R&D Costs and Accounting Profits

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Abstract

Opponents of SFAS-2, which required the immediate expensing of R&D, have cited research results documenting the long-term benefits of R&D. Both future operating income and current stock prices have been used to measure benefits. This paper re-examines the link between R&D investments and future operating income. We show why the specifications used in prior research might generate biased results, and offer an alternative approach. Although our approach is different, we confirm the main finding of prior research: capitalization and amortization allows better matching of R&D benefits, relative to immediate expensing. We also document differences in the magnitude, duration and statistical reliability of R&D benefits across industries. This evidence suggests that the potential informational benefits of capitalizing and amortizing R&D costs are likely to be industry-specific.

R&D Costs and Accounting Profits

1. INTRODUCTION

A debate has raged since Statement of Financial Accounting Standards (SFAS) No. 2 mandated that Research and Development (R&D) costs be expensed in the period incurred as the amount and timing of economic benefits from such costs are too uncertain to be estimated reliably. Those arguing for immediate expensing can point to evidence (e.g. Kothari, Laguerre, and Leone, 1999) which suggests that the benefits from R&D investments are considerably more variable than the benefits from other investments. A primary concern is that allowing managers discretion on the amount amortized could reduce the quality of reported earnings (e.g., Ely and Waymire, 1999). Those arguing for capitalization can point to a) evidence linking R&D investments with future operating income (e.g. Lev and Sougiannis, 1996) and b) an improved association between stock prices and accounting numbers when R&D, which is expensed in the income statement, is capitalized on the balance sheet and amortized in future income statements (e.g. Chambers, Jennings, and Thompson, 1998).[1] To allay concerns about earnings management, proponents of capitalization can cite evidence (e.g. Loudder and Behn, 1995) of higher earnings quality (earnings/price association) for firms capitalizing R&D, relative to firms expensing R&D, in the years immediately prior to SFAS 2.[2]

There are some potential disadvantages to using contemporaneous stock prices (or returns) when measuring the benefits from R&D investments. First, although stock prices reflect the expected benefits of current R&D investments, they also reflect the expected benefits of non-

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1 In addition, many studies provide evidence that investors view R&D cost as an asset and not an expense (e.g., Ben Zion (1978) and Hirschey and Weygandt (1985)).

2 Healy, Myers and Howe (1999) provide additional evidence. Using a simulation model, they find that capitalizing and subsequently amortizing successful R&D costs improve the relation between accounting information and economic values even when there is widespread earnings management.

R&D investments. More important, prices reflect expected rents from investments (both R&D and non-R&D) not yet made, and this effect is difficult to control for. Second, there is evidence to suggest that stock prices are inefficient with respect to R&D investments. Lev and Sougiannis (1996) and Chan, Lakonishok, and Sougiannis (1999) show that the stock market undervalues R&D investments, on average. Finally, while the debate has focused on the magnitude and duration of benefits from R&D, stock prices also reflect the risk associated with those benefits. As a result, we believe the research that measures R&D benefits using future operating income (specifically Sougiannis, 1994, Lev and Sougiannis, 1996, and Lev and Zarowin, 1998) represents the most reliable evidence supporting the capitalization view.

Our objective is to re-examine this empirical link, because the approach used in those studies to control for the effect of non-R&D activities on operating income may have generated biased estimates for the economic benefits of R&D (details provided in section 2). We propose an alternative methodology to measure the benefits from R&D and implement it empirically. While our method improves the controls for non-R&D activities, it requires us to impose additional structure by making assumptions about the processes underlying earnings from both R&D and non-R&D investments. Since we cannot determine the validity of our assumptions or the extent to which our approach offers additional control, our efforts are best viewed as an analysis that is complementary to the investigations conducted by others.

We find that on average each dollar of R&D generates about $1.30 of future benefits (measured in present value terms). While there is some variation in the duration of R&D benefits across different industries, for most industries a good match with the pattern of benefits is obtained by amortizing capitalized R&D over seven years, using the straight line method. There is, however, significant variation in the amount and reliability of the benefits across industries.

For some industries, the data indicate that R&D costs generate large and reliable benefits, while for other industries the amount and reliability of the benefits are relatively small. Importantly, observed variation in the amount, duration, and reliability of benefits across industries is consistent with popular perceptions of the profitability of R&D in those industries. For example, the amount and duration and reliability of benefits are relatively large in the Chemicals and Pharmaceutics industries, and are relatively small in the Machinery and Computer Hardware industries.

Despite substantial methodological differences between this paper and the three earlier studies, we confirm their primary finding that capitalization and amortization of R&D costs achieves better matching of costs and benefits than that obtained under immediate expensing. We also confirm the finding in Lev and Sougiannis (1996) that the amount and duration of R&D benefits varies across industries. The pattern of variation we observe is, however, different from that in Lev and Sougiannis. While these differences could be due to different samples, they could also be due to differences in the methodology used. A major differentiating feature of our study is that we also provide estimates of the reliability of observed R&D benefits. Whereas the three prior studies capitalize and amortize R&D for all industries, we do not recommend it for certain industries because the observed benefits are not sufficiently large and reliable.

Although we do not examine contemporaneous prices, for the reasons mentioned above, we find similarities between our study and Chambers, Jennings, and Thompson (1998) in the duration of benefits estimated across different industries. Since they do not report variation in the amount and reliability of R&D benefits, we are unable to compare those two attributes.

From a valuation perspective, our results support the recommendation of prior research that "as-if" statements that adjust reported numbers for R&D capitalization and amortization should improve the ability of investors to forecast future accounting profitability. From a standard-setting perspective, our results suggest that capitalization followed by straight-line amortization over seven years is a superior alternative to immediate expensing, for many (but not all) industries.

The study proceeds as follows. In Section 2 we discuss the methodology used in previous studies, and in Section 3 we develop our methodology. Sample selection procedures and measurement issues are discussed in Section 4. The empirical findings are presented in section 5, and section 6 concludes the paper.

2. PRIOR RESEARCH

To identify the relation between current R&D costs and future operating income benefits, prior research has examined the cross-sectional relation between current operating income and current and past R&D costs (e.g., Sougiannis (1994), Lev and Sougiannis (1996)). In essence, they regress current earnings on current and past R&D and include total assets to capture variation in income that is not due to R&D. The coefficients on the R&D variables are interpreted as measures of the benefits obtained from R&D outlays.

The prior studies have recognized that current R&D is often endogenously determined by the firm's success, as proxied by contemporaneous operating income. That is, firms that do well (poorly) allocate more (less) to R&D budgets that year. To avoid this problem, Sougiannis (1994) simply drops current R&D from the regression, and Sougiannis and Lev (1996) use an instrumental variable to proxy for current R&D.

We believe that there are two important specification issues with this approach. First, since many firm-specific factors that determine profitability are omitted from the regression, any correlation between those omitted variables and the included variables will result in biased coefficients. Second, and probably more important, the inclusion of total assets to control for operating income from non-R&D investments could bias the results. While total assets is likely to capture benefits from non-R&D activities, it may also be correlated with benefits generated by R&D. This follows because the level and success of past R&D determines investments in assets. As a result, the coefficients on the R&D variables are likely to be biased downward.

To illustrate this point, consider the following example. Assume all firms invest in R&D at the beginning of period 1. They may invest different amounts, and the success in R&D is not perfectly correlated across the firms. If the R&D is successful, at the end of period 1 the firm invests in a dollar of plant per dollar of R&D, and in period 2 the firm receives $4 of cash flow per dollar of R&D. The effects on the financial statements are as follows. In period 1, income is reduced by the R&D expenditure regardless of whether the R&D is successful or not. In period 2, if the R&D is successful, income is increased by $3 per dollar of R&D ($4 cash flow less $1 depreciation), and if the R&D is unsuccessful, there is no effect on income. Note how income is perfectly related to total assets in this example, but only stochastically related to R&D expenditures.[3] Therefore, regressing income in period 2 on total assets at the beginning of period 2 and R&D in period 1 would yield a zero coefficient for R&D and a positive coefficient (equals to 3) for total assets. That is, all the benefits will be captured by the coefficient on total assets, although it is the R&D that generated the benefits.

