The Economic Value of the R&D Intangible Asset

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Abstract

This study utilizes firm-specific time-series data to estimate the economic value of the Research and Development (R&D) expenditures that investors consider an asset to the firm. The study uses a modification of the Ohlson (1995) model to estimate the persistence of abnormal earnings, the proportion of current R&D expenditures that represents a source of future benefits to the firm, and the amortization rate of that asset. The parameters are estimated from time-series data of market and book values of equity, earnings, and R&D expenditures. The study further compares the firm-specific estimates with those resulting from an application of a cross-sectional estimation procedure based on all available companies in the sample and industry-specific subsamples. Results indicate the existence of significant differences in some 2-digit SIC code industries between the time-series and the cross-sectional estimates of the parameters and the economic value of the R&D asset. Differences in the capitalization parameter are associated with the growth in R&D, the profitability of the firm, R&D intensity and the concentration of the industry. Differences in the persistence of earnings are related to the concentration ratio. Finally, differences in the estimated economic value of the R&D asset are associated with the profitability of the company as measured by its return on assets. Overall, our results provide evidence that market participants behave as if R&D expenditures have significant future economic benefits to the firm, and show that the cross-sectional and time-series approaches followed when assessing its economic value provide significantly different estimates.

Keywords: R&D, Valuation Models, Intangibles, Fundamental Analysis.

JEL classification: M4, O3, G14.

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In recent years, accounting research has paid an increasing attention to the analysis and valuation of intangibles. Underlying a firm's investments in intangibles is the desire to strengthen the competitive position of the firm by creating, maintaining or enhancing sustainable advantages, leading to future profitability. If current expenditures on intangibles such as R&D and advertising are associated with future benefits and cash flows, then they should be considered assets by investors when market stock prices are set.

The purpose of this study is to estimate the R&D economic asset from the observed market values of the firm using past information about earnings, book values and R&D expenditures. Unlike most of the prior literature, this study uses a firm-specific, time-series approach to estimate the R&D asset that investors seem to have in mind when setting the firm's stock price. This approach requires different assumptions about the behavior of model parameters than prior studies, and may yield different results if these assumptions grossly violate reality. However, this approach does not require the assumption of cross-sectional equality of parameters in the sample or in an industry, as did most prior studies. Which approach is preferable is an empirical question; our approach allows us to assess whether a firm-specific approach yields significantly different estimates than a cross-sectional approach, as well as when firm-specific estimates are superior to cross-sectional estimates. However, to the extent that both approaches provide similar results, our confidence in using any of these approaches is increased.

Consistent with the prior literature, our results indicate that investors consider a significant proportion (about 80-90%) of R&D expenditures to have future benefits, and that the cumulative R&D asset accounts for over 40% of the difference between the market and book value of equity. Market participants behave as if R&D outlays are amortized over a period of about 6-7 years. These results are consistent with those found in prior studies, thus increasing our confidence about the documented benefits that investors seem to attribute to R&D expenditures.

We find that time-series, firm-specific estimates are preferable than cross-sectional estimates, even when the latter are based on within-industry firms. We find that cross-sectional estimates vary significantly across 2-digit SIC industries, and even within the same 2-digit SIC industry firm-specific (time-series) estimates are significantly different from the industry-wide estimates. Thus, to the extent possible, firm-specific estimates should be attempted. We also show that the differences between time-series, firm-specific and industry-wide estimates are related to the growth in R&D expenditures, profitability, R&D intensity and industry concentration. This makes intuitive sense, since the more are firms different in terms of their R&D activity and profitability within an industry, and in their size and ranking within an industry (related to the industry concentration levels), the more is the assumption of identical parameters for all firms within the industry is likely to be violated.

We also find the ratio of the R&D asset to market value of equity to be negatively correlated with size, profitability (ROA), the growth rate in both R&D expenditures and prior sales, suggesting that smaller firms earlier in their life cycle are more likely to be building their intangible R&D asset (relative to market value) than larger, more mature firms which had already been able to reap the benefits of prior R&D efforts in their profits.

It should be noted at the outset that this study does not address the question of whether R&D expenditures should be capitalized or expensed. This is a question for accounting regulators, who may require expensing even if R&D expenditures constitute an asset. In fact, our results indicate that investors undo the required expensing of R&D expenditures in the US and treat it as an asset. Instead, this study focuses on an alternative approach to an estimation of the R&D asset to test its conformity to prior studies and to various approaches to estimate it. Which valuation model of R&D expenditures is ultimately used by professionals to value this intangible asset or by academics in research studies is a matter of personal preference and available data. Our approach is limited in that it requires market values to assess the R&D intangible asset. However, estimates obtained from public-listed firms may be used for private firms, segments and divisions, through proper matching and adjusting for factors we identify in this study (such as growth rate of R&D expenditures, profitability, intensity, and ranking within an industry.

The next section of the paper discusses the current accounting rules governing R&D expenditures and reviews prior research studies. The following section describes the valuation model based on R&D adjusted abnormal earnings, and the equations we use to estimate the proportion of current R&D expenditures with future benefits, and the amortization rate of the R&D asset. Section IV discusses the data sources and the estimation procedures. The fifth section presents and discusses the results. The last section summarizes the study and discusses its implications.

II. Accounting for R&D and Prior Research

In the US, R&D expenditures are expensed immediately as prescribed by SFAS No. 2 (FASB, 1974). The full expensing of R&D expenditures was justified by the FASB on the grounds that there was no evidence about a consistent relationship between R&D outlays and subsequent benefits for any specific R&D project.[1] The uncertainty associated with the future earnings of R&D intensive companies is also argued as a sound reason for conservatism (Kothari *et al.*, 1998). However, the immediate expensing of R&D may induce a significant reporting bias, which is shown by Lev, Sarath and Sougiannis (1999) to be dependent on the difference between the growth rate of investment in R&D and the firm's ROE or ROA.

The International Accounting Standards Board addresses the accounting for internally generated intangible assets during the R&D phase in IFRS 38. According to this standard, research expenditures may not be capitalized and development costs could be recognized as an asset only if the company fulfils six restrictive requirements: the technical feasibility to complete the intangible asset for use or sale; the firms must intend to complete the asset for use or sale; it must be able to actually use or sell the intangible asset; there must be a reasonable certainty that the intangible asset will generate future economic benefits; there must be available technical, financial and other resources required for the completion of the asset and its sale or use; and the firm must be able to

[1] The only exception in the US is software development costs.

measure the expenditure attributable to the intangible asset during its developmental phase.

In December 2002, the IASB disclosed the Exposure Draft of Revised IAS 38 proposing that acquired *in-process R&D* should be recognized as an asset and that subsequent expenditures related to the *in-process* research or development project incurred after the acquisition of that project shall be accounted for following the general rule for R&D. The document introduces the fair valuation of intangible assets prescribing that in the absence of an organized market, fair value is the amount that the firm would pay for the asset at the acquisition date in an arms length transaction between knowledgeable parties based on the best information available. Among the amendments to IAS 38, the IASB states that the techniques developed by certain entities regularly involved in the purchase and sale of intangible assets may be applied for the purposes of their valuation where appropriate, including discounted cash flows or the application of multiples. Since no organized markets exists for in-process R&D, there may be a future need for widely accepted methods for the valuation of such investments. For that purpose, either industry-specific or firm-specific estimates of the capitalization and depreciation parameters and hence, of the economic value of the R&D asset resulting from a cross-sectional or a time-series analysis are likely to be helpful for standard setters as well as for the preparers and the users of financial statements.

