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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 exist no investigations for the continental countries in the European Union, partly 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 that 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 shareholder holds more than one third of the firm, but that R&D is essentially not valued in the other firms.

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1. Introduction

The question of how R&D investments affect 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, 1993b).[2] 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.[3] 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 exist 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 there is considerable evidence that capital markets and corporate governance systems in these countries are different in several important ways from those of Anglo-Saxon countries such as the US and the UK (see for example Franks and Mayer 1990; Hall 1994; Hall et al. 1999; La Porta et al. 1999). The basic idea is that some features as interlocking directorates and ownership structures (see Figure 1 on the percentage of share ownership held by institutional investors in France, Germany, Italy, the UK and the US), large-scale and stable relationships with banks and 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 stringent oversight by financial capital markets. 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

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

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

also imply market valuations of capital and R&D investments that may be either higher or lower on average than those in the US.

--- *Insert Figure 1 about here* ---

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). This evidence is consistent with previous work on the effect of financial constraints on firms' investments. In particular, Bond et al. (2003), 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.

Greater sensitivity to cash flow or profitability shocks is only one of the ways in which financial markets may affect investments and their market value. In a series of studies, La Porta and colleagues (1998, 1999, 2002) have shown that countries with a civil law system, such as France, Germany and Italy, protect external investors less than countries with a common law system, such as the United Kingdom and the United States. Thus higher ownership concentration in the countries of Continental Europe, together with poorer protection of minority investors, can lead to a lower market valuation of the firms. On the other side, other studies suggest the existence of potential benefits from block ownership, due to alliances between the firm and its corporate owner, alleviation of financial constraints, and more effective board monitoring.

Therefore, an investigation of the relationship between R&D investment and market value in European countries could be important at several different levels of analysis. At the firm level, a better understanding of the expected value created by spending on R&D could lead to better choices of the amount of resources to be allocated to R&D activities. With respect to innovation policy, a more thorough analysis of private returns to R&D could improve the assessment of the incentives for industrial research. This issue is particularly relevant if we consider that the analyzed countries adopt significantly different balances among the different kinds of government incentives for business R&D expenditures (see Hall and Van Reenen, 2000; Parisi and Sembenelli, 2001).

Analysis using data on French, German, and Italian firms is complicated by several specific problems that are closely related to the differences in capital market structure themselves. First, in these countries disclosure of annual R&D expenditures is not required by the national accounting laws and regulations. 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 few hundred companies are publicly traded at the Milan stock exchange. Third, as indicated above, 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 omitted firm effects 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 U.S. during this period, roughly twice as high in the U.K., and not 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 U. K. level, in French and Italian firms with no major shareholder. However, in firms with a major shareholder, there is a positive premium for such control, but the market places zero value on the R&D in such firms.

In the next section of the paper, we discuss the valuation model we use, which is the familiar hedonic model pioneered by Griliches (1981) in this 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. 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 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:

$$V_{it} = V\,(A_{it}, K_{it}, I_{\mathrm{it}}^{1},\ldots, I_{\mathrm{it}}^{n}) \qquad [1]$$

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}^{j} is the replacement value of the j^{th} intangible asset. If single assets are purely additive, it is possible to express the market value of the firm as a multiple of its assets:

$$V_{it} = b\,(A_{it} + \gamma K_{it})^{\sigma} \qquad [2]$$

where b is the market valuation coefficient of firm's total assets reflecting its differential risk and monopoly position, γ_K is the relative shadow value of knowledge capital to tangible assets, and the product $b\gamma$ is the absolute shadow value of the knowledge capital. In practice, $b\gamma$ 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. 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.

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

$$\log(V_{it}/A_{it}) = \log b + \log(1+\gamma K_{it}/A_{it}) \qquad [3]$$

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 [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. (2004) estimate [3] using non-linear least squares (NLLS). Other authors applying the same model have used the approximation (1+*x*) ≈ *x*, obtaining the equation below, which can be estimated by ordinary least squares (Griliches 1981; Jaffe 1986; Cockburn et al. 1988; Hall 1993a, 1993b):

$$\log(V_{it}/A_{it}) = \log b + \gamma K_{it}/A_{it} \qquad [4]$$

In order to investigate the appropriateness of equation [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 are reported in Appendix A. Briefly, we found that the relationship resembles a logistic curve, with zero and very small amounts of R&D capital (less than about one per cent 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 one per cent, the relationship is somewhat better described by equation [3] than equation [4], although we have explored the use of both specifications in this paper.[5]

[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.

The estimation of equations [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 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] This model allows estimation of the correlation of the disturbances the two equations; if they are uncorrelated, there is no bias in the estimated coefficients of the market value relationship. In fact, we find very little evidence of such bias.

We therefore turn to the investigation of the second potential problem with our model, which is that the 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 would also be 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, although the fixed-effects estimators account for unobserved firm-specific heterogeneity, they greatly reduce the degrees of freedom, and can introduce substantial downward bias from measurement error (Hausman and Griliches 1986). Like the pooled estimator, the within estimator also tends to have residuals with substantial serial correlation, which implies that

[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 with which to work. 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 U. S. data, along the lines suggested by Das, Newey, and Vella 2003, incorporating also the potential endogeneity of the right hand side variables.

the standard error estimates are incorrect, whereas the differenced estimator is known to have more severe downward bias. The downward bias is particularly problematic in this case, because R&D is a somewhat permanent characteristic of firms that changes rather slowly (Hall et al. 1986). In addition, the fact that R&D is merely predetermined rather than endogenous means that estimators which control for firm effects may be misspecified.[8]

For these reasons, in previous work on R&D and market value, a random-effects model has sometimes been estimated along with the fixed-effects model (Munari and Oriani, 2002). In the case of the random-effects model, the firm-specific component is treated as a random variable with mean $\overline{\nu}$ and variance σ_ν^2. As is well known, however, consistency of the random-effects estimator requires that the effects, which in this case can be interpreted as permanent profitability differences, be uncorrelated with the right hand side variables. In order to check the assumption of no correlation, we use the Hausman (1978) specification test of the null hypothesis that there are no systematic differences between fixed-effects and random-effects coefficients. 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.

3. Data

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 these countries. All the accounting data of Italian firms

[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.

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 U.S. firms we used accounting and market data drawn from the COMPUSTAT database, described by Hall (1999a). To increase the comparability of the samples, we removed very small firms from the U.K. and the U.S. database.[9]

As a result, our final dataset consists of an unbalanced panel of 2,156 publicly traded firms, 127 from France, 283 from Germany, 86 from Italy, 592 from the United Kingdom and 1,366 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.[10]

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.

