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Pitfalls in Estimating the Returns to Corporate R&D Using Accounting Data

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Abstract

Does R&D have an impact on the economic performance of an enterprise? To most economic observers, the obvious answer is yes. However, recent reports by Booz-Allen-Hamilton (BAH 2006, 2007) conclude that the share of spending devoted to research has no relationship to firm growth, profits, and value, and offers support to the view that it is possible to compete successfully in the modern economy without investing in R&D. We disagree with these conclusions and in this paper we critique some uses of accounting data to estimate corporate R&D returns and illustrate how one should use such data to answer the R&D-performance question.

Introduction

Does R&D have an impact on firm growth, profits, and value? Anyone reading the recent reports by Booz-Allen-Hamilton (2006, 2007, the "BAH Reports") might conclude the contrary. This report seems to offer support to those skeptics who believe that it is possible to compete successfully in the modern economy without investment in R&D and that the share of spending devoted to research has no relationship to the economic performance of an enterprise (or a country).

But this conclusion would not be warranted by the vast bulk of evidence in the economic and business management literature. Although it is certainly true that firm success is highly unpredictable and depends on many factors other than R&D investment and patenting, it is nevertheless the case that there is a strong relationship between these activities and the growth and profitability of firms, and it is extremely misleading to argue that there is not.

In this paper, we assess some of the pitfalls to be avoided in using accounting data to estimate corporate R&D returns and illustrate a proper use of such data. We first offer a critique of the analysis in the BAH report, bringing the considerable body of evidence in the research literature to bear. We discuss the ways in which BAH use their evidence to draw misleading conclusions which they then translate into recommendations that if they were followed, would leave most firms worse off than they are now. Using similar data and a comparable

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[2] We are grateful to Xabier Goenaga from DG Research at the European Commission, who initially drew our attention to the BAH report.

approach, we then present our own estimates of the impact of R&D on the growth, profitability, and market value of public corporations, and contrast our interpretations and conclusions with that of the report.

Perceptive readers and analysts may ask why we focus on the BAH report, as they will see immediately the weakness in its recommendations and conclusions. Our main motivation is that the report has had some impact in business and policy communities via its appearance in summarized form in newspapers, business magazines and on the worldwide web. While we have nothing against "a report having a big impact," if it were evidence-based and did not oversimplify the issues, we are concerned about the wide and rapid dissemination of a message that turns out to be largely wrong and misleading. At the minimum, there is risk that many readers will be confused and at worst will take away mostly what is written in bold or italics: "*firms that spend less on R&D than their competitors have superior financial performance,*"[3] or *"Innovation champions show a ratio of R&D expenditures to sales that is below the average,"*[4] or "*All these companies spend less than their competitors on research and development, yet outpace their industries across a wide range of performance metrics.*"[5]

The issue of the relationship between R&D and firm performance is also of course an important one in its own right, in particular because the large corporations which are considered in the BAH report and to which its recommendations are addressed, are responsible for the vast majority of private R&D spending in developed economies.

Our critique takes three parts: first, the data normally available in the financial accounts of firms is not well-suited to assessing the returns to R&D. This kind of expenditure (R&D) is an investment in the future, but is generally treated by accountants as immediately expensable. There are also a number of issues in the interpretation of results based on gross versus net profits and in the robustness of estimates to the presence of extreme outliers in the data. Second, we discuss the difficulties arising from the fact that the theory that posits a relationship between R&D investment and subsequent returns is difficult to test if all firms make the "correct" investment decisions in an expected value sense. In the absence of substantial out of equilibrium behavior, we do not expect supranormal or subnormal returns to R&D. Third and last, there are a number of statistical and interpretive problems in drawing conclusions from the results of regressing output indicators on R&D. Chief among these is the confusion of low explanatory power with lack of impact -- in the presence of highly variable outcomes, the two are not the same.

We then turn to our own analysis. Using data on approximately 1500 large public firms in R&D-intensive sectors from a number of OECD countries, we outline the underlying model that is used to measure returns to these kinds of investment, touching briefly on the measurement of depreciation that is needed to go from gross to net. We show that there are indeed strong relationships between investment in R&D and the market value and subsequent growth of firms on average. The relationship between R&D and current profitability is more variable, as one would expect given our earlier discussion of the pitfalls in using accounting

[3] The title of the web page presenting the report: www.boozallen.com/capabilities/services_article/18054973

[4] *Le Temps*, 8 December 2006.

[5] www.strategy-business.com/press/article/0645?gko=c3340-1876-20606671

data. Our results thus confirm the average productivity and economic profitability of R&D investment, in spite of their expected intrinsic uncertainty, both across firms and across time.

