R&D Productivity: An Exploratory International Study

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This draft – March 3, 2007

The authors would like to acknowledge the financial support of the HEC Foundation and the Research Center at the HEC School of Management (project F013). They would also like to thank Gualterio Brugger (discussant), Sandra Chamberlain, Elroy Dimson, Jennifer Francis, Dan Givoly, Zhaoyang Gu, Philip Joos, William Kinney, Baruch Lev, Michaël Rockinger, Katherine Schipper, Douglas Skinner, Andrew Stark (discussant), Theodore Sougiannis (discussant) and Eli Talmor, for their helpful comments. They also acknowledge participants at the following conferences: "Values and prices of intangible assets" (2002, Bocconi University), CRECCI (2002, University of Bordeaux IV), ESSEC (2003, Accounting and Control Research Seminar, Paris), "The International Accounting Summer Conference" (2003, Göttingen University), and the "London Business School Accounting Symposium" (2003). The authors are particularly grateful to the three anonymous reviewers and Ahmed Riahi-Belkaoui (the editor) for their insightful suggestions. The authors are Members of the GREGHEC, CNRS unit, UMR 2959. Finally, they are indebted to Ann Gallon for her much appreciated editorial help. Any remaining errors or omissions are our own.

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Abstract

The objective of this exploratory paper is to investigate the impact of R&D expenditures on company performance. R&D activities play an essential role in the future economic development and financial performance of firms. However, with the exception of some American studies, the economic effectiveness of such investment is seldom demonstrated explicitly by the literature, and to the best of our knowledge, there are no existing studies on R&D productivity taking an international approach. Our research design is based on an earnings equation associating earnings with recorded assets, R&D expenditures and selling, general and administrative (SG&A) expenses (proxying for advertising expenses). We determine a rate of return on R&D for each given sample of firms in six developed countries. Our results corroborate previous studies of American companies, which found that reported earnings, adjusted for expensing of R&D, reflect realized benefits from R&D. This study provides further evidence on the positive contribution of R&D activities to future company performance, although this contribution can vary from one country to another. Finally, being exploratory in nature, this article suggests several areas for investigation.

Keywords: R&D productivity, R&D profitability, R&D investment, international study

Data availability: Data used in this study were obtained from the Worldscope Database. A list of the sample firms is available from the authors upon request.

I. INTRODUCTION

The growth of R&D expenditures over the last two or three decades, together with the continuous substitution of knowledge (intangible) capital for physical (tangible) capital in firms' production functions, has elevated the importance of R&D in the performance of business enterprises (Lev 1999). A number of research studies (e.g., Lev and Sougiannis 1996) find a direct, positive correlation between a company's R&D expenditures and economic growth, future income, and productivity improvements. Lev (1999) also argues that outputs from R&D constitute the principal assets of high-tech (e.g., biotechnology) firms. He goes on to show that R&D expenditures contributes substantially to the firm's productivity and value creation, and that the financial market integrates these contributions into the firm's stock price. These studies have generally been based on a single-country sample of companies, mainly from the United States.

Our objective, however, is to explore the impact of R&D expenditures on company performance on an international basis, by estimating the relationship between R&D expenditures and subsequent earnings for a large cross-section of firms involved in R&D. Our result is the determination of a rate of R&D productivity for each given sample of firms in six developed countries.

In order to estimate R&D productivity, we define operating income as a function of the company's tangible and intangible assets. We then split intangible assets into R&D expenditures and other intangible assets. Our model assumes that a firm's operating income is a linear function of current and lagged values of research and development (Hand 2001). By including tangible assets and advertising expenses in the estimation model, we control for the contribution of other factors to productivity.

Lev and Sougiannis (1996) demonstrated that the useful life of R&D capital varied from five to nine years, depending on the sector. Constrained by data availability and the period surveyed (ten years), we have applied a six-year period in all cases. Our study covers the period 1991-2000, as the database we use (Worldscope) contains fewer pre-1991 data. We apply our model to each country using time-series of annual cross sections. Cross-sectional estimation was used because of estimation problems with individual firms' time series, resulting from a lack of sufficient data per company. We can thus only calculate sample-wide estimates based on individual countries. The six R&D coefficients to be estimated by our econometric technique reflect the "contribution to current operating income of each vintage of R&D expenditures" (Aboody and Lev 2001) or, in other words, the "long-run effect of R&D investment on earnings" (Sougiannis 1994). Once we have estimated the contribution to income of each vintage of R&D, we can estimate the total contribution of one currency unit of R&D to current and future income by adding up the annual contributions, and deriving the rate of return on R&D investment.

The initial sample is comprised of non-financial companies in most of the European Union member states plus eight other countries (Australia, Brazil, Canada, Japan, New Zealand, Norway, Switzerland and the USA). However, because complete information on R&D expenses over at least six consecutive years in the period 1991-2000 was unavailable for certain countries, only six country-based firm samples were finally used: Canada, Germany, Japan, Switzerland, the UK, and the USA.

Our results show that the R&D productivity rates calculated on country-based samples vary widely, from 17.6% (Swiss sample) to 35.6 % (Japanese sample).

Our work is related to a major stream of financial accounting research: R&D and value creation. It contributes to the literature both in research scope and in methodology. First, this is the first time the scope of an R&D productivity study has been extended internationally. The R&D productivity rates estimated in this study for the various countries are consistent with the hypothesis that R&D expenditures contribute to the future earnings of the firm. The disparity of R&D productivity rates between samples from different countries suggests complexity in determinants influencing the performance of a firm's R&D activity, and this opens a fertile field for future study. Regarding methodology, our research enriches previous approaches by extending the use of the polynomial Almon lag procedure to resolve the multicolinearity problem between highly autocorrelated independent variables in a multi-country database. Our results suggest the polynomial Almon lag procedure is suitable to remedy such a common problem in accounting research.

