The Stock Market's Valuation of R&D Investment During the 1980's

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This paper reports a rather surprising new finding, which may contribute to understanding some of the changes in the U.S. economy during the 1980's: the stock market's valuation of the intangible capital created by R&D investment in the manufacturing sector has fallen precipitously during this period. The major finding of the paper is that, although intangible R&D assets from 1973 through about 1983–1984 were about equally valued with tangible capital, this relationship broke down completely during the mid-1980's, with the R&D stock coefficient falling by a factor of 3 or 4. During the 1970's, advertising expenditures were worth roughly one-tenth of R&D expenditures, but by 1988–1990, the two expenditure streams were worth about the same. The conclusion section of the paper discusses several possible explanations or implications of this finding: a fall in the private rate of return to R&D, a rise in the depreciation rate of R&D capital, market irrationality or a change in risk aversion, and the restructuring wave of the 1980's. The present paper does not attempt to discriminate among these hypotheses, but merely documents the finding as carefully as possible. It is drawn from a larger and more detailed study available from the author upon request.

The methodology used in this paper is based on Tobin's q theory, in which the long-run equilibrium market value of the bundle of assets which compose a firm is equal to the book value of those assets, properly measured. Deviations from this relationship imply either that the market is in disequilibrium and that firms have an incentive to undertake additional investment or disinvestment or that there is an unmeasured source of rents driving a wedge between the market and book value of the assets. Many researchers have exploited the q relationship to infer the value of intangible corporate assets or sources of rents, either observable or unobservable: Zvi Griliches (1981), Iain Cockburn and Griliches (1988), and Hall (1988), who studied the value of technological assets (R&D and patents held by the firm); Michael Salinger (1984) (union rents); Birger Wernerfelt and Cynthia Montgomery (1988) (diversification); and Jeremy Bulow et al. (1985) (unfunded pension liabilities). These studies typically have found valuations for R&D spending or stock which are consistent with a depreciation rate of about 15–20 percent per year and valuation at par with ordinary assets, even when the focus of the study is on another variable. However, none of the previous studies uses data later than 1985; the results in this paper are consistent with these earlier results for the pre-1985 period but differ dramatically after 1985.

I. The Valuation Equation

An equation describing the valuation of corporate assets may be derived in the following way: a firm is viewed as solving the dynamic programming problem of choosing an investment strategy to maximize the ex-

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pected present discounted value of cash flow given a portfolio of stocks of capital assets. Because the assets cannot be adjusted costlessly, the present position of the firm in asset space matters in determining the value of the optimal program conditional on the assets. This implies that the value of the firm as an ongoing enterprise in any given period can be expressed as a function of the various stocks of capital. In this paper, I use a common but somewhat ad hoc functional form that has been used in previous research to describe the valuation of the bundle of assets that make up a firm.[1]

The value function of the firm is written as a sum of the composite physical capital A and the intangible stocks $K_1, K_2, \ldots$ that are valued by the market but are not in the measured capital of the firm:

$$(1)\quad V(A,\ldots,K_1,K_2,\ldots) = Q(A+\ldots+\gamma_1 K_1+\gamma_2 K_2+\ldots)^{\sigma}.$$

To derive the estimating equation, introduce a multiplicative disturbance term, and take logarithms of both sides. This gives an equation of the following form:[2]

$$(2)\quad \log V = \log Q + \sigma(\log A + \ldots + \gamma_1(K_1/A) + \gamma_2(K_2/A) + \ldots) + e.$$

The σ coefficient describes the overall scale effect and should be equal to 1 under constant returns to scale of the value function (and no measurement error in $\log A$). The parameter multiplying the left-out stocks K_i is the shadow value of those stocks relative to the value of A.