In order to assess the logical consistency of the conservative accounting standards limiting the recognition of these intangible investments, empirical research has examined the relationship between R&D (and in some cases also advertising) outlays and future earnings. Whereas early research failed to establish such relationship (Johnson, 1967;

Newman, 1968; Telser, 1969; Milburn, 1971), recent studies such as Bublitz and Ettredge, (1989), Sougiannis (1994) and Lev and Sougiannis (1996) have provided evidence supporting the view that increases in R&D investments are positively correlated with subsequent earnings.

If the market value of companies is set as a function of future expected earnings or cash flows, then one would expect to find a positive contemporaneous relationship between stock prices and intangible investments. Indeed, there exists consistent evidence about a positive association between the market value of companies and their R&D outlays (Bublitz and Ettredge, 1989; Sougiannis, 1994; and Lev and Sougiannis 1996), and between announcements of increases in R&D investments and abnormal stock returns (Jarrel, *et al*., 1985; Woolridge, 1988). Moreover, the evidence presented in Chan, Martin and Kensinger (1990) and Doukas and Switzer (1992) indicates that the impact of R&D increases on stock returns is greater the larger is the size of the firm. Taken together, these results provide support for stock prices that reflect capitalization of R&D expenditures and amortization over the assessed economic life.

Several empirical studies have attempted to estimate the R&D asset from either subsequent operating income (Sougiannis, 1994; Lev and Sougiannis, 1996 and 1999) or the ratio of market value to book value of equity (Cockburn and Griliches, 1988; Hirschey, 1982; Hall, 1993). Their approach has been based on the estimation of a cross-sectional regression of current earnings, stock prices or market-to-book ratios over past R&D and advertising expenditures using either cross-industry or intra-industry samples. The resulting cross-sectional estimates of the capitalization and amortization coefficients have then been used to derive firm specific R&D assets and amortization expenses. The assumption underlying this estimation procedure is that all the relevant parameters (the proportion of R&D expenditures that represents an asset and the amortization rate) are constant for all firms in an industry at a specific moment in time. Although this method is appealing because of its simplicity, cross-sectional estimates of the R+D capitalization and amortization rates represent averages for the specific cross-section, ignoring the variability of parameters within the cross-section (Hirschey, 1982).

In a recent study, Zarowin (1999) also estimates a firm specific R&D asset from regressions of operating income on past R&D expenditures, similar to Lev and Sougiannis (1996). He then associates the magnitude of the R&D coefficients with the R&D response coefficient from a return regression. Zarowin also finds there is a considerable variation in the estimated future benefits of R&D expenditures across firms. Thus, it seems important to estimate the R&D asset at the individual firm level, even though the estimated parameters may be subject to a greater estimation error.

Our study is also motivated by the recent developments in US accounting standards which require periodic tests for goodwill impairment, based on an assessment of the fair values of tangible and intangible assets. They are also motivated by the imminent adoption of the IASB’s International Financial Reporting Standards by all European listed companies, and by the growing debate on the possible recognition of internally developed intangibles and in-process R&D. These standards mean that companies would need to estimate their R&D assets, so that research into the various alternatives available for estimation may be beneficial to practitioners.

The approach followed in this paper differs from most of the previous research[2] in that our model estimates the firm-specific economic value of the R&D asset and the capitalization and amortization rates that would be applicable to that economic value based on a time series regression of market-to-book ratios on book values, earnings and R&D expenditures. Results of the firm-specific time series estimation procedure are compared to the cross-sectional estimates obtained on the basis of a cross-industry and an industry-specific sample. Ultimately, whether we get different results from prior studies is an empirical question that may be important for assessing the merits of various approaches. For example, if the variation is high within a group of firms used in a cross-section, a firm-specific model may be preferable. If there exists high variation for a given firm over time, using our approach is likely to introduce too much noise into the estimates, resulting in inferior valuations of R&D assets as compared to those yielded by cross-sectional studies. A close correspondence of the estimated results in both approaches increases our confidence in both.

III. Model Derivation

The model used in this study is closely related to that of Ohlson (1995). It uses most of the assumptions made by the original Ohlson (1995) and Feltham and Ohlson (1995), but it specifically addresses the existence of economic assets, such as the future

[2] An exception is the study of Megna and Mueller (1991), where the firm-specific R&D stocks are estimated by regressing sales on previous advertising and R&D expenditures. However, they also include in the model the aggregate advertising and R&D outlays of the firm's competitors in the industry.

benefits from R&D expenditures, which are expensed fully according to current U.S. accounting rules.

Similar to Ohlson (1995), and Feltham and Ohlson (1995), we begin by assuming the no arbitrage condition for market valuation, i.e., that the current market value, V_t, is equal to the present value of all expected future dividends, d_t, discounted at a constant rate, r:

$$V_t = \sum_{t=1}^{\infty} \frac{E(d_{t+t})}{(1+r)^t} \qquad (1, \text{PVED})$$

We further assume the Clean Surplus Relationship, i.e., that all changes in owners' equity are the result of accounting earnings and owners' contributions or distributions to owners:

$$BV_t = BV_{t-1} + E_t - d_t \qquad (2, \text{CSR})$$

where BV_t is the book value of equity at the end of period t, E_t is earnings during period t, and d_t represents net dividends (dividends paid to owners net of owners' contributions) during period t.

Using the above two assumptions, and assuming that the discounted present value of the terminal book value converges to zero, one can easily derive the Residual Income Valuation (RIV):

$$V_t = BV_t + \sum_{t=1}^{\infty} \frac{E(AE_{t+t})}{(1+r)^t} \qquad (3, \text{RIV})$$

where AE_t represent abnormal earnings, i.e., $AE_t = E_t - r\,BV_{t-1}$.