The above illustration describes an extreme case in which fixed assets are perfectly correlated with the benefits from R&D. In reality, both fixed assets and R&D costs are only partially correlated with the benefits from R&D (i.e., both relationships are stochastic). Thus, the

[3] When the R&D is successful, the incremental income ($3 per dollar of R&D) is three times the incremental total assets ($1 per dollar of R&D), and when the R&D is unsuccessful, the incremental income ($0) is again three times the incremental total assets ($0)

extent to which the coefficients on the R&D variables capture the benefits from R&D depends on the strength of the relation between R&D costs and the benefits from R&D, compared with the relation between fixed assets and the benefits from R&D. Kothari, Laguerre and Leone (1998) find that the contribution of R&D investments to future earnings variability is three times as large as that of capital expenditures. Thus, if successful R&D outlays lead to investments in fixed assets, the problem of the coefficient on fixed assets capturing R&D benefits is likely to be severe.

There is an additional reason for potential bias in the specification used in Lev and Sougiannis (1996) and Lev and Zarowin (1998) because they deflate each variable by sales in the corresponding year. As a result, their specification converts the unscaled relation into one that involves ratios. [4] Specifically, the operating profit margin (operating income divided by sales) is regressed on asset turnover and current and past R&D intensity ratios (R&D divided by sales) in each prior period. By focusing on operating profit margin, this approach ignores the R&D benefits due to sales growth and asset turnover. While R&D investments might increase operating margins (by reducing costs or increasing selling prices), they are also likely to improve asset turnover and sales growth, both of which represent benefits reflected in future operating income.

3. METHODOLOGY

The main methodological issue is how to control for the benefits from non-R&D activities when measuring the benefits from R&D. The second issue noted, relating to the ratio interpretation, is solved by deflating all variables by the same scaling variable. For example,

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4 Note that the intercept in the unscaled relation was not scaled by sales in the specification used in these two studies.

Sougiannis (1994) deflates all variables including the intercept by current “net capital stock”, representing the sum of (inflation-adjusted) net plant, property, and equipment, inventories, and recorded intangibles.

While we identify a potential problem in the methodology used by previous studies, we are unable to solve it in the context of their specifications. However, at the cost of imposing additional structure on the dynamics of earnings from R&D and non-R&D activities, we are able to develop a methodology that circumvents the problem. That methodology is described below.

Whereas previous studies use operating income to measure the benefits from R&D, we use *abnormal* operating income. Abnormal operating income is defined as the difference between operating income and the product of the cost of capital (*k*) and Net Operating Assets (NOA) at the beginning of the year. Since R&D costs are expensed as incurred, the same benefits that are captured by operating income are also captured by abnormal operating income. However, abnormal operating income is likely to be a better proxy for the economic benefits from R&D since it is not “contaminated” by irrelevant normal profitability on NOA. This is an important advantage since, for the reason discussed above, current NOA should not be included as an explanatory variable.

We decompose abnormal operating income (OI^a) into two components: a component that represents the effect of past R&D (OI^{RD}) and a component that reflects the benefits from all non-R&D activities (OI^{aNRD}),

$$OI_t^a = OI_t^{RD} + OI_t^{aNRD}. \quad (1)$$

We omit the superscript “a” from OI^{RD} since the book value of R&D is zero and hence “abnormal” and “normal” profits from R&D are the same.

We assume that shocks to the non-R&D component of abnormal operating income (OI^{aNRD}) decay geometrically; that is, OI^{aNRD} follows an AR(1) process:

$$OI_t^{aNRD} = \alpha OI_{t-1}^{aNRD} + \varepsilon_t , \tag{2}$$

where ε_t is uncorrelated with past R&D and past abnormal operating income, but it may be correlated with any other variable. This structure is consistent with the linear information dynamics in Ohlson (1995), except that here ε_t is allowed to follow any process as long as it is uncorrelated with past R&D and past abnormal operating income. (In Ohlson (1995), ε_t is specified as the sum of a white noise term and a variable that follows AR(1).) Dechow, Hutton and Sloan (1999) provide empirical evidence supporting Ohlson's information dynamics.

We further assume that the benefits from R&D are captured by the following equation:

$$OI_t^{RD} = \sum_{\tau=1}^{T} \gamma_\tau R\,\&\,D_{t-\tau} + \nu_t \tag{3}$$

where γ_τ represents the average current economic benefits from a dollar of R&D incurred τ years ago. Above (below) average success in R&D is likely to generate above (below) average profits for several years. That is, ν_t is likely to be auto-correlated. Moreover, since success in R&D means generating sales or reducing costs, which are both core activities, the persistence of shocks to profitability from R&D activities is likely to be similar to that of shocks from core non-R&D activities. We thus assume that $\nu_t = \alpha \nu_{t-1} + \eta_t$ where η_t is uncorrelated with past R&D and past abnormal operating income.

Similar to Sougiannis (1994), when specifying equation (3) we assume that R&D costs do not generate contemporaneous income. We make this assumption to avoid the problem of simultaneity, which would result if we include current R&D. Companies are likely to increase R&D in good earnings periods and cut R&D in poor periods. Including current R&D in an equation that explains current profitability will result in biased coefficients because current R&D is correlated with current residual profitability.

Substituting equations (2) and (3) into equation (1) yields

$$OI_t^a = \alpha OI_{t-1}^{aNRD} + \varepsilon_t + \sum_{\tau=1}^{T} \gamma_\tau R\&D_{t-\tau} + \nu_t \,. \tag{4}$$

Applying equations (1) and (3) to period t-1, we get

$$OI_{t-1}^{aNRD} = OI_{t-1}^{a} - OI_{t-1}^{RD} = OI_{t-1}^{a} - \sum_{\tau=1}^{T} \gamma_\tau R\&D_{t-\tau-1} - \nu_{t-1} \,. \tag{5}$$

Substituting equation (5) into equation (4) gives

$$OI_t^a = \alpha(OI_{t-1}^{a} - \sum_{\tau=1}^{T} \gamma_\tau R\&D_{t-\tau-1} - \nu_{t-1}) + \varepsilon_t + \sum_{\tau=1}^{T} \gamma_\tau R\&D_{t-\tau} + \nu_t \tag{6}$$

and after re-arranging terms, we get

$$OI_t^a = \alpha OI_{t-1}^{a} + \sum_{\tau=1}^{T} \gamma_\tau R\&D_{t-\tau} - \alpha \sum_{\tau=1}^{T} \gamma_\tau R\&D_{t-\tau-1} + \pi_t \tag{7}$$

where $\pi_t = \varepsilon_t + \nu_t - \alpha\nu_{t-1} = \varepsilon_t + \eta_t$ and thus is uncorrelated with past R&D and past abnormal operating income (the independent variables). The first term on the right hand side of Equation (7) captures the effect of non-R&D activities on current income, but it also includes a portion (α) of the effect of past R&D on the previous year's income. The second term captures the effect of past R&D on current income. The third term offsets the effect of past R&D on previous year's income that is included in the first term. Thus, the sum of the first and third terms equals income from non-R&D activities. Note that unlike the specifications in previous studies, the effect of non-R&D activities on income is eliminated here by quasi-differencing, and since no control variables are included, the problem of the control variables capturing R&D benefits is not present here.