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]

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[9] 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 the U.S. than in the other countries.

[10] Most Italian firms are small- and medium-sized and rely on bank credit in order to finance their activities (see for example Angelini et al. 1998).

[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 recognised as an expense" (ww.iasb.org.uk). See KPMG (1995), Lev and Sougiannis (1996) and Alexander and Archer (1998) for further information.

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.

--- Insert Table 1 about here ---

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] INVIND, 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.

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. Table 2 reports the total number of observations by country, and broken down by industry and by whether R&D data are available. The problem of R&D disclosure appears to be particularly severe for Germany, where we do not have data on R&D investments for 88% of the total observations, whereas it is less important for Italy, where the 65% of observations do not have firm-level R&D data. Clearly, in all the European countries the percentage of observations reporting R&D investments is quite a bit lower than in the United States, where only 36% of total

[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 4,500 companies.

observations do not report R&D data. We define a dummy variable *RDDUM* equal to 1 if R&D expenditures are reported and 0 otherwise.

--- Insert Table 2 about here ---

The distribution of the firms and the observations with R&D data availability by country and industry is also reported in Table 2. We have 51 firms and 308 observations for France, 79 firms and 339 observations for 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. All the countries in Continental Europe have a high percentage of observations in the motor vehicles industry (10.6% in France, 12.7% in Germany and 10.9% in Italy). Nearly a quarter of the observations in the German sample (24.8%) are concentrated in the machinery industry. A substantial share of the observations in the United States (21.6%) 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 representativeness 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 seem to be representative of 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 report it. A second conclusion is that in Continental Europe, as in the United States and United Kingdom, most industrial R&D is performed in publicly traded firms.

--- Insert Table 3 about here ---

Variables

In equations [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 1990a). This solution is not feasible for European samples because of the very limited development of corporate bond markets. Therefore, according to previous similar 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 (1990a). 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 (1990a). A constant annual depreciation (private obsolescence) rate of $\delta = 15\%$ has been used and a constant annual R&D growth rate of $g = 8\%$ 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 (K_5) or ten years (K_{10}).

Our regression equations also include other firm-specific variables, specifically the book value of intangible assets and the logarithm of sales. We obtained *I*, a measure of intangible assets, from the firm's balance sheet; it is mainly composed of goodwill and trademarks.[14] We included the total sales of the firm, *S*, in logarithmic form, in order to allow for nonconstant returns in the value function. 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. We include both firm-level and industry-level variables in this equation. Following the evidence provided by Hall (1990b), which shows a negative association between firm's debt level and R&D investments, we create a leverage variable, calculated as the ratio between total financial debt, *D*, and total tangible assets, *A*. Two industry level variables are also used: industry-level R&D intensity, *INDRD*, defined as the ratio between R&D expenditures from ANBERD database and gross output from STAN database for each industry in our sample, and the annual growth rate of the industry gross output, *INDGR*.

Descriptive statistics

Table 4 shows descriptive statistics for observations with and without R&D data availability. We used a *one-tailed 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 performance and 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. In Italy there is no statistically significant difference. 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 opposite evidence is shown for Italy and the United States (where the difference is significant

[14] Goodwill 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 may therefore include the purchased results of R&D done by an acquired firm. On the other hand, intangibles will not generally include assets created by a firm's own R&D. In fact, as said above in this section, R&D investments can be capitalized in all the countries only if very specific conditions subsist.

respectively at the 10% 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) and *INDGR* (the difference is not statistically significant in Italy). This evidence shows that there could be differences across industry in R&D performance and reporting decisions along with firm-specific factors. We will account for this in 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 .033 and .029 vs. .042 in France, .045 in Germany, and .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 .189 and .126 vs. .368 in France, .395 in Germany, and .529 in the United States). This conclusion does not change substantially when we replace K/A with either K_5/A or K_{10}/A.

--- *Insert Table 4 about here* ---

If we look at the time patterns of the main variables defined above, we can discern some interesting features. Figure 2 shows that the ratio V/A is erratic over time and follows a similar pattern in all the countries analyzed. However, the US sample is characterized on average by higher values as compared to the other countries (mainly Germany and Italy).

--- *Insert Figure 2 about here* ---

Figure 3 illustrates that the ratio of annual R&D expenditures to tangible assets, R/A, is increasing over time in the United States, is relatively steady in France and the United Kingdom, whereas it is decreasing in Germany and Italy. The anomalous peak in Germany between 1989 and 1990 is most likely explained by the entry of new firms in the sample.

--- *Insert Figure 3 about here* ---

Naturally, the trend of R/A is reflected into the dynamics of the ratios K/A and K_5/A illustrated in Figure 4. In France, both K/A and K_5/A increase over time exhibiting a very similar trend. In Italy the values of the two ratios appear to be relatively flat and to clearly converge after an initial difference. Finally, in Germany K/A and K_5/A follow a more unsteady pattern and present a greater difference, but they both monotonically decrease after 1995.

--- *Insert Figure 4 about here* ---

Finally, Figure 5 shows that the ratio *I/A* notably increases over time in all the countries. The growth is more accentuated in France, the United Kingdom and the United States.

--- Insert Figure 5 about here ---

4. Results

In this section we discuss the results obtained by the estimation of the models reviewed in Section 2. 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. Results using alternative measures of R&D capital (K_5 and K_{10}) appear in Appendix B. We then 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, but not for selection bias.

Basic results

In Table 5 the results of the OLS estimation of equation [4] and the NLLS estimation of equation [3] are presented. The first set of five columns show the basic equation for all five countries in our dataset estimated using ordinary least squares. The results show that in France and Germany the R&D capital is positively valued by the stock market. The coefficients of *K/A* are positive (.28 in France and .33 in Germany), statistically significant at the one per cent 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, 1993b) 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. These results do not change substantially when we use K_5/A or K_{10}/A instead of K/A to measure the firm's R&D capital.[15]

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 equation [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:

$$\frac{\partial \log Q}{\partial (K/A)} = \frac{b_K}{1 + b_K(K/A) + b_I(I/A) + b_S \log S}$$

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, 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.

---- *Insert Table 5 about here* -----

[15] See the appendix for the details of these estimates.

