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VALUE OF INTANGIBLES ARISING FROM R&D ACTIVITIES

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VALUE OF INTANGIBLES ARISING FROM R&D ACTIVITIES

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Abstract

This paper develops an empirical approach using econometric techniques for panel data which aims to contribute to the reduction/elimination of the deviation between the book and market value of firms. Based on 20 of the firms with the largest number of patents granted between 1996 and 2006, the results show that: (i) the increase in the return on equity following from an increase in the share of investment in R&D is greater in the long run; (ii) there is a positive relationship between the results (and the value of firms) and R&D activities; (iii) by updating the additional periodical results generated by investment in R&D, the present value of the intangible asset can be determined.

JEL Classification: C23, G12; G31, M41, O32.
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1. Introduction

In this paper an empirical approach is developed which aims to contribute to the reduction (or elimination) of the deviation between the book value and the market value of firms, a deviation which is largely a result of the incorrect valuation of intangible assets, in particular those that result from Research and Development (R&D) activities – e.g., Bueno, 1998; and Cañibano, 2001. In fact, since intangible assets play such a crucial role in developing firms' competitive advantages, it is not surprising that their undervaluation leads to a widening of the gap between the book and market values.

Recognising that the valuation of those assets is a delicate matter (e.g., Kerssens van Drongelen and Cook, 1997; Anthony and Govindarajan, 2007), in this paper we hope to develop a framework which, based as it is on econometric techniques, enables us to gauge the value of an intangible. The starting point for this framework is the specification behind the neoclassical Cobb-Douglas production function.[1]

We take into consideration that productivity growth relies on the technological progress stemming from R&D activities that takes the form of intangible assets (e.g., Griliches, 1992 and 1994; Lev and Sougiannis, 1996), and in line with several studies (e.g., Alpar and Kim, 1990**;** Siegel and Griliches, 1992; Dieweri and Smith, 1994; Kwon and Stoneman, 1995; Siegel, 1997; and Brynjolfsson and Hitt, 1995 and 2003), we aim to analyze the effect of that technological progress resulting from R&D activities on the results achieved by firms.

Brynjolfsson and Hitt (2003), for example, noted that investment by firms in information and communication technologies has, with some time lags, very significant effects on firms' results. Moreover, they find that the annual return on intangible assets, following from risky investments by firms, is very rewarding.

[1] The production function is called neoclassical because: (i) it has constant returns to scale; (ii) the marginal productivity of the inputs is positive but decreasing; and (iii) it has satisfied the Inada conditions.

In terms of the specific importance of investment in R&D, several studies show that these investments are related to firms' productivity, sales, results and market value. An overview of some of these studies follows. Kamien and Schwartz (1975), for example, emphasize the positive relationship between results and R&D activities; these authors conclude that the future benefits are a consequence of current R&D activity.

Johnson and Pazderka (1993) carried out a study which aimed to assess the relationship between R&D spending reported by firms and their market value, based on a sample of Canadian firms. They found a statistically significant positive relationship between investment in R&D and the market value of firms.

Sougiannis (1994) sought to determine the productivity of R&D activity, examining the impact it might have in the long run on the accounting results and market value, based on an accounting policy of capitalization. This author identified a positive relationship between investment in R&D and the market value of firms in the sample. This effect was divided into a direct and indirect effect. The direct effect consisted in analyzing the relationship between investment in R&D and the value of the firm. The indirect effect focused on whether the book value of the benefits of those investments influenced the market value. The results showed that the indirect effect was much larger than the direct effect.

Lev and Sougiannis (1996) estimated the contribution of investments in R&D to the development of future results. Their results suggest that one dollar invested in R&D at constant prices provided gains of 1.70 to 2.60 dollars over a subsequent period of five to nine years. These results clearly illustrate the positive relationship between investment in R&D and the results of firms. Subsequently, Lev and Sougiannis (1999) found that capitalized investments in R&D are associated with the listing of firms' future shares and that this association appears as a result of a risk factor inherent to R&D activity.

Mcquail *et al.* (2005) expanded on the study by Lev and Sougiannis (1999), introducing a further variable – the intensity of the capitalized R&D – and found that firms which invest heavily in R&D are rewarded with higher listed share prices due to the increased risk associated with those investments.

Han and Manry (2004) analyzed the Korean market – where firms can choose to capitalize or recognize R&D investments as expenses – and found that investments in R&D are positively related to share prices. The authors concluded that the capitalization of R&D is relevant for investors and when investments in R&D are considered as expenses, the effect on the price per share is lower than the effect observed when R&D is capitalized.

Oswald (2008) analyzed whether the value of R&D capitalized was relevant in a sample of listed firms in the United Kingdom. The results suggest that the value of the gains and of equity capital do not depend on the accounting policy – i.e. from this point of view, the decision to capitalize or expense does not have an impact.

Existing empirical investigation on the subject (e.g., Callen and Morel, 2005; and Balbester *et al*., 2003) has also found that R&D is crucial in determining the market value of firms, regardless of how the R&D expenditures are measured and the type of analysis carried out (time-series or cross-section). Basing the methodology followed here on this research, we resort to the use of panel data, given that by this means we can increase the size of the sample and thus the quality of the results obtained.

Thus, the greatest difficulty with the analysis carried out arose from preparing the sample. Obtaining the information required for a large number of firms which had invested heavily in R&D was especially complicated, particularly for the number of patents and assorted accounting information. In spite of this difficulty, we were able to obtain a sample of twenty of the firms with the highest R&D investment for the time period from 1996 to 2006.

Based on the framework put forward, in order to determine the value of intangibles resulting from R&D activities, independent variables were used (input, of entry, explanatory or exogenous) and dependent variables (output, of exit, explained or endogenous). The former include the number of patents recorded by firms and the share of investment in R&D. The latter are of a financial nature and include measures of turnover, returns and autonomy. The deliberate consideration of various output variables and therefore of different specifications and estimations was also intended to act as a robustness test of the results.

Starting with the form of the Cobb-Douglas production function, we propose specifications based on an exponential function. Using econometric techniques for panel data**,** and based on the results obtained, taking into account the effects caused by investments in R&D in the short and long run, the aim is to determine the value of an intangible asset resulting from R&D activities.

Following this introduction, the work continues in Section 2 with the empirical model. In Section 3 the procedures behind the estimation technique are described. In Section 4, the estimation results are presented and analyzed. In Section 5, the intangible asset resulting from investment in R&D is valued. The chapter ends in Section 6 with some concluding remarks.

2. Empirical model: sample, variables and estimation specification

The sample includes twenty of the firms with the largest investment in R&D (and with the greatest number of patents granted in the period analyzed, 1996-2006): *Canon*, *Epson*, *Fuji*, *Fujitsu*, *General Electric*, *Hitachi*, *Honda*, *HP*, *IBM*, *Infineon*, *Intel*, *Matsushita*, *Micron*, *Microsoft*, *Philips*, *Samsung*, *Siemens*, *Sony*, *Texas Instruments* and *Toshiba*. They are therefore very homogenous firms in terms of their attitude to the importance of R&D**,** and have been amongst the most dynamic firms at a global level during the period considered.

