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**The Value of Intangible Corporate Assets:
An Empirical Study of the Components
of Tobin's Q**

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Abstract

The relative stock market valuation of the intangible asset created by R&D investment in U.S. manufacturing firms has fallen from rough equality with ordinary tangible assets during the 1973-1982 period to about twenty to thirty percent of ordinary capital during the 1986-1990 period. At the same time, the relative market valuation of advertising expenditure has risen to parity with R&D spending. This finding is based on a large comprehensive panel of about 2500 U.S. industrial corporations, covering eighty to ninety percent of industrial R&D performed by U.S. firms and is robust to industry controls, sample selection, and various specification tests. Possible explanations for the finding are discussed, but definitive answers await future research.

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**THE VALUE OF INTANGIBLE CORPORATE ASSETS:
AN EMPIRICAL STUDY OF THE COMPONENTS OF TOBIN'S Q**

Bronwyn H. Hall ¹

1. Introduction

Tobin's Q (the measured divergence between the market value and book value of firms' capital stock) has been widely used in empirical economic research as an indicator of firm-level incentives for investment in corporate capital (see Brainard, Shoven, and Weiss 1980; Summers 1981; and Chirinko 1988a, for example). The idea of the method can be grounded in a theoretical model such as that proposed by Lucas (1967a), in which a value-maximizing firm undertakes investment in response to changes in the market value of its capital. Events that cause the market value of the firm to diverge from its book value in a positive direction signal that the capital stock of the firm is worth more than was paid for it, and that investment should be undertaken to increase it until the the equilibrium level of Q (unity) is restored. The opposite situation, where the book value of the capital stock is greater than the market value, signals that disinvestment should be occurring. From this basically simple idea comes the principle

¹University of California at Berkeley, the National Bureau of Economic Research, and The Hoover Institution on War, Revolution, and Peace, Stanford University. This paper is a substantial revision and update of Chapter 2 of my dissertation, *R&D Investment and the Evolution of the U.S. Manufacturing Sector: Econometric Studies at the Firm Level*, Department of Economics, Stanford University, May 1988. I am grateful to the National Bureau of Economic Research and the National Science Foundation for partial support of the data preparation effort, and to the Cox Econometrics Laboratory, University of California at Berkeley, for computer time. The current version of the paper was prepared during my stay as a National Fellow at the Hoover Institution.

that Q be treated as the price of investment goods faced by the firm and a demand equation for investment be constructed with Q as the independent variable driving demand.² Since the value of capital may be altered by the taxes that must be incurred when capturing its returns and the actual price of investment may be subsidized by the tax system, various researchers (including those cited above) have performed tax adjustments to Q and used the methodology to evaluate the effect on investment of changes in taxation regimes.

When applied to data for corporate firms, this technique has the defect that it must use the value of the entire firm (the value of debt and equity) to proxy for the *market* value of the capital stock, while the *book* value of the capital stock is generally observable distinctly from the firm's other assets (at least in principle). But this defect is also an opportunity: since the value of the firm includes many intangible assets as well as other tangible assets (inventories, unconsolidated subsidiaries, etc.), it is possible to learn something about the valuation of these other assets from the wedge between the market value and the book value of the firm. This opportunity has been exploited by, among others, Griliches (1981), Cockburn and Griliches (1988), and Hall (1988c), who studied the value of technological assets (R&D and patents held by the firm); Salinger (1984) (union rents); Montgomery and Wernerfelt (1988) (diversification); and Fullerton (1988) (R&D and advertising).

The present paper began as an update of some of the earlier results on R&D (which were based on manufacturing firms through 1985), extending both the method to include other types of assets and the data to include all of the publicly traded manufacturing

²The relationship developed by Lucas and others is an *equilibrium* one; therefore most researchers are careful to present instrumental variable estimates of the investment demand equation, or at least to use lagged Q as the regressor.

firms in the United States from 1973 through 1991, a sample of around 2500 firms with up to 20 years of data per firm. In the course of performing the update, I found major changes in the stock market valuation of the intangible assets of manufacturing firms during the nineteen-eighties. These changes are documented here and possible causes are discussed, but a definitive explanation of the phenomena described awaits future work.

The major finding of the paper is that although the value of R&D assets from 1973 through about 1985 fluctuated around levels which roughly imply that the intangible asset thus created is equally valued with tangible capital, this relationship broke down completely following 1985, with the R&D stock coefficient falling by a factor of 3 or 4. During the 1970s, advertising expenditures were worth roughly one-tenth of R&D expenditures, but by 1988-1990, the two expenditure streams were worth about the same. There are several possible implications of this finding: first, the *per-firm* increase in the performance of R&D, possibly induced by the R&D tax credit and other changes to the tax system, could have reduced the private rate of return to R&D. In the regressions presented here, the consequences of tax changes during the period have not been taken into account. A second possibility is simply that the average rate of depreciation of the intangible asset created by R&D spending has risen substantially, from approximately 20 percent to close to 100 percent. A third possibility is that the market valuation model on which the regressions are based is flawed because the market has suddenly become myopic, and discounts the cash flows which will be generated by R&D capital at a very high rate (again, close to 100 percent). This interpretation has somewhat different implications, since it does not mean that the private rate of return to R&D has actually fallen, but only that the market thinks it has. The present paper does not attempt to discriminate among these hypotheses, but merely documents the finding as carefully as

possible.

The dataset on which this study is based is a database constructed and maintained at the National Bureau of Economic Research over the past ten years and described in Hall (1990) and 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. These firms were drawn from the Compustat Files of 1978 and 1980 through 1991; the Industrial Research File was also used to find those firms that existed in 1976 or 1977 but were not on the 1978 files. A firm is in the manufacturing sector if its primary industrial classification number as 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.

2. 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 maximizing the expected 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 (including the option value of dissolution) can be expressed as a function of the various stocks of capital:

$$(1) V(\{C_{it}\}) = f(C_{1t}, C_{2t}, \dots)$$

Most of the early applications of this model specialize to only one type of capital (treat capital as if it can be aggregated over all types with unit weights) and use the equilibrium condition that the market value of this capital (V) must coincide with the (properly valued) book value (C); that is, the price one should pay for pieces of the capital is the same price one would pay when buying that share of the firm at the prevailing market price. When these two do not coincide (Tobin's Q is larger than or smaller than unity), the market is signaling either that the firm's capital is worth more than it costs and investment should be undertaken, or the converse. Obviously, many assumptions have been made to arrive at this interpretation. First, market efficiency has been assumed. Second, in the most common version of the model (using the level, or average value of Tobin's Q , V/C), it has been assumed that the marginal value of the capital in a firm is equal to its average value. Hayashi (1982) has shown that this assumption is valid under constant returns to scale and an adjustment cost function that is linear homogeneous in investment and capital, assumptions which are unlikely to hold rigorously in practice. Third, the capital has been assumed to aggregate in production with unit weights multiplying the book values of the different types of capital. Wildasin (1984) showed that a necessary condition for this type of aggregation is constant returns to scale in production together with linear homogeneous adjustment costs on all types of capital. Even so, the appropriate weights may not be unity. Chirinko (1988b) extended the Wildasin argument to show that gestation and delivery lags for capital will introduce the same kind of aggregation problem in the formulation.