I use two variables to measure the R&D capital of the firm: the first is just the flow of R&D expenditures (R/A), which is a fairly good proxy for long-run R&D behavior, owing to the low variance of the R&D series within a firm (Hall et al., 1986). The second is an R&D stock (K/A) that is constructed from past R&D expenditures under the assumption of a depreciation rate of 15 percent per annum, as described in Hall (1990). The variable is constructed with deflated R&D, and then the stock is reflated to current dollars.

In some industries, another important intangible asset is the value of the brand names, product differentiation, and goodwill arising from product reputation. This asset is typically a product of advertising expenditures and investments in sales and service; although I have no data on the latter input, about half the firms report advertising expenditures in any given year (Adv/A), and this is taken as an indicator of the rents accruing to brand-name reputation.

Finally, to proxy for any market power or long-run profitability of the firms that is not specifically related to advertising or R&D inputs, or that arises from differential success in using these inputs, I include a two-year moving average of cash flow (net of advertising and R&D expense, $\text{CF2}/A$). I also include the growth rate of sales in the current year ($\Delta \log S$) to capture the prospects for future growth of this particular firm, which may indeed be a product of its R&D and other investments but is not completely captured by the *current* level of R&D capital or spending.

II. Estimates

The data set on which this study is based is a data base constructed and maintained at the National Bureau of Economic Research over the past ten years and described in Hall (1990) and John Bound et al. (1984). It consists of all the publicly traded firms in the U.S. manufacturing sector that existed in 1976 or entered between 1976 and 1991. A firm is in the manufacturing sector if its primary industrial classification number as

[1]For theoretical development of the function used here, see Fumio Hayashi (1982) and David Wildasin (1984). For the first empirical use, see Griliches (1981).

[2]The approximation $(1+\varepsilon)\approx\varepsilon$ has been used. This approximation has an error of 10 percent when ε is 0.205 and 20 percent when ε is 0.425, which means it will not be very accurate for firms with high levels of R&D capital. A quarter of the firms have R&D capital greater than 0.25 times total physical capital stock.

TABLE 1—THE MARKET-VALUE EQUATION

Independent variable	Regression (i)	(ii)	(iii)
log A	0.882 (0.002)	0.879 (0.002)	0.879 (0.002)
CF2/A			1.87 (0.03)
Δ log S			0.54 (0.02)
R/A	3.10 (0.08)		2.44 (0.08)
K/A		0.48 (0.02)	
Adv/A	0.97 (0.07)	1.00 (0.07)	0.48 (0.06)
R^2:	0.917	0.912	0.940
SE:	0.511	0.527	0.437

Notes: The dependent variable is log V. The data represent 24,333 observations on 2,480 firms from 1973 to 1991. All regressions include year-specific dummies and variables describing the composition of physical assets: the share of inventories and the share of investments in intangibles and unconsolidated subsidiaries. Standard errors are heteroscedastic-consistent estimates.

coded by Compustat is between 2000 and 3999 inclusive. This includes firms that may have a large fraction of their sales in other sectors but have their *largest* product line (as a fraction of sales) in manufacturing.

Table 1 explores the specification of the log V regression [equation (2)], first with just the assets, tangible and intangible, and then with cash flow and the growth rate of sales added.[3] The coefficients of R&D are quite large and significant so that R&D explains a fair amount of the variance remaining after firm size is controlled for. They are not very affected by the inclusion of the other variables either, which indicates that the relatively simplified specifications used in the past may be reasonable approximations. The flow variable has slightly more explanatory power than the stock; in addition, it implies a higher valuation on recent R&D than on the history of R&D spending. To see this, note that the average ratio of stock to flow is around 5 in these data; if one applies this multiple to the regression, the expected stock coefficient is around 0.6 rather than 0.48, which means that the R&D stock of the firm is valued at 80 percent of the value of the stock implied by the current flow. This is not surprising if one thinks that the flow is a better forecast of future R&D spending plans, but it does mean that those future plans have a positive effect on value. Note, however, that this discrepancy is mostly eliminated when cash flow is included as a regressor, which suggests that part of the R&D flow effect arises from the correlation of this variable with cash flow in the same year. In contrast, the stock variable is unaffected by the inclusion of cash flow, and the ratio of the two coefficients is now 0.19.

