks, J., Mayer, C., 1990. Capital markets and corporate control: a study of France, Germany and the UK. Economic Policy 10, 189–232.

Gomes, A., 2000. Going public without governance: managerial reputation effects. Journal of Finance 55, 615–646.

Gompers, P., Ishii, J.L., Metrick, A., 2003. Corporate governance and equity prices. Quarterly Journal of Economics 118, 107–155.

Griliches, Z., 1981. Market value, R&D and patents. Economics Letters 7, 183–187.

Griliches, Z., Hausman, J.A., 1986. Errors in variables in panel data. Journal of Econometrics 31, 93–118.

Griliches, Z., Mairesse, J., 1984. Productivity and R&D at the firm level. In: Griliches, Z. (Ed.), R&D, Patents, and Productivity. Chicago University Press, Chicago.

Hall B.H. 1990. The manufacturing sector masterfile: 1959–1987. National Bureau of Economic Research Working Paper 3366, Cambridge, MA.

Hall, B.H., 1993a. Industrial research during the 1980s: did the rate of return fall? Brookings papers on economic activity. Microeconomics, 289–343.

Hall, B.H., 1993b. The stock market's valuation of R&D investment during the 1980's. American Economic Review 83, 259–264.

Hall, B.H., 1996. The private and social returns to research and development. In: Smith, B., Barfield, C. (Eds.), Technology, R&D and the Economy. AEI–Brookings Institutions, Washington, DC.

Hall, B.H., 2000. Innovation and market value. In: Barrell, R., Mason, G., O'Mahoney, M. (Eds.), Productivity, Innovation and Economic Performance. Cambridge University Press, Cambridge.

Hall, B.H., 2002. The financing of research and development. Oxford Review of Economic Policy 18, 35–51.

Hall, B.H., Kim, D. 2000. Valuing intangible assets: the stock market value of R&D revised, Working Paper. University of California at Berkeley and Harvard University, Berkeley, CA and Cambridge, MA.

Hall, B.H., Van Reenen, J., 2000. How effective are fiscal incentives for R&D? A review of the evidence. Research Policy 29, 449–469.

Hall B.H., Vopel K. 1996. Innovation, market share and market value, Working Paper, University of California at Berkeley and University of Mannheim: Berkeley, CA and Mannheim.

Hall, B.H., Jaffe, A.B., Trajtenberg, M., 2005. Market value and patent citations. Rand Journal of Economics 36, 16–38.

Hall, B.H., Mairesse, J., Branstetter, L., Crepon, B., 1999. Does cash flow cause investment and R&D: an exploration using panel data for French, Japanese, and United States scientific firms. In: Thurik, A.R. (Ed.), Innovation, Industry Evolution, and Employment. Cambridge University Press, Cambridge.

Hausman, J.A., 1978. Specification tests in econometrics. Econometrica 46, 1251–1272.

Hirschey, M., 1982. Intangible capital aspects of advertising and R&D expenditures. Journal of Industrial Economics 30, 375–390.

Jaffe, A.B., 1986. Technological opportunity and spillovers of R&D: evidence from firms' patents, profits, and market value. American Economic Review 76, 984–1001.

KPMG, 1995. TRANSACC. Transnational Accounting. Macmillan, London.

La Porta, R., Lopez-De-Silanes, F., Shleifer, A., Vishny, R., 1998. Law and finance. Journal of Political Economy 106, 1113–1135.

La Porta, R., Lopez-De-Silanes, F., Shleifer, A., 1999. Corporate ownership around the world. Journal of Finance 54, 471–516.

La Porta, R., Lopez-De-Silanes, F., Shleifer, A., Vishny, R., 2000. Investor protection and corporate governance. Journal of Financial Economics 58, 3–27.

La Porta, R., Lopez-De-Silanes, F., Shleifer, A., Vishny, R., 2002. Investor protection and corporate valuation. Journal of Finance 57, 1147–1170.

Lee, L.F., 1982. Some approaches to the correction of selectivity bias. Review of Economic Studies 49, 355–372.

Lev, B., Sougiannis, T., 1996. The capitalization, amortization, and value–relevance of R&D. Journal of Business, Accounting and Economics 21, 107–138.

Maddala, G.S., 1983. Limited–Dependent and Qualitative Variables in Econometrics. Cambridge University Press, Cambridge.

Meulbroek, L.K., Mitchell, M.L, Mulherin, J.H., Netter, J., Poulsen, A.B., 1990. Shark repellents and managerial myopia: an empirical test. Journal of Political Economy 98, 1108–1117.

Mulkay B., Hall B.H., Mairesse J., 2000. Firm level investment and R&D in France and the United States: A comparison. National Bureau of Economic Research Working Paper 8038: Cambridge, MA.

Munari, F., Oriani, R., 2005. Privatization and economic returns to R&D investments. Industrial and Corporate Change 14, 61–91.

Newey, W. K. 1988. Two-step series estimation of sample selection models, MIT Working Paper, Cambridge, MA.

Oriani, R., Sobrero, M., 2003. A meta-analytic study of the relationship between R&D investments and corporate value. In: Calderini, M., Garrone, P., Sobrero, M. (Eds.), Corporate Governance, Market Structure and Innovation. Edward Elgar, Cheltenham, UK.

Pagano, M., Panetta, F., Zingales, F., 1998. Why do companies go public? An empirical analysis. Journal of Finance 53, 27–64.

Parisi M. L., Sembenelli A. 2001. Is private R&D spending sensitive to its price? Empirical evidence on panel data for Italy, Boston College Working Paper in Economics 493. Boston.

Seaton, J., Walker, I., 1996. R&D in UK quoted companies: the effects of disclosure and finance. In: Belcher, A., Hassard, J., Procter, S. (Eds.), R&D Decisions. Strategy, Policy and Disclosure. Routledge, London.

Toivanen, O., Stoneman, P., Bosworth, D., 2002. Innovation and market value of UK Firms, 1989–1995. Oxford Bulletin of Economics and Statistics 64, 39–61.