In spite of these drawbacks, the value function methodology for the pricing of capital stocks, and hence their rates of return, is appealing for the following reasons. As Fisher and McGowan (1983) have argued forcefully, the alternative empirical

methodology for computing the returns to investment, which relies on accounting profits, is seriously flawed. Even if the measurement of current profits were perfect, which is far from being the case, this construct would be a very inadequate measure of the long-run enhancement to the firm's profitability from investment decisions, which is presumably the object of the manager. The use of the stock market value of the firm solves both these problems in principle: it is extremely well measured, since it is determined on one of the best functioning of markets and is not obviously subject to the manipulations of accountants, and it measures almost the exact concept described by the theoretical model of the firm, the value of its dynamic program. The most serious divergence is that due to the taxes faced by the investors in the firm, which may alter the actual payouts available to them and the form in which they would like to take them (as returns to equity or debt). Another possible divergence between the measured quantity and the theoretical model is the divergence arising from the discrepancy in the goals of the owners and the managers of the firm.

My interest and the focus of this paper is on the valuation of the intangible assets of the firm, of which the most important are likely to be R&D capital and brand reputation (consumer goodwill, proxied by advertising expenditures). In order to use the market value of the firm to say something about these, it is necessary to confront the multiple stocks issue head on and adopt a somewhat *ad hoc* functional form based on the ideas in Hayashi and Wildasin to describe the valuation of the bundle of assets that make up a firm. To do this, I consider two kinds of capital: the physical capitals A_1, A_2, \dots , which are added up to comprise the book value of the capital stock; and the intangibles K_1, K_2, \dots , which are valued by the market but are not in the measured capital of the firm. Write the value function of the firm as an aggregate of these

stocks (some of which may be liabilities), where the stocks have different shadow prices (or aggregation weights):

$$(2) V(A_1, A_2, \dots, K_1, K_2, \dots) = Q (A_1 + \lambda_2 A_2 + \dots + \gamma_1 K_1 + \gamma_2 K_2 + \dots)^\sigma$$

The coefficient σ is included to measure departures from constant returns to scale in the value function. Market efficiency considerations should guarantee that it be unity in the long run (the cross section); otherwise, there would be a return to combining or splitting up firms. The multiplier Q is analogous to Tobin's Q ; when σ is one and there is only one type of capital A_1 , it corresponds exactly to Tobin's Q .

Now set A equal to the sum of the physical capital (the measured net capital stock), ΣA_i , and factor A out of the expression in parentheses:

$$(3) V(\dots) = Q A^\sigma \left[1 + (\lambda_2 - 1) (A_2/A) + \dots + \gamma_1 (K_1/A) + \gamma_2 (K_2/A) + \dots \right]^\sigma$$

To obtain a regression equation, assume that the disturbance in this equation, which arises from misspecification, omitted stocks, and possibly mismeasurement of the observed stocks, is multiplicative (proportional to the size of the firm) and take logarithms of both sides. This leads to an estimating equation of the following form (where the approximation $\log(1+\epsilon) \approx \epsilon$ has been used; this is justified by the relatively small size of the capital stocks other than A):³

³This approximation has an error of 10 percent when ϵ is .205 and 20 percent when ϵ is .425, which means it will not be very accurate for firms with high levels of inventories or R&D capital K . A quarter of the firms have an inventory share greater than .42 and a quarter have R&D capital greater than .25 times total physical capital stock.

$$(4) \log V = \log Q + \sigma (\log A + (\lambda_2 - 1) (A_2/A) + \dots + \gamma_1 (K_1/A) + \gamma_2 (K_2/A) + \dots) + e$$

The σ coefficient describes the overall scale effect and should be equal to one under constant returns to scale of the value function (and no measurement error in $\log A$). The parameter multiplying the stocks that are included in A , but aggregated wrongly, represents the premium (or discount) appropriate for those stocks, whereas the parameter multiplying the left-out stocks is the entire shadow price of those stocks.

Note that Tobin's Q , the ratio of V to A , multiplied the original function and is now in the constant term for this regression. In equilibrium, this intercept should be zero, but in time series estimates it has diverged from zero substantially for most of the recent past (see Brainard, Shoven, and Weiss [1980] for measurements at the aggregate level). This is a problem for the interpretation of estimates of this kind of equation in the cross section dimension: to the extent that movements in V , A , and its components are common across all firms, they will be absorbed in the intercept or year dummies and the capital coefficients will be incomplete measures of the *average* market value of the capital stock, although they may be accurate measures of the *marginal* value of additional investment, depending on what else is in the regression. To illustrate this phenomenon, consider the semiconductor industry, from which there are about 40 firms in my sample: using a version of equation (4), the estimated shadow price of R&D capital in this industry is zero throughout the period, in spite of the fact that R&D capital is about 50 percent of the total book value of ordinary capital. However, the intercept for the semiconductor industry typically ranges from 1 to 1.5 during the same period, implying that semiconductor firms are valued at more than twice the book value

of their physical capital stock. The conclusion is not that R&D capital is not expected to yield cash flows in the future, but that the industry is in some kind of dynamic equilibrium where most firms must have a fair amount of R&D capital to compete, and the average returns from this capital are in the intercept. Therefore interpretation of the results of estimating an equation like equation (4) must be done with care.

Implementing the estimation of equation (4) requires consideration of both the set of observable assets which are likely to generate future returns, and the sources of unobservable variability in these returns, some of which may be related to, but not the same as, the current set of assets. The composition of the measured net capital stock A (NETCAP), which is described in Hall (1990) is considered first. This variable is composed of three components, each of which has been separately adjusted for inflation: the plant and equipment of the firm (NPLANT), the inventories (ADJINV), and the sum of investments in unconsolidated subsidiaries and intangibles (ADJTOT). Under the assumption that the first variable is the largest and the most important for the determination of V , I treat the other two as possibly misaggregated and include their ratio to A in the regression. Table 1, which displays some characteristics of the data in 1982, shows that the average level of inventories is 32 percent of the capital stock, while the other investments average 8 percent of the total. During the 20-year period I consider, the share of inventories has declined slightly (from .38 to .35) and the share of "other" assets increased (from .08 to .12).