R&D and the control premium or discount

Table 6 shows the result of our investigations into the reasons for the extremely small and insignificant coefficient of R&D capital for Italian firms. As remarked in the introduction, one possible explanation for the results we obtained for Italy is related to the ownership structure in this country, which is typically nested. 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 Faccio and Lang, 2002). Recent studies of the relationship between corporate governance and equity values have noted that it may be affected by the agency problem between the controlling shareholders and the minority shareholders (Gomes, 2000). Empirical evidence shows contrasting results. On the one hand, some studies report that shareholders with the majority of the voting rights are protected from takeover threats and monitoring activities, which has a negative effect on the market value of equity which has a greater magnitude when legal systems do not protect minority shareholders (La Porta et al., 1998, 1999, 2002). In the case of Italy and even France, the diffused presence of traded firms controlled by large shareholders, joint with a legal system offering a weak protection to external investors (La Porta, 1998), could generate underpricing phenomena (indeed, as the mean value of the ratio V/A in Table 3 would suggest) that, *ceteris paribus*, could lead to K/A being underpriced.

On the other hand, other studies have highlighted the benefits deriving from the presence of block ownership. In this respect, 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. This situation could also apply to Italy, where several traded firms are controlled by another corporation within business group structures.

In order to explore this issue, we created a dummy variable (CONTROL) that is equal to unity when the main shareholder holds a control stake higher than 33% and there is no other shareholder with a stake higher than 20%.[16] We used the database of Faccio and Lang (2002)

[16] The database of Faccio and Lang (2002), on which our analysis is based, only reports those shareholders having a stake greater than 20%. 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

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). This variable is one for slightly over half of the R&D-doing firms. A similar variable was created for firms from the other continental countries (France and Germany).

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 valued less in firms with a majority shareholder. In the NLLS results for Germany, having a majority shareholder gives a premium of 11 per cent, but 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 0.15 (0.10) for France and -0.10 (0.13) for Italy. The differences between the two types of firms are quite significant. In the next section we 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.

---- *Insert Table 6 about here* -----

Sample selection estimation

In Table 7 we show the results of the sample selection model, where equation [4] is jointly estimated with a Probit model for the probability of reporting R&D. The method of estimation is maximum likelihood, with the two equations allowed to be correlated, as in Bound et al. (1984). That is, we allow the error in predicting R&D reporting to be correlated with the error in the valuation equation, as it will be if the nonrandomness of the sample affects valuation. The model that we estimate is written as follows:

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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.

$$d_i = 1(Z_i\delta + \varepsilon_{1i} > 0)$$
$$y_i = d_i \bullet (X_i\beta + \varepsilon_{2i})$$
$$\begin{pmatrix}\varepsilon_{1i} \\ \varepsilon_{2i}\end{pmatrix} \sim \mathrm{N}\left[\begin{pmatrix}0 \\ 0\end{pmatrix}, \begin{pmatrix}1 & \rho\sigma_2 \\ \rho\sigma_2 & \sigma_2^2\end{pmatrix}\right]$$

where d_i is a dummy equal to one when R&D is reported and y_i is the value of Tobin's q (the market to book ratio). For this model, it can be shown that the regression of y on X for the observed data has the following form:

$$E[y_i \mid d_i = 1, X_i] = X_i\beta + E[\varepsilon_{2i} \mid \varepsilon_{1i} > -Z_i\delta] = X_i\beta + \rho\sigma_2\lambda(Z_i\delta)$$

where λ(.) is the inverse Mills' ratio for the normal distribution. Note that the last term drops out when the correlation ρ is zero. The well-known Heckman two-step estimator for this model involves estimating δ using a Probit equation, forming the estimated λ, and including it in the equation with the other regressors. Although we use maximum likelihood for estimation because it is more efficient, we use 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, or Das, Newey, and Vella 2003). This test is reported in the bottom row of Table 7, and it shows that although the US sample violates the normality assumption, the samples for all the other countries do not.

Turning to the results, the top panel of Table 7 presents the results of the estimation of the probability of reporting R&D jointly with the regression equation. With the possible exception of the debt to assets ratio, our predictor variables have a fair amount of explanatory power in the expected directions, with size, industry R&D intensity, and industry growth all being positive for performing and reporting R&D, with the exception of industry growth for France and Italy. 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 find that having a majority shareholder reduces the probability of reporting R&D slightly in Germany and Italy, but has not effect in France.

The bottom panel of Table 7 reports the estimates of the regression equation in the sample selection model. For all the countries, the correlation of the error terms in the two equations is 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 is confirmed when we look at the coefficient estimates, which are almost identical to those in Table 6. Thus the conclusion from our sample selection estimation is 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.

------- *Insert Table 7 about here* -------

Panel model estimates

In Table 8 we show the results of the first differences and of the fixed (within) and random effects estimation of equation [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 decreases the precision of the estimates considerably in France and Italy, and somewhat in the UK. Overall, the R&D capital coefficients are insignificantly different from zero but with large standard errors. In contrast, the German and U.S. results are similar to those obtained in levels. When we estimate fixed- and random-effects specifications we find that there exist 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 do 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 is 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 are confirmed by the coefficient estimates of the within and the random effects estimators: for France (respectively .26 and .38), Germany (respectively .27 and .30), Italy (respectively .74 and .65) and even the U.S. (respectively .15 and .22, but with much smaller standard errors), they are still significant and roughly consistent with those shown in Table 6. Thus controlling for firm effects makes little difference to the estimates (other than increasing the standard errors). The puzzle is now the UK, where R&D is valued very highly in the cross section, but zero within firm. That is firms can have permanently higher market value due to their R&D strategies, but changing those strategies has little impact. Note also that after controlling for firm effects, intangible assets are still valued roughly at unity in France (.66), Germany (1.56) and Italy (1.77), while they have a substantially lower valuation in the UK (.24) and the US (.35).

Our tentative conclusion from this investigation into the presence of firm fixed effects in the valuation relation is that they do not seem to be important for the continental economies. For Germany, we can have some confidence in this conclusion, but for the other two countries, the sample sizes are probably too small to produce a definitive test.

---- Insert Table 8 about here ------

5. 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 (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 such an investigation is important for several reasons: the importance of these economies, the specificity of their corporate governance 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 2, 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 valuation analysis. First, we built a sample selection model in which the probability that a firm discloses R&D investments was modeled as a Probit function of firm size and leverage as well as industry-specific variables (R&D intensity and output growth). Second, we used panel techniques in order to account for left out unobserved firm-specific effects.