For practitioners, our study contributes in two main ways. First, the R&D productivity rates estimated in this research provide strong evidence that R&D investment contributes to companies' economic growth, future income, and productivity improvements across national boundaries. This result should encourage firms to focus more on this high value-added activity. It also provides support for the idea that investors and analysts should pay more attention to firms with substantial intangibles and R&D expenditures, most of which are not recognized in firms' financial statements[1], since there is more information asymmetry between managers and investors and more inherent uncertainty about corporate value in these

[1] Even in countries like France, where the capitalization of R&D expenditures is permitted under certain conditions, firms seldom choose this option. Our survey on the 2000 annual reports of the 250 largest French listed companies shows that only 93 mention an R&D activity, and of these only 18 capitalize their R&D expenditures.

firms than others (Barth et al. 2001). Secondly, our study provides a means of assessing the average return on investment of R&D, which is a major concern for companies and "crucial for optimal resource allocation at both corporate and national levels" (Aboody and Lev 2001).

The remainder of this paper is organized as follows. Section two provides a review of the relevant literature and presents our main hypothesis and the models used in the article. Section three raises some variable measurement issues while Section four deals with some model estimation issues. Section five sets out the sample, and Section six presents the statistical results. Section seven provides a summary and concluding remarks.

II. HYPOTHESIS AND MODELS

Sougiannis (1994) notes that earlier work by researchers such as Johnson (1967) and Newman (1968) used cross-sectional correlation and regression analysis, "but detected no significant relationship between R&D and future benefits". Sougiannis suggests that these results may be attributed to the small sample sizes, research design, econometric techniques, and quality of the R&D data used.

Many surveys have evidenced the contribution of research and development (R&D) to corporate growth and performance (Sougiannis 1994; Aboody and Lev 2001), as well as to the market value of the firm. For example, studies such as Ben-Zion (1978), Griliches (1981), Hirschey (1982), Hirschey and Weygandt (1985), Bublitz and Ettredge (1989), and Shevlin (1991) found a significant relationship between market values and R&D expenditures. Previous research has identified a positive and significant contemporaneous relationship between (1) stock prices and R&D expenditures and (2) stock returns and increases in R&D investments (see Cañibano et al. 2000).

As early as 1982, Ravenscraft and Scherer (1982) had already observed considerable evidence that industrial research and development (R&D) was an important, perhaps even the most important, contributor to technological progress and hence productivity growth (Griliches 1979; Mansfield 1980; Scherer 1982).

Over the years, many studies have documented that R&D spending affects future profitability (Grabowski and Mueller 1978; Ravenscraft and Scherer 1982; Sougiannis 1994; Nissim and Thomas 2000).

It is important to indicate that the over-mentioned studies limit often to the U.S. data. The main objective of this study is to go beyond one national border and to explore the R&D productivity in an international context.

As Lev and Sougiannis (1996) and Aboody and Lev (2001) explain, R&D productivity can be estimated using a profit function, where operating income (OI_{it}) of firm i in year t is defined as a function of its property, plant and equipment (tangible assets), PPE_{it}, and intangible assets, IA_{it}:

$$OI_{it} = g(PPE_{it}, IA_{it}) + \varepsilon_{it} \tag{1}$$

While operating income and tangible assets (at historical costs) are disclosed in the financial statements, the value of intangible capital, IA, is not published and thus has to be estimated. The intangible assets (IA_{it}) include R&D capital. Concentrating principally on R&D, we define its value as the sum of all unamortized past R&D expenditures. These expenditures are assumed to generate current and future income. We replace IA_{it} by RDC_{it} + OIA_{it} (which represents other -i.e. non R&D- intangible assets - e.g., unrecorded brand values). We arrive at the following formula:

$$OI_{it} = g(PPE_{it}, \sum_k \alpha_k RD_{i,t-k} + OIA_{it}) + \varepsilon_{it} \tag{2}$$

where α_k is the contribution of one currency unit R&D expenditure in year $t - k$ ($k = 0, \ldots, N$) to subsequent earnings.

Given this development, we can formulate our hypothesis as:

> H: The R&D expenditures over a given period are positively associated with earnings of the last year of the period.

III. VARIABLE MEASUREMENT ISSUES

The model below (3), derived from equation (2), will be applied. Adapted from Aboody and Lev (2001) and Sougiannis (1994), it is used to estimate the returns on R&D, by a least squares regression method associating earnings with recorded assets and R&D expenditures.

$$OI/S_{it} = \alpha_0 + \alpha_1 (TA/S)_{i,t-1} + \sum_k \alpha_{2,k} (RD/S)_{i,t-k} + \alpha_3 (SGA/S)_{i,t-1} + \varepsilon_{it} \tag{3}$$

This model assumes that a firm’s operating income is a linear function of current and k lagged values of research and development (Hand 2001). This equation is applied to each country using time-series of annual cross sections. Cross-sectional estimation was used because of problems with estimation with individual firms’ time series, resulting from a lack of sufficient data per company. We can thus only calculate estimates on country-based firm samples.

The variables in model (3) are defined as follows.

- Operating income, OI_{it}, is measured as reported operating income (sales minus cost of sales) before depreciation, expensing of R&D expenditures and Selling, General and Administrative (SG&A) expenses. Depreciation, R&D expenses, and SG&A expenses are excluded from (added back to) operating income since they represent largely ad hoc write-offs of the independent variables in (3) – tangible and intangible assets. In other words, adjustment of R&D expenditures is required in order to avoid including them in both sides of the equation, as a component of both earnings and independent variables.