The period between 1996 and 2006 was chosen due to the unavailability of data for a very broad time frame. Still, it was not possible to obtain all the information required for some of the firms; in fact, we were not able to obtain 10 annual observations for all the firms and all the variables. Furthermore, the use of one-period lagged variables meant it was necessary to lose one time observation per firm.

The need to limit the sample to those 20 firms also has some advantages, such as the fact that they are large firms that invest heavily in R&D, and mainly because of this are firms with homogenous production structures. This means that the coefficients associated with the variables are fairly similar.

The independent variables considered *a priori* included the number of patents recorded by firms[2] and the share of investment (or expenditure) in R&D. In terms of the number of patents recorded, the sources of data used were *IFI Announces top patent winners* and the *list of top patenting organizations*. The share of investment in R&D can in turn be measured in relation to assets (R&D expenditure/assets), equity (R&D expenditure/equity) and sales (R&D expenditure/sales). In all cases, the data were taken from the annual accounts reports of the twenty firms considered.

The dependent variables included the already mentioned measures of:[3] (i) turnover – asset turnover (sales/asset) and equity turnover (sales/equity); (ii) returns – asset returns (net result/asset), returns on equity (net result/equity) and sales returns (net result/sales); (iii) autonomy – share of equity in assets (financial autonomy). This data was also collected from the annual accounts of the firms.

As will become clear further on, the analysis requires an endogenous returns variable to be able to determine the results generated by investment in R&D in successive time periods (the value of the related intangibles will then be the present value of those results). Turnover

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[2] From the outset, we have been aware that this is unlikely to be a relevant explanatory variable. Based on the work of Czarnitzki and Kraft (2004, 2008), for example, we should consider not the flow of patents but the stock per firm. However, we were unable to acquire information on the stock of patents per firm.

[3] We decided not to consider growth variables – for example, asset, equity and sales growth – in order not **to** lose another observation for each firm.

and financial autonomy measures are used to confirm that it would be possible to obtain good fits with other variables; that is, these additional adjustments will act as a robustness check on the quality of the adjustments. The variables used are summarized in Table 1.

Table 1. Summary of the variables used in the empirical study

Possible independent / explanatory / entry / exogenous variables	
$Id_{n,t}$	Value of R&D expenditure for firm *n* in year *t*
$IdAct_{n,t}$	Share of expenditure on R&D in the total assets of firm *n* in year *t*
$IdCap_{n,t}$	Share of expenditure on R&D in the equity capital of *n* in *t*
$IdVnd_{n,t}$	Share of expenditure on R&D in sales of *n* in *t*
Possible dependent / explained / exit / endogenous variables	
$RtAct_{n,t}$	Share of sales in the asset (asset turnover) for *n* in year *t*
$RtCap_{n,t}$	Share of sales in equity (equity turnover) of *n* in *t*
$RdAct_{n,t}$	Share of net results in the asset (asset returns) of *n* in *t*
$RdCap_{n,t}$	Share of net results in equity (return on eq. cap.) of *n* in *t*
$RdVnd_{n,t}$	Share of net results in sales (sales return) of *n* in *t*
$AutFin_{n,t}$	Share of equity in the asset (financial autonomy) of *n* in year *t*

In order to derive the relationship between the firms' R&D activities and their effective value using econometric techniques, a specification is required; i.e. a specification for estimation must be deduced where R&D activities (input) generate a given result (output). The estimation results should allow us to determine the contribution of R&D activities to the market value of a firm, bearing in mind that the measure corresponds to the present value of induced (or generated) future benefits. It is therefore a matter of quantifying and determining the degree of dependence between items and predicting the values of the dependent variable from the values of the independent variables.

The influence of R&D on productivity has aroused wide interest in the economic literature in general. Starting with Solow's (1956) work, this interest has been particularly strong in the endogenous growth literature. Following from Solow's work, the use of the Cobb-Douglas production function (or more generally the form of this function) to study the relationship between R&D, technological progress, productivity and growth has been a constant (e.g., Jorgenson and Stiroh, 2000).

Therefore, based on the form of the Cobb-Douglas production function, the relationship to be estimated follows from the expression:

$$Q_{n,t} = Q_{n,t\text{-}1}^{\alpha} \, Z_{n,t}^{\beta} \text{, where:} \qquad (1)$$

(i) $Q_{n,t}$ measures the business result of firm *n* assessed using a turnover, return or growth variable (Q may be measured by *RtAct*, *RtCap*, *RdAct*, *RdCap*, *RdVnd* and *AutFin*), for time *t*; (ii) $Q_{n,t\text{-}1}$ is a measure of the business result of *n* in the previous period and works as a control variable;[4] (iii) $Z_{n,t}$ reflects the effects of R&D activities of firm *n* on the explained variable over time (Z can be measured using *IdAct*, *IdCap*, *IdVnd* and *Id*); (iv) α and β represent the contribution of $Q_{n,t\text{-}1}$ and $Z_{n,t}$, respectively to evaluate $Q_{n,t}$. Taking the logs of (1) we get:

$$q_{n,t} = \alpha \, q_{n,t-1} + \beta \, z_{n,t} \text{, where:} \qquad (2)$$

the lower case variables represent the log of the corresponding upper case variable and therefore measure changes.

The inclusion of the lagged dependent variable as an explanatory variable allows us, on the one hand, to encompass all factors that affect business results and, on the other, to ensure the robustness of the model's coefficient estimates. Moreover, as we will see, it allows us to take into account both the short run effect given by the coefficient associated with the explanatory variable related to R&D activities, β, and the long run effect due to the relationship between the coefficients α and β.

[4] The principle underlying the use of panel data models is the utilization of the dynamic structure of the data. Therefore the specification should be dynamic (i.e. should include lagged variables) – e.g., Nickel (1981), Kiviet (1995) and Hauk and Wackziarg (2009). The regressions considered are therefore dynamic, in the sense that in each case we include lags of the dependent variable.

3. Estimation using panel data

Initial considerations

To apply econometric techniques correctly, the following basic assumptions must be satisfed (e.g., Hair *et al.*, 1999; Greene, 2003):

(i) The specification should, preferably, be linear in the parameters to be estimated, given the greater ease of estimation. In the present case, it is clear that the model is linear in the parameters, since it is based on a logarithmic function.

(ii) Use relevant explanatory variables with a theoretical foundation in an appropriate and non-redundant model. In the present case, the explanatory variables are based on the appropriate theory, and in order to avoid loss of precision in the coefficients estimated, their number is sufficient to explain the variation in the dependent variable.

(iii) Ideally, the dependent variable should be continuous, in the sense that the values should be sequential. In the case analyzed here, although the data are discrete – i.e. referring to the different years – the dependent variable (as well as the independent variables) presents a sequence and is thus continuous.

(iv) The sample size should be significant in order to reduce the estimation error, giving greater reliability to the results. In our case, although it was not possible to collect all the information, i.e. a total of 200 observations (20 firms and 10 years), since all (of) the variables and lags of the dependent variable are included, there are at least 130 complete observations. According to Afifi *et al.* (2004), the number of observations should be 5 to 10 times greater than the number of explanatory variables, which is broadly surpassed using a specification with two explanatory variables. Therefore, the number of observations is sufficient for the results to be acceptable.