The results we obtained exhibit several interesting features. German and French samples show a statistically significant and robust positive evaluation of the R&D capital by the stock market. Moreover, when we correct for fixed effects, the valuation of the R&D capital in the countries is very similar. However, 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 U.S. and the UK. Nevertheless, when we correct for firm effects, we find similar results also for the Anglo-Saxon countries, suggesting in line with previous contributions (Hall 1993a, 1993b 2000; Oriani and Sobrero 2003) that the market valuation of R&D expenditures has decreased in all the countries over time. In addition, the very narrow gap observed between the R&D coefficients across countries is consistent with the anecdotal evidence of a progressive alignment of the European financial markets to the Anglo-Saxon ones within the last two decades (Rajan and Zingales, 2003)

An interesting finding is that 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 (2002) find much higher productivity of this R&D in the UK than in Germany confirms that our result is probably real.

A second interesting finding is that in France and Italy, only firms without large shareholders place a significantly positive value on R&D spending, even though there are quite a few firms controlled by a major shareholder that spend positive amounts on R&D. In some cases, especially in France, this may be because the large shareholder is the government (e.g., Bull, which is in our sample). In other cases, it may simply be that majority holders do not respond to market pressures that signal low values for their investment strategies. One avenue for future research could be further exploration of the relationship between the types of large shareholders (governments, families, or other firms) and R&D strategy.

The evidence presented in this paper poses important questions to managers and policy makers. First, 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 percent) is too low, and that the value of R&D depreciates considerably faster.[17] This interpretation moves the focus to the reasons why these investment are depreciating so quickly. One possibility is that the pace of competition in some industries is leading to more rapid obsolescence of the results of any particular firm's innovative activities. Our data for the continental European countries is insufficient to investigate this question in a detailed manner but it might be possible to explore the issue more thoroughly using data for the United States.

On the other hand, it is possible that lack of an R&D disclosure obligation in these countries has a negative effect on R&D evaluation, exacerbating the information asymmetries between firms and investors that critically concern R&D investments (see for example, Aboody and Lev, 2000). 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. From this perspective, it would be interesting to analyze the possible effects of a reform in national accounting rules making R&D disclosure compulsory on the market value of R&D in the other European countries. But it is important to note that for France and Germany at least, the undervaluation of R&D is at the same level that it is for the United States, which makes this explanation less likely here.

Alternatively, the focus could be on the effectiveness of the R&D investments. In fact, the lower evaluation of firms' R&D capital in the countries analyzed as compared to the Anglo-Saxon countries could be explained by lower expected economic returns. This problem would relate to the management of R&D at the firm level. In particular, it would be interesting to search for inter-firm differences in the value of the R&D capital that could be explained by firm-specific variables related to the nature and the orientation of the company innovation activities. The results presented in this paper show that the valuation of R&D investments is affected by corporate ownership structure. This is especially true for Italy, for which we found a positive relationship between R&D and market value only after controlling for the eventual control by the major shareholder. This evidence would require a further investigation on the effect of corporate control dynamics on the innovation activities at the firm level.

[17] A "back of the envelope" computation suggests a depreciation rate of about 50 percent per year. The shadow value is roughly 0.35, which is the ratio of $(g + \delta) = (.08+.15)$ to $(.08+.55)$.

However, 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). In fact, the goal of government-funding is usually to produce just this result. Accordingly, it would be interesting to investigate the nature and the characteristics of the publicly funded firms' R&D investments in the analyzed countries, in order to disentangle the differences in their expected economic returns as compared to privately financed investments. This theme is 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.

Finally, if we relax the assumption of market efficiency, the research could address the question of the short-termism of the stock market, with particular respect to the underestimation of the firms' R&D investments, whose existence has already been suggested by the previous empirical studies of Lev and Sougiannis (1996) and Chan et al. (2001).

This study, which has explored the valuation of R&D for firms in previously unstudied European countries and provided new and sometimes puzzling evidence, can stimulate the actual debate on R&D financing in the European Union and represent a first step into a deeper investigation of the interactions between firms, markets and institutions in countries where the corporate governance regime is significantly different from that of the United States or the United Kingdom.

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Appendix A

Kernel Regression Estimation

This appendix describes an exploration of the functional form of the Tobin's q-R&D relationship using semi-parametric methods and data for the United States, where the sample size is large enough to use this methodology. The kernel regression of a variable *y* on a variable *x* is the conditional expectation of *y* given *x*, estimated in the following way:

$$f(y \mid x) = \frac{\sum_{i=1}^{N} y_i \kappa\left(\frac{x - x_i}{h}\right)}{\sum_{i=1}^{N} \kappa\left(\frac{x - x_i}{h}\right)}$$

where κ(.) is a kernel function, usually the normal density, and *h* is the bandwidth, which may be varied to obtain curves with varying degrees of smoothness. Silverman (1986) showed that the following bandwidth had good mean squared error properties:

$$h = h_0 0.9 N^{-0.2}$$

where h_0 is the standard deviation of the *x* variable and *N* is the sample size.

Figures A1 and A2 show the results for a kernel regression of logQ on K/A, plotted as a function of K/A and then as a function of log(K/A) so that the lower end of the distribution can be seen. In computing these regressions, we first removed the average value of logQ in each year from the observations in that year. This was necessary in order to make our regression simple; kernel regressions with many variables are difficult to compute and plot.

The figures show that the relationship between logQ and K/A has a shape that is approximately logistic. Up until a value of K/A equal to approximately .05 (a log of -3), the log of Tobin's q is not a function of K/A, suggesting that the firm's R&D capital is not "salient" to investors when it is very small. From .05 to around 1 (a log of 0), the relationship is approximately linear. The curvature gradually flattens for values of K/A above 1, so that there are diminishing returns to having a very R&D-intensive firm.

Our conclusion from the kernel regression results is that the nonlinear model provides a pretty good approximation to the data, since it has the necessary flattening of curvature at higher K/A ratios. These results also suggested that we treat small values of K/A as zeroes (or missing), which is what we did.