- Sales, S_{it}, annual sales in t.
- Total assets, TA_{it}, consist of all assets reported in the balance sheet (see Aboody and Lev 2001).
- R&D capital, the major intangible asset, is represented here by the lag structure of annual R&D expenditures, where R&D expenditures stretch over the preceding five years, since Lev and Sougiannis (1996) showed in their study the minimal duration of R&D benefits is five years.
- $SGA_{i,t-1}$, represents Selling, General and Administrative expenses for the previous year; its purpose is to approximate the intangible capital generated by expenses other than R&D. Advertising expenses (particularly the costs of product promotion or brand development) could be incorporated as a separate intangible asset. Although we have not included advertising expenses in our model (3), there is a potential omitted variable problem, in a situation where R&D capital is the only intangible asset present in the model. However, the database we used (Worldscope, see below) does not carry figures for advertising expenses, and so we decided to take SG&A expenses as a proxy for advertising expenses. We are aware that this approximation likely introduces a bias: SG&A expenses are much higher than advertising expenses, and as a result, R&D capital will be diminished in the model. This factor will be taken into account in interpreting our results. In theory, advertising capital (proxied by the SG&A capital) could be determined in the same way as is R&D capital; i.e., using a lag structure (current and past expenditures). However, this method was unsuitable as our database did not contain SG&A expenses for every year, and a reasonable number of consecutive years is required. We decided instead to refer to past SG&A expenses alone, in keeping with the method applied by Aboody and Lev (2001) to advertising expenses, which is similar to the practice of using advertising intensity (advertising expenses over sales) to proxy for advertising capital (see Hall 1993). Empirical studies (e.g., Ravenscraft and Scherer 1982; Bublitz and Ettredge 1989; Hall 1993) have shown that advertising expenses have a shorter-term impact than R&D on subsequent earnings (generally within one or two years). For this reason, approximating advertising capital (replaced in our model by SG&A capital) by an annual advertising

expense (in our model, an annual SG&A expense) could perhaps accurately proxy for the value of brands in our model (3).

IV. MODEL ESTIMATION ISSUES

Model (3) raises several important econometric issues which must be considered.

Model

The six R&D coefficients estimated in our econometric model, $\alpha_{2,k}$, reflect the "contribution to current operating income of each vintage of R&D expenditures" (Aboody and Lev 2001) or, in other words, the "long-run effect of R&D investment on earnings" (Sougiannis 1994).

Once we have estimated the contribution to income of each vintage of R&D, we can estimate the total contribution of one R&D currency unit to current and future income by adding up the annual contributions, and deriving the rate of return on R&D investment.

Model (3) concerns the relationship between current operating income and current and lagged R&D expenditures. The lagged estimated coefficient for the previous year (year t–1) can thus be considered to represent the impact of the previous year's R&D expense on current operating income. This relationship can also be interpreted as the impact of current year R&D expense on next year's operating income, and for the purposes of our paper, we use this second interpretation.

R&D is, of course, not the sole contributor to companies' operating income. Physical assets contribute as well. Accordingly, we include the values of assets (TA/S) in the estimation model (3), in order to focus on the incremental contribution of R&D to corporate productivity. Coefficient α_1 therefore represents the gross pre-tax benefit for a given single currency unit[2] investment in assets. In other words, in estimating the contribution of R&D to productivity, we control for the contribution of other factors to productivity.

Heteroscedasticity

The variables are scaled (divided) by sales to mitigate the econometric problem of heteroscedasticity, due to the varying sizes of sample companies.

Serial correlation

In estimating distributed lags, our model (3) is used to estimate the effects of R&D expenditures on earnings: $\sum_k \alpha_{2,k}$. In this context, we must investigate the possibility of high autocorrelation between consecutive R&D variables (R&D lag structure) in the formula

[2] The currency unit is not specified since each country's currency is used.

$\sum_k \alpha_{2,k}(RD/S)_{i,t-k}$ contained in the model (3). One solution is to reduce the parameters, i.e., estimate a smaller number of parameters than the number of lags, *k*, in the time series. This can be done based on an a priori hypothesis that the lag coefficients, $\alpha_{2,k}$, which correspond to R&D benefits, follow a general pattern such as a polynomial structure. This improvement to the model has a drawback: the estimation of an a priori structure for the coefficients.

In view of all this, in order to guarantee the robustness of our findings, we apply the polynomial Almon lag procedure (for details, see Almon 1965; Johnston 1984, 352-358; Griffiths et al. 1993; for an application, see Sougiannis 1994; Lev and Sougiannis 1996). Lev and Sougiannis (1996) state very clearly that "the Almon procedure has a flexibility advantage over several competitors (e.g., the Koyck lag or the binomial lag), since it allows experimentation with polynomials of various degrees and the consequent fitting of a suitable polynomial to the data". The method used to determine the $\alpha_{2,k}$ coefficients is based on a second-order polynomial.

A breakdown of the model (3) over the 6 years is as follows:

$$OI/S_{it} = \alpha_0 + \alpha_1 TA/S_{i,t-1} + \alpha_{2,0} RD/S_{i,t-0} + \alpha_{2,1} RD/S_{i,t-1} + \alpha_{2,2} RD/S_{i,t-2} + \alpha_{2,3} RD/S_{i,t-3} + \alpha_{2,4} RD/S_{i,t-4} + \alpha_{2,5} RD/S_{i,t-5} + \alpha_3 SGA/S_{i,t-1} + \varepsilon_{it} \quad \text{(3bis)}$$

The polynomial is a second-order type:

$$\alpha_{2,k} = ak^2 + bk + c$$

Additionally, we included the constraints: $\alpha_{2,k} \geq 0$.