Ohlson (1995) further assumes a Markovian process for the abnormal earnings, which can be described as follows:

$$AE_{t+1} = \omega \, AE_t + \varepsilon_{t+1} \qquad (4)$$

where ω is the persistence of abnormal earnings, and is assumed to be between zero and one. ε_{t+1} is a random shock with a mean of zero and is assumed to be serially independent. Using this Markovian process, Ohlson (1995) shows that the firm's market value is:

$$V_t = BV_t + \frac{\omega}{1+r-\omega} AE_t \qquad (5)$$

Model Modifications

Let X_t denote the R&D expenditures in period t. We assume that a proportion of the R&D expenditures, α, represents an economic asset to the firm, i.e., yielding future benefits to the firm, with the remainder, (1-α), expiring by the end of the period. Let I_t denote the cumulative intangible asset that corresponds to the present value of the remaining future benefits expected from the R&D expenditures to date. We assume that I_t decreases by a constant fraction δ every period[3], so the balance at the end of the period can be written as:

$$I_t = (1-\delta)\, I_{t-1} + \alpha \, X_t \qquad (6)$$

It should be emphasized that the rate of amortization, δ, is **not** assumed equal to the expensed current R&D expenditures, 1-α. Although in accounting we typically use a constant depreciation or amortization rate every year, we assume here that some of the first-year R&D expenditures have benefited current earnings and are not expected to

[3] The assumption about the constant rates a and ß is made for simplification of estimation. In reality, both are likely to vary depending on the specific stage in the life cycle of the firm. However, any non-constant series can be converted into a constant series as shown by certainty equivalent discount rates in finance.

benefit any future years. However, the first-year expense also includes such R&D expenditures that were completely unsuccessful, not benefiting the first-year revenues at all. Thus, the model assumes different depreciation (expense) rates for the first-year R&D expenditures and future years' expensing of the asset. To draw an analogy, all capital expenditures are likely to include two components,[4] the net price paid for the asset and subsequent capital improvements (a), and repairs and maintenance (1-a). The resulting fixed asset is amortized at rate δ, which does not have to be equal to (1-a).

Let AE_t^R be the abnormal earnings in period t calculated by using the reported earnings and book value under full expensing of the R&D expenditures. Let AE_t^C denote abnormal earnings in period t calculated from an accounting system that capitalizes the portion of R&D expenditures that have future benefits. Under the above assumptions and definitions, it is easy to see that[5]:

$$AE_t^{C} = E_t + a X_t - d I_{t-1} - r(BV_{t-1} + I_{t-1}) =$$

$$= AE_t^{R} + a X_t - (d + r) I_{t-1} \qquad (7)$$

We can substitute for the reported abnormal earnings in the RIV equation (3), the abnormal earnings under capitalization of R&D expenditures from equation (7) to obtain the firm's value at the end of period t:

$$V_t = BV_t + \sum_{t=1}^{\infty} \frac{E[AE_{t+t}^{C} - a X_{t+t} + (d + r) I_{t+t-1}]}{(1+r)^{t}} \qquad (8)$$

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[4] We thank an anonymous reviewer for drawing our attention to capital expenditures besides drilling expenses.

[5] The model in this paper assumes a world without taxes, just like the Ohlson (1995) model.

Note that Equation (8) is identical to Equation (3). It uses reported book value and abnormal reported earnings to value the firm. The only modification is the substitution of abnormal earnings assuming capitalization of R&D for the abnormal reported earnings. To simplify the valuation equation, we make two additional assumptions. The first is the Markovian generating process of abnormal earnings made by Ohlson (1995), but instead of reported abnormal earnings under full expensing, the assumption is that abnormal earnings under capitalization of some R&D expenditures evolve according to a Markovian process. The second assumption is that R&D expenditures grow at a constant rate g, where $g<r$.

We feel that the Markovian process for reported abnormal earnings is less appropriate than for earnings with capitalization of R&D expenditures. The reason is that the reported book value is systematically understated when R&D expenditures are fully expensed immediately, and when the firm's R&D expenditures grow (or decline). Reported abnormal earnings therefore include a persistent component that actually grows with the increase in R&D expenditures, since the understatement of book value increases with time. Furthermore, to remain competitive, the firm needs to continue making R&D expenditures, which are expected to grow over time. Thus, the persistent bias due to the full expensing of R&D expenditures does not diminish over time, as assumed in the Ohlson's Markovian process (where $\omega<1$), but actually grows as long as R&D expenditures grow. Therefore, it seems more reasonable to remove the bias in abnormal reported earnings that is induced by full expensing of R&D, and assume the Markovian process for the abnormal earnings after capitalization of R&D, where the book value is not necessarily understated.

We also assume that R&D expenditures grow at a constant rate which is lower than the discount rate, r. This assumption is reasonable for firms that must maintain their competitive edge by product innovations, and by continuously reducing operating costs. R&D expenditures are typically budgeted as a proportion of sales, and grow with the growth of the firm. The upper limit on growth (i.e. $g<r$) is economically justified, because otherwise the firm may potentially grow infinitely. A similar assumption is made in Feltham and Ohlson (1996) about capital expenditures. Formally, our two assumptions are:

$$AE_{t+1}^{C} = w\, AE_{t}^{C} + e_{t+1} \qquad (9)$$

$$X_t = (1+g)\, X_{t-1} \qquad (10)$$

Using the assumption of constant growth in Equation (10) and the assumption about depreciation of the capitalized R&D asset, I_t, in Equation (6), we can recursively expand Equation (6) as:

$$I_t = a\, X_t + (1-d)\, I_{t-1} =$$

$$= a\, X_t + (1-d)\, [a\, X_{t-1} + (1-d)\, I_{t-2}] =$$

$$= a\, X_t + (1-d)\, a\, X_{t-1} + (1-d)^2\, I_{t-2} =$$

$$= a\, X_t + (1-d)\, a\, \frac{X_t}{(1+g)} + (1-d)^2\, a\, \frac{X_t}{(1+g)^2} + (1-d)^3\, I_{t-3}$$

which converges (with long enough series) to:

$$I_t = \frac{(1+g)}{(g+d)}\, a\, X_t \qquad (11)$$

We can now rewrite Equation (8) as:

$$V_t = BV_t + \sum_{t=1}^{\infty} \frac{E[AE_{t+t}^{\ c}]}{(1+r)^t} - \sum_{t=1}^{\infty} \frac{aX_{t+t}}{(1+r)^t} + (d + r) \sum_{t=1}^{\infty} \frac{(1+g)a X_{t+t-1}}{(g+d)(1+r)^t}$$

which can be reduced to:

$$V_t \quad = \quad BV_t + \frac{w}{(1+r-w)} AE_t^{\ c} - a \ \frac{(1+g)}{(r-g)} X_t + \frac{(d+r)(1+g)}{(r-g)(g+d)} a \ X_t$$

$$= \quad BV_t + \frac{w}{1+r-w} AE_t^{\ c} + \left[\frac{d+r}{d+g} - 1 \right] \frac{(1+g)}{(r-g)} a \ X_t \qquad (12)$$

Substituting (11) into the definition of AE_t^C in Equation (7) and defining

$$d' = \frac{d+r}{d+g} \qquad \text{and} \qquad w' = \frac{w}{(1+r-w)}$$

Equation (12) can be rewritten as:

$$V_t \quad = \quad BV_t + w' E_t - w' \ r \, BV_{t-1} + w' (1-d') a \ X_t + (d'-1) \ \frac{(1+g)}{(r-g)} a \ X_t$$

$$= \quad BV_t + w' E_t - w' \ r \, BV_{t-1} + [w' - \frac{(1+g)}{(r-g)}] \, (1-d') a \ X_t \qquad (13)$$