------Insert Figure A1 about here -------

------Insert Figure A2 about here -------

Appendix B

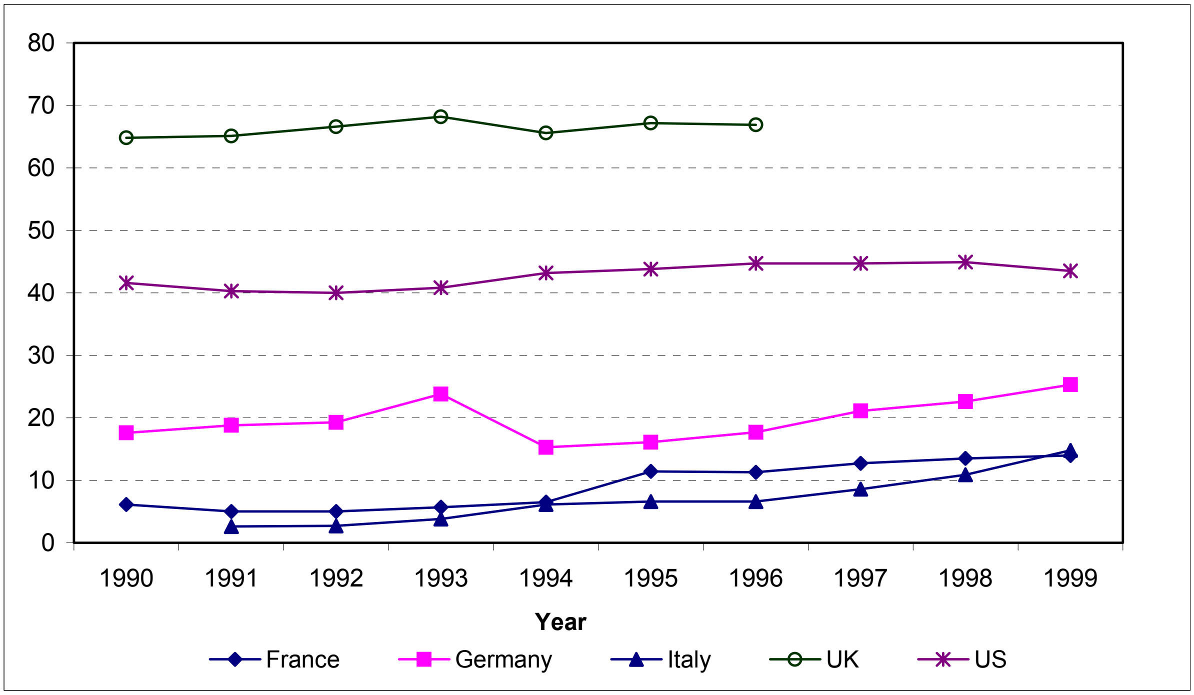
OLS: When K_5/A and K_{10}/A are introduced in the equation in the place of K/A, we observe some minor changes in the results. The coefficient of K_5/A is a bit lower in France (.21 instead of .28) and Germany (.25 instead of .34), where it is still significant respectively at five and one percent. The coefficients of K_{10}/A in the two countries is closer to that of K/A (.27 in France and .29 in Germany). In Italy the two coefficients are negative and not statistically significant, as in the original estimation.

TABLE B1
OLS results (Dependent variable: ln V/A)

	France	*Germany*	*Italy*	*France*	*Germany*	*Italy*	*France*	*Germany*	*Italy*
K/A	.28***	.34***	-.15						
	(.08)	(.05)	(.12)						
K_5/A				.21**	.25***	-.18	.		
				(.07)	(.04)	(.14)			
K_{10}/A							.27**	.29***	-.21
							(.08)	(.04)	(.14)
I/A	.87***	.99**	.78**	.89***	.90***	.78**	.87***	.96***	.77**
	(.11)	(.18)	(.26)	(.11)	(.18)	(.26)	(.11)	(.18)	(.26)
ln (S)	-.03	-.06***	-.07***	-.02	-.05***	-.07***	-.02	-.06***	-.06***
	(.02)	(.01)	(.01)	(.02)	(.01)	(.01)	(.02)	(.01)	(.01)
Const.	.57*	.77***	1.04***	.58*	.70***	1.05***	.58*	.72***	1.05***
	(.25)	(.19)	(.22)	(.25)	(.19)	(.22)	(.25)	(.19)	(.22)
Observations	308	339	267	308	339	267	308	339	267
Adjusted R^2	.22	.25	.18	.21	.26	.18	.21	.26	.18

*** *$p < .001$; ** $p < .01$; * $p < .05$; † $p < .1$; standard errors in parentheses*
All equations include a complete set of year dummies.

FIGURE 1
Percentage of domestic shares held by institutional investors



Source: OECD, Institutional Investors database

FIGURE 2
Average V/A ratio (only R&D-doing firms)

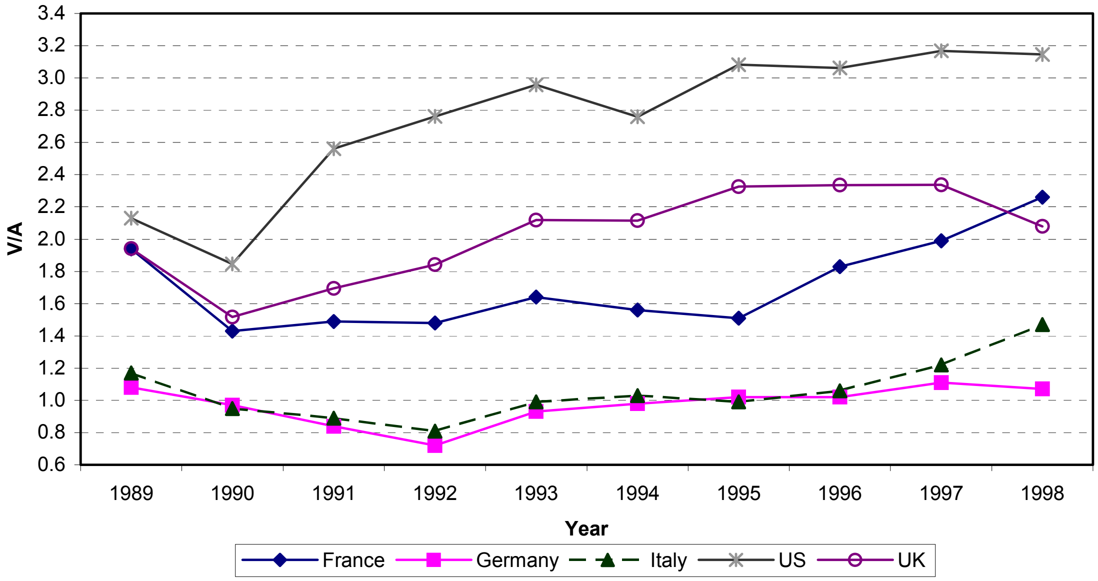


FIGURE 3
Average R/A ratio (only R&D-doing firms)