The paper concludes with a short best practice summary for the problem of evaluating R&D performance as well as the performance of other innovation investments using accounting data, which is often all that is available to analysts and policy makers.

A misleading analysis…

We want first to caution readers that the BAH report completely ignores the previous literature on the returns to R&D, what has been learned from this research, and what the results mean for a firm. If, as been shown long since by economic researchers, the uncertainty inherent in the processes of research and innovation imply an equivalent uncertainty in the profitability of these investment at the level of an individual firm, there is no doubt that such profitability – when it is measured at the aggregate level or for the whole society - has been shown to be as high, or possibly higher, than the profitability of investment in the physical capital. Econometricians are the first to recognize the great difficulties of measuring the output of the R&D at the firm level and of the interpretation of the results – in particular, difficulties related to the question of the lags between firm investment in R&D and its contribution to performance, and the related question of reverse causality (or endogeneity) from firm performance to its R&D, as well as the very important difficulties of the measurement of the prices in the case of the new and substantially improved products.[6] Even if taken separately each econometric study might seem fragile, the fact that on the whole their results agree to a large extent makes the conclusion more convincing. Such an intellectual achievement, to which scholars like Griliches, Mansfield, and Scherer have greatly contributed, cannot be simply discarded without more careful study than has been presented by BAH in their reports.[7]

These reports use very simple tools, essentially "cross-sectional" correlations without any controls for other firm characteristics that affect measured performance. These include not only industrial sector and country but also other inputs (capital, labor, materials. and purchased inputs).[8] The report interprets a low correlation value as being economically as well as statistically insignificant, which is not always the case. It resorts to ex-post endogenous grouping of high-performing-low R&D firms versus low-performing high R&D firms, which is likely to produce biased results. In addition, it analyzes only R&D firms, without even alluding to the fact that this is also a potential source of selectivity bias. What about those firms that do no R&D? Do they perform ("other things equal") better or worse than the firms in the sample?[9] In short, the BAH report confuses what is true for a group of

[6] When price measurement does not account for the quality improvement from R&D, one obtains an undervaluation of the contribution of R&D to growth. During the past quarter century, this has been an especially severe problem in the case of the ICT sector.

[7] E.g., Griliches (1998), Mansfield (1965), and Scherer (1965).

[8] Simple tools such as correlation analyses are of course important, but as long as they are properly used and their results presented for what they really are and not over- or misinterpreted.

[9] For a discussion of the misleading results on firm performance that can be introduced by selectivity bias, see Denrell (HBR 2005).

selected trees (high-performing-low R&D firms) with what is true for the forest as a whole (the overall positive impact of R&D) and for each individual tree (the huge heterogeneity in R&D impact, which is to be expected at the micro economic level).

The report also misinterprets even its own results. Assume that the sample consists of a number of firms, each of which is pursuing an optimal R&D investment strategy as far as they can, but under considerable uncertainty about the market, the competition, and future prices. Assume also that entry into the relevant sector is not restricted. Both of these assumptions are plausible and rather weak. They imply that on average we would expect the risk-adjusted returns to R&D to be the same as the returns to any other investment activity. That is, if R&D is expensed and is not fluctuating a great deal over time within firm (as is usually the case for large firms), we would not observe much of a correlation between profits (properly accounted and net of R&D) and R&D. On average the firms get what they pay for and do not earn supranormal returns to R&D.[10] There will be winners and losers, but winning will not be especially related to the level of R&D spending. Note that this does not mean that firms should not spend on R&D, simply that if all firms pursue what appears to them to be a good policy, we would not expect to see a strong relationship between firm profitability and R&D.

At the same time, the level of R&D investment or R&D intensity *will* be correlated with the firm's future growth, because firms that invest greater amounts given their current size are those that expect (or desire) growth in the future. In this respect, R&D investment is like ordinary investment. Summing up, we expect *normal* but not *supranormal* returns to R&D in equilibrium.

The report uses seven performance screens: market capitalization growth, shareholder returns, gross profit to sales ratio, gross profit growth, operating income to sales ratio, gross profit growth, operating income growth, and sales growth. For subsequent analysis, it is important to understand exactly how these performance indicators are defined (or should be defined). Table 1 summarizes the definitions of these variables and their expected relationship to R&D. We discuss each of them in turn.