Attempting to estimate equation (7) would result in imprecise estimates due to the high level of auto-correlation in R&D costs. We address this issue by assuming that all the R&D coefficients are equal: $\gamma_t = \gamma$ for all $\tau = 1,\ldots,T$. That is, on average, each dollar of R&D generates the same amount of operating income in each of the subsequent T years.[5] Substituting into equation (7), we get

$$OI_t^a = \alpha OI_{t-1}^a + \gamma \sum_{\tau=1}^{T} R\&D_{t-\tau} - \alpha\gamma \sum_{\tau=1}^{T} R\&D_{t-\tau-1} + \pi_t \, . \tag{8}$$

Since equation (8) is non-linear in the parameters we use non-linear least-squares estimation. We repeat the estimation for different values of T and analyze the coefficients to obtain insights on the amount, duration and reliability of the benefits. To mitigate the effect of heteroskedasticity, we weight the observations by the reciprocal of operating assets at the beginning of year t.[6] Note that since the model is non-linear, weighted estimation is not equivalent to ordinary estimation with deflated variables.

4. DATA

4.1 Sample

The sample includes all firm-year observations that satisfy the following criteria. The company (i) was listed on the NYSE or AMEX, and (ii) is not a financial institution (SIC 6000-6999). In addition, (iii) R&D expense and total assets for the previous two years, and income

5 Note that this assumed pattern of operating income from R&D implies straight-line amortization based on the technique employed by Lev and Sougiannis (1996). Consistent with the matching principle, Lev and Sougiannis (1996) calculate amortization rates that result in a constant expected profit margin (but increasing expected return on investment).

6 Although abnormal operating income is measured relative to net operating assets, we deflate by operating assets. We do so for two reasons: (1) net operating assets may be small or even negative, and (2) the cost of operating liabilities is relatively stable and thus variability in abnormal operating income is due mainly to variability in the profitability of operating assets. The results, however, are not sensitive to weighting by net operating assets instead.

before extraordinary items in the current and previous year, are all available in the COMPUSTAT Industrial Annual and Research files.

Although some companies disclosed R&D outlays prior to 1975, disclosure of the R&D expense is required only since 1975. To avoid selection bias, we do not use R&D prior to 1975. Since we require a minimum of two years of non-missing (but possibly zero) R&D expense, the sample covers the period 1977 through 1998. To mitigate the effect of influential observations, we delete observations for which any of the variables, deflated by operating assets at the beginning of the current year, is outside the 1%-99% range of its empirical distribution. These sample selection criteria resulted in a maximum sample of 18,879 firm-year observations (2,015 firms). Panel A of Table 1 provides the number of observations per year.

4.2 Variables Measurement

We measure net operating assets as operating assets minus operating liabilities. Operating assets are measured as total assets (Compustat item #6) minus financial assets. Financial assets are measured as cash and short term investments (#1) plus investments and advances-other (#32). Operating liabilities are measured as total liabilities (#181), minus minority interest (#38), minus long-term debt (#9) and minus debt in current liabilities (#34). (See Nissim and Penman, 1999, for a discussion of these measurement choices.)

Abnormal operating income before R&D is measured as core operating income before R&D, minus the product of net operating assets at the beginning of the year and an estimate for the cost of capital. We use core operating income (instead of total operating income) because R&D costs are not likely to generate income items that are classified as "unusual." We measure core operating income before R&D as income before extraordinary items (#18), plus minority interest in income (#49), minus after tax special items (#17 × (1- marginal tax rate)), minus after tax nonoperating income (#61 × (1- marginal tax rate)), plus after tax interest expense (#15 × (1- marginal tax rate)) and plus after tax R&D expense (#46 × (1- marginal tax rate)).[7] We measure the marginal tax rate as the statutory federal tax rate plus 2% average state tax rate.[8]

We measure the R&D variable as #46 × (1- marginal tax rate). We adjust R&D for the tax shield since the benefits (i.e., operating income) are also measured after tax.[9] We estimate the cost of capital as the one-year interest rate at the beginning of the year plus 6%. Robustness checks indicate that this assumption does not affect our inferences.[10] We extract the risk-free interest rate from the Fama-Bliss Discount Bond file on CRSP.

Panel B of Table 1 provides descriptive statistics for the regression variables. R&D is on average more than 2% of operating assets and is positive for almost 90% of the observations.

Table 2 provides the Pearson (lower triangle) and Spearman (upper triangle) correlation coefficients among the variables. The coefficients in both triangles are similar, indicating that outliers are not likely to affect the inference. All coefficients are significant at conventional levels. As expected, both R&D costs and abnormal operating income are highly auto-correlated. Also, abnormal operating income is positively related to R&D in each of the previous 11 year.

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7 When any of the data items, except of R&D expense, total asset and income before extraordinary items, were recorded as missing we set their value to zero.

8 We measure the federal tax rate as 48% for 1975-1978, 46% for 1979-1986, 40% for 1987, 34% for 1988-1992 and 35% for 1993-1998.

9 We use after-tax operating income because we attempt to measure the average after-tax effect of R&D and the marginal and effective tax rates are not equal and not constant.

10 We repeated the analysis using a constant rate of 10% and obtained similar results, except that the estimated benefits were slightly larger. This difference is due to the high interest rates during many of the sample years, which resulted in an average discount rate above 10%.

5. RESULTS

5.1 Full sample

Table 3 presents estimation results of equation (8) for values of T ranging between 1 and 10. In Panel A, each regression is based on all available observations. The number of observations decreases with T for two reasons: (1) survivorship, and (2) the number of sample years decreases with T (e.g., for T = 1 the sample covers the period 1977 through 1998 but for T = 10 the sample covers the period 1986 through 1998). In Panel B, only observations with non-missing values for all ten regressions are used.

In both panels, α and γ are positive and highly significant in all the regressions. α, the persistence of abnormal operating income, is also relatively stable: it ranges from 0.80 to 0.86. The estimates of α are larger than the 0.62 persistence coefficient reported by Dechow, Hutton and Sloan (1999), mainly because we measure income before special and nonoperating items, which are relatively transitory. The fact that γ is positive and significant confirms that R&D costs generate future economic benefits. The similarity of the estimates in the two panels indicates that the results are generally not sensitive to survivorship bias.

In addition to the coefficient estimates and their t-statistics, each panel presents three test statistics (the Wald statistic, the likelihood ratio and the Lagrange multiplier) and two measures of the total benefits from R&D (total undiscounted benefits and total discounted benefits). Each of the three test statistics is distributed chi-square with one degree of freedom under the null hypothesis of no benefits (i.e., that γ is zero). The Wald statistic measures the extent to which the unrestricted estimates fail to satisfy the hypothesized restriction.[11] The likelihood ratio measures the extent to which imposing the restriction results in a reduction in the value of the log-

[11] The Wald statistic equals the square of the t-statistic of γ.

likelihood function. The Lagrange multiplier measures the extent to which the slope of the log-likelihood function is different from zero at the restricted parameter estimate. The Wald test and the Lagrange multiplier test have the shortcoming that the alternative hypothesis does not enter the computation, which may result in limited power. The likelihood ratio and Lagrange multiplier tests have the disadvantage of assuming normality. (For further discussion, see, e.g., Green (1997).) Since no one statistic is clearly superior, we report all three.

The two measures of benefits, the implied total undiscounted and discounted benefits from a dollar of R&D, are based on the estimated value of γ. The total undiscounted benefits from a dollar of R&D is calculated as the sum of the γs over T periods ($\gamma \times T$). The total discounted benefits is calculated as the discounted sum of the γs over the T periods, based on a 10% discount rate ($\gamma \times [1/1.1 + 1/1.1^2 + 1/1.1^3 + \ldots + 1/1.1^T]$).

In both panels, the discounted sum of the coefficients increases monotonically with T until T = 7, and is relatively stable for T = 8, 9, and 10. The average discounted benefits for T = 7, 8, 9, and 10 are estimated at about $1.3 for each dollar of R&D. Also, in both panels, the null hypothesis that R&D costs provide no future economic benefits is rejected at a high level of significance for all T.