The chief intangible asset in which I am interested is the stock of knowledge capital, the R&D position of the firm. I use two variables to measure this quantity: the first is just the flow of R&D expenditures, 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,

Griliches, and Hausman 1987). The second is an R&D stock that is constructed from past R&D expenditures under the assumption of a 15 percent per annum depreciation rate, as described in Hall (1990). The variable is constructed with deflated R&D and then the stock is reflatd to current dollars since all the variables in these regressions are in current dollars. In either case, I included a dummy variable equal to one for those firms that do not have an R&D program during the year (or in prior years, in the case of the stock variable). The coefficient for this variable tends to be insignificant, negative, and fairly stable, suggesting that not too much harm is done by pooling across both types of firms.⁴

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, and this is taken as an indicator of the rents accruing to brand name reputation. The assumption is that these expenditures are immaterial for the remainder; this assumption is confirmed by the fact that a dummy for zero advertising expenditures in the market value regression is insignificantly different from zero, so that nonreporting of advertising can be treated as roughly zero

⁴Whenever one uses R&D capital or spending in the same equation as a capital stock variable, there is the potential for biases due to double-counting of R&D capital expenditures (Schankerman 1980). In principle, accounting data ought to keep R&D spending which is expensable separate from the R&D spending which is actually investment in depreciable capital stock, but it is unclear how carefully this is done in 10-Ks and annual reports. The existence of this problem introduces a bias of unknown sign and magnitude in the estimates of the R&D capital coefficient. To the extent that R&D capital is being double-counted, the estimated coefficient will be biased downward (if interpreted as the full shadow price) or upward (if interpreted as a premium). That is, the coefficient is a weighted average of a premium on the part of R&D capital which is also in physical capital and the shadow price of the remainder.

expenditures in most cases.

Under the assumption that the market value of a firm is the present discounted value of the future stream of cash flows generated by this bundle of assets (capital stock, inventories, investments in other firms, R&D capital, product differentiation and reputation) and by the assets produced by *the optimal stream of future investments* in these capital stocks, what is likely to be left in the disturbance after the current level of assets and the overall market level has been controlled for? I would argue that two effects are likely to be important; both of them will be somewhat related to my proxies for intangible capital (advertising and R&D) but are not identical to these assets. These are: 1) any market power or longrun profitability of the firms which is not specifically related to advertising or R&D inputs, or which arises from differential success in using these inputs, and 2) 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. Consider the contrast between a biotechnology firm and an ordinary pharmaceutical firm, for example. The former has tended in the recent past to be valued at a substantial premium over the latter, even given R&D spending patterns, primarily because the expectation of future sales and R&D growth tends to be higher.

To proxy for these factors, I include two variables in the regression: first, the measure of profitability is a 2-year moving average of past cashflow, which is measured as operating income less interest payments. This variable is also net of both advertising and R&D spending, so that the residual market power effect can be separated as much as possible from the effect of investment in intangibles. The second variable included is the contemporaneous growth rate of sales, which is intended to proxy for

expected future growth of the firm.

All variables have been divided by the level of assets to place them on a common footing, and they have been measured at the same time as market value (in the case of stocks) or during the year preceding (in the case of flows). The flow variables R&D, advertising, and cash flow, have to be converted to stocks in some way before the coefficients can be interpreted or, alternatively, an assumption of unit price can be used to derive the appropriate conversion factor. That is, if one assumes that all prices in the relationship described by equation (1) must be one in equilibrium, the coefficients of R&D and advertising are just the inverse of the associated depreciation rate for the asset which they create. The coefficient of cashflow is the inverse of the rate at which the market discounts the cash flow stream.

3. Estimates

Table 1 shows the means, medians, and interquartile range of the various variables in 1982, together with the means at the beginning and end of the period to give some idea of how the variables change.⁵ The most important change is the increase in R&D intensity during the period: the rate of R&D investment more than doubles (from 2.3 percent of assets to 5.7 percent), while the rate of investment in ordinary capital remains roughly the same (about 10 percent of assets). The stock of R&D capital is almost one-third that of ordinary capital at the end of the period, up from 0.12 at the beginning.

⁵The 1991 data is somewhat incomplete, since it lacks firms whose fiscal year actually closes in early 1992; accordingly, I have shown the means for 1990, to avoid a sample selection bias in the numbers.

TABLE 1
SAMPLE CHARACTERISTICS

1982: 1,281 Firms

Variable	Mean*	S.D.	Median*	Q1*	Q3*	No. ≤ 0	Mean* in 1973	Mean* in 1990
Log Q	.210	.730	.115	-.298	.648	550	.282	.274
Log V	148.4	1.70	111.1	42.5	437.4	NA	67.4	194.4
Log A	119.9	1.97	91.7	28.6	407.4	NA	50.9	146.9
ΔLog S	-.008	.206	-.007	-.107	.090	672		
Invest/A	.086	.063	.069	.045	.109	0	.097	.105
R&D/A	.035	.053	.014	0.0	.048	443	.023	.053
K/A	.166	.230	.084	0.0	.255	435	.117	.273
Adv/A	.023	.057	0.0	0.0	.024	723	.021	.029
CF/A	.125	.124	.122	.054	.194	152	.184	.150
Inv/A	.315	.172	.296	.190	.422	4	.386	.349
Oth/A	.079	.114	.033	0.0	.110	448	.080	.122

*The antilogarithm is shown for log V and log A in these columns.

- Log V Logarithm of the total market value of the firm's equity, debt, and preferred stock.
 Log A Logarithm of the net inflation-adjusted value of the capital stock.
 Log Q Logarithm of the ratio of V and A (Tobin's Q).
 ΔLog S Growth rate of sales during the year.
 Invest/A Capital expenditures relative to A.
 R&D/A R&D expenditures relative to A.
 Adv/A Advertising relative to A.
 CF/A Operating income before depreciation and after interest expense, relative to A.
 Inv/A Share of inventories in A.
 Oth/A Share of investments in intangibles and unconsolidated subsidiaries in A.

All variables are in millions of current dollars.