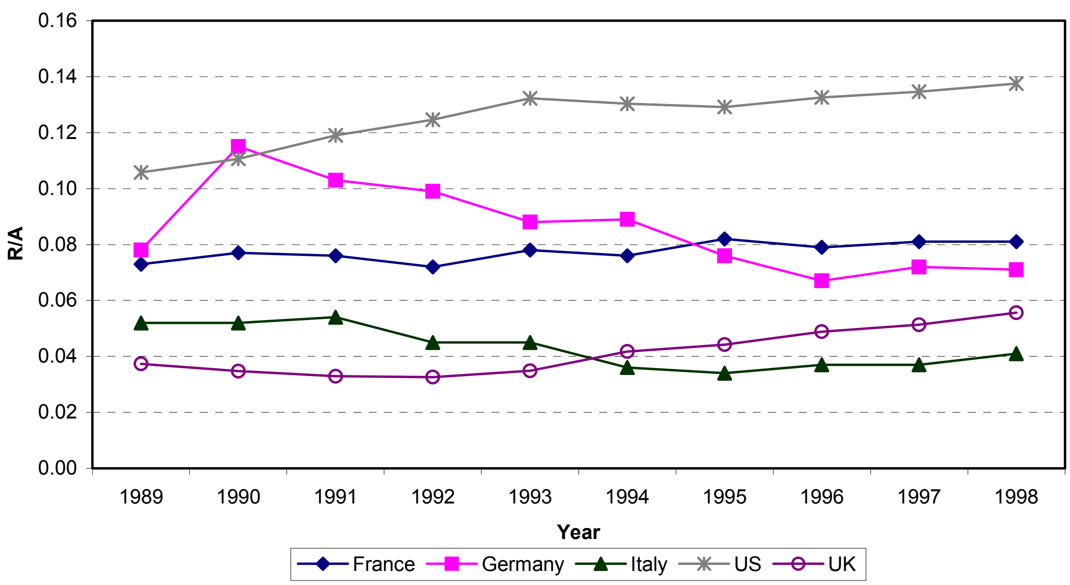


FIGURE 4
Average K/A ratio (only R&D-doing firms)

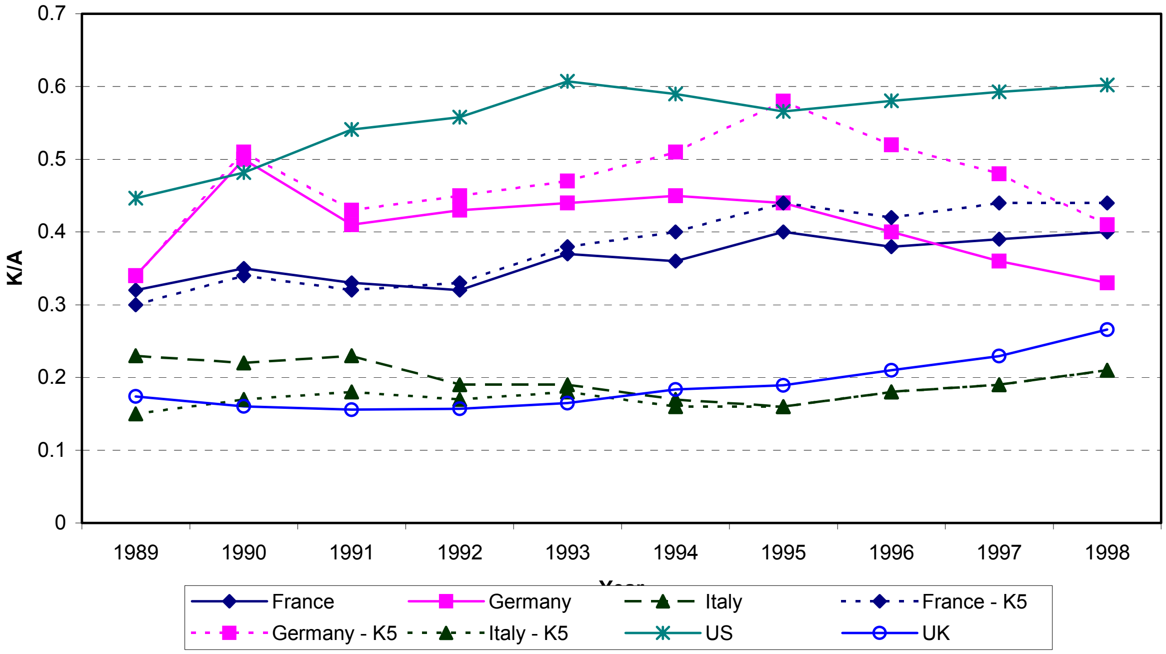


FIGURE 5
Average I/A ratio (only R&D-doing firms)

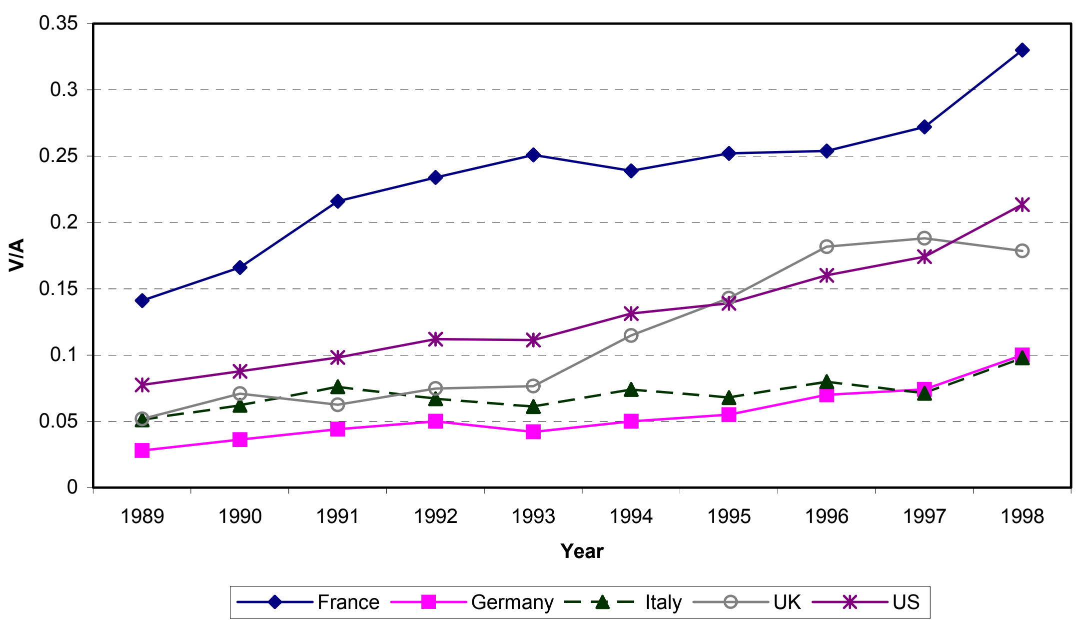


Figure A1
Kernel regression for log Q on K/A (year means removed)