The coefficients should be interpreted with caution. For example, for T = 1 (i.e., if we assume that all the benefits are recognized in earnings in the year subsequent to the recognition of the R&D expense), the implied undiscounted benefits from a dollar of R&D is $0.88 (Panel A). This number seems unreasonably large: a dollar of R&D is not likely to increase earnings in the subsequent period by $0.88. The reason for this large coefficient is that R&D costs generate benefits over more than one year, and those benefits are highly auto-correlated (see Table 2). In other words, the coefficient is biased upward due to the effect of correlated omitted variables (R&D in the years preceding the previous year).

The three test statistics can be used to estimate the duration of the benefits. An increase in the test statistics from adding past R&D costs indicates that those past costs provide benefits in the current period. Otherwise, their inclusion would have reduced the test statistics as it adds measurement error to the R&D term. Similarly, a decrease in the test statistics implies that the past R&D costs do not generate income in the current period, and thus including them adds measurement error that reduces the value of the tests statistics. This interpretation is subject to the assumption that the benefits follow the assumed straight-line structure.

In Panel A, all the test statistics reach their maximum in year T = 7, implying that on average R&D costs provide seven years of benefits (excluding the year of R&D investment). Note that since the sample size decreases with T, comparisons of test statistics for different T are not completely valid. This concern does not apply to Panel B where only observations with non-missing values in all the regressions (i.e., for all T) are used. The results in Panel B, however, are sensitive to survivorship bias, and survivorship bias is likely to bias the estimated duration of the benefits upward. Therefore we focus on the results in Panel A.[12]

5.2 Selected Industries

Different industries have different persistence of abnormal earnings (see, e.g., Dechow, Hutton and Sloan (1999)). Also, the amount, size and reliability of benefits from R&D are likely to vary across industries. Lev and Sougiannis (1996) document significant differences in implied R&D amortization rates across industries. Chan, Martin, and Kensinger (1990) find that

[12] Fortunately, the differences between the results in Panels A and B are small. In Panel B, the Wald statistic reaches its maximum for T = 8, LR reaches its maximum for T = 9, and LM increases monotonically through T = 10. But the changes in the test statistics are relatively small after T = 7.

abnormal stock returns triggered by announcement of increases in R&D spending are on average positive for high-technology firms and negative for low-technology firms. Lev and Zarowin (1998) find that the market valuation of R&D varies across industries. We thus repeat the analysis at the 2-digit SIC industry classification level.[13]

Table 4 presents results of estimating equation (8) for five industries with relatively high R&D intensity as well as for all other industries combined (see Lev and Sougiannis, 1996). The five industries are Chemicals and Pharmaceutics (SIC 28, results presented in panel A), Machinery and Computer Hardware (35, Panel B), Electrical and Electronics (36, Panel C), Transportation Vehicles (37, Panel D), Scientific Instruments (38, Panel E), and all other industries (Panel F).

There are large differences across the industries in the magnitude and significance of the coefficients as well as in the size and behavior of the test statistics. These differences support the view that the analysis and inference should be performed at the industry level.

Chemicals and Pharmaceutics (panel A). The Wald statistic and the likelihood ratio are large suggesting that the benefits are reliably positive. Although the Lagrange multiplier is small, the combination of high Wald statistic and likelihood ratio suggests that the Lagrange multiplier is small because the likelihood function is not monotonically concave, rather than because the benefits are small. (That is, the Lagrange multiplier has low power in this case.) The pattern of all the three test statistics is similar: they increase through year 7 and then decline, suggesting that on average R&D costs provide benefits for seven years. The discounted benefits are large, about $2.4 per dollar of R&D for T = 7. Hence, for this industry, to achieve good matching of

13 Monahan (1999) finds that the capitalization of R&D improves the value relevance of earnings only for firms with high past growth in R&D. Since there is significant cross-industry variation in past R&D growth, this evidence also supports an industry analysis.

costs and benefits, R&D costs should be capitalized and amortized using the straight-line method over a period of seven years.

Machinery and Computer Hardware (Panel B). The test statistics are significant and reach their maximum for T = 1. The discounted benefits are about $0.66, and this result is robust to values of T ranging between 1 and 10. The short duration of the R&D benefits as well as the fact that they are less than the R&D cost suggest that for this industry capitalization and amortization of R&D is not likely to significantly improve the financial statements.

Electrical and Electronics (Panel C). The test statistics are significant and reach their maximum for T = 5, implying 5 years of benefits on average. The discounted benefits are about $0.7, and this result is robust to values of T ranging between 2 and 10.

Transportation Vehicles (Panel D). The test statistics, although significant, are not high, implying that the benefits are not very reliable. The test statistics reach their maximum for T = 7. The amount of discounted benefits is about $0.9.

Scientific Instruments (Panel E). The results are similar to those of the pooled regressions. The test statistics are significant and reach maximum for T = 7. The discounted benefits are about $1.3 and are insensitive to T ranging between 6 and 10. Thus, for this industry, to achieve good matching of costs and benefits, R&D costs should be capitalized and subsequently amortized using the straight-line method over a period of seven years.

All other industries (Panel F). The test statistics are significant and reach maximum for T = 7. The discounted benefits are about $1.1. These results suggest that even for non-R&D intensive industries, proper matching of costs and benefits is achieved by capitalizing R&D costs and subsequently amortizing them using the straight-line method over a period of seven years.

The results described in section 5.1 (for the overall sample) and in section 5.2 (for the different industries) appear reasonable and consistent with economic intuition. However, at least three caveats are in order. First, the assumption that R&D costs do not generate contemporaneous earnings may result in biased coefficients especially when the benefits from R&D are short-term. Second, the assumption that the benefits follow a straight-line structure may result in biased inference especially when the benefits are long-term. Third, in each regression we assume the same persistence of operating income and the same size and duration of R&D benefits for all firms in the industry. For some industries, identified using two-digit SIC, these assumptions may be inappropriate.

5.3 Cross-sectional Results

Since the pooled regressions in Tables 3 and 4 do not provide any indication of the extent to which the observed relationships remain consistent over time, we repeat the analysis separately for each year. Table 5 provides summary statistics from annual cross-sectional regressions of Equation (8) for all firms (Panel A), for selected industries (Panels B through F), and for all other firms (Panel G). In each panel, we report results only for one value of T: the value that provides the best fit in the corresponding pooled regressions (most likely duration of R&D benefits). For each of the coefficients, α and γ, the table reports five statistics: (i) the time series mean of the cross-sectional coefficients; (ii) the time series median of the cross-sectional coefficients; (iii) the *t*-statistic associated with the time series distribution of the cross-sectional coefficients; (iv) a *z*-statistic that incorporates the information in the cross-sectional *t*-statistics; and (v) the proportion of times that the coefficient is positive. The *t*-statistic tests the hypothesis that the coefficient is constant over time and differs from zero. The *z*-statistic allows the coefficient to vary over time, and it tests the hypothesis that the average coefficient differs from zero.[14]

Table 5 also reports the cross-sectional mean and median of each of the three test statistics (Wald, LR, and LM), the mean and median of the undiscounted and discounted benefits, and mean and median of the number of observations. Note that the t- and z-statistics that correspond to γ, and the proportion of positive γs, apply to the undiscounted and discounted benefits as well, since the latter constructs are proportional to γ.

The results in Panels A (all firms), B (Chemicals and Pharmaceutics) and F (Scientific Instruments) are consistent with the pooled regressions. Specifically, the mean and median coefficients (and thus the mean and median discounted and undiscounted benefits) are similar to the pooled regression results. Moreover, the significance of γ and the proportion of times it is positive are high.