(v) The variables should be normally distributed. Although according to Afifi *et al.* (2004), when the sample size is large, as is the case here, slight non-compliance with this assumption is not too relevant, since normality enables a correct assessment of the global significance of the regression and the coefficients to be made. Using a logarithmic function, we can ensure the variables have frequency histograms that indicate a normal distribution, as do the graphs of the estimation residuals.

(vi) For statistical inference based on the results obtained, the error term must have a constant variance and cannot be autocorrelated. Transforming the variables into logs provides a stable variance.

(vii) The precision of the estimation also depends on the absence of multicollinearity between independent variables. Imperfect multicollinearity (i.e. partial correlation between explanatory variables) is generally a problem associated with small sample sizes and means that the variability of the explanatory variables in the sample is insufficient. The sample size is sufficiently large to ensure that this problem does not arise. The problem of perfect multicollinearity follows from the incorrect specification of the model**,** and in this case the model cannot be estimated. This is not a problem in the present instance.

The use of Panel data means that the sample includes cross-section information for each of the *n* entities (data for the 20 firms in each year) and for each time period *t* (data between 1996-2006 for each firm). In this case we may have unbalanced panel data comprising 20 firms and 10 time periods. It is unbalanced because there is some missing data which prevents the sample from being complete for the 200 potential observations (otherwise we would have balanced panel data).

Given that the use of unbalanced panel data does not interfere with the quality of the results (see, for example, Greene, 2003, pp. 289-290, for further details)**,** and that econometric software capable of dealing with this sort of sample exists – in fact Limdep 8, which was used here –we decided not to limit the sample size from the outset.

Estimation employing panel data is typically used for cases where there are more entities per time period (cross-section) than time periods (time series). This is why the issue of homogeneity between firms is crucial (e.g., Greene, 2003). In our case, the (common) features of the 20 firms considered ensure the existence of homogeneity between entities. The main advantage of panel data lies in its flexibility, which allows us to consider differences between entities with an increase in the precision of the estimators.

We shall now briefly describe the main estimation methods used in this context and considered in the estimations carried out: Pooled OLS, the Fixed Effects Model (FEM) and the Random Effects Model (REM).

Pooled OLS method

The pooled OLS method is analogous to the traditional OLS cross-section method. Generally, by using different time moments for the same firm**,** we can increase the size of the sample and thus the precision of the estimators and the quality of the statistical tests (e.g., Wooldridge, 2003). The model can be expressed in the form:

$$q_{n,t} = \eta + \alpha\, q_{n,t-1} + \beta\, Z_{n,t} + \varepsilon_{n,t}\text{, where:} \qquad (3)$$

$\varepsilon_{n,t}$ can be defined generally as the random error term (more specifically, it may include the effect of unobserved – entity specific – variables and the stochastic disturbance).

This method processes all the variables for each firm in each period, in a completely independent way, and we therefore lose information in the estimation. Greene (2003), for example, mentions that this method wastes individual heterogeneity and that the result is an average of different independent estimations. We can say that the method is appropriate when η is constant, as in (3). Wooldridge (2003) is clear in stating that the method is appropriate if the relationship between the dependent and (at least some of) the independent variables remains constant through time.

The specificities of each firm over time are ignored and η may include an unobserved component for each firm which is correlated with one of the explanatory variables. The estimators obtained are then biased and inconsistent**,** due to the incorrect specification of the model.[5] Often, to capture particularities of each entity, dummy variables are introduced which interact with the explanatory variables. However**,** if the dummy variables do not vary over time, there may be multicollinearity between the dummy and the related explanatory variable.

To sum up, this method is equivalent to the standard OLS method**,** with an increase in sample size which, because it does not take into account the variation of the dependent and independent variables, loses valuable information and leads to less efficient estimators.[6]

Fixed Effects Model

The FEM assumes that the heterogeneity of firms (cross-section) is captured by the constant term (Greene, 2003). Compared with the previous method, it considers the time variation of the explanatory variables for each firm and therefore, even in the presence of specific effects, produces consistent estimators.[7] Even in relation to the REM, the FEM is always an option if the Hausman test cannot be performed. However, the REM estimators are more efficient when the effects of the unobserved variables present in $\varepsilon_{n,t}$ are not correlated with any of the explanatory variables. Nevertheless, the FEM estimators, although they may not always be as efficient as the REM estimators, are always consistent (Wooldridge, 2003, and Greene, 2003).

The FEM is appropriate for models where there is a significant risk of omitting relevant explanatory variables. If all the relevant explanatory variables are included, the unobserved component will be captured by those variables and the REM estimators would be "blue" (i.e., more efficient and consistent in the class of linear estimators). To remove a_n present in

[5] In this case, relevant variables have been omitted and therefore the model is incorrectly specified.

[6] An estimator is efficient when the error between the estimated value and the observed value is minimized.

[7] Only a consistent estimator enables the statistical inference to be carried out.

$\varepsilon_{n,t} = (a_n - \mu_{n,t})$ and obtain consistent estimators, the model estimated results from the following transformation of the original model:

$$q_{n,t} - \overline{q}_{n,t} = \alpha\left(q_{n,t-1} - \overline{q}_{n,t-1} \right) + \beta\left(Z_{n,t} - \overline{Z}_{n,t} \right) + \varepsilon_{n,t} - \overline{\varepsilon}_{n,t}$$
$$\Leftrightarrow \dot{q}_{n,t} = \alpha\, \dot{q}_{n,t-1} + \beta\, \dot{Z}_{n,t} + \dot{\mu}_{n,t}\,. \tag{4}$$

Thus, (4) is similar to (3) but in variation terms – $\varepsilon_{n,t} - \overline{\varepsilon}_{n,t} = (\mu_{n,t} - \overline{\mu}_{n,t}) + (a_n - \overline{a}_n) = = (\mu_{n,t} - \overline{\mu}_{n,t}) = \dot{\mu}_{n,t}$, as $a_n = \overline{a}_n$, and η is eliminated since $\eta - \overline{\eta} = 0$. In sum, the slope is assumed to be homogenous for all firms and we implicitly estimate an intercept for each *n* by including a dummy (implicit for each *n*) which captures the specific features. It is possible to recover the estimates of the coefficients for each firm.

Random Effects Model

The REM assumes that the differences between firms (cross-section) are not captured by the independent variables; in other words, the unobservable structural differences are not related to the explanatory variables (Wooldridge, 2003). The REM is the preferred method when the specification is complete**,** in the sense that no relevant variables .have been omitted. The advantage of using the REM lies in the reduction of the number of parameters estimated when compared with the FEM – which may include a large number of implicit dummy variables to capture individual effects**.** For this reason it is often referred to as the Least Squares Dummy Variable (LSDV) model.