Dividing Equation (13) by BV_{t-1}, yields the following equation, which has non-linear restrictions on its coefficients:

$$\frac{V_t}{BV_{t-1}} \quad = \quad A_0 + A_1 \ \frac{BV_t}{BV_{t-1}} + w' \frac{E_t}{BV_{t-1}} + [w' - \frac{(1+g)}{(r-g)}] \, (1-d') a \ \frac{Xt}{BV_{t-1}} \qquad (14)$$

Note that the coefficients A_0 and A_1 in Equation (14) can be estimated as free coefficients, or alternatively can be restricted to their theoretical values:

$$A_0 = -\omega' r \qquad \text{and} \qquad A_1 = 1 \qquad (15)$$

In the Ohlson (1995) and Feltham and Ohlson (1995) derivation, they introduce another variable that surrogates for other information, which also decays according to a Markovian process, and can affect abnormal earnings. This variable is also included in their valuation equation. Empirically, it is difficult to construct such a variable. Myers (1999) uses backlog orders, but finds this variable to not improve the estimation of the Ohlson model. Allowing the coefficients A_0 and A_1 to deviate from their values as derived above is consistent with potentially capturing the effects of the "other information" variable in the intercept and the book value variable. We provide below estimates of Equation (14) in an unrestricted form, but also tested the model when the intercept and the book value coefficient are restricted as in (15).

Note that the abnormal earnings under capitalization of R&D expenditures in Equation (7), AE_t^C, can be written as:

$$AE_t^c = AE_t^R + a\,X_t - \frac{d+r}{g+d}\,a\,X_t \quad = \quad AE_t^R + (1-d')\,a\,X_t$$

Substituting for the abnormal earnings under capitalization from, AE_t^C, in Equation (9):

$$E_{t+1} + (1-d')\,a\;\;X_{t+1} - rBV_t \;=\; w\,[E_t + (1-d')\,a\;\;X_t - rBV_{t-1}]$$

and dividing by BV_{t-1} and rearranging terms, we obtain the following equation that is also non-linear in its restrictions on the coefficients:

$$\frac{E_{t+1}}{BV_{t-1}} \;=\; B_0 + B_1\frac{BV_t}{BV_{t-1}} + w\,\frac{E_t}{BV_{t-1}} + [w - (1+g)]\,(1-d')\,a\,\frac{X_t}{BV_{t-1}} \quad (16)$$

Equation (14) is the valuation equation in the system of equations used for deriving the firm's value. Equation (16) is the abnormal earnings dynamic, which is also used to derive the firm's value. Note that there are three parameters that are unknown and need to be estimated -- ω, the persistence level, α, the proportion of R&D expenditures that have future benefits, and δ, the depreciation rate of the R&D asset. We use the system of Equations (14) and (16) to estimate these parameters. Note that just like in Equation (14), we can estimate Equation (16) with free coefficients B_0 and B_1, or alternatively restrict these coefficients to:

$$B_0 = -r\omega \quad \text{and} \quad B_1 = r \tag{17}$$

We provide below estimates of Equations (14) and (16).

III. Sample and Estimation Procedure

Sample

For the purposes of our analysis we use data from the 2002 Compustat Annual Industrial and Research data files. Using annual R&D data, we estimate the proportion of R&D expenditures that constitutes an investment, and the amortization rate of the R&D asset.[6]

To be included in our sample, each firm had to have data on the following items for 2001:

[6] In a prior version of this paper, we repeated the analysis with quarterly data. Parameter estimates and further analyses were very similar to those reported for the annual results.

1. Market value of equity at fiscal year end[7].
2. Positive book value of equity at year-end, at the beginning of the year, and at the beginning of the prior year.
3. Income before extraordinary items and discontinued operations for the current and the prior year.
4. R&D expenditures for the current and the prior year.
5. The 5-year growth rate in R&D expenditures can be calculated as of the end of 2001.

These data are used to estimate the parameters according to the system of equations (14) and (16) in a cross-sectional analysis, applying two approaches – (i) using all firms, basically assuming that all firms have identical parameters, and (ii) using all firms in a 2-digit SIC industry (with a minimum of 10 observations), essentially assuming that all firms in the same industry have identical parameters.

To examine the sensitivity of the estimation to the assumption about identical parameters for all firms (or for all firms within a 2-digit SIC industry), we use a third approach, which is based on time-series estimation of the parameters for each firm with at least 10 observations meeting the data criteria (1-5) above, during the period 1985-2001. This estimation approach assumes that the underlying firm's parameters remain unchanged throughout the estimation period. Ultimately, which assumption is more realistic is an empirical issue on which we shed some light below.

Consistent with prior applications of the Ohlson (1995) model, we eliminate observations where the change in book value from the beginning of the year to its end

[7] We also used market values three months after the fiscal year-end with very similar results to those reported in the text.

was in excess of 10 or below 0.10, and observations where the ratio of market value of equity to book value at the beginning of the year exceeded 100. The elimination of observations with extreme changes in book values is intended to exclude outliers. Similarly, observations with M/B ratios in excess of 100 are considered outliers.

Method

Most prior studies of the value relevance of R&D expenditures have estimated the cumulative R&D asset and its depreciation rate based on cross-sectional samples. Lev and Sougiannis (1996 and 1999) estimate their model for each SIC industry, and then use the industry-average parameters to estimate the unrecorded R&D asset and the annual net investment in R&D for each firm within that industry. The underlying assumption is that the percentage of R&D expenditures that is an asset, as well as the amortization rate, is constant for all firms in the same industry. Our cross-sectional estimates follow a similar approach, but are based on data for the year 2001 alone.

In contrast, when we estimate our model using the time series data for each firm individually, we attempt to reduce any errors caused by intra-industry variation. At the same time, our estimates are based on fewer observations, and can introduce additional measurement errors due to lack of sufficient data points. Note also that, unlike Lev and Sougiannis (1996) and Zarowin (1999), we only estimate three important parameters in our model, while they allow for an extended lag structure in the data (nine lags in some industries). Our time-series estimation procedure assumes that the relevant parameters are constant across time for the same firm. Ultimately, which approach introduces more measurement errors is an empirical question that is investigated explicitly in this paper.

The model outlined in Equations (14) and (16) is estimated using the procedure MODEL in SAS, which allows for an estimation of a system of equations with non-linear restrictions on the parameters. Our estimation procedure restricts the important parameters ω, α, and δ to fall between zero and one, in accordance with their theoretical values. To avoid convergence of α and δ to their boundaries, we place high penalties on convergence at the boundaries. However, unlike OLS estimation, the system may not converge to a meaningful solution, and there is no assurance that convergence occurs at a global optimum. We attempt to reduce the likelihood of a local optimum by a selection of many starting points on the interval [0,1] for the important parameters. A similar estimation procedure is used by Ballester et al (2002) for the human capital investments of a firm.

In estimating Equations (14) and (16), we use a non-restricted version as is described by (14) and (16), but also a version in which we restrict certain coefficients according to Equations (15) and (17). Since the results of the estimation using the restricted system of equations are similar to those reported below, we do not report them in the current version of the paper.