This can be broken down as follows:

$$\alpha_{2,0} = a0^2 + b0 + c = c \geq 0$$
$$\alpha_{2,1} = a1^2 + b1 + c = a + b + c \geq 0$$
$$\alpha_{2,2} = a2^2 + b2 + c = 4a + 2b + c \geq 0$$
$$\alpha_{2,3} = a3^2 + b3 + c = 9a + 3b + c \geq 0$$
$$\alpha_{2,4} = a4^2 + b4 + c = 16a + 4b + c \geq 0$$
$$\alpha_{2,5} = a5^2 + b5 + c = 25a + 5b + c \geq 0$$

Each $\alpha_{2,k}$ coefficient is then replaced by the corresponding polynomial equation.

$$OI/S_{it} = \alpha_0 + \alpha_1 TA/S_{i,t-1} + cRD/S_{i,t-0} + (a+b+c)RD/S_{i,t-1} + (4a+2b+c)RD/S_{i,t-2} + (9a+3b+c)RD/S_{i,t-3} + (16a+4b+c)RD/S_{i,t-4} + (25a+5b+c)RD/S_{i,t-5} + \alpha_3 SGA/S_{i,t-1} + \varepsilon_{it}$$

Variables a, b and c are factored out to generate model (4).

$$
\begin{aligned}
OI/S_{it} &= \alpha_0 + \alpha_1 TA/S_{i,t-1} \\
&+ c(RD/S_{i,t-0} + RD/S_{i,t-1} + RD/S_{i,t-2} + RD/S_{i,t-3} + RD/S_{i,t-4} + RD/S_{i,t-5}) \\
&+ b(RD/S_{i,t-1} + 2RD/S_{i,t-2} + 3RD/S_{i,t-3} + 4RD/S_{i,t-4} + 5RD/S_{i,t-5}) \\
&+ a(RD/S_{i,t-1} + 4RD/S_{i,t-2} + 9RD/S_{i,t-3} + 16RD/S_{i,t-4} + 25RD/S_{i,t-5}) \\
&+ \alpha_3 SGA/S_{i,t-1} + \varepsilon_{it}
\end{aligned} \tag{4}
$$

Number of years

Lev and Sougiannis (1996) suggest that the length of the statistically significant lagged R&D coefficients, $\alpha_{2,k}$, indicates "the average duration of R&D benefits (useful life of R&D capital)". These durations vary from five to nine years, depending on the sector. In view of data availability and the period surveyed (ten years), we have applied a six-year period in all cases. The data used for estimation of R&D productivity cover the 10-year period 1991-2000 including five six-year periods: 2000-1995, 1999-1994, 1998-1993, 1997-1992 and 1996-1991.

V. SAMPLE

We estimate a rate of return on R&D based on country-firm sample, and therefore use an international database. Our data was taken from the Worldscope database, which contains the financial statements of listed companies from 53 countries: a total of 37,606 companies as of September 1, 2002 (28,256 in active operation). Our study covers the period 1991-2000, as Worldscope contains fewer pre-1991 data. Table 1 below shows details of our sample.

Insert table 1 about here

The initial sample was composed of firms from most of the European Union member states plus eight other countries (Australia, Brazil, Canada, Japan, New Zealand, Norway, Switzerland and the USA). Only non-financial companies were included (Worldscope General Industry Classification: 01 Industrial, 02 Utility and 03 Transportation). The number of companies from each country is indicated in Table 1, column (1).

We then identified which of these companies had their R&D expenditure data well documented in the Worldscope base. An advantage of Worldscope over other databases is that the R&D data it contains derive not only from published income statement figures, but also from figures included elsewhere in the annual report: notes to financial statements, or the Management Discussion and Analysis (MD&A).

Although collection of data in this way considerably increases the number of companies and items covered[3], many companies were in fact lost from the original sample because (a)

[3] We compared Worldscope with the Osiris database (Bureau VanDijk) which largely includes the same companies, but only records R&D expenditure for those that disclose a specific "R&D expenses" item in their income statement.

not all companies have an R&D activity, (b) in some countries R&D expenses are not disclosed in any part of the annual report. This situation is clearly noticeable in countries such as Australia (1,009 companies in the database, with only 50 companies disclosing R&D figures) and Spain (195 companies, but only 2 that publish R&D figures). Table 1, column (2) shows how many companies disclosed R&D expenses over at least six consecutive years in the period 1991-2000.

Finally, as explained above, our model requires input of the SG&A expenses for the previous year. Several countries do not publish SG&A expenses in their income statements, mainly because the income statement shows expenses classified by nature (purchases of raw materials and merchandise, change in inventories, external expenses, taxes other than income tax, salaries and related costs, depreciation and amortization expenses, etc). We therefore selected companies for which we had SG&A expenses for at least one year between 1995 and 1999. The number of companies remaining after this further filter is shown in column (3) of Table 1.

When the number of companies from a country is small, we encounter a difficulty. To solve this problem, we went back to the regression of our model (4) as shown earlier, to determine whether, if coefficients a, b and c were significant, they could be used even with a small sample. This meant we had to eliminate certain countries where the data were not sufficient to generate significant a, b and c coefficients, and so the Greek, Irish and Norwegian samples were excluded.

Since for estimation purposes we require each company to have at least six years of data (in the 10-year period 1991-2000), some sample companies with fewer years are not included in the estimation. Some sample companies have shorter time series than the 10 years examined; this is why the number of companies varies between the five periods studied, and is generally lower than the number indicated in Table 1, column (3). Columns (4) and (5) of Table 1 show the minimum and maximum number of companies included in the statistical model, according to the period and column (6) displays the average number of companies over the five studied periods. In order not to have the results in small samples being driven by a few dominant firms, e.g., Nokia for the Finnish sample, we eliminate the countries with an average number of companies lower than 20.