In Panel C (Machinery and Computer Hardware), the mean and especially median benefits are close to zero. Moreover, the proportion of positive R&D benefits is exactly 50%, which is the expected value under the hypothesis that R&D costs provide no future benefits. These results are inconsistent with the pooled regressions in which the benefits, although short-term and small, are significant. Examination of the cross-sectional estimates reveals that the R&D benefits are more significant when they are positive, relative to when they are negative. This evidence suggests that the cross-sectional regressions in which the estimated benefits are negative were affected by a small number of firms with a strong negative relation between R&D and abnormal operating income. In the pooled regressions, the effect of such observations is

[14] The *z*-statistics equal the product of the square root of the number of cross-sectional regressions and the mean of the cross-sectional *t*-statistics. Under the null of zero coefficient, each *z*-statistic has a standard normal distribution.

smaller. These results provide further support for our inference (in Section 5.2) that capitalization and subsequent amortization of all R&D costs in the Machinery and Computer Hardware industries is not likely to substantially improve the financial statements.

In the other three panels, the mean and median R&D benefits are quite different from each other, making it difficult to compare the annual regressions with the pooled regressions. These are Panel D (Electrical and Electronics), panel E (Transportation Vehicles), and Panel G (All other industries). Examination of the cross-sectional coefficients reveals that in each of these Panels the mean R&D benefits is affected by one extreme negative estimate (1985, 1990, and 1984 respectively). So for these sub-samples the median estimates are more representative. Indeed, the median estimates in Panels D, E and G are similar to the estimates from the corresponding pooled regressions, where outliers have a smaller effect.

6. SUMMARY AND CONCLUSIONS

This study develops and implements a new methodology for measuring the benefits from R&D costs, as reflected in future operating income. We find that on average each dollar of R&D generates about $1.3 in discounted future benefits. However, the reliability, amount, and duration of benefits vary across industries, and these patterns are observed consistently year after year.

The results on reliability of future benefits suggest that capitalization and subsequent amortization of R&D costs is likely to improve the matching of costs and benefits in financial statements for certain industries. But for other industries our results suggest that the benefits are not reliable and the advantages of capitalization and amortization are not as clear. The results on duration suggest that if R&D costs are capitalized in certain industries, the period of amortization should vary across industries, based on the average observed duration of those benefits. Our results on the magnitude of benefits imply that the extent of profitability of investments in R&D

varies across industries, and that level of profitability is observed with some consistency over time.

Overall, the results on the reliability and duration of R&D benefits offer support for the proponents of R&D capitalization. By observing similar results using a different methodology, we confirm the general findings of earlier studies. One important difference is, however, that we would not recommend capitalization for certain industries. Our results on the reliability, duration, and amount of R&D benefits have implications for valuation. Again, for certain industries, our description of the average industry experience offers a simple way to value current, past, and future R&D.

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Table 1
Description of Sample

Panel A: Frequency of firm-year observations by fiscal year

Year	Obs.	Year	Obs.	Year	Obs.	Year	Obs.
1977	1,013	1983	801	1989	777	1995	900
1978	947	1984	791	1990	795	1996	931
1979	913	1985	792	1991	833	1997	1,009
1980	857	1986	770	1992	866	1998	901
1981	830	1987	775	1993	889		
1982	810	1988	779	1994	900		
						Total	18,879

Panel B: Descriptive statistics for the regression variables

	Obs.	Mean	STD	1%	5%	10%	25%	50%	75%	90%	95%	99%
OI^a_0	18,879	1.42	10.68	-27.0	-12.8	-8.77	-3.99	0.58	5.93	13.25	19.48	36.01
OI^a_{-1}	18,879	0.67	9.82	-31.6	-13.1	-8.49	-3.59	0.62	5.17	10.94	15.72	28.94
$R\&D_{-1}$	18,879	2.24	2.93	0.00	0.00	0.00	0.39	1.27	2.99	5.60	7.85	13.88
$R\&D_{-2}$	18,879	1.98	2.60	0.00	0.00	0.00	0.35	1.13	2.59	4.91	6.78	12.63
$R\&D_{-3}$	16,814	1.81	2.33	0.00	0.00	0.00	0.35	1.06	2.37	4.49	6.12	11.25
$R\&D_{-4}$	15,059	1.66	2.14	0.00	0.00	0.00	0.33	0.98	2.16	4.10	5.57	10.63
$R\&D_{-5}$	13,518	1.53	1.97	0.00	0.00	0.00	0.32	0.89	1.99	3.72	5.13	9.84
$R\&D_{-6}$	12,152	1.42	1.84	0.00	0.00	0.00	0.30	0.83	1.83	3.42	4.75	9.24
$R\&D_{-7}$	10,903	1.31	1.68	0.00	0.00	0.00	0.28	0.77	1.68	3.10	4.42	8.63
$R\&D_{-8}$	9,776	1.22	1.58	0.00	0.00	0.00	0.27	0.72	1.55	2.87	4.17	7.91
$R\&D_{-9}$	8,732	1.12	1.45	0.00	0.00	0.00	0.25	0.66	1.42	2.63	3.88	7.48
$R\&D_{-10}$	7,770	1.02	1.31	0.00	0.00	0.00	0.22	0.59	1.30	2.35	3.52	6.66
$R\&D_{-11}$	6,897	0.92	1.17	0.00	0.00	0.01	0.20	0.54	1.18	2.15	3.18	6.03

OI^a is core abnormal operating income before R&D but after taxes. R&D is after-tax research and development expense. All variables are deflated by operating assets at the beginning of year zero and are expressed as percentages.

Table 2
Pearson (Lower Triangle) and Spearman (Upper Triangle) Correlation Coefficients among the Regression Variables

	OI^a	OI^a_{-1}	$R\&D_{-1}$	$R\&D_{-2}$	$R\&D_{-3}$	$R\&D_{-4}$	$R\&D_{-5}$	$R\&D_{-6}$	$R\&D_{-7}$	$R\&D_{-8}$	$R\&D_{-9}$	$R\&D_{-10}$	$R\&D_{-11}$
OI^a_0	.	0.76	0.35	0.33	0.32	0.32	0.32	0.31	0.31	0.29	0.28	0.26	0.26
OI^a_{-1}	0.71	.	0.34	0.29	0.28	0.27	0.27	0.26	0.26	0.25	0.24	0.23	0.21
$R\&D_{-1}$	0.34	0.27	.	0.97	0.94	0.90	0.87	0.83	0.80	0.77	0.74	0.71	0.68
$R\&D_{-2}$	0.30	0.20	0.91	.	0.97	0.94	0.90	0.86	0.83	0.80	0.77	0.74	0.71
$R\&D_{-3}$	0.28	0.18	0.84	0.92	.	0.97	0.93	0.90	0.86	0.83	0.80	0.77	0.74
$R\&D_{-4}$	0.26	0.17	0.78	0.85	0.93	.	0.97	0.93	0.90	0.86	0.83	0.80	0.77
$R\&D_{-5}$	0.26	0.17	0.73	0.79	0.87	0.94	.	0.97	0.93	0.90	0.87	0.83	0.81
$R\&D_{-6}$	0.24	0.16	0.68	0.74	0.81	0.88	0.95	.	0.97	0.93	0.90	0.87	0.84
$R\&D_{-7}$	0.22	0.17	0.64	0.69	0.75	0.82	0.88	0.95	.	0.97	0.94	0.90	0.88
$R\&D_{-8}$	0.19	0.15	0.59	0.64	0.69	0.76	0.83	0.89	0.95	.	0.97	0.94	0.91
$R\&D_{-9}$	0.17	0.12	0.55	0.59	0.65	0.70	0.77	0.83	0.89	0.95	.	0.97	0.94
$R\&D_{-10}$	0.17	0.11	0.52	0.57	0.63	0.67	0.72	0.78	0.83	0.89	0.95	.	0.97
$R\&D_{-11}$	0.17	0.12	0.51	0.55	0.60	0.65	0.70	0.74	0.79	0.84	0.89	0.95	.