V. Results

Table 1 reports summary statistics about various variables used in the study based on the data for 2001. Panel A reports the data for all firms included in our sample according to the selection criteria discussed above, panel B refers to those companies in our sample for which we did not have ten observations of R&D investments during the period 1985-2001 and were only used in the cross-sectional analysis. Panel C reports descriptive statistics for the firms that are included in the time-series analysis. The table indicates that firms are quite dispersed in terms of size, measured both by market value of equity and total assets. The average company in our sample reports negative earnings of around 20% of their market capitalization for the year 2001, in line with the negative market conditions in the high-tech sector. However, their sales increased on average 13 per cent annually over the three-year period ending in 2001, with an impressive median R&D-to-sales intensity of 7.7% over the same three-year period.

Firms included in the time-series analysis are bigger than those that are included only in the cross-sectional estimation, seem to have lower growth opportunities as indicated by higher book to market ratios, and are more profitable than the cross-sectional firms. They also tend to invest less in the R&D expenditures and have lower R&D intensity. Thus, they seem to be more mature companies, further along their life-cycle than the firms used only in the cross-sectional estimation.[8] Other variables seem to reflect the typical distribution of Compustat firms, with the exception of the four-firm concentration ratios, which are higher than in other studies, possibly due to the barriers to entry caused by the high R&D intensity.

(Insert Table 1 about here)

Table 2 reports the distribution of the parameter estimates from Equations (14) and (16) obtained from the cross-sectional analysis of the entire sample corresponding to 2001 (panel A) and the sub-sample of industry-specific firms (panel B). Parameter estimates resulting from the time-series, firm-specific, approach are presented in panel C.

[8] One must bear in mind that the companies in panel C are not representative of the entire Compustat population; they are selected to the sample if they disclose R&D expenditures for at least 10 years between 1985 and 2001. Thus, R&D is likely to be an important concern for these firms which have also survived

The persistence of abnormal earnings under capitalization of R&D expenditures that have future benefits is quite high with means of about 80% for the time-series estimation and slightly below 70% for the cross-sectional industry-specific analysis. The average proportion of R&D expenditures that represents an asset is over 88% for the time-series analysis and 76% for the cross-sectional intra-industry analysis. Conversely, the estimated amortization rate of the R&D intangible asset was greater in the case of the cross-sectional analysis (13.9%) than in the time-series approach (12%). Thus, regardless of the estimation approach, results suggest that the market perceives a very significant portion of first-year R&D expenditures to have future benefits in subsequent years.

(Insert Table 2 about here)

Table 2 also reports the distribution of other parameters (intercept and the coefficient on book value of equity) that are not restricted in the estimation. While the means deviate from the expected values, the medians are reasonably close to the expected values, indicating some possible outliers for the estimated coefficients. Still, these estimates are not explicitly utilized in the estimation of the R&D asset -- the focus of the study. The ratio of the R&D asset to the market value resulting from the time-series estimation procedure (0.379) is greater than the estimate obtained with the cross-sectional approach (0.321) and so is the ratio of the R&D asset to the difference between the market and the book value of equity (0.507 versus 0.422). Both approaches indicate the perceived importance of the R&D asset to the market valuation of the firm, as well as to the explanation of the differences between market and book values.

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for a long time. Our sample selection criteria may have different implications for size and growth opportunities in these companies than in the rest of the population.

In order to gain further insight into possible existence of differences in the value of the parameter estimates across industries we grouped companies in industry-specific portfolios according to their 2-digit SIC code and performed a cross-sectional estimation of the persistence, capitalization and depreciation parameters within an industry. Based on the industry-specific parameters we then estimated the value of the unrecorded R&D asset for each company, and computed the industry average values of the R&D asset to market value and the R&D asset to the market minus the book value of equity ratios. Results for industries that have at least 10 firms are reported in table 3. As indicated in the notes to the table, we applied an analysis of variance and found the mean parameters and the ratios of the R&D asset to market value of the firm (and to the difference between the market and the book value of equity) to be significantly different across industries with significance levels below 0.001. Even a casual observation of the table results shows that industries differ in the estimated parameters, and in the ratio of the R&D asset to market value. Thus, at a minimum, the results in Table 3 show that cross-sectional estimates of the R&D asset should not be based on firms from different industries.

(Insert Table 3 about here)

To test whether firm-specific parameters are different across firms within an industry, we computed the differences between the estimated parameters from the time-series estimation for the individual firm with those obtained by using all firms in the same 2-digit SIC industry. If the mean difference is statistically close to zero, we can argue that the average time-series parameter is identical to the cross-sectional (within industry) parameter. If the mean difference is statistically not equal to zero, then it can be argued that the individual companies within the 2-digit SIC industry are sufficiently different to warrant firm-specific estimation. Thus, we examined the differences between the individual, time-series, parameters with those obtained cross-sectionally for all firms within the 2-digit SIC industry, for those industries in which there were at least 20 firms with available time-series estimates and their associated *t*-statistics. Table 4 reports the results of the tests for the same SIC industries identified in Lev and Sougiannis (1996), plus the fabricated metal products (SIC 32) and the business services (SIC 73) industries.

(Insert Table 4 about here)

Our results indicate that in four of the seven industries, there is sufficient variation in the time-series estimate of the R&D proportion that represents an asset (a) to be different from the cross-sectional estimate to reject the null hypothesis that all estimates are the same. For the estimates of the amortization rate (d) and the persistence (?), the differences are statistically different from zero in the three of the seven industries. Thus, we can argue that there is sufficient dispersion of individual-firm, time-series, parameters to justify an individual estimation rather than cross-sectional estimation, even when the latter uses firms from the same 2-digit SIC industry.

In reality, when estimation of the R&D asset is required, practitioners may face cases where market prices are unavailable, such as the cases of private companies, segments and divisions of public firms, etc. In these cases, the tendency would be to use as benchmarks firms from the same industry, using industry-wide parameters to estimate the specific-case R&D asset. However, since we showed above that there are many industries in which the cross-sectional estimates are sufficiently different from the firm-specific estimates, it may be important to investigate the causes of the differences between the firm-specific and industry-wide estimates. If we are able to identify the variables that are associated with these differences, investors and practitioners can make adjustments to the cross-sectional, industry-based estimates to approximate the time-series, individual, estimates. Thus, we regress the differences between the time-series and the within-industry estimates on several variables that are related to the estimation of the R&D asset. These results are available in Table 5.

(Insert Table 5 about here)

As can be seen in the table, the differences between individual and cross-sectional estimated proportion of R&D expenditures that represents an asset are associated with the growth rate in R&D expenditures, profitability, R&D intensity and concentration. Thus, firms that are more mature, profitable, and that operate in industries with high levels of concentration are likely to not have differences from the industry-wide estimates. In contrast, firms that invest progressively larger amounts in R&D expenditures, and that are presumably earlier in their life-cycle are more likely to exhibit deviations from the industry-wide estimates. Results for the other parameters are more ambiguous. Thus, our study can offer some clues about when individual-firm estimates are likely to deviate from the industry-wide estimates.