One other implication of Table 1 is notable: advertising and R&D, which are sometimes treated as similar rent-creating activities by industrial-organization economists, have quite different consequences for the total value of a manufacturing firm. Although the mean level of expenditure is almost the same, the associated market valuation is four to five times as high for R&D as for advertising.

The regressions reported in Table 1 are averaged over all years and industries; the only concession to possible coefficient variation is the inclusion of time dummies to adjust for the overall level of the market. Because the model of equation (2) is at best a rough summary of the pricing of capital stocks in a very wide range of situations, there is no reason to think that the coefficients are anything other than a particular weighted average of coefficients which may differ from year-to-year. To investigate the importance of variation in relative market values over time, year-by-year estimates of the regressions shown in columns (i) and (ii) of Table 1 were computed; the results are summarized in Figures 1 and 2.

[3]Other regressions (not shown) reveal that the coefficients shown are unaffected by the inclusion of inventories and other assets and that the cash-flow coefficient falls only slightly when other variables are added, implying that multicollinearity is not severe.

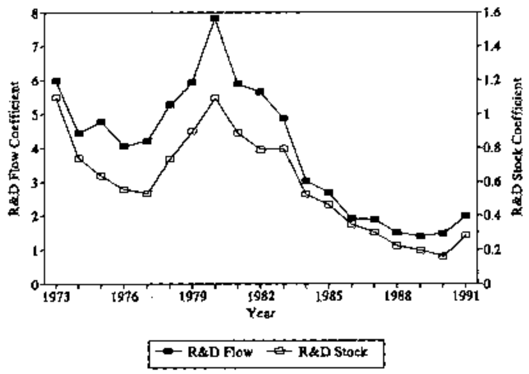

FIGURE 1. RELATIVE MARKET VALUATION OF R&D

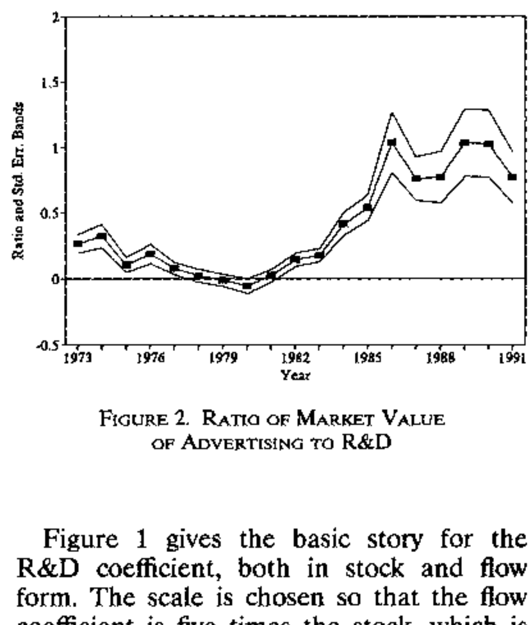

FIGURE 2. RATIO OF MARKET VALUE OF ADVERTISING TO R&D

Figure 1 gives the basic story for the R&D coefficient, both in stock and flow form. The scale is chosen so that the flow coefficient is five times the stock, which is what one would expect with a depreciation rate of 15 percent and a growth rate of 5 percent for R&D expenditures;[4] in fact, the current R&D flow is valued slightly higher than the stock, as in Table 1. The figure shows that the value of R&D capital relative to ordinary capital was somewhere between 0.6 and 1.0 until about 1983 or 1984, at which time it declined precipitously, reaching a level of almost 0.2 by 1989–1990 (a typical robust standard error for the coefficients on this graph is on the order of 0.04). This is in stark contrast to advertising expenditure; the ratio between the two flow coefficients (R&D and advertising) is plotted in Figure 2, and this ratio is roughly zero until 1983, when it starts rising toward unity in 1989 and 1990.[5]