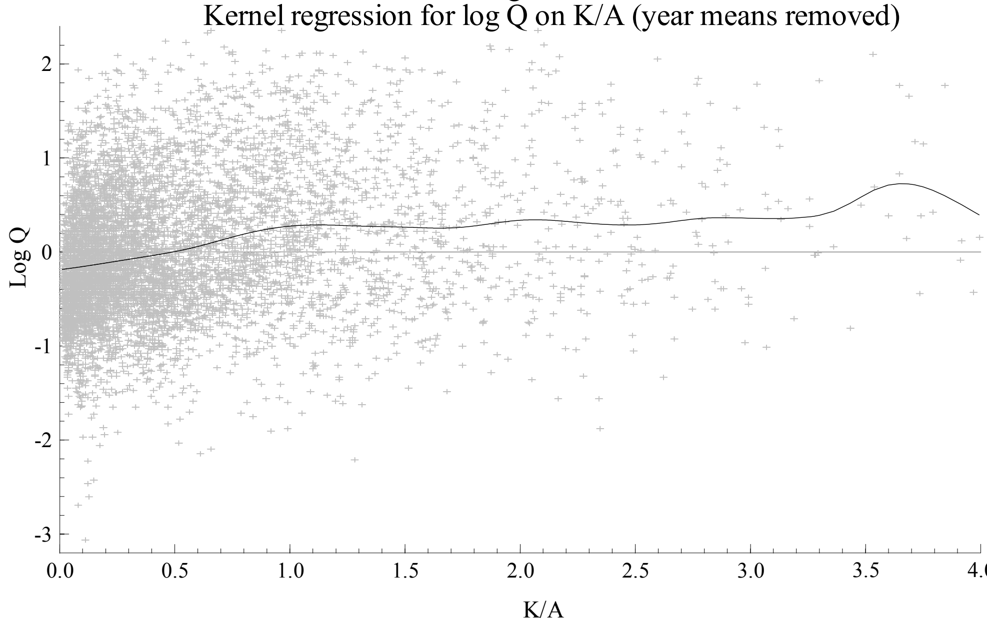


Figure A2
Kernel Regression of LogQ on Log(K/A)

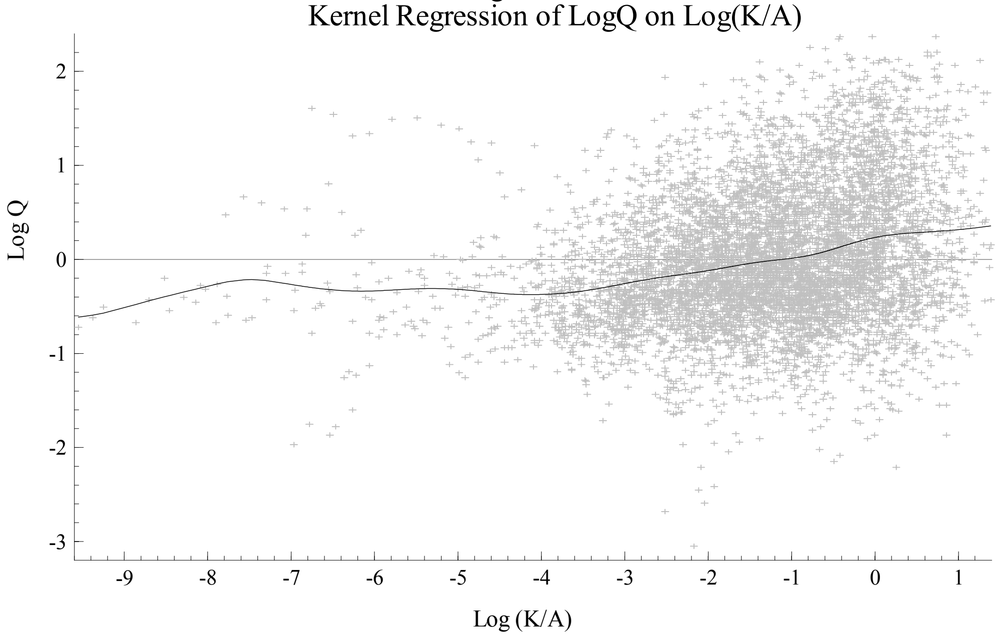


TABLE 1
Accounting regimes for R&D expenditures: Summary

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 (2001); Alexander and Archer (1998)

TABLE 2

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

	France			*Germany*			*Italy*			*United Kingdom*			*United States*		
Industry	Firms	Obs.	Obs. (%)	Firms	Obs.	Obs. (%)	Firms	Obs.	Obs. (%)	Firms	Obs.	Obs. (%)	Firms	Obs.	Obs. (%)
Food & tobacco	5	31	10.1%	0	0	0.0%	3	23	9.6%	18	119	5.9%	23	174	2.5%
Textiles & apparel	1	8	2.6%	2	4	1.2%	1	3	1.3%	10	72	3.6%	13	105	1.5%
Wood & furniture	0	0	0.0%	0	0	0.0%	0	0	0.0%	5	34	1.7%	20	165	2.4%
Paper & 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 & 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 & 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	6,980	99.8%
Reporting R&D in some years	29	100	32.5%	69	237	70.3%	14	57	23.8%	195	1,172	58.3%	4	15	0.2%
Total for R&D-doers	51	462		79	741		40	306		305	2,571		870	7,006	
Total non-R&D Doers	76	683		204	1,947		46	379		287	2,152		496	3,886	
Total	127	1,145		283	2,688		86	685		592	4,723		1,366	10,892	

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

Country	Sample	manufacturing & utility firms+	Sample as a share of population
France*	7,897	15,601	50.6%
Germany*	18,180	28,577	63.6%
Italy*	3,631	5,096	71.2%
United Kingdom**	7,753	8,411	92.2%
United States***	109,102	188,644	57.8%

+Source: ANBERD database, OECD.
*Millions of euros
**Millions of pounds sterling
***1997, Millions of US dollars

TABLE 4

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

	France			*Germany*			*Italy*			*UK*			*US*		
Variable	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*	1,591	***	340	1518	***	175	975	***	225	218	***	59	472	***	283
A*	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
INDGR	0.036	**	0.026	0.034	***	0.012	0.062		0.055	0.051	***	0.040	0.052	***	0.039
Control>33%	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		--
K5/A	0.392		--	0.479		--	0.175		--						
K10/A	0.358		--	0.439		--	0.162		--						
Observations	308		837	337		2,351	239		446	2005		2689	6995		3897
Share of obs.	26.9%		73.1%	12.5%		87.5%	34.9%		65.1%	42.7%		57.3%	64.2%		35.8%

*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: *** $p < .01$; ** $p < .05$; * $p < .1$

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

Model	*OLS*					*NLLS*				
	U.S.	*U.K.*	*France*	*Germany*	*Italy*	*U.S.*	*U.K.*	*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	1.36	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 < .01; ** p < .05; * p < .1; heteroskedastic-consistent standard errors in parentheses

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 (p-value)#	13.1*** (.000)	3.04** (.049)	5.25*** (.006)	27.2*** (.000)	11.2*** (.004)	19.0*** (.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 < .01; ** p < .05; * p < .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.