The REM is estimated automatically**,** using Generalized Least Squares (GLS) when the structure of the variance is known and Feasible Generalized Least Squares (FGLS) when the variance is unknown (Park, 2005). In any case, the estimates of the coefficients are consistent and more efficient than those obtained using the FEM. As with the FEM, the REM is also subject to transformation:

$$q_{n,t} - \lambda \bar{q}_{n,t} = \eta\left(1-\lambda\right) + \alpha\left(q_{n,t-1} - \lambda \bar{q}_{n,t-1}\right) + \beta\left(Z_{n,t} - \lambda \bar{Z}_{n,t}\right) + \varepsilon_{n,t} - \lambda \bar{\varepsilon}_{n,t}. \qquad (5)$$

Main considerations regarding the choice of method

To sum up, the more advanced methods, the FEM and the REM, are theoretically more appealing and empirically more appropriate than the Pooled OLS method. In any case, it is possible to statistically test their suitability. The F test is a global significance test which allows us to determine whether the group of dummy variables is relevant for the analysis. If the null hypothesis that the constant terms are all equal is rejected, then there is evidence to support the presence of specific effects for each firm, and hence the FEM is preferred to Pooled OLS (Greene, 2003). The Lagrange multiplier test, LM, does the same for the comparison between the REM and Pooled OLS (Breusch and Pagan, 1980). Finally, as already stated, the Hausman test is generally used to decide whether to use the FEM or the REM. This test compares fixed effects and random effects under the null hypothesis that the specific effects of each entity are not correlated with other regressors (Park, 2005). If they are correlated, for example, the null hypothesis is rejected and the FEM should be selected.

Given that the sample covers a period which, depending on the firm, may be up to 10 years, the time question is still relevant. That is, there may be time effects to add to the specific effects of each firm. In this case, Pooled OLS, FEM and REM models may also be estimated taking time effects into account. Essentially, the introduction of time effects into the models implies only some small changes, and we can work in a similar fashion to the way we operate when the time effects are ignored (Greene, 2003). Hence, in this case $\varepsilon_{n,t} = a_n + a_t + \mu_{n,t}$ and thus the FEM will include a constant.

4. Estimation results

In this section we estimate specifications which follow from the base expression (2). In order to boost the robustness of the results, different proxies are considered, both for the specification and for the variables. The proxies for the base specification (2) follow from the distinct estimation methods used. The different variables used aim firstly to examine the coherence of the estimation results and secondly to arrive specifically the estimated value.[8] Tables 2 to 7 summarize the main results obtained.

Table 2 below summarizes the estimation results for the specification in which the explained variable is the logarithm of the asset turnover $\text{Ln}RtAct_{n,t}$, the explanatory variables being the lagged explained variable $\text{Ln}RtAct_{n,t\text{-}1}$, along with the log of the ratio between R&D expenditures and the asset $\text{Ln}IdAct_{n,t}$.

Ignoring the existence of specific time effects (no-constant case), the most suitable model according to the different statistical tests is the FEM. In fact, the F test shows that there are entity-specific effects at the 1% significance level and we therefore conclude that the FEM model is preferable to the Pooled OLS model. The LM test in turn shows that the REM model is also preferable to the Pooled OLS model, given that it is significant at the 1% significance level. Lastly, the Hausman test rejects the hypothesis that the appropriate method is the REM at the 1% significance level, thus suggesting the use of the FEM.

As expected, the coefficients associated with the explanatory variables have a positive sign and are statistically significant at the 1% level. Thus, the estimates suggest that the independent variables are relevant in explaining the dependent variable. In particular, the estimates arrived at suggest that on average**,** holding everything else constant, a 1% increase in $\text{Ln}IdAct_{n,t}$ is associated with an increase in $\text{Ln}RtAct_{n,t}$ of 0.1997%, and therefore investment in R&D is clearly relevant in asset turnover.

Moreover, the quality of the adjustment is confirmed by the relatively high values of the coefficients of determination R^2 and adjusted R^2. The estimates suggest that the model

[8] The estimation results confirm the need to discard the independent variable 'number of patents recorded by firm'. As we mentioned above, according to Czarnitzki and Kraft (2004, 2008) for example, we should consider the stock of patents per firm. However, we were unable to acquire that information.

explains around 80% of the total variation in the explained variable around its sample mean, which supports the quality of the adjustment.

Table 2. Estimation results – dependent variable ln*RtAct*

		$\mathrm{Ln}RtAct_{n,t}$	$\mathrm{Ln}RtAct_{n,t}$
Constant (Student's t-statistic)			0.4945 (3.686)*
$\mathrm{Ln}RtAct_{n,t\text{-}1}$ (Student's t-statistic)		0.1564 (3.258)*	0.2321 (4.778)*
$\mathrm{Ln}IdAct_{n,t}$ (Student's t-statistic)		0.1997 (4.401)*	0.2220 (5.260)*
F Test [(a)]	G [(b)]	8.959*	
	G&T [(c)]		5.779*
LM Test [(d)]	G [(b)]	47.62*	
	G&T [(c)]		47.82*
Hausman Test [(e)]	G [(b)]	29.25*	
	G&T [(c)]		4,76***
Model Used		FEM	REM
Number of observations		187	187
R^2		0.8129	0.8206
Adjusted R^2		0.7891	0.7847

Notes: *, ** and *** mean that the coefficient is significant at the 1%, 5% and 10% significance level respectively. [(a)] This test allows us to choose between Pooled OLS and the FEM. [(b)] Means that only specific effects of each entity are considered. [(c)] Means specific effects of each entity and time effects are considered. [(d)] This test allows us to choose between Pooled OLS and the REM. [(e)] This test allows us to choose between the FEM and the REM. In the F, LM and Hausman test, whenever G&T are statistically relevant, the model with specific and time effects should be chosen. The REM method does not allowus to derive a specific value for the R^2 and adjusted R^2; however, their values can be approximated, although it is clear that these values will be greater than those resulting from the FEM method. The results were derived using the Limdep 8.0 software.

Estimation of the model, taking into account possible time-specific effects (that is, with a constant to capture those effects), also reveals the quality of the adjustment. Our main conclusions are: (i) the F test suggests that the FEM method performs better than the Pooled OLS method, given that the hypothesis of insignificance of firm-specific effects is statistically rejected – there is a firm effect at the 1%, 5% and 10% significance level(s); (ii) the LM test indicates the presence of random firm and time effects, and therefore the REM is preferable to the Pooled OLS method at the 1%, 5% and 10% significance level(s); (iii) the Hausman test confirms that the REM is the preferred model (the FEM would only be preferable at a 10% significance level, i.e. a not very rigorous significance level); (iv) the signs of the coefficients associated with the explanatory variables arepositive, as expected, and the estimates obtained are statistically significant at the 1% significance level;(v) the estimates of the coefficients of the explanatory variables are not very different from the estimates arrived at when no constant is included. For example, on average, providing all else is held constant, a 1% increase in $\mathrm{Ln}IdAct_{n,t}$ is associated with an increase in $\mathrm{Ln}RtAct_{n,t}$ of 0.222%, which is close to the value obtained in the previous adjustment. The quality of the adjustments is therefore assured.