- **Market capitalization growth**

The proper measure of market capitalization is the market value of all claims on the firm's assets, which includes debt and any preferred or convertible stock. If the firm's investments in R&D are creating intangible assets, market value itself will be correlated with R&D, once we control for the book value of the tangible assets. The growth of market cap or market value is an indicator of the growth of the firm, and as such, is expected to be correlated with the rate of past investment, either ordinary tangible investment or R&D investment. However, the magnitude of the correlation is difficult to predict, and the relationship may be somewhat volatile due to the fact that market cap is dominated by the value of common stock, which fluctuates in response to many other stimuli.[11]

[10] In making this argument, we assume (as do BAH, in effect) that R&D is not highly variable so that current spending can be used as a proxy for the capital created by R&D. R&D capital is the appropriate concept for R&D input if returns are intertemporal. On this point, see also Fisher and McGowan (1983).

[11] We hasten to add that any analysis of this kind must include time dummies or the market return in order to purge relationships of the overall market effects.

- **Shareholder returns**

This is the one period return to holding one share of the firm's common stock, defined as the current price less the price last period plus any dividends paid during the period, divided by the price last period. The usual efficient markets hypothesis tells us that there should be little relationship between (lagged) R&D or R&D intensity and shareholder returns: if there were such a systematic relationship, then there is a clear profit opportunity because R&D intensity could be used as a trading rule.[12] This does not mean that we will not experience periods or episodes where R&D systematically leads to higher or lower returns, but it does mean that these periods will not be predictable on the basis of past information and therefore that we do not expect a systematic relationship over time.

- **Gross margin percentage**

Gross margin percentage is the gross profit to sales ratio, where gross profits is sales less the cost of goods sold, and is therefore gross of R&D expenditure. Together with the fact that net margins (see the next item) are expected to be unrelated to R&D, this means that there will be a simple accounting correlation between the gross profit to sales ratio and the R&D to sales ratio and that we expect the relationship to be roughly one for one, with any increase in R&D matched by an increase in gross profits.

- **Operating margin percentage**

Operating margin percentage is the operating income to sales ratio, where operating income is a measure of profits that is net of R&D expenditure. By the arguments given earlier, we do not expect much if any correlation between R&D intensity and the operating income to sales ratio if the firms are behaving in a profit-maximizing way in competitive markets.

- **Gross margin growth (gross profit growth)**

We do not expect the growth in gross profit to be systematically related to the *level* of R&D intensity, although it might be related to growth in R&D or R&D intensity. However, if gross profit growth reflects overall firm growth, there may be a weak relationship to the level of all investments, R&D and tangible.

- **Operating margin growth (operating income growth)**

As in the case of gross profit, there may be a weak relationship between the growth in operating income or profits and the level of R&D intensity due to the fact that profit growth is related to the overall growth of the firm.

- **Sales growth**

As in the case of market capitalization, sales growth is an indicator of firm growth and we expect that this will be correlated with R&D investment intensity.

[12] This is a fundamental result from the financial economics literature. In the case of R&D, it has been discussed and verified in Griliches (1981), Pakes and Griliches, 1984; Pakes 1985 and Griliches, Hall and Pakes, 1991.

Using data on large publicly traded US firms from Compustat, we looked at the relationship between these seven performance measures and lagged R&D intensity to examine the findings reported by BAH more carefully and systematically.[13] The first thing to note is that large databases of firm accounting data frequently contain errors and other data problems that can lead to misleading conclusions if the data are not cleaned and if non-robust estimation methods are used.[14] It is usually not feasible to manually correct the numbers, because the typical database size is on the order of one million numbers. Therefore two approaches are commonly used: ordinary least squares regression with outliers removed from the data or median regression, which is robust to the presence of outliers in the dependent variable. We have used both in this study, after cleaning the data first for the most egregious outliers (stock returns greater than 10,000 per cent, and so forth). We refer the reader to the Appendix A for details and to Appendix B for a comparison of trimmed OLS estimation to LAD estimation using period 2002-2005 data.

Table 2 shows the results of our estimation of the following simple model:

$$y_{it} = \beta r_{it} + \lambda_t + \delta_j + \varepsilon_{it}, \qquad (1)$$

where y is one of the seven performance measures, r is the R&D to sales ratio lagged two years earlier to avoid simultaneity bias, the λ's are time (year) means, and the δ's are industry means (included in the second columns), and ε stands for "errors" in the model, mainly related to omitted variables and measurement errors in the included variables. That is, we control for the average performance in each year and two digit industry, but not for capital, labor and other relevant factors such as quality of organization and management. We estimated this relation for two time periods: the 4 years 1996-1999 and the 4 years 2002-2005, to illustrate how things can change over time. Note that these two periods bracket a period in which the technology part of the stock market experienced a large rise and fall due to the dotcom boom and investment in readiness for the year 2000 rollover from 1999.[15]

Our discussion above had two clear predictions of a relationship, which are partially confirmed by Table 2. First, the growth in gross margins, operating margins, and sales are positively related to R&D intensity. Second, gross income to sales is correlated slightly more than one for one with the R&D to sales ratio, as we would expect given that it is gross of R&D.