Corporate characteristics associated with the economic R&D asset

Table 6 indicates possible variables that affect (or are associated with) the R&D asset. The table presents regression results across the three methods used in our study to estimate the unrecorded R&D asset: a cross-section of all companies in the sample, a cross-sectional intra-industry approach and a time-series, firm-specific, procedure. The first three columns of the table report the regression estimates obtained including the market-to-book ratio as an explanatory variable. The last three columns exclude the market-to-book ratio, because it is likely correlated with the ratio of the R&D asset to the market value since market value appears in both variables. Intuitively, we expect that the ratio of the R&D asset to market value will be larger for firms that are earlier in their life-cycle with strong potential ahead of them. In contrast, when firms are already large, profitable, and increasing their investments in R&D, the existing R&D is smaller in proportion to the market value, which already has captured the growth opportunities of the R&D. As can be seen in the table, the variables are generally consistent with this intuition. This increases our confidence about the estimated parameters and the the R&D asset.

(Insert Table 6 about here)

VI. Summary and Conclusions

Previous studies of the value relevance of R&D expenditures have generally estimated the unrecorded R&D asset from cross-sectional samples of firms, implicitly assuming constant capitalization rates of R&D expenditures and amortization rates of the R&D assets for all firms in an industry. In contrast, we estimate time-series, firm-specific capitalization and amortization parameters, assuming these parameters are constant for each firm during the period in our analysis. We further compare our time-series estimates with cross-sectional, cross-industry estimates, as well as with cross-sectional, 2-digit SIC industry-specific estimates.

Based on Ohlson's (1995) Valuation model, and assuming an autoregressive process for R&D adjusted abnormal earnings, we draw from stock prices inferences about the market's assessment of the economic value of unrecorded R&D assets and their associated amortization rates. Using a time-series estimation procedure we find that the perceived proportion of R&D expenditures with expected future benefits beyond the first year is high -- on average, 88.2% of current R&D expenditures are considered by investors to yield benefits beyond the year of the expenditure. This proportion varies considerably (and statistically significantly) across industries. The distribution of the estimated amortization rate of the perceived (but unrecorded) R&D asset showed a first decile of 0.030 and a ninth decile of 0.227 implying that the perceived useful live of the R&D asset varies at least between 4.4 and 33 years. The time-series firm-specific estimates of the unrecorded R&D asset accounts for a significant proportion (over 50% on average) of the difference between the market value and the book value of companies. The time-series estimates of the R&D asset are negatively associated with size, past profitability, and the growth rates in sales and R&D expenditures.

The comparison between the time-series, firm-specific, and the cross-sectional, industry-specific, estimates of the parameters (and the economic value of the R&D asset) reveal the existence of significant differences in most industries. The divergence in the estimates of the capitalization parameter between the time-series and cross-sectional estimates is associated with recent growth in R&D expenditures, the concentration ratio of the industry, the firm's profitability and its R&D intensity. This is consistent with more mature, profitable firms having similar characteristics to the industry average, whereas the rapidly growing, younger, firms with more growth opportunities, showing more deviation from industry averages.

Taken together, the evidence presented here provides support to the contention that investors consider most of the R&D expenditures an economic asset. Moreover, our results document the existence of significant differences between the firm-specific, time-series, estimates of the economic value of the R&D asset and the cross-sectional, industry-wide, estimates generally used in the literature. Our findings contribute to the current debate on the recognition and the fair valuation of the future benefits arising from R&D investments. The time-series approach assumes the invariance of the firm-specific parameter along with time, and the cross-sectional approach is based on the presumption that all companies have the same capitalization and depreciation rates for their R&D expenditures. Which of the two methods provides more accurate estimates depends on the particular circumstances. Our results provide initial suggestions for identification of these circumstances.

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Table 1
Summary Statistics

Panel A: All Observations	N	Mean	10%	25%	Median	75%	90%
Market Value	1804	4570	9	34	201	1119	6031
Book/Market	1804	0.674	0.132	0.253	0.457	0.810	1.399
Earnings/Market	1804	-0.199	-0.500	-0.144	-0.007	0.038	0.069
Total Assets	1804	3746	10	31	146	861	4611
R&D Exp./Market	1804	0.117	0.009	0.021	0.047	0.118	0.264
5-year Growth in R&D	1804	0.153	-0.108	-0.011	0.102	0.249	0.438
ROA	1804	-0.144	-0.536	-0.173	-0.006	0.052	0.097
5-year Std. Dev. Of ROE	1804	0.633	0.036	0.067	0.142	0.385	1.076
3-Year growth in sales	1761	0.130	-0.129	-0.027	0.064	0.193	0.413
3-year average R&D/Sales	1795	3.344	0.009	0.024	0.077	0.187	0.505
4-Firm Concentration ratio	1737	0.689	0.413	0.461	0.710	0.845	0.943
R&D asset/ Market	1644	0.340	0.028	0.074	0.196	0.528	1.000
Panel B: Observations included only in the cross-sectional analysis							
Market Value	1152	3111	8	31	143	722	3303
Book/Market	1152	0.652	0.120	0.222	0.426	0.799	1.386
Earnings/Market	1152	-0.262	-0.686	-0.220	-0.037	0.026	0.062
Total Assets	1152	2229	9	25	104	511	2149
R&D Exp./Market	1152	0.130	0.009	0.023	0.055	0.135	0.293
5-year Growth in R&D	1152	0.192	-0.118	-0.004	0.134	0.302	0.544
ROA	1152	-0.213	-0.755	-0.290	-0.054	0.039	0.093
5-year Std. Dev. Of ROE	1152	0.810	0.044	0.087	0.195	0.550	1.465
3-Year growth in sales	1111	0.173	-0.154	-0.028	0.085	0.251	0.500
3-year average R&D/Sales	1143	5.146	0.009	0.039	0.120	0.254	0.991
4-Firm Concentration ratio	1120	0.658	0.413	0.457	0.706	0.818	0.915
R&D asset/ Market	1052	0.318	0.023	0.061	0.171	0.465	1.000
Panel C: Observations included in the time-series analysis							
Market Value	652	7148	9	46	420	2724	12829
Book/Market	652	0.714	0.169	0.307	0.494	0.821	1.399
Earnings/Market	652	-0.087	-0.192	-0.039	0.026	0.051	0.082
Total Assets	652	6427	14	50	332	2381	12793
R&D Exp./Market	652	0.093	0.009	0.018	0.038	0.087	0.182
5-year Growth in R&D	652	0.083	-0.096	-0.018	0.066	0.169	0.269
ROA	652	-0.021	-0.176	-0.031	0.025	0.065	0.106
5-year Std. Dev. Of ROE	652	0.319	0.028	0.049	0.092	0.177	0.409
3-Year growth in sales	650	0.057	-0.104	-0.027	0.047	0.133	0.236

3-year average R&D/Sales	652	0.185	0.008	0.017	0.043	0.098	0.185
4-Firm Concentration ratio	617	0.745	0.456	0.607	0.772	0.889	0.974
R&D asset/ Market	592	0.379	0.044	0.106	0.239	0.613	1.000

Notes:

1. The table is based on all firms with available data to apply our model in 2001.
2. The R&D asset is estimated using the parameters obtained from Equations (14) and (16).
3. R&D expenditures is Compustat item # 46.
4. Book (market) value is Compustat item # 60 (#25 * # 199).
5. Total assets is Compustat item # 6. Earnings is Compustat item # 18.
6. Return on assets and on equity is Compustat item # 18 divided by Compustat item # 6 and 60, respectively.
7. The 3-year average R&D/Sales is calculated as the 3-year sum of R&D expenditures divided by the 3-year sum of sales (Compustat item # 12).
8. The four--firm concentration ratio is the sum of revenues of the four largest firms in the 4-digit SIC industry divided by the sum of revenues for all firms in that industry.