In the end, six country-based firm samples were retained in the sample: Canada, Germany, Japan, Switzerland, the UK, and the USA. For comparison purposes, we could refer to the sample used by the UK Department of Trade and Industry (London), which since 1991 has published an annual “R&D Scoreboard” prepared by Company Reporting Limited

(Edinburgh). This Scoreboard includes two different samples: a certain number of UK companies (597 in 2000/2001) and the top 500 R&D investing international companies (300 companies in recent years). The countries best represented are the USA (208) and Japan (127). Our sample covers a much broader range.

In theory, the accounting treatment applied to R&D in each individual country is a factor to be taken into account. For practical purposes, we took the view that since capitalization of R&D expenses, even in the several countries that allow it (e.g., Canada, Denmark and France) is still the exception, it is acceptable to consider that R&D expenditure is in fact included in the income statement expenses of the companies included in our sample. As Bhagat and Welch (1995) had already observed, in our sample countries, firms overwhelmingly expense (rather than capitalize) R&D.

It was quite straightforward to obtain the other data (operating income, sales and total assets) from the Worldscope base[4].

VI. RESULTS

Descriptive statistics

Table 2 shows the R&D intensity by year and by country. The table provides some interesting results: R&D intensity varies a lot from one nation to another. Meanwhile, within each country, it is very difficult to see a general increasing or decreasing trend during the 1990s: while the R&D intensity decreases steadily in Germany, it increases significantly in the UK.

Insert Table 2 about here

Regressions

The model was used to obtain separate estimates for the five following periods: 2000-1995, 1999-1994, 1998-1993, 1997-1992 and 1996-1991[5].

Next, the means were calculated for the five periods in order to determine six R&D estimates. The results are shown by country in Table 3.

Insert Table 3 about here

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[4] In all, the following Worldscope variables were used: "OperatingIncomeAfterDepr": Operating income after depreciation; "Sales": Net sales or revenues; "DepreciationDepletAmortExpense": Depreciation, depletion and amortization expense; "TotalAssets": Total assets; "ResearchAndDevelopmentExpense": R&D expense; "SellingGeneralAdminExpense": Selling, General and Administrative Expense.

[5] The regressions were programmed into the SAS software. It was not possible to use its PDLREG Procedure, which contains an Almon lag algorithm, because it can only function in a time-series context. We used the MODEL Procedure, because it allows estimating a regression model subject to constraints on the regression coefficients.

The internal rate of return of R&D is the rate required to discount the series of six annual contributions to one currency unit. In other words, one currency unit is the present value of the six R&D estimates, discounted at that rate.

The sum of the R&D coefficients, $\sum \hat{\alpha}_{2,k}$, represents the (undiscounted) total effect of one currency unit invested in R&D on current and future operating income.

The coefficients for each period are averaged and reported in the far right-hand column of the table. These mean values are very important, as they will be used to calculate the rate of return on R&D (see Lev and Sougiannis 1996, 122).

Table 4 below lists the rates of return on R&D for the six country-based firm samples examined.

Insert Table 4 about here

The tangible capital coefficients, α_1, show the contribution of total assets at the start of the year to operating income. These coefficients range from 0.050 (Japanese sample) to 0.11 (German sample) and reflect the average annual return on total assets by country-based sample (see Lev and Sougiannis 1996, 120, for sectorial results for the USA over an earlier period than ours).

Similarly, the SG&A intensity coefficients, α_3, indicate the contribution of SG&A at the start of the year to operating income. These coefficients range from 0.445 (British sample) to 1.130 (Swiss sample). A single currency unit of SG&A expenditure is thus associated with an increase in operating income (before SG&A) of roughly 0.4-1.1 currency units. Lev and Sougiannis (1996, 120) present sectorial results for the USA over an earlier period.

VII. SUMMARY AND CONCLUDING REMARKS

Our study is the first to attempt to define rates of return on R&D taking an international approach. Basing our work on the Almon lag procedure, we computed the rates of return on R&D investment for six country-based firm samples. For the countries concerned, the results validated the hypothesis that R&D expenditures contribute to the future earnings of a firm. Our findings also revealed wide variations in rates, from 17.6% (Swiss sample) to 35.6 % (Japanese sample).

Several limitations should be mentioned. First, the decision to use SG&A expenses as a proxy for advertising expenses reduces the R&D-coefficient estimates in our model, and very probably the actual rates of return are higher. This would not be surprising, as operating income is a “gross” level of earnings, i.e., stated before a certain number of charges including depreciation expenses, R&D expenses and SG&A expenses.

Looking at the results for countries for which we had fewer observations (Canada, Germany, and Switzerland), the impact of a small number of large companies on the country's overall results must still be taken into consideration, despite the elimination of even smaller samples.

National differences in accounting treatment of R&D expenses were not integrated in detail. It was assumed, based on past literature, that most companies do not capitalize R&D, even when accounting standards allow them the option.

Finally, in econometric terms, there is the cost of misspecification - that is, assuming that the lag structure is second-order polynomial Almon when it is not (Hand 2001). We must also turn to the important issue of causality. So far, we have interpreted model (3) in a strictly causal manner—from R&D to income. R&D expenditures (and other assets) have been assumed to contribute to current and future income. The fact that assets contribute to profits is undisputed. However, a simultaneous reverse causation cannot be ruled out. A decrease in current or expected productivity (due, say, to sharp increases in energy prices, or the onset of an economic recession) will undoubtedly have a dampening effect on firms' willingness to invest in R&D. As explained by Barth et al. (1998), "this possibility raises concerns about whether any relation we document" using equation (4) "is attributable to simultaneity bias".

The disparity of R&D productivity rates between firm samples from different countries suggests a high degree of complexity in determinants influencing the performance of a firm's R&D activity, opening a fertile field for future research.