[13] The BAH report does a useful task in collecting the accounting data for the world's 1000 largest corporate R&D doing firms. Many of these firms are firms publicly traded in the U.S., and our sample from Compustat overlaps considerably, with half of the top 20 global R&D spenders that they identify in their report. Although we do not have a complete list of their sample, we were able to compare our sample to a list of 94 high leverage innovators supplied in the report, finding 40 out of 48 North American firms, but only 5 of 46 firms headquartered outside North America.

[14] As an example, a few of the shareholder returns for firms in our sample were very large (e.g., one of 9400 per cent) . Closer inspection of the data and a check of the firm in question on yahoo.com revealed that the closing price of the common stock for the calendar year had not been adjusted for a 1:100 stock split, contrary to the documentation supplied by Compustat. In general, however, this adjustment had been done. The extent of this problem is unknown, although it is unlikely that it affects more than a few cases. Using robust estimators and trimming unreasonably large or small values avoids excess influence from data observations of this kind.

[15] A great deal of older software that relied on two-digit years had to be rewritten or replaced in order to accommodate the new century commencing in the year 2000.

The remaining results are more equivocal although not inconsistent with the arguments presented earlier. Shareholder returns are largely uncorrelated with R&D intensity, with the exception of a slightly negative relationship during the 2002-2005 period when we do not control for two-digit industry. Operating margins are correlated with R&D intensity, but with opposite signs during the two periods. Because there is no reason to expect stable relationships between R&D and the profit rate, this result is not as surprising as it might first appear to be. The most striking result is that the growth in market capitalization is insignificantly (although positively) related to R&D intensity during the first time period and unrelated during the second. As we will see in subsequent tables, somewhat unstable estimates for the market cap growth-R&D relationship arise partly from market volatility during this period, and the so-called "dotcom" bubble during the late 1990s.

Table 3 looks at the same relationship in a slightly different way, to focus on more long term relationships and average out some of the year-to-year volatility. The results in this table are based on a single cross section of average performance over a four-year period (1996-1999 and 2002-2005) as it relates to R&D performed two years prior to the beginning of the period (1994 and 2000). With one exception, the results are now somewhat clearer. Those for the gross margin and sales growth are essentially the same as in Table 2. None of the other income measures are very significantly related to R&D, although what relationship there is is positive. The growth in market capitalization is now quite positively related to R&D, as expected.

The surprising result is that shareholder returns are now very positively related to R&D during the first period, although still not at all related to R&D during the second period. What this means is that firms with high R&D intensity relative to their two-digit industry in 1994 experienced substantial positive returns between 1996 and 1999, but that firms with high R&D intensity in 2000 experienced no higher returns than other firms in 2002-2005. A likely explanation of this finding lies in the growth and then bursting of the dotcom bubble, which did impact a number of firms in various Information and Communication Technology (ICT) sectors. It would be misleading without further evidence to draw strong conclusions from the finding, as transitory variations in returns to R&D over time are to be expected and indeed, have been observed during other periods (Hall 2007).

The last two columns of Table 3 show the expected impact of changes in R&D intensity for these firms. The R&D-to-sales ratio for our sample ranges from 0 to 100 per cent with a median of 1.2 per cent and an interquartile range of 7 per cent. In the table we show the impact for a firm whose R&D intensity moves from the 25^{th} percentile to the 75^{th} percentile of the distribution. Because all of the performance measures are effectively in per cent (either growth rates or shares), what is shown in these columns is the absolute change in the value. For example, increasing R&D from the first the third quartile implies that sales growth is higher by 1.5 per cent in both periods, and that the gross margin percentage is higher by 9 per cent.

Our conclusion is that for the sample as a whole, the predictions of the simple theory outlined earlier are supported: gross margins are roughly proportional to R&D intensity, shareholder returns are not, and the growth rates of market capitalization, sales, gross margins, and operating margins are weakly related. In an unpublished appendix, we examined the differences between ICT firms and the others. There we see some support for the idea that R&D intensity and performance have little relationship during the second period in ICT (as was argued by the BAH report), but that the relationship in non-ICT firms is fairly positive.

We want to emphasize that this kind of inconsistent result is to be expected, given the level of uncertainty when undertaking R&D.