The share of other assets (ADJTOT) has risen by .04 and the share of inventories (ADJINV) fallen by the same amount. The other assets variable consists of investments in unconsolidated subsidiaries, leases (where the firm is the lessor), and intangibles. The latter are generally created when an acquisition is performed at a price which exceeds the book value of the acquired firm; for accounting purposes, the gap between the market and book value must be recorded somewhere on the balance sheet to offset the price paid. The increase in ADJTOT is undoubtedly due to the high level of acquisition activity throughout the eighties, and possibly also to an increase in leasing activity.

Tables 2 and 2A explore the specification of the Log V regression (equation (4)), first with only cash flow, then with all the assets, tangible and intangible, and finally with the growth rate of sales rather than cashflow as a proxy for changes in output demand. Note that most of the explanatory power is in the firm size variable and that the other variables add very little to the R-squared; this is to be expected in a cross-section regression on firms with a size range of one-half million dollars to roughly 100 billion dollars. The scale coefficient is not quite unity, although nearly so; this could arise from mismeasurement of A as well as some kind of decreasing returns in the value function. Including A's components separately does increase the scale coefficient slightly, which suggests that one of the causes of the discrepancy is downward bias from measurement error in A.

Note also that there is apparently very substantial positive serial correlation in the relationship from year-to-year; this can be interpreted as the presence of left-out variables which are firm or industry specific, or as a sign that the relationship is not stable over time. If there were such a misspecification and the coefficients were slowly changing over time, serial correlation would also result; this possibility is

investigated in the next section and rejected. Table 2A shows that the observed serial correlation is not due to industry effects, since the "Durbin-Watson" statistics hardly change when these are included. This leaves firm effects as the most likely explanation for serial correlation in the market value relationship: unmodelled and unmeasured heterogeneity across firms in their access to market opportunities, niches, types of intangible assets, and what some would term "competences." A variance decomposition of the total estimated variance of the disturbance in the regressions of Table 2 shows that about half the variance of the disturbances is within firm, while only seven percent is within industry.

TABLE 2
THE MARKET VALUE EQUATION
 1973-1991

24,333 Observations on 2,480 Firms

Dependent Variable: Log V

Indep. Variable	(1)	(2)	(3)	(4)	(5)	(6)
Log A	.869(.002)	.882(.002)	.879(.002)	.879(.002)	.881(.002)	.879(.002)
CF2/A	2.21(.04)			1.87(.03)	1.84(.03)	1.94(.03)
$\Delta \log S$				.54(.02)	.54(.02)	.61(.02)
R/A		3.10(.08)		2.44(.08)	2.41(.08)	
K/A			.48(.02)			.46(.02)
Adv/A		.97(.07)	1.00(.07)	.48(.06)	.58(.06)	.56(.06)
Inv/A		.11(.02)	.15(.02)	.08(.02)		
Oth/A		.38(.03)	.37(.03)	.49(.03)		
D-W stat.	.29	.26	.24	.37	.36	.36
R-squared	.928	.917	.912	.940	.939	.937
Std. err.	.477	.511	.527	.437	.441	.447

All regressions include year-specific dummies. All standard errors are heteroskedastic-consistent estimates. The Durbin-Watson statistic is the weighted average over that for each firm, and does not have the exact small-sample distribution.

See Table 1 and the text for a description of the variables. CF2/A is the two-year moving average of CF/A for the current and previous years.

TABLE 2A
THE MARKET VALUE EQUATION
WITH TWO-DIGIT INDUSTRY DUMMIES

1973-1991

24,333 Observations on 2,480 Firms

Dependent Variable: Log V

Indep. Variable	(1)	(2)	(3)	(4)	(5)	(6)
Log A	.878(.002)	.884(.002)	.883(.002)	.880(.002)	.881(.002)	.880(.002)
CF2/A	2.03(.03)			1.85(.03)	1.81(.03)	1.87(.03)
$\Delta \log S$				.49(.02)	.50(.02)	.53(.02)
R/A		2.12(.09)		1.70(.08)	1.62(.08)	
K/A			.19(.02)			.25(.02)
Adv/A		.35(.07)	.34(.07)	-.03(.06)	.02(.06)	-.01(.06)
Inv/A		.13(.02)	.14(.02)	.11(.02)		
Oth/A		.22(.03)	.18(.03)	.38(.03)		
D-W stat.	.33	.27	.26	.38	.37	.37
R-squared	.939	.924	.921	.944	.945	.942
Std. err.	.440	.493	.501	.422	.424	.428

The regressions and variables are the same as those in Table 2, except for the inclusion of 19 industry dummies at the (approximately) two-digit level. The industries are those defined in the Appendix of Bound *et al* (1984), and roughly follow the NSF applied R&D categories.

The cash flow variable is highly significant and not very sensitive to the presence of other variables, although it does affect *their* coefficients. A value of 2 for this coefficient means that if cash flow doubles one year, the market value of the firm increases by 25 percent, other things equal. Another way to interpret this number is to write the market value of the firm as

$$(5) \log V = \log Q + \sigma \log (A + PDV(\text{rents}))$$

and approximate the right-hand-side expression as before so that

$$(6) \log V - \sigma \log A \sim \sigma PDV(\text{rents})/A$$

Then the coefficient of cash flow would just be σ divided by the rate at which the market discounts this stream. Using this interpretation, the discount rate is high, about 40 percent, which may reflect a large transitory component in cash flow, the fact that it is measured before investment (both ordinary and R&D), or tax considerations.

In Table 2, inventories and other investments are valued more highly than plant and equipment, with premiums of about 10 and 40 percent, respectively. The latter result, in particular, may reflect the fact that these investments are carried on the books in some unknown accounting manner and could be mismeasured.

Turning to the coefficients of R&D, I first note that they are quite large and significant and explain a fair fraction of the variance remaining after firm size is controlled for. They are not very affected by the inclusion of the other variables either, which is good news for the relatively simplified specifications used by myself

and others in the past. 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, which would imply a depreciation rate of around 20 percent if R&D expenditures are constant in real terms. If we applied this multiple to the regression, we would expect the stock coefficient to be around 0.6 rather than 0.48, which means that the R&D stock of the firm is valued at eighty percent of the value of the stock implied by the current flow. This is not surprising if we think 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.