We suggest four major areas for investigation. The first group of determinants concerns firm-specific characteristics. Bah and Dumontier (2001) focused on the relationship between a firm's R&D intensity and its corporate financial policies. It would be also interesting to analyze the impact of a company's characteristics and its corporate financial policies on its R&D productivity. Possible determinants would include debt ratio, dividend policy, cash on hand, R&D intensity, β risk, ownership structure, size, cross-listing, industry, etc.

The second group of determinants relates to macroeconomic characteristics of a firm's home country, such as the origin of R&D financing (government or private financing), GDP per capita (GDP is a good indicator of the overall productivity of a nation) and annual growth rate, the proportion of high-technology exports in manufactured exports, etc.

It would also be interesting to study the marginal effect of legal systems on the relationship between R&D and profitability (e.g., the differential effects of common law versus code law on the relationship).

Finally, a fourth area of research would be the study of the stock return performance over the same period. International rates of return on R&D investment (operating performance) should be consistent with stock rates of return (market performance), if markets are efficient.

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TABLE 1
Countries and number of companies by country

Country	Number of non financial companies in Worldscope	Companies with R&D expense available (6 years minimum)	Companies with R&D expense (6 years minimum) and SG&A expense available (1 year minimum)	Minimum number of companies	Maximum number of companies	Average number of companies (over the five studied periods)	Countries eliminated (E) or included (I) in the study
	(1)	(2)	(3)	(4)	(5)	(6)	
Australia	1,009	50	3	-	-	-	E[1]
Austria	130	7	2	-	-	-	E[1]
Belgium	171	2	2	-	-	-	E[1]
Brazil	393	3	3	-	-	-	E[1]
Canada	857	69	49	19	24	21.2	I
Denmark	210	15	12	8	9	8.4	E[3]
Finland	186	39	26	8	15	13	E[3]
France	1,142	76	38	15	23	18.8	E[3]
Germany	1,019	69	46	17	31	28	I
Greece	297	11	11	-	-	-	E[2]
Ireland	99	11	9	-	-	-	E[2]
Italy	310	27	27	12	16	13.2	E[3]
Japan	3,283	808	796	320	592	522.8	I
Luxembourg	20	2	2	-	-	-	E[1]
Netherlands	278	20	15	6	10	8.4	E[3]
New Zealand	99	4	0	-	-	-	E[1]
Norway	248	14	8	-	-	-	E[2]
Spain	195	2	0	-	-	-	E[1]
Sweden	419	24	21	6	14	10	E[3]
Switzerland	238	45	42	12	27	21	I
UK	2,465	235	234	154	176	167.2	I
USA	10,838	1,762	1,711	572	993	784	I
Total	23,906	3,295	3,057	1,149	1,930	-	

1. These countries are eliminated because of the too small number of companies with R&D expense (6 years minimum) and SG&A expense available (1 year minimum).
2. These countries are eliminated because their data are not sufficient to generate significant coefficients of the Almon lag estimates.
3. These countries are eliminated because the average number of companies over the five studies periods is too small (lower that 20).

TABLE 2
R&D intensity by year and by country-based firm sample

	2000	1999	1998	1997	1996	1995	1994	1993	1992	1991	Mean (1)
Canada	0.082	0.043	0.043	0.046	0.047	0.040	0.039	0.049	0.052	0.059	0.050
Germany	0.044	0.054	0.049	0.050	0.048	0.048	0.050	0.064	0.069	0.071	0.055
Japan	0.037	0.033	0.032	0.031	0.023	0.023	0.025	0.025	0.023	0.022	0.027
Switzerland	0.049	0.051	0.051	0.049	0.049	0.051	0.054	0.052	0.055	0.065	0.052
UK	0.033	0.033	0.034	0.035	0.027	0.026	0.026	0.026	0.025	0.024	0.029
USA	0.066	0.057	0.051	0.047	0.047	0.047	0.049	0.050	0.058	0.058	0.053
Mean (2)	0.311	0.271	0.26	0.258	0.241	0.235	0.243	0.266	0.282	0.299	0.266

R&D intensity = R&D expenses/Sales revenue
(1) Mean by country
(2) Mean by year

TABLE 3
Statistical results by country-based firm sample

Canada						
Period	1995-2000	1994-1999	1993-1998	1992-1997	1991-1996	Mean
No. of firms	19	20	21	22	24	21.2
$\hat{\alpha}_0$	0.086	0.108	0.131	0.218	0.107	
$\hat{\alpha}_1$	0.067	0.050	0.070	0.029	0.070	0.057
(sig. level)	0.01	0.10	NS	NS	0.01	
$\hat{\alpha}_3$	0.902	0.568	0.404	0.237	0.801	0.582
(sig. level)	0.01	0.10	0.10	0.10	0.01	
$\hat{a}$	0.018	0.053	0.053	0.031	0.034	
(sig. level)	0.01	0.01	0.01	0.01	0.01	
$\hat{b}$	-0.163	-0.473	-0.481	-0.282	-0.305	
(sig. level)	0.01	0.01	0.01	0.01	0.01	
$\hat{c}$	0.363	1.052	1.069	0.626	0.678	
(sig. level)	0.01	0.01	0.01	0.01	0.01	
						-1 (a)
$\hat{\alpha}_{2,0}$	0.363	1.052	1.069	0.626	0.678	0.758
$\hat{\alpha}_{2,1}$	0.218	0.631	0.642	0.375	0.407	0.455
$\hat{\alpha}_{2,2}$	0.109	0.316	0.321	0.188	0.203	0.227
$\hat{\alpha}_{2,3}$	0.036	0.105	0.107	0.063	0.068	0.076
$\hat{\alpha}_{2,4}$	0	0	0	0	0	0
$\hat{\alpha}_{2,5}$	0	0	0	0	0	0
$\sum_k \hat{\alpha}_{2,k}$	0.726	2.104	2.139	1.251	1.356	1.515
Adj. R²	0.8722	0.8	0.6467	0.7438	0.838	
Rate of return on R&D						28.5%