… and misleading recommendations

The BAH report mixes the incorrect conclusions obtained from an uninformed and simplistic analysis with some common sense advice, such as the French saying "*il vaut mieux etre riche et bien portant que pauvre et malade*" ("It is better to be rich and healthy than poor and sick") We can give here two or three examples out of the report; such as: "*it is better to be good (lucky) at doing R&D than bad (unlucky) at it*"; or "*innovation must be achieved by different departments and business units within the same organization working in parallel rather than in isolation…….it also means looking outside your organization to partners, suppliers and customers for new and innovative ideas.*" (BAH 2006, p. 61)

The report also conveys the idea that you can "free ride" on R&D done by others, which even at the firm level and even in the short run is unrealistic, and more so at the industry and economy level and in the long run. Firms need to have R&D and innovative activities themselves in order to appropriate efficiently the benefits of other firms' R&D and/or public R&D; and in a world of strong intellectual property rights they also have to buy the knowledge from other firms' R&D or cooperate with them in their R&D activities. It cannot be expected that all R&D spillovers will come from public R&D activities only, freely and in a sustained way, in all fields and in an increasingly competitive and globalized world economy.

Another claim is that the lower R&D-to-sales ratio of larger companies relative to smaller is advantageous (BAH 2006, pp. 54-55). But this is comparing apples to oranges: smaller companies in the publicly traded sector tend to be those specializing in the innovative end of the value chain (such as chip design in semiconductors) and will perforce have larger R&D input (for their size) than large firms, which are often capital-intensive and specialize more in other activities that have scale economies. The question of the relationship of R&D, size, and returns may be of interest, but it cannot be asked in isolation without taking account of other aspects of the firm's production function, such as its vertical integration.

Conclusion: how should we assess R&D performance?

We do not want to close this discussion without offering an alternative approach to this important question.[16] In the econometric literature on this topic, there are two main methodologies for measuring the returns to R&D: production function estimation and market value estimation. The former estimates an extended production function for the firm with R&D as one of the inputs and the latter relates the market value to book value ratio (Tobin's q) to a measure of R&D capital.

We applied the production function method to the data for the second period (2002-2005) by regressing revenue (sales S) on capital (C), labor (L), and R&D capital (K) in logarithms and obtained the following result:

[16] There is a very large economic literature on the question of measuring the returns to R&D investment at the firm level. See Mairesse and Sassenou (1991), Hall (1996), and Griliches (1998) for surveys.

$$\log S = 0.19 \log C + 0.65 \log L + 0.17 \log K + \text{time and industry dummies}$$
$$\qquad\quad (0.01) \qquad\quad (0.01) \qquad\quad (0.01)$$

Thus the elasticity of sales with respect to R&D capital for the firms in our sample is 0.17. This estimate is quite high, partly because we do not observe purchased inputs for our firms, so there is an omitted variable bias. Correcting for this bias would yield a value closer to 0.05.[17]

To compute a gross rate of return from this number requires multiplying it by a measure of the median ratio of sales to R&D capital, which for our sample is approximately 5, yielding an estimated rate of return equal to 25 per cent. However, this number is not corrected for the fact that the labor and capital in the regression also included R&D labor and R&D capital. Correcting for this fact would increase the return estimate by approximately 5-10 per cent, for an estimated rate of return equal to 30-35 per cent. Although the exact numbers will vary depending on sample and time period, this is hardly evidence of a weak relationship between R&D and firm output!

Using the market value equation and an estimate of the R&D capital asset derived by depreciating past R&D investment by 15 per cent per annum, we obtained the following results:

$$\log (\text{market-to-book}) = \text{year effects} + 0.74\ (\text{R\&D asset/book value})$$
$$\qquad\qquad\qquad\qquad\qquad\qquad\qquad\qquad (.04) \qquad R2 = .062$$

These results imply either that the required return to R&D is lower than that for ordinary capital, or that the depreciation rate that we should have used when constructing the asset is greater than 15 per cent (equal to about 22 per cent).[18] See Hall (2007) for further explanation and analysis. But note that even if it is the case that the asset created by R&D depreciates at somewhat higher rates than ordinary capital, it is still true that there is a strong relationship between a firm's market-to-book ratio and its R&D investment, which implies that R&D is creating value for the firm.

[17] See Cuneo and Mairesse (1984) for discussion of this issue and Mairesse and Hall (1996) for a comparison of manufacturing sector production functions using sales and value added as the dependent variable. Because purchased inputs are typically about 75 per cent of firm revenue for manufacturing firms, the coefficients of capital, labor, and R&D capital in the sales regression will be approximately four times those obtained when purchased inputs are included in the same equation.

[18] See Hall (2007) for further explanation and analysis.