Table 2
Distribution of Parameter Estimates

$$\frac{V_t}{BV_{t-1}} = A_0 + A_1 \frac{BV_t}{BV_{t-1}} + w' \frac{E_t}{BV_{t-1}} + [w' - \frac{(1+g)}{(r-g)}](1-d')a \frac{Xt}{BV_{t-1}} \quad (14)$$

$$\frac{E_{t+1}}{BV_{t-1}} = B_0 + B_1 \frac{BV_t}{BV_{t-1}} + w \frac{E_t}{BV_{t-1}} + [w - (1+g)](1-d')a \frac{X_t}{BV_{t-1}} \quad (16)$$

$$d' = \frac{d+r}{d+g} \quad \text{and} \quad w' = \frac{w}{(1+r-w)}$$

Cross-sectional All Observations	N	Mean	10%	25%	50%	75%	90%
Persistence (w)	1804	0.817	0.817	0.817	0.817	0.817	0.817
Proportion Asset (a)	1804	0.858	0.858	0.858	0.858	0.858	0.858
Amortization (d)	1804	0.142	0.142	0.142	0.142	0.142	0.142
V-Intercept (A0)	1804	-0.698	-0.698	-0.698	-0.698	-0.698	-0.698
V-Book (A1)	1804	3.965	3.965	3.965	3.965	3.965	3.965
E-Intercept (B0)	1804	0.242	0.242	0.242	0.242	0.242	0.242
E-Book (B1)	1804	-0.297	-0.297	-0.297	-0.297	-0.297	-0.297
R&DASS/MV	1644	0.340	0.028	0.074	0.196	0.528	1.000
R&DASS/(MV-BV)	1395	0.450	0.037	0.101	0.306	1.000	1.000
Cross-sectional Using 2-digit SIC Industries	**N**	**Mean**	**10%**	**25%**	**50%**	**75%**	**90%**
Persistence (w)	1092	0.699	0.134	0.800	0.820	0.841	0.841
Proportion Asset (a)	1092	0.759	0.233	0.850	0.859	0.860	0.860
Amortization (d)	1092	0.139	0.133	0.133	0.140	0.150	0.150
V-Intercept (A0)	1092	-0.323	-1.224	-0.200	-0.200	-0.200	-0.196
V-Book (A1)	1092	2.305	1.000	1.000	1.000	3.707	4.993
E-Intercept (B0)	1092	0.017	-0.064	-0.060	-0.060	-0.055	0.337
E-Book (B1)	1092	-0.058	-0.441	-0.018	0.050	0.050	0.050
R&DASS/MV	1000	0.321	0.024	0.065	0.178	0.467	1.000
R&DASS/(MV-BV)	852	0.422	0.036	0.090	0.256	0.942	1.000
Time-Series, Firm-Specific Estimation	**N**	**Mean**	**10%**	**25%**	**50%**	**75%**	**90%**
Persistence (w)	652	0.807	0.565	0.784	0.860	0.930	0.946
Proportion Asset (a)	652	0.882	0.773	0.850	0.902	0.960	0.970
Amortization (d)	652	0.120	0.030	0.042	0.100	0.150	0.227
V-Intercept (A0)	652	-0.543	-3.821	-0.529	-0.200	-0.019	1.960
V-Book (A1)	652	2.397	0.894	1.000	1.025	2.745	6.911
E-Intercept (B0)	652	0.000	-0.135	-0.060	-0.059	0.004	0.284
E-Book (B1)	652	0.000	-0.239	0.008	0.050	0.053	0.137
R&DASS/MV	592	0.379	0.044	0.106	0.239	0.613	1.000
R&DASS/(MV-BV)	498	0.507	0.056	0.153	0.411	1.000	1.000

Notes:

1. The system of Equations (14) and (16) is estimated for all firms in the first panel, for all firms within a 2-digit SIC industry with at least 10 observations in the second panel, and for each individual firm using all available time series observations in the third panel. The growth rate of R&D is the 5-year

annual growth rate of R&D expenditures. The risk-free rate, r, is assumed to be 5%. The table reports results only for firms where the non-linear system of equations converged to an optimal solution.

2. Persistence represents the persistence of abnormal earnings assuming capitalization of R&D expenditures.
3. 'Proportion Asset' is the proportion of R&D expenditures, which is assumed to be an asset with future benefits.
4. Amortization is the rate at which the R&D asset is amortized.
5. R&DASS/MV (R&DASS/(MV-BV)) represents the ratio of the R&D asset, estimated according to Equation (11) using the parameters above, to the market value of equity at the end of 2001 (the difference between market value of equity and book value of equity at the end of 2001), respectively.

Table 3
Parameter Estimates for Various Industries

SIC	N	Proportion Asset (a)	Amortization (d)	Persistence (w)	Ratio of R&D Asset to Market Value	Ratio of R&D Asset to Market Value Minus Book Value
20	21	0.919	0.082	0.920	0.187	0.357
25	17	0.899	0.101	0.817	0.295	0.418
26	24	0.975	0.025	0.965	0.301	0.562
28	295	0.859	0.141	0.841	0.309	0.403
29	12	0.901	0.100	0.927	0.088	0.163
30	27	0.870	0.130	0.880	0.375	0.474
32	12	0.552	0.459	0.028	0.089	0.231
33	29	0.923	0.077	0.922	0.189	0.392
34	35	0.960	0.040	0.930	0.358	0.582
35	258	0.860	0.140	0.820	0.434	0.574
36	296	0.233	0.133	0.134	0.264	0.384
37	58	0.830	0.170	0.728	0.311	0.493
38	271	0.860	0.140	0.800	0.363	0.429
39	23	0.842	0.159	0.620	0.333	0.352
48	13	0.828	0.174	0.328	0.111	0.328
50	10	0.908	0.108	0.939	0.275	0.351
67	10	0.764	0.269	0.717	0.146	0.127
73	275	0.850	0.150	0.820	0.438	0.535
87	29	0.967	0.033	0.624	0.380	0.405
99	89	0.858	0.142	0.817	0.257	0.376

Notes:

1. The table is based on classifying firms into industries according to their 2-digit SIC codes. The table is based on estimated parameters and estimates of the R&D asset obtained from cross-sectional analysis using the 2001 data according to Equations (14) and (16).
2. ‘Proportion Asset’ is the proportion of R&D expenditures, which is assumed to be an asset with future benefits.
3. Amortization is the rate at which the R&D asset is amortized.
4. Persistence represents the persistence of abnormal earnings assuming capitalization of R&D expenditures.
5. R&DASS/MV (R&DASS/(MV-BV)) represents the ratio of the R&D asset, estimated according to Equation (11) using the parameters above, to the market value of equity at the end of 2001 (the difference between market value of equity and book value of equity at the end of 2001), respectively.
6. ANOVA tests indicate that the mean parameters and the ratios of the R&D asset to either market value or to market value minus book value are different across industries with significance levels below 0.001.