TABLE 7
Sample selection estimates

	France	*Germany*	*Italy+*	*UK*	*USA*
Observations	1145	2688	685	4694	10892
Number reporting R&D	308	337	239	2005	6995
Share reporting R&D	26.9%	12.5%	34.9%	42.7%	64.2%
Probit equation for reporting R&D#					
Debt to assets	.092 (.051)*	.050 (.022)***	-.059 (.081)	-.041 (.048)	.002 (.009)
Log sales	.081 (.008)***	.052 (.003)***	.112 (.011)***	.085 (.004)***	.050 (.003)***
Industry R&D/sales	1.46 (.32)***	1.58 (.13)***	4.28 (.91)***	4.55 (.41)***	3.19 (.12)***
Industry growth	-0.04 (.38)	0.34 (.11)***	0.41 (.27)	.75 (.14)***	.72 (.10)***
D (control>33%)	0.01 (.03)	-.02 (.01)**	-0.09 (.03)***	--	--
Scaled R-squared	0.177	0.254	0.300	0.234	0.143
Regression equation with dependent variable Log (V/A)					
K/A	0.68 (.19)***	0.38 (.03)***	0.73 (.26)***	.90 (.11)***	.33 (.02)***
K/A * D(control)	-0.49 (.20)**	-0.17 (.10)	-0.89 (.21)***	--	--
I/A	0.69 (.14)***	0.94 (.14)***	1.17 (.28)***	.59 (.08)***	.60 (.04)***
Log (sales)	0.08 (.06)	-.06 (.02)***	-0.05 (.01)***	.08 (.02)***	.02 (.01)***
D (control>50%)	0.49 (.11)***	-0.04 (.07)	0.23 (.07)***	--	--
Estimated correlation	0.53 (.37)	0.00 (.20)	0.05 (.14)	.08 (.17)	-.05 (.06)
Estimated std. error	0.52 (.09)***	0.37 (.02)***	0.32 (.02)***	.68 (.01)***	.66 (.01)***
Log likelihood	-768.2	-834.8	-404.7	-4,714.1	-13,300.0
quasi-F-test for normality (num df=2, p-value)	3.18 (.043)**	1.59 (.206)	2.07 (.128)	1.21 (.299)	70.8 (.000)***
Likelihood ratio test for control variables (df=2)	25.4 (.000)***	6.3 (.043)**	10.9 (.004)***	--	--

#Dp/Dx, the change in probability for a unit change in x, and its standard error is shown.
*** p < .01; ** p < .05; * p < .1; heteroskedastic-consistent standard errors in parentheses
+the estimates for Italy converged to the boundary of the parameter space for rho.
The specification test for normality is based on the two-step estimator with additional Mills' ratio terms included.
All equations include a complete set of year dummies.

TABLE 8
Panel fixed and random effects estimation (Dependent variable: ln V/A)

	First Differences					Within (Fixed Effects)					Random effects				
	Germany	*France*	*Italy*	*UK*	*USA*	*Germany*	*France*	*Italy*	*UK*	*USA*	*Germany*	*France*	*Italy*	*UK*	*USA*
Observations	251	256	199	1653	6124	337	308	239	2005	6995	337	308	239	2005	6995
No of firms	67	47	39	280	869	79	51	40	304	870	79	51	40	304	870
K/A	0.26***	-0.61	-0.16	0.16	0.31***	0.27***	0.26	0.74	-0.01	0.15***	0.30***	0.38	0.65	0.50***	0.22***
	(0.04)	*(0.62)*	*(1.12)*	*(0.21)*	*(0.05)*	*(0.07)*	*(0.24)*	*(0.51)*	*(0.15)*	*(0.04)*	*(0.07)*	*(0.24)*	*(0.46)*	*(0.07)*	*(0.02)*
K/A * D(control)	0.01	-0.63	-0.28	--	--	-0.55*	0.12	0.34	--	--	-0.27*	-0.09	-0.40	--	--
	(0.23)	*(0.64)*	*(1.32)*			*(0.33)*	*(0.30)*	*(0.76)*			*(0.15)*	*(0.26)*	*(0.52)*		
I/A	0.85***	0.42**	1.53**	0.19**	0.31***	1.56***	0.66***	1.77***	0.24**	0.35***	1.32***	0.70***	1.63***	0.35***	0.42***
	(0.28)	*(0.17)*	*(0.62)*	*(0.08)*	*(0.04)*	*(0.21)*	*(0.16)*	*(0.47)*	*(0.12)*	*(0.04)*	*(0.18)*	*(0.12)*	*(0.28)*	*(0.07)*	*(0.03)*
ln (S)	-0.06	0.11	0.10	-0.51***	0.31***	-0.09	-0.02	0.01	-0.27***	0.18***	-0.07***	0.03	-0.04	-0.01	0.05***
	(0.13)	*(0.14)*	*(0.11)*	*(0.08)*	*(0.04)*	*(0.11)*	*(0.14)*	*(0.08)*	*(0.04)*	*(0.03)*	*(0.02)*	*(0.03)*	*(0.02)*	*(0.02)*	*(0.01)*
D (control>33%)	--	--	--	--	--	--	--	--	--	--	0.05	0.27	0.20	--	--
											(0.10)	*(0.16)*	*(0.13)*		
Durbin-Watson	1.33	1.57	1.68	1.62	2.15	1.10	0.93	0.99	0.89	0.91	0.23	0.20	0.28	0.18	0.27
Adjusted R2	0.258	0.164	0.295	0.217	0.121	0.768	0.799	0.712	0.800	0.715	0.225	0.251	0.173	0.115	0.152
Hausman test for correlated effects						8.48	8.09	3.17	80.4***	107.5***					
(p-value)						(.292)	(.044)	(.673)	(.000)	(.000)					

*** p < .01; ** p < .05; * p < .1; heteroskedastic-consistent standard errors in parentheses.
All equations include a complete set of year dummies.