What do we learn about the valuation of the R&D program of the firm? Remember that the depreciation rate used to construct the R&D stock of the firm from its past history was 15 percent, so we have built in an assumption about obsolescence. It appears from the regression that this assumption is much too optimistic -- knowledge capital is valued at only fifty percent of the level of plant and equipment, which suggests a far greater rate of obsolescence. One possible reason for this result is that the obsolescence that matters for the future profits of the firm is of a different character than the picture of incorrect or displaced knowledge that we have. Much of the R&D performed by a modern manufacturing firm has the character of "keeping up with the Jones's"; that is, it is performed because the competition performs R&D, and the firm

must match this expenditure to stay in the race. It is not surprising that the returns to such R&D dissipate quickly, but it does not necessarily imply that too much R&D has been performed in the past (from the firm's point of view). It is simply that we do not know how to construct the relevant stock of knowledge.

One implication of Table 2 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. This is undoubtedly because R&D is associated with a very important source of future profits for the firm, namely growth, whereas advertising expenditures may simply be maintenance expenditures, related only to current profits. Note that when profits are excluded from the regressions in Table 2 the advertising coefficient is approximately unity rather than 0.5. Interpreted literally, this would imply that advertising creates some kind of intangible capital, but that it depreciates to zero every year. In the next section I probe the relative valuation of R&D and advertising somewhat more carefully, and find that the coefficients displayed in Table 2 mask some dramatic shifts in the relationship which have occurred over time.

4. The Change in the Valuation Relation over Time

The regressions reported in Table 2 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. Since the model of equation (4) 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 (2) and (3) of Tables 2 and 2A were computed; this section discusses the results of this exercise.⁶

The overall conclusion is that averaging over time has obscured very substantive changes in the relative valuation of different assets. This is displayed in a series of figures: Figure 1 gives the basic story for the coefficient of R&D spending over time, and Figure 2 compares the stock vs. flow effect for R&D. The scale is chosen so that the flow coefficient is five times the stock, which is what one would expect with a 15 percent depreciation rate and 5 percent growth rate of R&D expenditures;⁷ in fact, the current R&D flow is valued slightly higher than the stock, as in Tables 2 and 2A. The figures show 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. This is in stark contrast to advertising expenditure; the ratio between the two flow coefficients (R&D and advertising) is plotted in Figure 3, and this ratio is roughly zero until 1983, when it starts rising towards unity in 1989 and 1990.

⁶These specifications were chosen since they include only stocks, thus mitigating the difficulties of interpretation which arise when control variables are included in the regression, as discussed in section 2 of the paper. It makes little difference for the time series result which I report here which specification is chosen; the only effect is on the overall level of the coefficients, which is mismeasured if other variables which are correlated with the stocks are included.

⁷With 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 $\delta=.15$ and $g=.05$, the stock will be approximately $5R_t$.