Table 3 shows that when we use the log of equity turnover $\mathrm{Ln}RtCap_{n,t}$ as our explained variable, and the one-period lagged explained variable $\mathrm{Ln}RtCap_{n,t-1}$, together with the log of the ratio between R&D expenditures and equity $\mathrm{Ln}IdCap_{n,t}$ as our explanatory variables, the quality of the adjustment (with and without a constant) is equally good.

The coefficients associated with the explanatory variables havea positive sign, as expected, and are statistically significant at the 1% level. We should stress that, on average**,** holding everything else constant, a 1% increase in Ln*IdCap* is associated with an increase in Ln*RtCap* of 0.4622%; in other words, investment in R&D has a strong impact on the equity turnover. The quality of the adjustment is also confirmed by the R^2 and adjusted R^2 values.

If we take into account possible time-specific effects (adjustment with a constant), we find that the adjustment is also good. In this case, the F test suggests that the FEM is more appropriate than Pooled OLS. The LM test shows there are random entity and time effects, thus suggesting that the REM performs better than Pooled OLS. Moreover, the Hausman test shows that the FEM is the preferred model.

Table 3. Estimation results – dependent variable ln*RtCap*

		$LnRtCap_{n,t}$	$LnRtCap_{n,t}$
Constant (Student's t-statistic)			1.7922 (6.277)*
$LnRtCap_{n,t-1}$ (Student's t-statistic)		0.2800 (4.652)*	0.2784 (4.228)*
$LnIdCap_{n,t}$ (Student's t-statistic)		0.4622 (5.076)*	0.4196 (4.390)*
F Test [(a)]	G [(b)]	6.522*	
	G&T [(c)]		4.275*
LM Test [(d)]	G [(b)]	6.19*	
	G&T [(c)]		6.19**
Hausman Test [(e)]	G [(b)]	39.72*	
	G&T [(c)]		9.08*
Model Used		FEM	FEM
Number of observations		183	183
R^2		0.7656	0.7757
Adjusted R^2		0.7351	0.7297

Notes: see Table 2.

Table 4 below summarizes the results for the case where the explained variable used is the log of returns on equity $LnRdCap_{n,t}$, while the explanatory variables are the one-period lagged explained variable $LnRdCap_{n,t-1}$ and the log of the ratio between R&D expenditures and equity, $LnIdCap_{n,t}$.

The quality of the adjustments is still good. Omitting specific time effects (adjustment without a constant), the best model is once again the FEM: (i) the F test suggests the FEM is preferred over Pooled OLS; (ii) the LM test suggests Pooled OLS is better than the REM; (iii) the Hausman test suggests that the FEM performs better than the REM; (iv) the coefficients associated with the explanatory variables still have a positive sign and are statistically significant at the 1% level; in this case, providing everything else is held constant, a 1%

increase in Ln$IdCap_{n,t}$ is associated with an average increase in Ln$RdCap_{n,t}$ of 0.774%; i.e. investment in R&D plays a very significant role in explaining the returns on equity; (v) the quality of the adjustment is still supported by the R^2 and adjusted R^2 values.

Table 4. Estimation results – dependent variable ln*RdCap*

		Ln$RdCap_{n,t}$	Ln$RdCap_{n,t}$
Constant (Student's t-statistic)			0.1147 (0.317)
Ln$RdCap_{n,t-1}$ (Student's t-statistic)		0.2484 (2.804)*	0.2627 (2.936)*
Ln$IdCap_{n,t}$ (Student's t-statistic)		0.7740 (4.349)*	0.9127 (5.024)*
F Test [(a)]	G [(b)]	3.358*	
	G&T [(c)]		3.013*
LM Test [(d)]	G [(b)]	0,000	
	G&T [(c)]		0.700
Hausman Test [(e)]	G [(b)]	25.51*	
	G&T [(c)]		13.57*
Model Used		FEM	FEM
Number of observations		145	145
R^2		0.6844	0.7337
Adjusted R^2		0.6305	0.6607

Notes: see Table 2.

Allowing for possible time effects (adjustment with a constant), the results also suggest that the FEM is the preferred model. The signs on the coefficients associated with the explanatory variables are positive, while the estimates arrived at are statistically significant at the 1% level and are not very different from the estimates when time effects are not included. The R^2 and adjusted R^2 values confirm the quality of the adjustment.

Table 5 below summarizes the main results when the explained variable is the log of asset returns Ln$RdAct_{n,t}$, and the explanatory variables are the one-period lagged explained variable Ln$RdAct_{n,t\text{-}1}$, together with the log of the ratio between R&D expenditures and the asset Ln$IdAct_{n,t}$. The relative quality of the adjustments is not as good as in the previous cases and consequently these adjustments will not be taken into account in the subsequent analysis.

Table 5. Estimation results – dependent variable ln*RdAct*

		Ln$RdAct_{n,t}$	Ln$RdAct_{n,t}$
Constant (Student's t-statistic)			-0.8354 (-0.896)
Ln$RdAct_{n,t\text{-}1}$ (Student's t-statistic)		0.2807 (3.028)*	0.2693 (2.775)*
Ln$IdAct_{n,t}$ (Student's t-statistic)		0.3879 (1.251)	0.5182 (1.642)***
F Test [(a)]	G [(b)]	3.216*	
	G&T [(c)]		2.797*
LM Test [(d)]	G [(b)]	0.070	
	G&T [(c)]		1.78
Hausman Test [(e)]	G [(b)]	23.52*	
	G&T [(c)]		8.97*
Model Used		FEM	FEM
Number of observations		147	147
R^2		0.7099	0.7503
Adjusted R^2		0.6612	0.6830

Notes: see Table 2.

In the adjustment without a constant, the model that performs best is still the FEM: the F test suggests that statistically the FEM performs better than Pooled OLS, the LM test suggests that Pooled OLS performs better than the REM and the Hausman test suggests that the FEM performs better then the REM. The coefficients of the explanatory variables also have a positive sign, but only the coefficient associated with the explanatory variable Ln$RdAct_{n,t\text{-}1}$ is statistically significant (at the 1% significance level). The relative quality of the adjustment also seems to be confirmed by the R^2 and adjusted R^2 values.

In the adjustment with a constant, the FEM is again the preferred model: the F test suggests that the FEM performs better than Pooled OLS, the LM test shows that Pooled OLS performs better than the REM and the Hausman test suggests that the FEM performs better than the REM. The signs on the coefficients associated with the explanatory variables are positive and are not very different from the estimates arrived at when time effects are not included. However, the coefficient associated with Ln$IdAct_{n,t}$ is only significant at the 10% significance level (i.e. a very weak significance level). The R^2 and adjusted R^2 also suggest that the quality of the adjustment is relatively good.

Table 6 confirms that when the explained variable used is the log of sales returns Ln$RdVnd_{n,t}$, and the explanatory variables are Ln$RdVnd_{n,t\text{-}1}$ together with the log of the ratio of R&D expenditures and sales Ln$IdVnd_{n,t}$, the adjustments are worse when compared with the ones above. Thus, these adjustments will also be disregarded in the analysis that follows.