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Table 1

Variable	Symbol	Formula	Expected Relation to R/S
Market cap growth	gval	(V-V(-1)) / V(-1)	positive
Shareholder returns	r	(P-P(-1)+D) / P(-1)	zero
Gross margin percentage	gm	(S-CGS) / S	positive (=1)
Operating margin percentage	go	(S-CGS-R) / S	zero
Gross margin growth	ggm	(gm-gm(-1)) / gm(-1)	weakly positive
Operating margin growth	ggo	(go-go(-1)) / go(-1)	weakly positive
Sales growth	gs	(S-S(-1)) / S(-1)	positive
total market value	V		
price of common stock	P		
dividends per share	D		
sales	S		
total book value	A		
cost of goods sold	CGS		
R&D	R		

Table 2

Impact of lagged R&D intensity on various performance measures (LAD estimates)

Dependent variable	1996-1999		2002-2005	
Market cap growth	.28 (.16)	.30 (.22)	-.04 (.01)	-.00 (.12)
Shareholder returns	.05 (.15)	.06 (.18)	**-.29 (.11)**	-.17(.11)
Gross margin percentage	**1.82 (.08)**	**1.53 (.09)**	**1.45 (.05)**	**1.34 (.06)**
Operating margin percentage	**.14 (.03)**	**.14 (.03)**	**-.09 (.03)**	-.06 (.03)
Gross margin growth	**.14 (.06)**	**.16 (.08)**	**.17 (.06)**	**.19 (.06)**
Operating margin growth	**.34 (.15)**	**.37 (.15)**	**1.10 (.13)**	**1.05 (.14)**
Sales growth	**.30 (.08)**	**.21 (.07)**	**.14 (.03)**	**.16 (.04)**
Year dummies	yes	yes	yes	yes
2-digit industry dummies (25)	no	yes	no	yes
Number of observations (firms)	5688 (1422)		5800 (1450)	

Source: S&P Compustat annual industrial file, authors' computations.

Sample is manufacturing plus oil and gas, communications, wholesale trade, and business services (R&D-doing firms only)

R&D intensity = R&D to sales ratio, lagged two years

Gross margin = sales less cost of goods sold (gross of R&D)

Operating margin = operating income (net of R&D)

Percentages are relative to sales

Shareholder returns are holding period capital gains plus dividends per share

Market cap is the total market value of the firm, including long term debt

Table 3

Impact of lagged R&D intensity on various performance measures
(LAD estimates using 4-year averages)

	Period					
Dependent variable	**1996-1999**		**2002-2005**		**1996-1999**	**2002-2005**
	LAD estimates		**LAD estimates**		**Approximate impact of an increase in R&D***	
Market cap growth	**1.02 (.21)**	**.81 (.26)**	**.43 (.12)**	**.41 (.13)**	**6%**	**3%**
Shareholder returns	**2.36 (.47)**	**2.04 (.64)**	.22 (.13)	.27 (.16)	**14%**	0
Gross margin percentage	**1.57 (.18)**	**1.33 (.19)**	**1.36 (.15)**	**1.27 (.15)**	**9%**	**9%**
Operating margin percentage	.16 (.07)	.08 (.09)	-.08 (.05)	-.03 (.06)	0	0
Gross margin growth	.24 (.12)	.19 (.18)	**.14 (.06)**	**.18 (.07)**	0	**1.5%**
Operating margin growth	.42 (.22)	.35 (.18)	.34 (.26)	.41 (.27)	3%	3%
Sales growth	**.28 (.07)**	**.23 (.08)**	**.15 (.04)**	**.17 (.05)**	**1.5%**	**1.3%**
2-digit industry dummies (25)	no	yes	no	yes		
Number of observations (firms	1427		1454			

Source: S&P Compustat annual industrial file, authors' computations.

Sample is manufacturing plus oil and gas, communications, wholesale trade, and business services (R&D-doing firms only)

R&D intensity = R&D to sales ratio in 1994 (first 2 columns) or 2000 (last 2 columns)

Gross margin = sales less cost of goods sold (gross of R&D)

Operating margin = operating income (net of R&D)

Percentages are relative to sales

Shareholder returns are holding period capital gains plus dividends per share

Market cap is the total market value of the firm, including long term debt

*These columns show the expected increase in the dependent variable when R&D intensity increases from the 25th percentile to the 75th percentile.

Appendix A: Data and sample

The sample of firms comes from the 2005 Standard and Poor Compustat Annual Industrial file. Domestic US R&D-performing firms in SICs 13 (oil and gas), 20-39 (manufacturing), 48 (communications), 50-51 (wholesale trade), and 73 (business services including software) were selected. These are the only SICs with significant amounts of R&D. The distribution of the firms across industry is shown in Table A1. Almost half of the firms are in machinery including computer equipment, electrical equipment, scientific instruments, communications, and software, which can be loosely termed the ICT sector. The reminder are spread throughout manufacturing, with fewer than 10 per cent outside manufacturing.