FIGURE 1

R&D Spending - U.S. Manufacturing Firms

Relative Market Valuation Coefficient

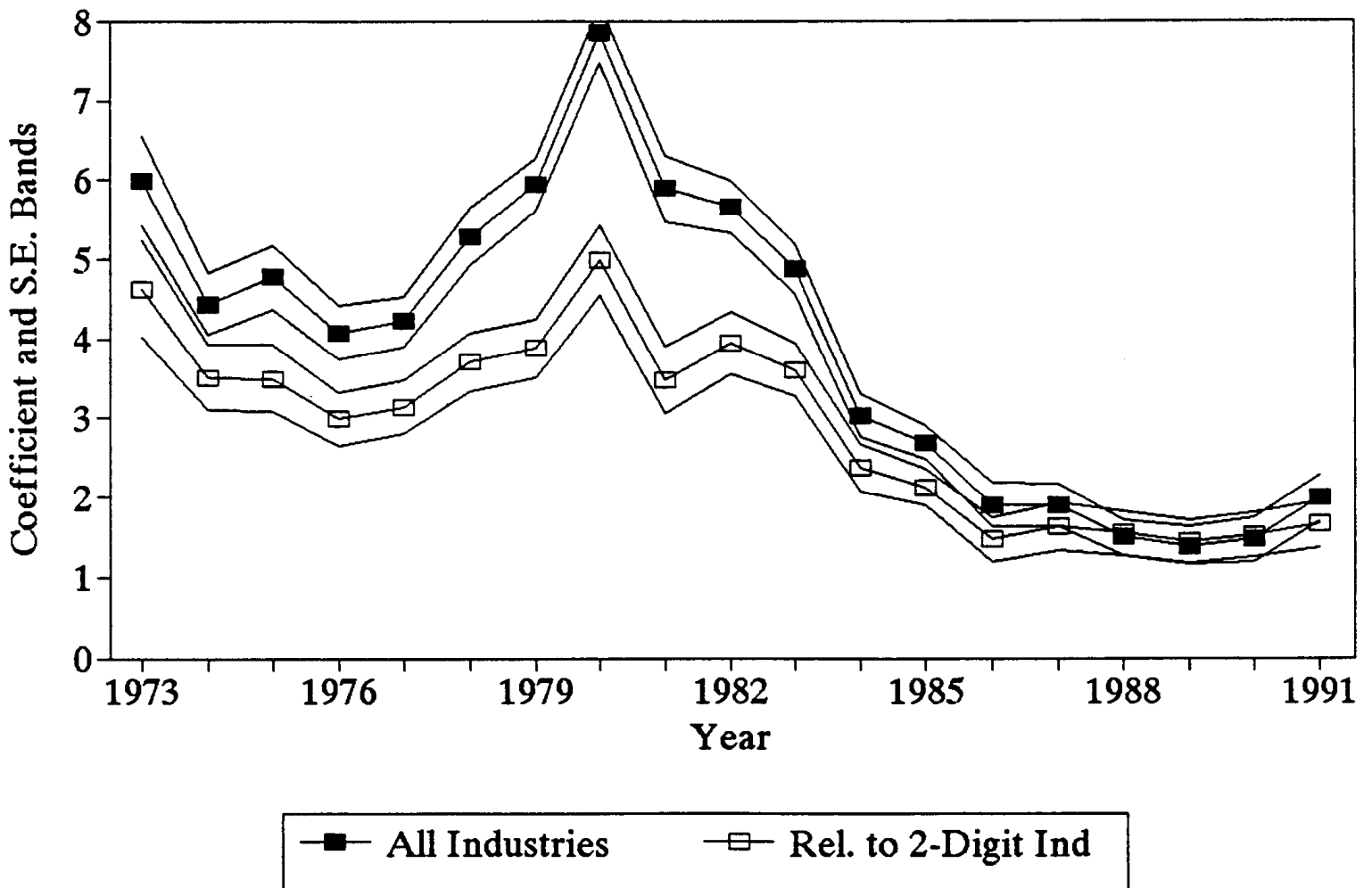
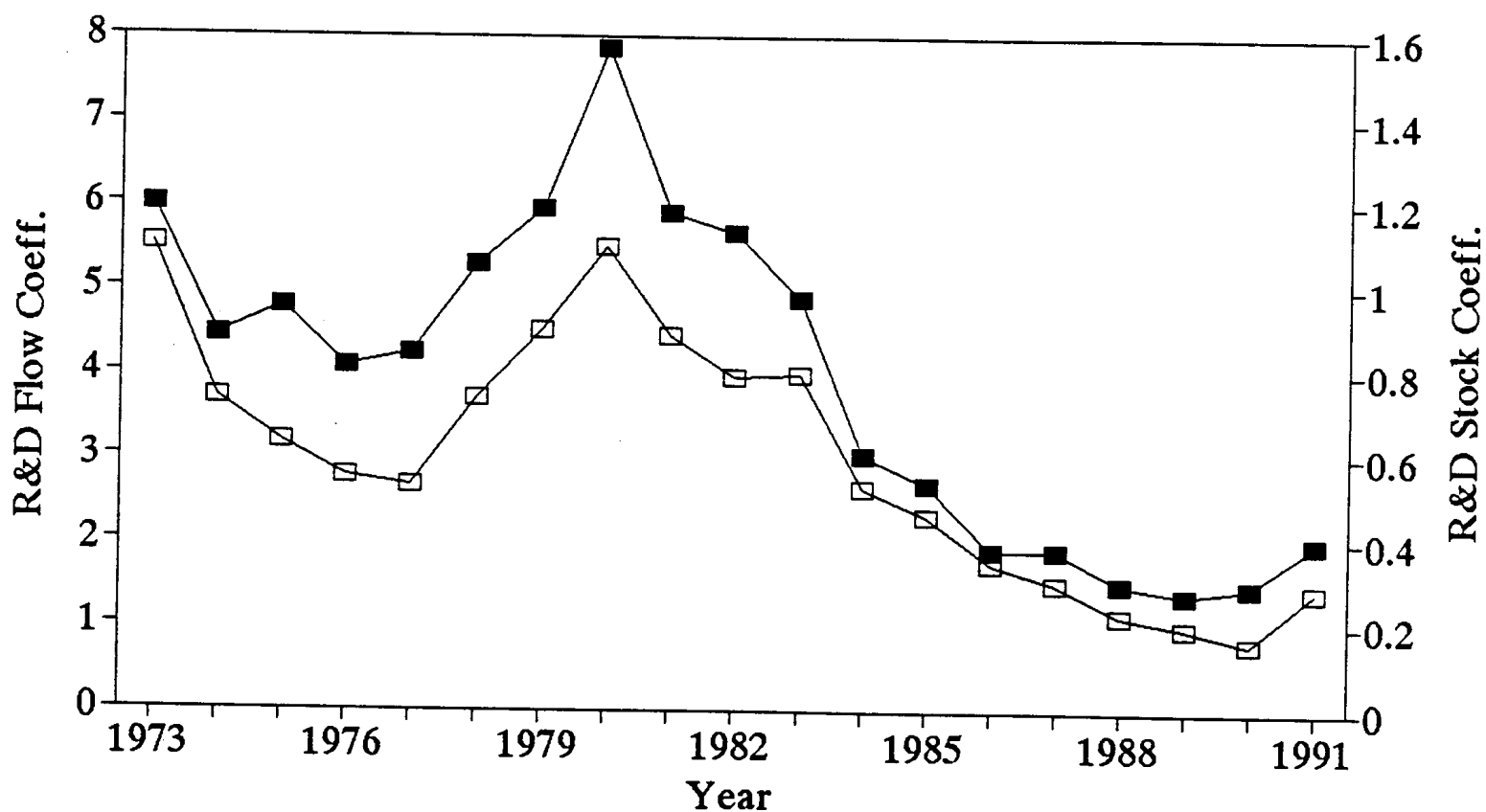