Coefficient estimates of regressions (3) (coefficients α_s) and (4) (coefficients a, b and c), run cross-sectionally for each of the six-year periods 1995-2000, 1994-1999, 1993-1998, 1992-1997 and 1991-1996, using the Almon lag procedure (with indication of sig. level):

$$OI/S_{it} = \alpha_0 + \alpha_1 (TA/S)_{i,t-1} + \sum_k \alpha_{2,k} (RD/S)_{i,t-k} + \alpha_3 (SGA/S)_{i,t-1} + \varepsilon_{it} \quad (3)$$

$$\begin{aligned} OI/S_{it} &= \alpha_0 + \alpha_1 TA/S_{i,t-1} \\ &+ c(RD/S_{i,t-0} + RD/S_{i,t-1} + RD/S_{i,t-2} + RD/S_{i,t-3} + RD/S_{i,t-4} + RD/S_{i,t-5}) \\ &+ b(RD/S_{i,t-1} + 2RD/S_{i,t-2} + 3RD/S_{i,t-3} + 4RD/S_{i,t-4} + 5RD/S_{i,t-5}) \qquad (4) \\ &+ a(RD/S_{i,t-1} + 4RD/S_{i,t-2} + 9RD/S_{i,t-3} + 16RD/S_{i,t-4} + 25RD/S_{i,t-5}) \\ &+ \alpha_3 SGA/S_{i,t-1} + \varepsilon_{it} \end{aligned}$$

OI/S_{it} = annual operating income (before depreciation, R&D expenses, and Selling, General and Administrative (SG&A) expenses) over sales of firm *i* in year *t*, $TA/S_{i,t-1}$ = balance sheet value of total assets at year *t-1*, over sales, $RD/S_{i,t-k}$ = annual R&D expenditures over sales of firm *i* (current and lagged R&D expenditures), $SGA/S_{i,t-1}$ = Selling, General and Administrative (SG&A) over sales, of firm *i*, of year *t-1*.

Adj. R²: related to equation (4)

(a): figure added to compute the internal rate of return.

Germany						
Period	1995-2000	1994-1999	1993-1998	1992-1997	1991-1996	Mean
No. of firms	27	31	25		17	28
$\hat{\alpha}_0$	-0.053	-0.017	-0.043		0.094	
$\hat{\alpha}_1$	0.145	0.172	0.156		-0.033	0.110
(sig. level)	0.01	0.01	0.01		NS	
$\hat{\alpha}_3$	1.037	0.571	0.939		1.094	0.910
(sig. level)	0.01	0.01	0.01		0.01	
$\hat{a}$	0.029	0.050	0.033		0.030	
(sig. level)	0.01	0.01	0.01		0.01	
$\hat{b}$	-0.264	-0.446	-0.295		-0.269	
(sig. level)	0.01	0.01	0.01		0.01	
$\hat{c}$	0.587	0.990	0.654		0.598	
(sig. level)	0.01	0.01	0.01		0.01	
						-1
$\hat{\alpha}_{2,0}$	0.587	0.990	0.654		0.598	0.707
$\hat{\alpha}_{2,1}$	0.352	0.594	0.393		0.359	0.424
$\hat{\alpha}_{2,2}$	0.176	0.297	0.196		0.179	0.212
$\hat{\alpha}_{2,3}$	0.059	0.099	0.065		0.060	0.071
$\hat{\alpha}_{2,4}$	0	0	0		0	0
$\hat{\alpha}_{2,5}$	0	0	0		0	0
$\sum_k \hat{\alpha}_{2,k}$	1.175	1.981	1.309		1.196	1.415
Adj. R^2	0.9164	0.626	0.817		0.8679	
Rate of return on R&D						23.1%

Data not significant in 1997-1992.

Japan						
Period	1995-2000	1994-1999	1993-1998	1992-1997	1991-1996	Mean
No. of firms	320	563	592	584	555	522.8
$\hat{\alpha}_0$	0.015	0.003	-0.004	0.006	0.029	
$\hat{\alpha}_1$	0.056	0.056	0.063	0.050	0.027	0.050
(sig. level)	0.01	0.01	0.01	0.01	0.01	
$\hat{\alpha}_3$	1.010	0.993	1.012	1.021	0.995	1.006
(sig. level)	0.01	0.01	0.01	0.01	0.01	
$\hat{a}$	0.039	0.040	0.040	0.041	0.037	
(sig. level)	0.01	0.01	0.01	0.01	0.01	
$\hat{b}$	-0.348	-0.360	-0.358	-0.373	-0.335	
(sig. level)	0.01	0.01	0.01	0.01	0.01	
$\hat{c}$	0.788	0.815	0.806	0.830	0.796	
(sig. level)	0.01	0.01	0.01	0.01	0.01	
						-1
$\hat{\alpha}_{2,0}$	0.788	0.815	0.806	0.830	0.796	0.807
$\hat{\alpha}_{2,1}$	0.478	0.495	0.487	0.498	0.498	0.491
$\hat{\alpha}_{2,2}$	0.246	0.255	0.249	0.249	0.275	0.255
$\hat{\alpha}_{2,3}$	0.091	0.095	0.089	0.083	0.126	0.097
$\hat{\alpha}_{2,4}$	0.014	0.015	0.010	0	0.051	0.018
$\hat{\alpha}_{2,5}$	0.014	0.015	0.010	0	0.051	0.018
$\sum_k \hat{\alpha}_{2,k}$	1.630	1.691	1.651	1.660	1.797	1.686
Adj. R^2	0.8473	0.841	0.8526	0.8606	0.848	
Rate of return on R&D						35.6%