As preliminary screening to remove clear outliers and observations with incorrectly entered data, the following tests were applied:

- No missing values
- More than 100 employees
- R&D to sales less than 100 per cent
- Gross income positive (i.e., sales greater than the cost of goods sold)
- Operating income to sales greater than -100%
- Growth rates for gross income, operating income, sales, and equity less than 10,000 per cent in absolute value
- Tobin's q (market to book) less than 100
- A full 6 years of data during the relevant period (1994-1999 or 2000-2005)

The net result of these screens reduced the number of firms in 2005 from about 2400 to 1450; this is the sample whose sectoral distribution is shown in Table A1. All these data were used in the LAD (least absolute deviations) regression. Additional screens were applied to choose the OLS sample:

- Growth rates for gross income, operating income, sales, and equity less than 150 per cent in absolute value
- Tobin's q (market to book) less than 10

Together, these screens reduced the sample form 1450 firms to 1402 firms in the 2000-2005 sample.

Table A1: SIC distribution

SIC	Industry name	# firms	Share
13	Oil and gas extraction	51	3.5%
20	Food and Kindred Products	52	3.6%
21	Tobacco Products	4	0.3%
22	Textile Mill Products	7	0.5%
23	Apparel & Other Finished Prods	26	1.8%
24	Lumber and Wood Prods, ex Furn	8	0.6%
25	Furniture and Fixtures	19	1.3%
26	Paper and Allied Products	31	2.1%
27	Printing,Publishing & Allied inds	34	2.3%
28	Chemicals & Allied Products	128	8.8%
29	Petroleum Refining & Related Inds	18	1.2%
30	Rubber & Misc Plastics Prods	25	1.7%
31	Leather and Leather Products	14	1.0%
32	Stone,Clay,Glass,Concrete Prods	18	1.2%
33	Primary Metal Industries	33	2.3%
34	Fabr Metal,ex Mach,Trans Eq	39	2.7%
35	Indl, Comml Mach,Computer Eq	145	10.0%
36	Electrical Eq, ex Computers	181	12.5%
37	Transportation Equipment	55	3.8%
38	Meas Inst; Photo Goods; Watches	146	10.1%
39	Misc Manufacturng Industries	26	1.8%
48	Communications	75	5.2%
50	Durable Goods - wholesale	51	3.5%
51	Nondurable Goods - wholesale	26	1.8%
73	Business services	238	16.4%
	Total in 2005	**1450**	

Appendix B: Comparison of OLS and LAD estimates

Table B1

Impact of lagged R&D intensity on various performance measures (2002-2005)

	Method of estimation			
Dependent variable	**OLS***		**LAD****	
Tobin's q (market to book)	**7.88 (.70)**	**5.23 (.74)**	**13.19 (.78)**	**9.32 (1.09)**
Shareholder returns	**-.60 (.08)**	**-.44 (.09)**	-.29 (.10)	-.17(.11)
Gross margin percentage	**1.31 (.07)**	**1.27 (.08)**	**1.45 (.05)**	**1.34 (.06)**
Operating margin percentage	**-.35 (.07)**	**-.26 (.09)**	**-.09 (.02)**	-.06 (.03)
Gross margin growth	-.06 (.06)	-.00 (.07)	**.17 (.05)**	**.19 (.06)**
Operating margin growth	.09 (.12)	.13 (.14)	**1.10 (.14)**	**1.05 (.14)**
Sales growth	-.04 (.05)	.01 (.06)	**.14 (.04)**	**.16 (.04)**
Year dummies	yes	yes	yes	yes
2-digit industry dummies (25)	no	yes	no	yes

*OLS with all growth rate variables trimmed at 150%, q<10; 4728 observations on 1402 firms; clustered standard errors

**Median quantile regression; 5800 observations on 1450 firms; bootstrap standard errors

Source: S&P Compustat annual industrial file, authors' computations.