OI^a is core abnormal operating income before R&D but after taxes. R&D is after-tax research and development expense. All variables are deflated by operating assets at the beginning of year zero.

Table 3
Weighted Non-linear Regressions of Abnormal Core Operating Income before R&D on its Lagged Value and Past R&D

Panel A: Regressions with all available observations

$$OI_t^a = \alpha OI_{t-1}^a + \gamma \sum_{\tau=1}^{T} R\&D_{t-\tau} - \alpha\gamma \sum_{\tau=1}^{T} R\&D_{t-\tau-1} + \pi_t \quad (8)$$

	α	γ	Wald	LR	LM	Undis. Benefits	Dis. Benefits	Obs.
T = 1	0.82	0.88	727.59	445.80	287.21	0.88	0.80	18,879
	160.39	26.97						
T = 2	0.81	0.56	862.32	571.73	423.55	1.12	0.97	16,814
	154.75	29.37						
T = 3	0.81	0.41	842.48	578.58	449.68	1.24	1.03	15,000
	147.27	29.03						
T = 4	0.81	0.35	857.70	622.14	508.35	1.40	1.11	13,406
	142.71	29.29						
T = 5	0.81	0.32	946.15	709.95	588.46	1.58	1.20	11,983
	137.19	30.76						
T = 6	0.81	0.29	916.58	698.56	599.66	1.71	1.24	10,700
	130.21	30.28						
T = 7	0.80	0.27	1048.62	807.21	702.35	1.88	1.31	9,541
	121.93	32.38						
T = 8	0.82	0.24	790.23	577.73	510.20	1.91	1.27	8,478
	115.59	28.11						
T = 9	0.81	0.22	728.09	531.29	481.03	1.97	1.26	7,508
	107.40	26.98						
T = 10	0.86	0.21	556.92	380.03	329.23	2.10	1.29	6,624
	107.46	23.60						

Panel B: Regressions with the same observations

$$OI_t^a = \alpha OI_{t-1}^a + \gamma \sum_{\tau=1}^{T} R\&D_{t-\tau} - \alpha\gamma \sum_{\tau=1}^{T} R\&D_{t-\tau-1} + \pi_t \quad (8)$$

	α	γ	Wald	LR	LM	Undis. Benefits	Dis. Benefits	Obs.
T = 1	0.85	0.92	294.42	108.71	34.96	0.92	0.83	6,624
	96.82	17.16						
T = 2	0.84	0.59	424.23	184.27	72.00	1.18	1.02	6,624
	99.35	20.60						
T = 3	0.84	0.44	468.94	224.29	103.70	1.31	1.09	6,624
	101.21	21.66						
T = 4	0.84	0.37	516.15	277.93	155.99	1.47	1.16	6,624
	102.95	22.72						
T = 5	0.84	0.32	549.93	319.25	206.15	1.61	1.22	6,624
	104.35	23.45						
T = 6	0.85	0.29	565.52	352.57	256.09	1.73	1.25	6,624
	105.52	23.78						
T = 7	0.85	0.26	567.27	365.63	283.69	1.82	1.27	6,624
	106.19	23.82						
T = 8	0.85	0.24	568.17	375.83	306.31	1.92	1.28	6,624
	106.75	23.84						
T = 9	0.85	0.22	564.03	380.39	321.98	2.01	1.29	6,624
	107.17	23.75						
T = 10	0.86	0.21	556.92	380.03	329.23	2.10	1.29	6,624
	107.46	23.60						

OI^a is core abnormal operating income before R&D but after taxes. R&D is after-tax research and development expense. The observations are weighted by the reciprocal of operating assets at the beginning of year t.

Table 4
Weighted Non-linear Regressions of Abnormal Core Operating Income before R&D on its Lagged Value and Past R&D for Selected Industries

Panel A: Chemicals and Pharmaceutics (28)

$$OI_t^a = \alpha OI_{t-1}^a + \gamma \sum_{\tau=1}^{T} R\&D_{t-\tau} - \alpha\gamma \sum_{\tau=1}^{T} R\&D_{t-\tau-1} + \pi_t \quad (8)$$

	Regressions with all available observations								Regressions with the same observations (Obs. = 987)						
	α	γ	Wald	LR	LM	Undis. Ben.	Dis. Ben.	Obs.	α	γ	Wald	LR	LM	Undis. Ben.	Dis. Ben.
T = 1	1.07	0.08	0.35	0.11	0.06	0.08	0.07	2384	1.10	-0.08	0.24	0.19	0.14	-0.08	-0.08
	124.74	0.59							105.95	-0.48					
T = 2	0.90	1.02	504.24	47.22	0.22	2.04	1.77	2181	0.87	1.21	489.81	22.35	0.35	2.42	2.10
	70.06	22.46							46.25	22.13					
T = 3	0.90	0.76	521.48	66.82	0.18	2.27	1.89	1991	0.88	0.88	498.41	36.22	1.46	2.63	2.18
	69.28	22.84							48.22	22.33					
T = 4	0.90	0.65	560.77	107.71	4.55	2.58	2.04	1820	0.88	0.73	528.87	65.76	0.01	2.91	2.30
	69.02	23.68							50.74	23.00					
T = 5	0.90	0.58	592.37	135.59	8.88	2.89	2.19	1653	0.89	0.63	526.25	81.79	0.46	3.13	2.37
	68.51	24.34							52.71	22.94					
T = 6	0.90	0.52	550.17	134.52	11.22	3.11	2.26	1497	0.90	0.56	506.47	94.93	2.38	3.34	2.43
	67.32	23.46							54.57	22.50					
T = 7	0.90	0.49	606.15	162.72	17.49	3.44	2.39	1358	0.90	0.51	477.82	97.13	3.09	3.54	2.46
	65.53	24.62							55.82	21.86					
T = 8	0.92	0.45	463.54	115.85	11.14	3.64	2.43	1226	0.91	0.47	461.82	106.21	7.18	3.77	2.52
	63.42	21.53							57.25	21.49					
T = 9	0.92	0.44	430.34	106.31	8.88	3.93	2.52	1101	0.92	0.44	438.35	103.57	7.59	3.97	2.54
	61.01	20.74							58.01	20.94					
T = 10	0.92	0.42	417.91	101.40	8.39	4.18	2.57	987	0.92	0.42	417.91	101.40	8.39	4.18	2.57
	58.69	20.44							58.69	20.44					

Panel B: Machinery and Computer Hardware (35)

$$OI_t^a = \alpha OI_{t-1}^a + \gamma \sum_{\tau=1}^{T} R\&D_{t-\tau} - \alpha\gamma \sum_{\tau=1}^{T} R\&D_{t-\tau-1} + \pi_t \qquad (8)$$