Without specific time effects, and using the appropriate tests, we can confirm that the model that performs best is once again the FEM. Contrary to what we would expect, the coefficient associated with the explanatory variable Ln$IdVnd_{n,t}$ has a negative sign. Even so, the R^2 and adjusted R^2 suggest that the relative quality of the adjustment is reasonable. With specific time effects, the FEM method is still the preferred one. The signs of the coefficients of the explanatory variables are positive, but the coefficient associated with the variable Ln$IdVnd_{n,t}$ is not significant. In this case also the R^2 and adjusted R^2 indicate a reasonable quality of the adjustment.

Table 6. Estimation results – dependent variable ln*RdVnd*

		$\text{Ln}RdVnd_{n,t}$	$\text{Ln}RdVnd_{n,t}$
Constant (Student's t-statistic)			-1.9286 (-1.546)
$\text{Ln}RdVnd_{n,t-1}$ (Student's t-statistic)		0.2546 (2.991)*	0.2215 (2.446)*
$\text{Ln}IdVnd_{n,t}$ (Student's t-statistic)		-0.075 (-0.166)	0.1543 (0.339)
F Test [(a)]	G [(b)]	4.224*	
	G&T [(c)]		3.352*
LM Test [(d)]	G [(b)]	0.24	
	G&T [(c)]		1.51
Hausman Test [(e)]	G [(b)]	27.58*	
	G&T [(c)]		11.28*
Model Used		FEM	FEM
Number of observations		147	147
R^2		0.7534	0.7840
Adjusted R^2		0.7120	0.7258

Notes: see Table 2.

Lastly, Table 7 summarizes the results for the case where the explained variable used is the log of financial autonomy $\text{Ln}AutFin_{n,t}$, and the explanatory variables are $\text{Ln}AutFin_{n,t-1}$ and the log of R&D expenditures $\text{Ln}Id_{n,t}$. The quality of the adjustments is still reasonable.

In the adjustment that does not include a constant, the model that performs best is also the FEM**.** The FEM performs better than Pooled OLS (F test), Pooled OLS performs better than the REM (LM test)**,** and the FEM performs better than the REM (Hausman test). Although the coefficient associated with $\text{Ln}AutFin_{n,t-1}$ is not significant, the R^2 and adjusted R^2 indicate a considerable quality of the adjustment. In the case where a constant is included, the FEM method is stillthe preferred method, for the reasons mentioned above. The signs on the coefficients associated with the explanatory variables are positive, but the coefficient associated with the explanatory variable Ln$AutFin_{n,t\text{-}1}$ is also not significant. However, the R^2 and adjusted R^2 indicate the quality of the adjustment.

Table 7. Estimation results – dependent variable ln*AutFin*

		Ln$AutFin_{n,t}$	Ln$AutFin_{n,t}$
Constant (Student's t-statistic)			-2.004 (-8.204)*
Ln$AutFin_{n,t\text{-}1}$ (Student's t-statistic)		0.0917 (1.199)	0.0619 (0.779)
Ln$Id_{n,t}$ (Student's t-statistic)		0.0841 (5.628)*	0.0823 (5.286)*
F Test [(a)]	G [(b)]	5.981*	
	G&T [(c)]		4.099*
LM Test [(d)]	G [(b)]	0.01	
	G&T [(c)]		0.53
Hausman Test [(e)]	G [(b)]	53.67*	
	G&T [(c)]		15.53*
Model Used		FEM	FEM
Number of observations		183	183
R^2		0.7670	0.7809
Adjusted R^2		0.7366	0.7360

Notes: see Table 2.

The computation of the adjustments carried out clearly shows the robustness of the results obtained. It is also clear from this that the quality of the first three adjustments is greater than the quality of the three remaining adjustments. In our analysis below, we have used the third adjustment because it includes a measure of returns as its dependent variable. Given that the results are just as sound with and without a constant, we have chosen the adjustment where a constant is not included. Therefore, with the results in Table 4 in mind, to determine the value of the intangible asset associated with investment in R&D we have focused on the relationship:

$$\ln RdCap_{n,t} = 0.2484 \ln RdCap_{n,t-1} + 0.7740 \ln IdCap_{n,t} . \tag{6}$$

Given the statistical significance of the coefficients and the values of the estimates, we conclude that investment in R&D has a strong impact on the firm's operations. Based on the estimated and statistically significant values in (6), the long run effects of investment in R&D can be deduced. In order to do this, a relationship must be established between the coefficients of the explanatory and explained variables according to the expression:[9]

$$\text{Long Run Effect} = \frac{\text{Estimate of the coefficient associated with R \& D expenditures}}{1 - \text{Estimate associated with the lagged explained variable}} . \tag{7}$$

The short and long run effects of the variables that include investment in R&D are shown in Table 8 below.

Table 8. Short and long run effects induced by investment in R&D

	Short run	Long run
Effect induced by *IdCap* on *RdCap*	0.7740	1.030

If we keep everything constant, a 1% increase in the share of investment in R&D in equity leads to an average increase in the profitability of equity of 0.774% in the short run and 1.03% in the long run – is in line with the results obtained by Crespo and Velázquez (1999), Crespo *et al.* (2004) and Brynjolfsson and Hitt (2003), among others, insofar as these authors have obtained more significant results in the long run. This result is worth emphasizing**,** since the lower, albeit still satisfactory**,** results in the short run may lead firms to carry out lower investments in R&D, and hence compromise their competitive advantages in the future.

[9] The denominator in (7), with an expected theoretical value between 0 and 1, can be seen as a measure of the speed of correction of deviations of ln*RdCap* from the equilibrium level; i.e., as a partial adjustment coefficient.

To sum up, if firms only take into account the immediate (short run) effect(s) of investment in R&D, the level of investment in R&D may be below the optimal value**,** in which case the profitability of the firm will suffer in the long run.

5. Value of the intangible asset associated with investment in R&D

Investment in R&D, and the intangibles associated with it, have contributed to the growth in the value of the firm in a systematic way, which is why it is extremely important to be able to measure them correctly (e.g., Lev and Radhakrishnan, 2005).

The main problem with this appraisal lies in the (in)ability to distinguish the specific effects generated by investment in R&D. The resulting intangibles are incorporated into the firm as a whole**,** and interact logically with the tangibles as a coordinated whole and are therefore difficult to assess. In fact, it has been difficult to identify the ensuing benefits directly, in addition to which these benefits endure over time and frequently relate to several areas of the firm (e.g., Mylonopoulos *et al.*, 1995).

We have found that investment in R&D has a particularly positive and statistically significant effect on the return on equity. Basing our conclusions on these results, which have been derived from a specification estimated using econometric techniques, in this section we develop a methodology which will allow us to assess the intangible value generated by investment in R&D. Given the coefficients arrived at and starting from a situation of stability, we can predict the likely effect of a given increase in R&D investment (1% for example) in year *t* on the (future) returns on equity.[10]

By comparing the returns on capital in a generic/base/standard firm (in the sample) with and without the increase in the share of investment in R&D in equity we can, by taking differences into account, arrive at the periodic effect of that increase on the results. The

[10] That is, we consider the existence of an increase in investment in R&D in the firm at time *t*, maintaining the remaining productive capacity through maintenance investments and amortizations.

standard firm chosen was *Matsushita*.[11] Given the periodic effect, we can derive the present value of the ensuing intangible asset using a suitable rate for the cost of capital.