FIGURE 2

R&D Stock vs. Flow - U.S. Manufacturing Relative Market Valuation Coefficient

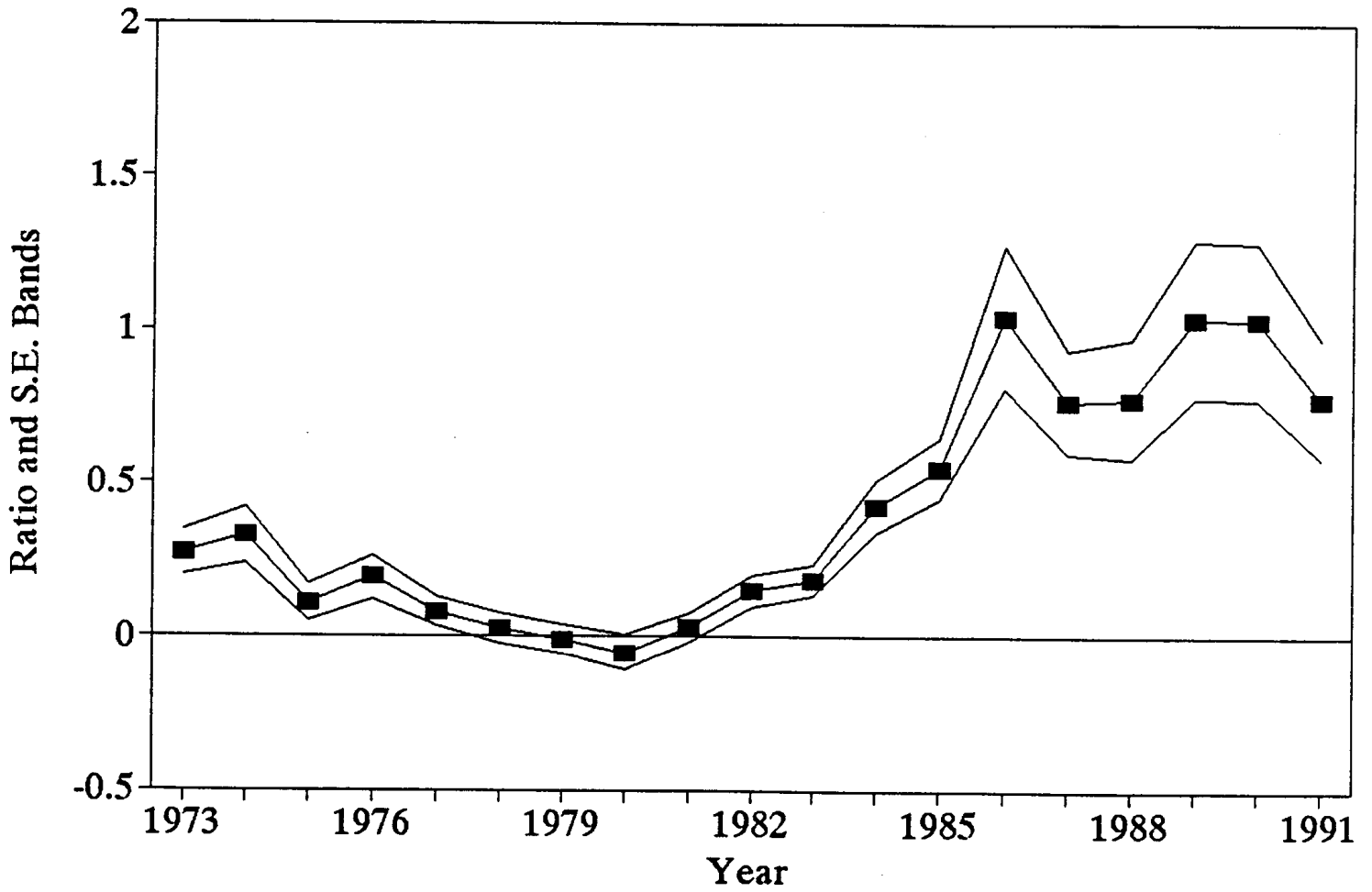


—■— R&D Flow Coeff. —□— R&D Stock Coeff.

FIGURE 3

Ratio: Market Value of Adv. to R&D

U.S. Manufacturing Firms



As an illustration of this phenomenon, Table 3 shows all the regression coefficients for 4 individual years of interest: 1976, 1983, 1984, and 1990. This table shows that the steep declines in the valuation of R&D investment and the increase in the value of advertising is not associated specifically with movements in any of the other coefficients. The other major changes in Table 3 are first that the intercept (which is a measure of logarithm of the overall ratio of market to book value) has increased from about zero to 50 percent, and then fallen again to almost zero. Second, the premium on other assets increased during the period from about zero to around 50 percent. This change does not turn out to be correlated with the R&D and advertising effects (regressions not shown).

Figure 1 also shows that some of the high valuation of R&D spending during the seventies and early eighties was common across industry; this does not necessarily mean it is not associated with R&D, merely that all firms in any particular industry tend to have similar R&D profiles, so some of the effect can be interpreted as an industry effect. What is a bit surprising is that this too disappears in the late eighties: the R&D in high-technology industries like computers is worth exactly as much (or as little) as that in medium-technology industries such as autos.

TABLE 3
THE MARKET VALUE EQUATION
Selected Years
 Dependent Variable: Log V

Indep. Variable	1976	1983	1984	1990
Log A	.92(.01)	.83(.01)	.85(.01)	.93(.01)
CF/A	1.88(.14)	2.02(.13)	1.54(.14)	1.72(.18)
$\Delta \log S$	.34(.07)	.36(.07)	.34(.08)	.47(.11)
R/A	3.41(.31)	4.20(.27)	2.79(.21)	1.02(.31)
Adv/A	.24(.25)	.37(.20)	.86(.18)	.90(.21)
Inv/A	.07(.07)	.18(.09)	.04(.08)	-.12(.11)
Oth/A	.15(.10)	.42(.10)	.55(.10)	.53(.12)
Intercept	-.08(.06)	.70(.06)	.55(.10)	.21(.09)
No. obs.	1508	1237	1224	1082
R-squared	.945	.942	.950	.930
Std. err.	.394	.396	.378	.540

Standard errors are heteroskedastic-consistent estimates.
 See Table 1 and the text for a description of the variables.

Two reasons why this decline in R&D value might be spurious were investigated, with negative results: the first possibility 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. Figure 4 displays the same coefficients as Figure 2, calculated from regressions which do not include an intercept. Although the overall level of the coefficients is about 10-20 percent higher, there is no real change in the results.

The second possibility considered was that this was a sample selection phenomenon, since all of the regressions used an unbalanced panel of firms where exits and entries occurred each year; the composition of the panel was changing during the latter half of the eighties, in particular, as Compustat added substantially more OTC (Over-the-Counter) firms to the data files. To check whether the changes in valuation were due to sample changes, I constructed a balanced panel of firms from 1980 to 1990 (the period was chosen to cover the period of interest but to avoid losing too many firms at either end) and re-estimated the regressions of Figures 1 and 2. An example of the results, which were all similar, is shown in Figure 5. Although this balanced panel has at most half as many firms as the whole panel, the estimated coefficients are almost identical, and, if anything, they decline even more than those for the whole panel.