	Regressions with all available observations								Regressions with the same observations (Obs. = 929)						
	α	γ	Wald	LR	LM	Undis. Ben.	Dis. Ben.	Obs.	α	γ	Wald	LR	LM	Undis. Ben.	Dis. Ben.
T = 1	0.72	0.72	133.17	95.80	83.84	0.72	0.66	2461	0.73	0.72	56.22	34.26	26.68	0.72	0.66
	44.59	11.54							27.61	7.50					
T = 2	0.74	0.38	100.78	76.05	72.44	0.75	0.65	2216	0.74	0.40	61.19	41.38	37.42	0.81	0.70
	44.63	10.04							28.72	7.82					
T = 3	0.75	0.25	79.81	60.07	55.16	0.75	0.62	1997	0.74	0.27	53.05	36.11	31.83	0.81	0.67
	43.27	8.93							29.17	7.28					
T = 4	0.75	0.20	74.38	57.98	54.31	0.80	0.63	1802	0.75	0.21	52.62	37.00	33.24	0.85	0.68
	41.59	8.62							29.62	7.25					
T = 5	0.75	0.17	72.72	58.04	55.11	0.86	0.65	1629	0.75	0.18	52.92	38.35	35.23	0.90	0.68
	39.83	8.53							29.95	7.27					
T = 6	0.75	0.16	71.27	58.07	55.99	0.94	0.68	1466	0.76	0.16	53.64	40.03	37.63	0.96	0.69
	38.29	8.44							30.19	7.32					
T = 7	0.75	0.14	72.89	59.36	57.31	1.01	0.70	1318	0.76	0.14	53.77	40.87	39.05	1.01	0.70
	36.83	8.54							30.34	7.33					
T = 8	0.75	0.13	64.13	51.44	50.09	1.06	0.71	1182	0.76	0.13	53.65	41.23	39.88	1.06	0.71
	34.60	8.01							30.44	7.32					
T = 9	0.74	0.12	60.49	47.91	46.51	1.08	0.69	1053	0.76	0.12	52.55	40.62	39.46	1.11	0.71
	32.07	7.78							30.51	7.25					
T = 10	0.76	0.11	50.62	39.03	37.66	1.15	0.71	929	0.76	0.11	50.62	39.03	37.66	1.15	0.71
	30.54	7.12							30.54	7.12					

Panel C: Electrical and Electronics (36)

$$OI_t^a = \alpha OI_{t-1}^a + \gamma \sum_{\tau=1}^{T} R\&D_{t-\tau} - \alpha\gamma \sum_{\tau=1}^{T} R\&D_{t-\tau-1} + \pi_t \qquad (8)$$

	regressions with all available observations								Regressions with the same observations (Obs. = 833)						
	α	γ	Wald	LR	LM	Undis. Ben.	Dis. Ben.	Obs.	α	γ	Wald	LR	LM	Undis. Ben.	Dis. Ben.
T = 1	0.74	0.69	168.60	71.48	26.53	0.69	0.62	2122	0.71	0.62	73.83	30.37	12.21	0.62	0.56
	39.74	12.98							24.65	8.59					
T = 2	0.74	0.39	167.65	93.82	63.00	0.79	0.68	1931	0.72	0.35	82.32	38.77	20.43	0.70	0.61
	39.87	12.95							25.58	9.07					
T = 3	0.73	0.27	147.31	91.44	69.47	0.80	0.66	1755	0.72	0.25	87.13	45.11	28.02	0.76	0.63
	36.90	12.14							26.14	9.33					
T = 4	0.72	0.21	139.44	92.66	75.67	0.85	0.68	1590	0.73	0.21	95.99	54.52	39.48	0.85	0.67
	34.72	11.81							26.56	9.80					
T = 5	0.69	0.18	181.74	126.40	103.79	0.92	0.70	1440	0.73	0.18	98.25	58.22	44.63	0.91	0.69
	33.62	13.48							26.77	9.91					
T = 6	0.73	0.16	141.11	94.89	79.40	0.96	0.69	1306	0.73	0.16	100.26	61.17	49.19	0.97	0.70
	33.40	11.88							26.88	10.01					
T = 7	0.72	0.15	144.11	98.83	85.64	1.05	0.73	1179	0.73	0.15	101.50	63.92	53.80	1.03	0.71
	31.78	12.00							27.01	10.07					
T = 8	0.72	0.13	129.24	86.70	76.21	1.07	0.71	1056	0.74	0.13	101.97	65.25	56.66	1.08	0.72
	29.95	11.37							27.09	10.10					
T = 9	0.72	0.12	120.60	79.69	70.30	1.12	0.72	942	0.74	0.13	101.12	65.38	57.97	1.13	0.72
	28.05	10.98							27.15	10.06					
T = 10	0.74	0.12	100.11	65.15	58.68	1.18	0.73	833	0.74	0.12	100.11	65.15	58.68	1.18	0.73
	27.19	10.01							27.19	10.01					

Panel D: Transportation Vehicles (37)

$$OI_t^a = \alpha OI_{t-1}^a + \gamma \sum_{\tau=1}^{T} R\&D_{t-\tau} - \alpha\gamma \sum_{\tau=1}^{T} R\&D_{t-\tau-1} + \pi_t \quad (8)$$

	Regressions with all available observations								Regressions with the same observations (Obs. = 417)						
	α	γ	Wald	LR	LM	Undis. Ben.	Dis. Ben.	Obs.	α	γ	Wald	LR	LM	Undis. Ben.	Dis. Ben.
T = 1	0.74	0.42	14.47	11.49	9.59	0.42	0.38	1053	0.73	0.58	12.81	9.57	7.81	0.58	0.53
	29.09	3.80							17.72	3.58					
T = 2	0.73	0.24	15.00	12.76	11.40	0.49	0.42	949	0.73	0.33	13.52	10.48	8.79	0.65	0.57
	27.87	3.87							17.92	3.68					
T = 3	0.72	0.17	13.12	11.01	9.52	0.52	0.43	860	0.73	0.22	12.68	9.57	7.68	0.67	0.55
	26.20	3.62							17.90	3.56					
T = 4	0.72	0.17	20.26	18.76	17.02	0.70	0.55	782	0.73	0.19	14.74	11.53	9.45	0.76	0.60
	24.93	4.50							17.90	3.84					
T = 5	0.70	0.20	40.78	40.34	35.74	1.00	0.76	709	0.73	0.17	17.41	14.35	12.24	0.86	0.65
	24.80	6.39							17.88	4.17					
T = 6	0.71	0.18	40.51	39.37	34.60	1.11	0.81	640	0.73	0.16	19.42	16.46	14.39	0.94	0.68
	22.38	6.37							17.85	4.41					
T = 7	0.66	0.19	60.89	60.24	51.22	1.34	0.93	580	0.72	0.14	20.42	17.38	15.25	0.99	0.69
	19.97	7.80							17.78	4.52					
T = 8	0.74	0.16	36.54	30.83	25.76	1.29	0.86	523	0.72	0.13	21.66	18.53	16.37	1.06	0.71
	20.49	6.04							17.73	4.65					
T = 9	0.74	0.13	26.41	21.95	19.28	1.20	0.77	468	0.72	0.13	23.36	20.28	18.25	1.14	0.73
	19.56	5.14							17.73	4.83					
T = 10	0.72	0.12	24.23	21.09	19.14	1.20	0.74	417	0.72	0.12	24.23	21.09	19.14	1.20	0.74
	17.74	4.92							17.74	4.92					

Panel E: Scientific Instruments (38)

$$OI_t^a = \alpha OI_{t-1}^a + \gamma \sum_{\tau=1}^{T} R\&D_{t-\tau} - \alpha\gamma \sum_{\tau=1}^{T} R\&D_{t-\tau-1} + \pi_t \quad (8)$$