Detailed calculations for a sample firm – *Matsushita*

In period *t-1* (i.e., in 2005), the figures for the firm Matsushita were:

Table 9. Data for the firm *Matsushita*

	Year t-1
Equity capital, *EC* (thousand yen)	646 243
Investment in R&D, *II&D* (thousand yen)	60 769
Ln *RdCap*	-2.9284
Ln *IdCap*	-2.3641

Next we detail the various steps (i.e., the algorithm) in the methodology developed to arrive at the value of the intangibles.

1st step: determining the estimated value of Ln*RdCap* at *t* with and without an increase in investment in R&D. Given a 1% increase in investment in R&D at *t*, the level of investment in R&D for this firm rose to 61376.69 (= 60769 x 1.01) and consequently Ln *IdCap* increased from de –2.3641 to –2.3541; therefore,

$$\ln RdCap_{n,t}\Big|_{\text{with an increase in } II\&D} = 0.2484\times(\text{-}2.9284)+0.7740\times(-2.3541)=-2.5495\,;$$

$$\ln RdCap_{n,t}\Big|_{\text{without an increase in } II\&D} = 0.2484\times(\text{-}2.9284)+0.7740\times(-2.3641)=-2.5572\,.$$

2nd step: determining the estimated value of *RdCap* at *t* with and without an increase in investment in R&D. Given the value arrived at in the 1st step, the value of the returns on equity at *t* follow from the exponential of the logarithm:

$$RdCap_{n,t}\Big|_{\text{with an increase in } II\&D} = \exp(\ln RdCap_{n,t}) = \exp(-2.5495) = 0.0781\,;$$

$$RdCap_{n,t}\Big|_{\text{without an increase in } II\&D} = \exp(\ln RdCap_{n,t}) = \exp(-2.5572) = 0.0775\,.$$

[11] Analysis of the remaining firms in the sample will be summarized in a final Table.

3rd step: determining the estimated value of net results at *t* with and without an increase in investment in R&D. We must now determine the new value of the net results, *RL*, assuming that equity capital has not changed:

$$RL_t\big|_{\text{with an increase in } II\&D} = RdCap_{n,t} \times CP_t = 0.0781 \times 646243 = 50485.57$$

$$RL_t\big|_{\text{without an increase in } II\&D} = RdCap_{n,t} \times CP_t = 0.0775 \times 646243 = 50096.32$$

4th step: repeating the 1st, 2nd and 3rd steps to determine the estimated value of net results in the years after year *t* with and without an increase in investment in R&D. In order to compare the firm's results for the cases with and without an increase in investment in R&D, in this step we repeat the previous steps for all years after year *t* and calculate the difference between net results in the two cases – with and without an increase in investment in R&D. These differences between the net results in each case are an indicator of the value of the intangible asset associated with that increase in investment (in the long run).

Table 10 below summarizes the results for the various time periods.

Table 10. Results for *Matsushita* with and without an increase in investment in R&D

Time	*RL* no increase in *IR&D*					*RL* w/increase in *IR&D*					Difference *RL, DRL*
	Log of:				RL_t	Log of :				RL_t	
	$RdCap_t$	$RdCap_{t-1}$	$IdCap_t$	$RdCap_t$	(1)	$RdCap_t$	$RdCap_{t-1}$	$IdCap_t$	$RdCap_t$	(2)	(2)-(1)
t	-2.5572	-2.9284	-2.3641	0.0775	50096.32	-2.5495	-2.9284	-2.3541	0.0781	50485.57	389.25
t+1	-2.4650	-2.5572	-2.3641	0.0850	54934.79	-2.4554	-2.5495	-2.3541	0.0858	55468.17	533.39
t+2	-2.4421	-2.4650	-2.3641	0.0870	56207.43	-2.4320	-2.4554	-2.3541	0.0879	56780.29	572.85
t+3	-2.4364	-2.4421	-2.3641	0.0875	56528.11	-2.4262	-2.4320	-2.3541	0.0884	57111.00	582.90
t+4	-2.4350	-2.4364	-2.3641	0.0876	56608.04	-2.4247	-2.4262	-2.3541	0.0885	57193.45	585.41
t+5	-2.4347	-2.4350	-2.3641	0.0876	56627.92	-2.4244	-2.4247	-2.3541	0.0885	57213.95	586.03
t+6	-2.4346	-2.4347	-2.3641	0.0876	56632.86	-2.4243	-2.4244	-2.3541	0.0885	57219.04	586.19
t+7	-2.4346	-2.4346	-2.3641	0.0876	56634.08	-2.4243	-2.4243	-2.3541	0.0885	57220.31	586.22
t+8	-2.4346	-2.4346	-2.3641	0.0876	56634.39	-2.4243	-2.4243	-2.3541	0.0885	57220.62	586.23
t+9	-2.4346	-2.4346	-2.3641	0.0876	56634.46	-2.4243	-2.4243	-2.3541	0.0885	57220.70	586.24
t+10	-2.4346	-2.4346	-2.3641	0.0876	56634.48	-2.4243	-2.4243	-2.3541	0.0885	57220.72	586.24

Note: Values for *RL* and *DRL* are in thousands of yen.

With the adjustment considered here – in (6) – we arrive at the evolution in returns and, in this way, the evolution in the results. Note that the last column in Table 10 shows the difference between the results for the firm with and without a 1% increase in investment in R&D at t, $t+1$, $t+2$, …, $t+10$.

5th step: determining the value of the intangible asset associated with an increase in investment in R&D (i.e. the actual value of the difference in the results arrived at with and without an increase in investment in R&D). The periodic difference in the value of the results of the firm with and without an increase in investment in R&D follows from the increase in investment in R&D and is thus an indicator of the time value of that asset. Thus, we must now determine the Present Value of the Difference, *VAD*, in the results achieved with and without an increase in investment in R&D - that is, the value of the associated intangible asset. To do this, we use the firm's cost of capital as our discount rate. Thus, *VAD* at *t* (investment period) is:

$VAD_t = \sum_{t=1}^{\infty} DRL_t \times (1+r)^{-t+1}$; given that after t+9 the rent stabilizes the VAD_t we get:[12]

$$VAD_t \cong 329{,}25 + \frac{533{,}39}{1+r} + \frac{572{,}85}{(1+r)^2} + \frac{582{,}90}{(1+r)^3} + \frac{585{,}41}{(1+r)^4} + \frac{586{,}03}{(1+r)^5} + \frac{586{,}19}{(1+r)^6} + \frac{586{,}22}{(1+r)^7} + \frac{586{,}23}{(1+r)^8} + \frac{586{,}24}{r(1+r)^9} \quad (8)$$

With a cost of capital of 5%, the VAD_t, or equivalently the value of the intangible asset associated with an increase in investment in R&D, is 11**,** 667 thousand yen. We could also have calculated the value of the firm – measured by the present value of future results –[13] with

[12] Note that the last term, $\frac{586{,}24}{r(1+r)^9}$, follows from verifying the stability of the value of the estimated results after period *t+9*; we assume that after this period there is a sort of constant perpetual rent.