Switzerland						
Period	1995-2000	1994-1999	1993-1998	1992-1997	1991-1996	Mean
No. of firms	27	27	24	15	12	21
$\hat{\alpha}_0$	-0.041	-0.012	-0.001	0.023	-0.020	
$\hat{\alpha}_1$	0.062	0.089	0.093	0.042	0.072	0.071
(sig. level)	0.10	0.01	0.05	0.10	0.05	
$\hat{\alpha}_3$	1.252	1.135	0.889	1.089	1.285	1.130
(sig. level)	0.01	0.01	0.01	0.01	0.01	
$\hat{a}$	0.036	0.029	0.045	0.035	0.021	
(sig. level)	0.01	0.01	0.01	0.01	0.01	
$\hat{b}$	-0.320	-0.258	-0.401	-0.315	-0.187	
(sig. level)	0.01	0.01	0.01	0.01	0.01	
$\hat{c}$	0.710	0.574	0.891	0.699	0.415	
(sig. level)	0.01	0.01	0.01	0.01	0.01	
						-1
$\hat{\alpha}_{2,0}$	0.710	0.574	0.891	0.699	0.415	0.658
$\hat{\alpha}_{2,1}$	0.426	0.344	0.535	0.420	0.249	0.395
$\hat{\alpha}_{2,2}$	0.213	0.172	0.267	0.210	0.125	0.197
$\hat{\alpha}_{2,3}$	0.071	0.057	0.089	0.070	0.042	0.066
$\hat{\alpha}_{2,4}$	0	0	0	0	0	0
$\hat{\alpha}_{2,5}$	0	0	0	0	0	0
$\sum_k \hat{\alpha}_{2,k}$	1.420	1.148	1.782	1.399	0.830	1.316
Adj. R^2	0.9143	0.852	0.8719	0.969	0.9822	
Rate of return on R&D						17.6%

UK						
Period	1995-2000	1994-1999	1993-1998	1992-1997	1991-1996	Mean
No. of firms	154	165	176	173	168	167.2
$\hat{\alpha}_0$	0.153	0.097	0.233	0.234	0.080	
$\hat{\alpha}_1$	0.072	0.088	0.026	0.089	0.082	0.071
(sig. level)	0.01	0.01	NS	0.01	0.01	
$\hat{\alpha}_3$	0.561	0.749	0.362	0.109		0.445
(sig. level)	0.01	0.01	0.01	0.10	0.01	
$\hat{a}$	0.030	0.039	0.036	0.037	0.031	
(sig. level)	0.01	0.01	0.01	0.01	0.01	
$\hat{b}$	-0.271	-0.349	-0.321	-0.333	-0.276	
(sig. level)	0.01	0.01	0.01	0.01	0.01	
$\hat{c}$	0.602	0.776	0.713	0.739	0.614	
(sig. level)	0.01	0.01	0.01	0.01	0.01	
						-1
$\hat{\alpha}_{2,0}$	0.60168	0.7759	0.71325	0.73902	0.61408	0.689
$\hat{\alpha}_{2,1}$	0.36101	0.46554	0.42795	0.44341	0.36845	0.413
$\hat{\alpha}_{2,2}$	0.1805	0.23277	0.21397	0.22171	0.18422	0.207
$\hat{\alpha}_{2,3}$	0.06017	0.07759	0.07132	0.0739	0.06141	0.069
$\hat{\alpha}_{2,4}$	0	0	0	0	0	0
$\hat{\alpha}_{2,5}$	0	0	0	0	0	0
$\sum_k \hat{\alpha}_{2,k}$	1.203	1.552	1.426	1.478	1.228	1.378
Adj. R^2	0.552	0.6456	0.4379	0.3011	0.7558	
Rate of return						21.0%

USA						
Period	1995-2000	1994-1999	1993-1998	1992-1997	1991-1996	Mean
No. of firms	993	824	572	747	786	784
$\hat{\alpha}_0$	0.201	0.180	0.060	0.130	0.111	
$\hat{\alpha}_1$	0.029	0.059	0.100	0.045	0.056	0.058
(sig. level)	0.01	0.01	0.01	0.01	0.01	
$\hat{\alpha}_3$	0.524	0.495	0.936	0.782	0.830	0.713
(sig. level)	0.01	0.01	0.01	0.01	0.01	
$\hat{a}$	0.035	0.035	0.033	0.032	0.030	
(sig. level)	0.01	0.01	0.01	0.01	0.01	
$\hat{b}$	-0.316	-0.317	-0.293	-0.289	-0.267	
(sig. level)	0.01	0.01	0.01	0.01	0.01	
$\hat{c}$	0.702	0.705	0.651	0.641	0.594	
(sig. level)	0.01	0.01	0.01	0.01	0.01	
						-1
$\hat{\alpha}_{2,0}$	0.702	0.705	0.651	0.641	0.594	0.659
$\hat{\alpha}_{2,1}$	0.421	0.423	0.391	0.385	0.356	0.395
$\hat{\alpha}_{2,2}$	0.211	0.211	0.195	0.192	0.178	0.198
$\hat{\alpha}_{2,3}$	0.070	0.070	0.065	0.064	0.059	0.066
$\hat{\alpha}_{2,4}$	0	0	0	0	0	0
$\hat{\alpha}_{2,5}$	0	0	0	0	0	0
$\sum_k \hat{\alpha}_{2,k}$	1.405	1.409	1.302	1.283	1.188	1.317
Adj. R^2	0.5669	0.5484	0.7734	0.6914	0.6476	
Rate of return on R&D						17.7%

TABLE 4
Rates of return on R&D by country-based firm sample

Canada	28.5%
Germany	23.1%
Japan	35.6%
Switzerland	17.6%
UK	21.0%
USA	17.7%