Two reasons why this decline in R&D value might be spurious were investigated: the first was that the changes in the value of the intercept from year to year might be soaking up the R&D effect in the later period, as firms increased their R&D and became more convinced of the necessity of R&D for competitive reasons; in that case one could interpret the results in the earlier period as some kind of disequilibrium in the market. The second possibility considered was that this was a sample-selection phenomenon because the composition of the panel was changing during the latter half of the 1980's, as Compustat added substantially more OTC (over-the-counter) firms to the data files. Neither of these possibilities explained the result.

III. Conclusions

This paper has reported a rather startling stylized fact which seems to be robust to the various measurement and specification tests applied to it: the stock market valuation of R&D capital in U.S. manufacturing firms collapsed rather quickly from a high of 0.8–1.0 during 1979–1983 to a low of 0.2–0.3 during 1986–1991. For economists who have

[4]With a depreciation rate of δ and a constant growth rate of real R&D expenditures equal to g, the R&D stock of a firm at time t will be $R_t/(\delta+g)$, where R_t is R&D spending at time t. In the present case, with $\delta = 0.15$ and $g = 0.05$, the stock will be approximately $5R_t$.

[5]The relationship between market value and R&D was also investigated using two-digit industry dummies, with the result that, although the dummies reduce the coefficients by about one-third in the 1973–1983 period, they have almost no effect in the later period, implying that whatever happened to the productivity of R&D, it is now the same in all industries.

been accustomed to using market-value relationships as one measure of the "success" of R&D investment, this is rather sobering news. What does it indicate about the private rate of return to R&D during the 1980's?

The first possibility is that the private rate of return to R&D has indeed fallen. If R&D capital is assumed to depreciate at the same rate it always has (which may be an untenable assumption), then a coefficient of 0.25 implies that the expected rate of cash flow from the asset created by R&D investment is one quarter that of ordinary investment. That is, if ordinary capital yields 10 percent per year, R&D capital is expected to yield 2.5 percent. If this were the whole story, the R&D tax credit has been a tremendous success in driving down the private rate of return to R&D! The effects of corporate tax changes in the Tax Reform Act of 1986 on the valuation of capital need to be considered, although they are unlikely to be large enough to account for the result here.

A second possibility is that R&D capital depreciates much more rapidly than it used to; a depreciation rate of 0.67 instead of 0.15 would account for the fall in the R&D capital coefficient from 0.9 to 0.25, if R&D expenditures were growing at 5 percent per year. Although there may be some truth to this story, especially in the computer and electronics sectors, the effect seems implausibly high; it says that two-thirds of the capital becomes nonproductive in one year.

A third possibility is that the stock market has become more myopic and is discounting the cash flows from R&D capital at a very high rate, treating them as if they were highly uncertain. Again the numbers seem so high as to be implausible: if the cash flows from ordinary capital are discounted at 0.95, the implied discount for R&D capital is 0.19 (i.e., an interest rate of 0.81!). This is really the same as the second possibility, because the required rate of return is very high but has a different interpretation: in this version, the market is making some kind of shortsighted mistake, rather than just responding to increasing obsolescence of technical knowledge.

A final interpretation of the results in this paper is related to the wave of mergers and leveraged buyouts during the 1980's. Because much of this activity in manufacturing took place in consumer-products industries where advertising is likely to be important, part of the shift in valuation from R&D toward advertising may be due to the market's attempt to identify takeover candidates which are likely to experience supranormal returns at the time of takeover or buyout. There is some doubt about whether the timing is precisely right, because the buyout wave really began in about 1984, and the real changes in valuation happened more often in 1986–1987, but the idea seems worth exploring further using a more detailed industry-level examination. I plan to pursue both this question and the importance of changes in the discounting of risky investments in future work.

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