Table 4
Tests of Differences Between Time-series and Cross-sectional Estimates of Parameters Within 2-Digit SIC Industries

SIC	N	Difference in Proportion Asset (a)	Significance	Difference in Amortization (d)	Significance	Difference in Persistence (w)	Significance
28	89	**0.047**	**0.001**	**-0.050**	**0.001**	-0.044	0.066
34	25	**-0.062**	**0.001**	**0.062**	**0.001**	**-0.109**	**0.001**
35	110	**0.027**	**0.002**	**-0.024**	**0.015**	-0.006	0.738
36	118	**0.647**	**0.001**	-0.013	0.225	**0.674**	**0.001**
37	30	0.031	0.069	-0.021	0.296	**0.084**	**0.005**
38	111	0.003	0.795	-0.003	0.728	-0.015	0.408
73	38	0.031	0.157	-0.025	0.296	0.018	0.511

Notes:

1. The table reports the mean differences between the parameter estimates obtained in the time series estimation for individual firms and those in the cross-sectional estimation using all firms within a 2-digit SIC industry in 2001. The table reports data for those industries in which there were at least 20 firms with time-series estimates.
2. Significance represents the significance level of a t-test that the mean difference in the immediate cell to the left is statistically equal to zero. Rejection of the null hypothesis of zero mean indicates that the estimated parameters for the subset of firms with sufficient data for time-series estimation are different from that estimated for all firms in the industry. Thus, rejection of the null hypothesis implies that the assumption of identical parameters for all firms within an industry is wrong.
3. Bolded figures represent rejection of the null hypothesis at levels of significance below 5%.
4. Untabulated results show that the difference in the ratio of the estimated R&D asset to market value is significantly different from zero for all the industries in the table, except for industry 38.

Table 5
Regression Results
Variables That Are Related To The Differences Between Estimates Based on Time-Series And Cross-Sectional (Within An Industry) Approaches

Variable	Difference in Proportion Asset (a)	Difference in Amortization (d)	Difference in Persistence (w)	Differences in The Ratio of R&D Asset to Market Value
Intercept	**0.338**	0.013	**0.302**	**0.167**
	0.001	0.616	**0.001**	**0.001**
5-year growth in R&D	**0.162**	-0.025	0.105	-0.074
	0.023	0.438	0.236	0.234
Log(Total Assets)	-0.009	-0.003	-0.002	0.001
	0.065	0.131	0.686	0.770
Market/Book ratio	-0.004	-0.002	-0.006	0.004
	0.187	0.100	0.086	0.103
ROA	**-0.174**	0.015	-0.108	**-0.130**
	0.011	0.633	0.202	**0.031**
Standard Deviation of ROE	-0.001	-0.001	-0.002	0.001
	0.792	0.475	0.661	0.750
3-year Growth in Sales	0.059	-0.012	-0.015	-0.062
	0.362	0.678	0.855	0.275
R&D Intensity	**-0.036**	0.002	-0.036	-0.009
	0.020	0.818	0.058	0.512
Concentration Ratio	**-0.210**	0.003	**-0.207**	-0.109
	0.001	0.922	**0.009**	0.051
N	552	552	552	552
R-Square	**0.063**	0.015	**0.029**	0.026
	0.001	0.414	**0.039**	0.067

Notes:

1. The dependent variables are the differences between the parameter estimates obtained in the time series estimation for individual firms and those in the cross-sectional estimation using all firms within a 2-digit SIC industry in 2001. Significance levels are reported below the coefficient estimates. Bold figures represent variables with significance levels below 5%.
2. For the definition of independent variables, see notes to Table 1.

Table 6
Regression Results
Corporate characteristics associated with the economic R&D asset

Variable	**Expected Sign**	**Ratio of R&D Asset to Market Value Time-Series Estimation**	**Ratio of R&D Asset to Market Value Within-Industry Estimation**	**Ratio of R&D Asset to Market Value All-Firm Estimation**	**Ratio of R&D Asset to Market Value Time-Series Estimation**	**Ratio of R&D Asset to Market Value Within-Industry Estimation**	**Ratio of R&D Asset to Market Value All-Firm Estimation**
Intercept		**0.706**	**0.625**	**0.716**	**0.673**	**0.563**	**0.643**
		0.001	**0.001**	**0.001**	**0.001**	**0.001**	**0.001**
5-year growth in R&D	-	**-0.665**	**-0.358**	**-0.350**	**-0.661**	**-0.369**	**-0.363**
		0.001	**0.001**	**0.001**	**0.001**	**0.001**	**0.001**
Log(Total Assets)	-	**-0.020**	**-0.035**	**-0.040**	**-0.023**	**-0.035**	**-0.041**
		0.001	**0.001**	**0.001**	**0.001**	**0.001**	**0.001**
Market/Book ratio	-	**-0.010**	**-0.011**	**-0.013**			
		0.001	**0.001**	**0.001**			
ROA	-	**-0.457**	**-0.202**	**-0.230**	**-0.467**	**-0.224**	**-0.256**
		0.001	**0.001**	**0.001**	**0.001**	**0.001**	**0.001**
Standard Deviation of ROE	-	0.000	0.000	0.000	0.000	-0.001	-0.001
		0.989	0.848	0.787	0.953	0.565	0.467
3-year Growth in Sales	-	**-0.255**	**-0.057**	**-0.059**	**-0.278**	**-0.074**	**-0.079**
		0.001	**0.001**	**0.001**	**0.001**	**0.001**	**0.001**
R&D Intensity	+	-0.006	-0.001	-0.004	-0.011	-0.004	-0.008
		0.720	0.861	0.326	0.503	0.348	0.061
Concentration Ratio		-0.115	-0.056	**-0.105**	-0.087	-0.018	-0.059
		0.093	0.141	**0.005**	0.204	0.636	0.116
N		558	1555	1572	558	1555	1572
R-Square		**0.309**	**0.293**	**0.340**	**0.300**	**0.262**	**0.298**
		0.001	**0.001**	**0.001**	**0.001**	**0.001**	**0.001**

Notes:

1. The dependent variable is the ratio of the R&D asset to market value of equity. The table reports regression results across the three methods to estimate it, time-series for individual firms, 2-digit SIC industries in 2001, and using all observations in 2001. Significance levels are reported below the coefficient estimates. Bold figures represent variables with significance levels below 5%.

2. For the definition of independent variables, see notes to Table 1.