[13] Based in particular on the seminal works by Brigham (1985), Dodd (1986), Brilman and Maire (1988), Shleifer and Vishny (1988), Viallet and Koracjzk (1989), Vermaelen (1989), van Horne (1995), Brealey and Myers (2000), Copeland et al. (2000) and Amihud (2002), among many others, we can say that calculating the value of the firm is controversial, but is also of enormous practical importance; the best known and most consensual assessment methods are divided into five groups: (i) returns/yield methods, (ii) assets methods, (iii) dualist methods, (iv) comparative methods and (v) methods based on averages.

and without additional investment in R&D. The value of the intangible asset associated with an increase in investment in R&D would, in this case, be the difference between the value of the firm with and without the increase in investment in R&D – see Table 11 below.

Table 11. Value of *Matsushita* with and without an increase in investment in R&D

Cost of Capital	RL sem aumento do $II\&D$		RL com aumento do $II\&D$		Difference
4%	Value of Firm at t = Present Value RL	1 424 014	Value of Firm at t = Present Value RL	1 438 578	14 564
5%	Value of Firm at t = Present Value RL	1 144 152	Value of Firm at t = Present Value RL	1 155 820	11 667
6%	Value of Firm at t = Present Value RL	958 382	Value of Firm at t = Present Value RL	968 127	9 745

Note: The last column (Difference) shows the increase in value due to additional investment in R&D; it is therefore equivalent to the value of the intangible asset(s) ensuing from additional investment in R&D.

Table 11 summarizes the value of the firm using three alternative discount rates (cost of capital) for future results. As expected, using a 5% rate, the value of the firm with and without additional investment in R&D is 1155820 and 1144152 respectively.

Summary analysis of the results for the other firms in the sample

Lastly, Table 12 presents a summary of the results obtained for the value of each firm in the sample with and without additional investment in R&D, i.e. focusing on the value of the intangible(s) associated with the increase in investment in R&D.

The results arrived at confirm the positive relationship between results and R&D activities, as Kamien and Schwartz (1975), Johnson and Pazderka (1993), Sougiannis (1994), Lev and Sougiannis (1996, 1999), Mcquail *et al.* (2005), Balbester *et al*. (2003) and Callen and Morel (2005suggest, among many others. We can see that the increase in investment in R&D has a very similar effect for most of the firms; as a rule, a 1% increase in investment in R&D leads to an increase in the value of the firm by around 1.01%.

Table 12. Value of each firm in the sample with and without an increase in investment in R&D

Firm	Value of the firm without increase R&D, 5% discount rate	Value of the firm with increase in R&D, 5% discount rate	Δ Firm value
Canon [a)]	49 562 009	50 063 550	501 541
Epson [a)]	15 929 308	16 090 935	161 627
Fuji [a)]	27 803 735	28 086 642	282 907
Fujitsu [a)]	41 705 880	42 129 556	423 676
General Electric [a)]	69 528 999	70 228 847	699 848
Hitachi [a)]	64 093 958	64 747 108	653 150
Honda [a)]	89 595 497	90 503 109	907 612
HP [a)]	119 615 937	120 827 955	1 212 018
IBM [a)]	119 702 777	120 913 994	1 211 217
Infineon [b)]	22 815 821	23 048 577	232 756
Intel [a)]	77 246 933	78 029 066	782 133
Matsushita [c)]	1 144 152	1 155 820	11 667
Micron [a)]	325 887	329 218	3 331
Microsoft [a)]	128 527 525	129 827 073	1 299 548
Philips [b)]	32 113 715	32 437 759	324 044
Samsung [d)]	115 104 564	116 265 281	1 160 717
Siemens [b)]	96 458 564	97 437 178	978 615
Sony [a)]	85 974 390	86 848 883	874 493
Texas Instruments [a)]	43 079 685	43 515 223	435 538
Toshiba [a)]	61 585 016	62 211 607	626 590

Notes: [a)] figures in thousands of dollars; [b)] figures in thousands of euros; [c)] figures in thousands of yen; [d)] figures in thousands of won;

6. Concluding remarks

In this paper we have developed an empirical methodology for valuing the intangible assets ensuing from investment in R&D. We started with a specification which allows us to analyze the effect of investment in R&D on the results of firms by resorting to econometric techniques for panel data. The estimation methods used and considered in the estimations carried out were Pooled OLS, the Fixed Effects Model and the Random Effects Model.

For our sample, we considered twenty of the firms with the largest number of patents during the years between 1996 and 2006, and in so doing we endeavoured to include particularly homogenous entities; that is, firms with similar production structures – with similar technology or production functions –which should therefore have identical coefficients of the production function. The majority of the information required was taken from the relevant annual accounts reports.

The variables considered were essentially the following: (i) as our entry variables, independent or explanatory, we considered investment in R&D, the share of investment in R&D in assets, in equity and in sales, and also lagged exit variables; in particular, the most relevant variable in our analysis was the share of investment in R&D in equity; (ii) as our exit variables, dependent or explained, we used economic/financial measures, the most relevant for the analysis being equity returns and turnover.

The specifications estimated included different proxies both for the specification and for the variables. Generally, the Fixed Effects Model proved to be the best estimation method and the quality of the adjustments was better when: (i) the explained variable was asset turnover and the explanatory variables were lagged asset turnover and the share of investment in R&D in the asset; (ii) the explained variable was equity turnover and the explanatory variables were lagged equity turnover and the share of investment in R&D in equity; (iii) the explained variable was returns on equity and the explanatory variables were lagged returns on equity and the share of investment in R&D in equity.

Having gauged the robustness of the results obtained, we chose this last adjustment for the subsequent analysis with the aim of obtaining the effect induced by investment in R&D on results. Since the quality of the adjustment was equally good with and without a constant, we decided to consider the case where no constant was included.

Before carrying out a detailed analysis of the effect of investment in R&D on the results, we obtained a measure of the long run effect of investment in R&D. We found that, in line with the results in the literature, the effect induced is significantly larger in the long run: on average, if everything else holds constant, a 1% increase in the share of investment in R&D in equity results in an increase in returns on equity of 0.7740% in the short run and 1.030% in the long run. This finding suggests that if firms only take into account short run effects, they will tend to invest sub-optimally in R&D and may therefore compromise the future competitive advantages of the firm and consequently their long run profitability.

From the estimates obtained we developed a methodology comprising several steps to assess the intangible effect generated by that investment in R&D. Assuming that the only change in the firm was a 1% increase in investment in R&D, we started by comparing the returns on capital for a standard firm in the sample (*Matsushita*) with and without that increase in investment in R&D. By measuring differences we thus obtained the periodic effect on the results. Given this periodic effect, we are able to derive the present value of the intangible asset generated by investment in R&D, using a rate for the cost of capital of 5%, since this seemed an adequate rate.

The exercise was repeated for all firms in the sample and the results arrived at confirm the positive relationship between the results (and the value of the firm) and R&D activities, as suggested by Lev and Sougiannis (1996, 1999), Balbester *et al*. (2003) and Callen and Morel (2005), among many others.

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