Sample is manufacturing plus oil and gas, communications, wholesale trade, and business services (R&D-doing firms only)

R&D intensity = R&D to sales ratio, lagged two years

Gross margin = sales less cost of goods sold (gross of R&D)

Operating margin = operating income (net of R&D)

Percentages are relative to sales

Shareholder returns are holding period capital gains plus dividends per share

Tobin's q is the ratio of total market value to the book value of tangible assets

Table B2

Impact of lagged R&D intensity on various performance measures (LAD estimates using 4-year averages 2002-2005)

	Method of estimation			
Dependent variable	**OLS***		**LAD****	
Tobin's q (market to book)	**8.7 (1.2)**	**6.3 (1.1)**	**14.2 (1.8)**	**10.0 (1.9)**
Shareholder returns	.05 (.15)	.11 (.17)	.22 (.15)	.27 (.16)
Gross margin percentage	**1.15 (.13)**	**1.07 (.14)**	**1.36 (.18)**	**1.27 (.14)**
Operating margin percentage	-.17 (.09)	-.08 (.09)	-.08 (.04)	-.03 (.05)
Gross margin growth	.12 (.09)	**.22 (.09)**	.14 (.05)	.18 (.07)
Operating margin growth	.14 (.20)	.23 (.22)	.34 (.25)	.41 (.27)
Sales growth	.06 (.06)	.12 (.07)	**.15 (.04)**	**.17 (.04)**
2-digit industry dummies (25)	no	yes	no	yes

*Ordinary least squares with all growth rate variables trimmed at 150%, q<10; 1203 firm observations

** Least absolute deviations (median) regression with 1454 firm observations; bootstrap standard errors

Source: S&P Compustat annual industrial file, authors' computations.

Sample is manufacturing plus oil and gas, communications, wholesale trade, and business services (R&D-doing firms only)

R&D intensity = R&D to sales ratio in the year 2000

Gross margin = sales less cost of goods sold (gross of R&D)

Operating margin = operating income (net of R&D)

Percentages are relative to sales

Shareholder returns are holding period capital gains plus dividends per share

Tobin's q is the ratio of total market value to the book value of tangible assets

Appendix C: ICT vs non-ICT sectors

Table C1 breaks down our sample of firms into those in the Information and Communication Technology sector and the other sectors, in order to probe a bit further the reasons for differences across the two periods. There are relatively few differences between these two sectors: the only significant ones are that the relationship between gross margin growth and R&D intensity is substantially lower in the ICT sector in both periods and that between operating margin growth and R&D intensity is lower in the second. Although the relationship between shareholder returns and R&D intensity fell substantially in ICT and much less in the non-ICT sector, the differences are not significant.

Table C1

Impact of lagged R&D intensity on various performance measures
ICT vs non-ICT (LAD estimates using 4-year averages)

	ICT		non-ICT		Difference	
Dependent variable			**1996-1999**			
	Coeff.	**S.E.**	**Coeff.**	**S.E.**	**Coeff.**	**S.E.**
Market cap growth	0.77	0.47	**0.81**	**0.25**	-0.04	0.53
Shareholder returns	**3.27**	**1.38**	**1.49**	**0.49**	1.78	1.46
Gross margin percentage	**1.45**	**0.19**	**0.92**	**0.36**	0.53	0.41
Operating margin percentage	0.04	0.08	**0.25**	**0.12**	-0.21	0.14
Gross margin growth	-0.08	0.17	**0.73**	**0.26**	**-0.81**	**0.31**
Operating margin growth	0.29	0.37	0.42	0.35	-0.13	0.51
Sales growth	-0.01	0.15	**0.34**	**0.14**	-0.35	0.21
Number of observations (firms)	457		970			
			2002-2005			
Market cap growth	0.21	0.24	0.22	0.20	-0.01	0.31
Shareholder returns	0.21	0.20	**0.49**	**0.21**	-0.28	0.29
Gross margin percentage	**1.20**	**0.17**	**1.20**	**0.27**	0.00	0.32
Operating margin percentage	**-0.13**	**0.06**	**0.21**	**0.08**	**-0.34**	**0.10**
Gross margin growth	0.06	0.09	**0.57**	**0.13**	**-0.51**	**0.16**
Operating margin growth	0.56	0.37	0.39	0.26	0.17	0.45
Sales growth	0.11	0.08	**0.35**	**0.13**	-0.24	0.15
Number of observations (firms)	559		895			

Source: S&P Compustat annual industrial file, authors' computations.
Sample is manufacturing plus oil and gas, communications, wholesale trade, and business services (R&D-doing firms only)
All regressions include two-digit industry dummies
ICT sector is electrical machinery, computers, scientific instruments, telecommunications equipment, and software
R&D intensity = R&D to sales ratio in 1994 (first 2 columns) or 2000 (last 2 columns)
Gross margin = sales less cost of goods sold (gross of R&D)
Operating margin = operating income (net of R&D)
Percentages are relative to sales
Shareholder returns are holding period capital gains plus dividends per share
Tobin's q is the ratio of total market value to the book value of tangible assets