	Regressions with all available observations								Regressions with the same observations (Obs. = 496)						
	α	γ	Wald	LR	LM	Undis. Ben.	Dis. Ben.	Obs.	α	γ	Wald	LR	LM	Undis. Ben.	Dis. Ben.
T = 1	1.07	-0.81	48.94	33.90	17.91	-0.81	-0.73	1418	1.07	-1.02	32.46	25.70	15.77	-1.02	-0.93
	92.69	-7.00							66.61	-5.70					
T = 2	0.82	0.57	124.49	5.51	1.40	1.15	0.99	1286	0.76	0.66	98.26	0.79	4.41	1.32	1.14
	37.09	11.16							21.51	9.91					
T = 3	0.82	0.45	136.26	18.23	0.33	1.36	1.12	1154	0.76	0.51	119.55	15.38	2.27	1.53	1.27
	35.97	11.67							22.26	10.93					
T = 4	0.82	0.39	147.96	39.24	1.66	1.55	1.23	1034	0.77	0.43	125.73	30.53	0.01	1.71	1.35
	34.85	12.16							23.06	11.21					
T = 5	0.80	0.32	145.09	46.36	4.80	1.60	1.21	924	0.78	0.36	124.06	36.87	0.31	1.80	1.37
	32.13	12.05							23.42	11.14					
T = 6	0.80	0.29	144.43	57.64	12.12	1.77	1.28	825	0.79	0.32	122.32	43.81	2.81	1.90	1.38
	30.18	12.02							23.83	11.06					
T = 7	0.79	0.26	154.59	65.93	18.10	1.85	1.28	735	0.80	0.28	119.53	47.39	6.72	1.97	1.37
	28.69	12.43							24.09	10.93					
T = 8	0.80	0.24	134.33	54.53	13.12	1.92	1.28	650	0.80	0.25	116.49	47.52	9.04	2.03	1.35
	27.54	11.59							24.17	10.79					
T = 9	0.82	0.22	110.66	44.12	10.60	2.01	1.29	570	0.80	0.23	114.21	48.48	12.84	2.09	1.34
	26.04	10.52							24.31	10.69					
T = 10	0.81	0.22	112.37	48.85	16.33	2.16	1.33	496	0.81	0.22	112.37	48.85	16.33	2.16	1.33
	24.42	10.60							24.42	10.60					

Panel F: All other industries

$$OI_t^a = \alpha OI_{t-1}^a + \gamma \sum_{\tau=1}^{T} R\&D_{t-\tau} - \alpha\gamma \sum_{\tau=1}^{T} R\&D_{t-\tau-1} + \pi_t \qquad (8)$$

	Regressions with all available observations								Regressions with the same observations (Obs. = 2,962)						
	α	γ	Wald	LR	LM	Undis. Ben.	Dis. Ben.	Obs.	α	γ	Wald	LR	LM	Undis. Ben.	Dis. Ben.
T = 1	0.79 110.86	0.71 9.47	89.62	84.50	78.93	0.71	0.65	9441	0.79 59.25	0.63 5.51	30.40	23.29	18.02	0.63	0.57
T = 2	0.78 103.15	0.46 10.27	105.41	99.13	93.65	0.93	0.81	8251	0.78 59.43	0.39 6.06	36.78	27.75	21.21	0.78	0.68
T = 3	0.77 96.13	0.37 11.31	128.01	124.16	119.63	1.12	0.93	7243	0.78 59.85	0.36 7.98	63.65	53.01	45.12	1.07	0.88
T = 4	0.77 92.66	0.31 11.44	130.88	128.30	123.57	1.25	0.99	6378	0.78 60.08	0.30 8.56	73.26	63.37	55.66	1.19	0.94
T = 5	0.77 86.48	0.28 11.55	133.38	131.89	127.15	1.38	1.04	5628	0.78 60.21	0.26 9.00	81.07	72.53	65.25	1.29	0.98
T = 6	0.76 80.72	0.25 12.18	148.37	148.18	142.89	1.51	1.10	4966	0.78 60.37	0.23 9.39	88.20	80.76	74.22	1.39	1.01
T = 7	0.73 73.90	0.22 13.02	169.62	169.28	162.57	1.57	1.09	4371	0.79 60.48	0.21 9.56	91.32	85.52	79.58	1.45	1.01
T = 8	0.74 66.85	0.19 11.49	132.07	128.56	123.94	1.52	1.01	3841	0.79 60.52	0.19 9.70	94.01	87.65	82.09	1.52	1.01
T = 9	0.71 59.12	0.17 11.62	134.95	130.98	125.93	1.52	0.97	3374	0.79 60.52	0.17 9.74	94.84	88.64	83.37	1.57	1.01
T = 10	0.79 60.57	0.16 9.86	97.20	91.48	86.57	1.65	1.01	2962	0.79 60.57	0.16 9.86	97.20	91.48	86.57	1.65	1.01

OI^a is core abnormal operating income before R&D but after taxes. R&D is after-tax research and development expense. The observations are weighted by the reciprocal of operating assets at the beginning of year t.

Table 5
Summary Statistics from Cross-sectional Weighted Non-linear Regressions of Abnormal Core Operating Income before R&D on its Lagged Value and Past R&D

$$OI_t^a = \alpha OI_{t-1}^a + \gamma \sum_{\tau=1}^{T} R\&D_{t-\tau} - \alpha\gamma \sum_{\tau=1}^{T} R\&D_{t-\tau-1} + \pi_t \qquad (8)$$

Panel A: All firms (T = 7)

	α	γ	Wald	LR	LM	Undis. Benefits	Dis. Benefits	Obs.
Mean	0.82	0.27	85.19	95.56	55.45	1.86	1.30	596.31
Median	0.83	0.25	46.30	49.49	19.50	1.73	1.20	594.50
t-statistics	22.05	4.76						
z-statistics	135.29	29.10						
Positive	1.00	0.94						

Panel B: Chemicals and Pharmaceutics (28) (T = 7)

	α	γ	Wald	LR	LM	Undis. Benefits	Dis. Benefits	Obs.
Mean	0.92	0.47	44.21	25.04	7.67	3.30	2.29	84.88
Median	0.93	0.43	25.18	7.04	1.97	3.00	2.09	86.50
t-statistics	23.82	6.59						
z-statistics	74.31	21.42						
Positive	1.00	0.94						

Panel C: Machinery and Computer Hardware (35) (T = 1)

	α	γ	Wald	LR	LM	Undis. Benefits	Dis. Benefits	Obs.
Mean	0.84	0.35	20.17	19.85	11.15	0.35	0.32	111.86
Median	0.82	0.06	3.65	6.51	5.09	0.06	0.06	110.00
t-statistics	17.61	0.78						
z-statistics	72.44	8.10						
Positive	1.00	0.50						

Panel D: Electrical and Electronics (36) (T = 5)

	α	γ	Wald	LR	LM	Undis. Benefits	Dis. Benefits	Obs.
Mean	0.76	0.03	19.05	24.30	12.86	0.16	0.12	80.00
Median	0.79	0.18	8.30	8.62	7.95	0.91	0.69	80.50
t-statistics	17.83	0.20						
z-statistics	46.81	10.78						
Positive	1.00	0.72						

Panel E: Transportation Vehicles (37) (T = 7)

	α	γ	Wald	LR	LM	Undis. Benefits	Dis. Benefits	Obs.
Mean	0.74	0.04	9.71	15.60	7.61	0.31	0.22	36.25
Median	0.70	0.21	8.53	8.56	5.01	1.46	1.01	35.50
t-statistics	7.91	0.33						
z-statistics	41.47	6.84						
Positive	0.94	0.69						

Panel F: Scientific Instruments (38) (T = 7)

	α	γ	Wald	LR	LM	Undis. Benefits	Dis. Benefits	Obs.
Mean	0.81	0.21	13.06	10.79	5.36	1.46	1.01	45.94
Median	0.82	0.23	11.21	7.79	3.68	1.64	1.14	47.00
t-statistics	13.38	1.39						
z-statistics	69.70	10.92						
Positive	1.00	0.81						

Panel G: All other industries (T = 7)

	α	γ	Wald	LR	LM	Undis. Benefits	Dis. Benefits	Obs.
Mean	0.79	0.08	27.04	38.07	27.37	0.53	0.37	273.19
Median	0.81	0.20	16.34	21.10	19.13	1.40	0.97	268.00
t-statistics	15.70	0.47						
z-statistics	106.83	10.82						
Positive	1.00	0.69						

OI^a is core abnormal operating income before R&D expense but after taxes. R&D is after-tax research and development expense. The observations are weighted by the reciprocal of operating assets at the beginning of year t. The *t*-statistic is the ratio of the mean cross-sectional coefficient to its standard error. The z-statistics is calculated as the mean cross-sectional t-statistic multiplied by the square root of the number of cross-sections. “Positive” is the proportion of annual cross-sectional regressions in which the coefficient is positive.