FIGURE 4

R&D Stock vs. Flow - U.S. Manufacturing Market Valuation - No Intercept

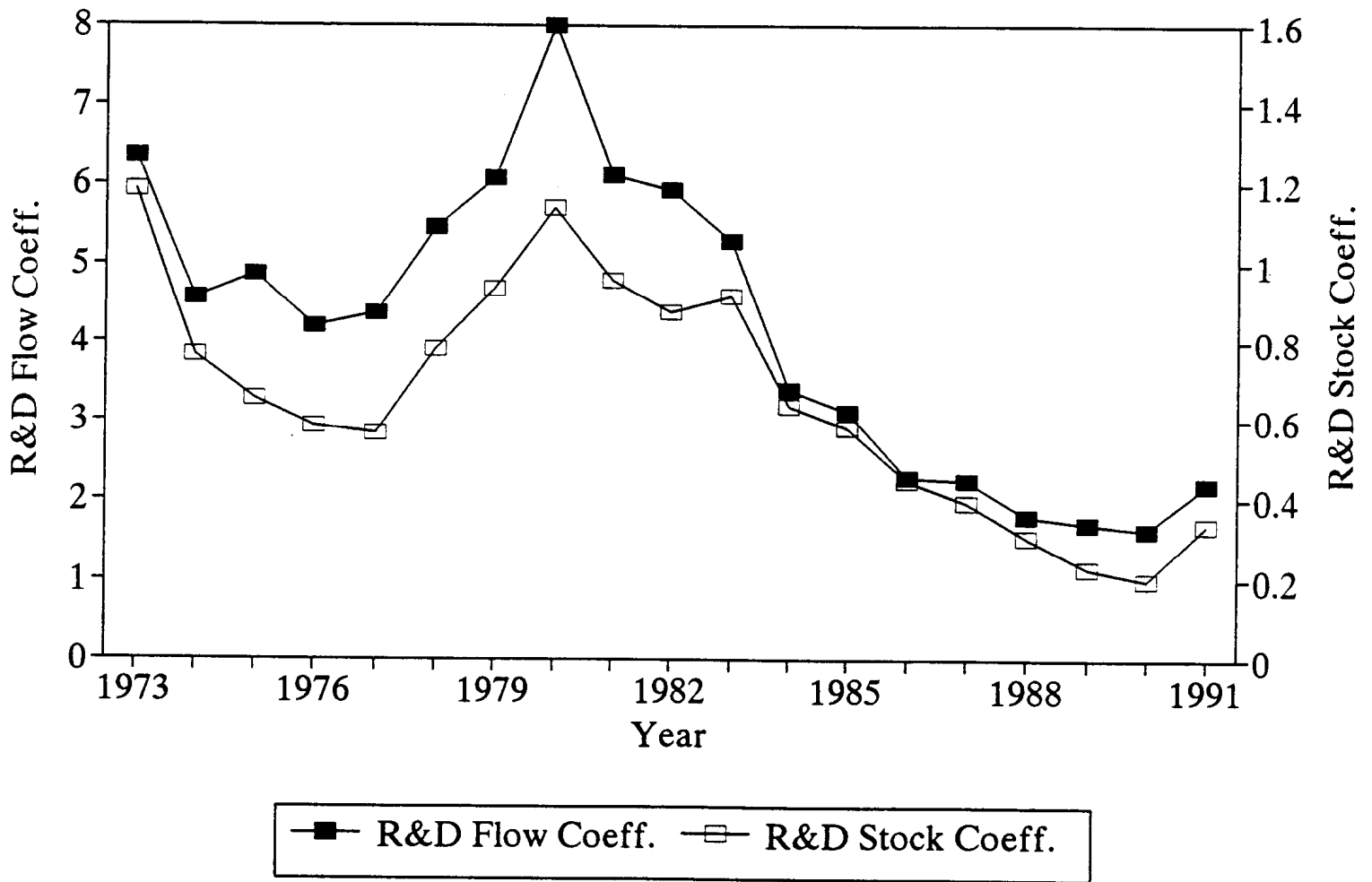
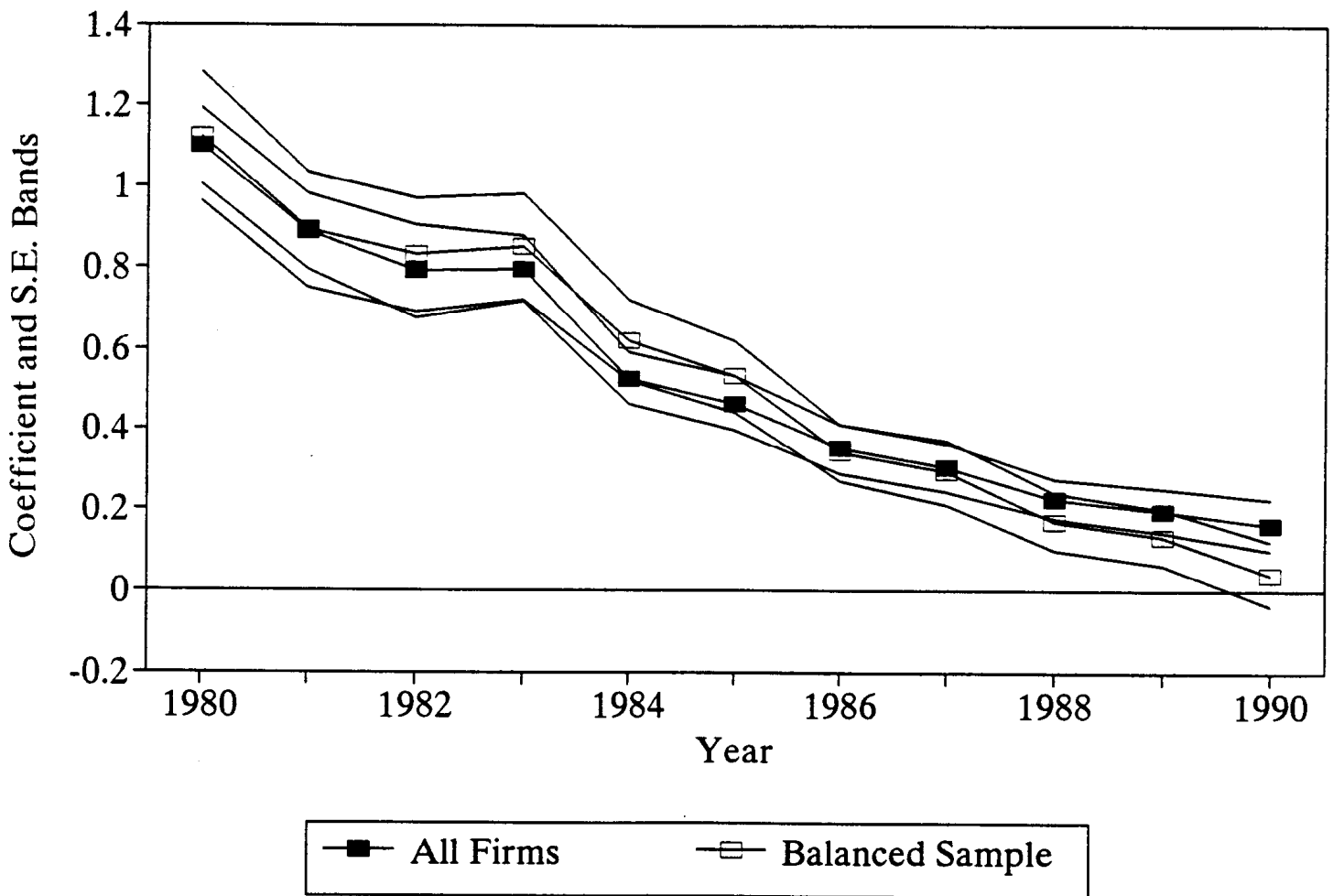


FIGURE 5

Market Valuation for the Stock of R&D U.S. Manufacturing Firms - Level Est.



5. 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 in 1979-1983 to a low of 0.2-0.3 in 1986-1991. For those of us who have 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 tell us about the private rate of return to R&D during the eighties? I offered several interpretations of this result in the introduction and I will discuss them more thoroughly here.

The first possibility is that the private rate of return to R&D has indeed fallen. If we assume that R&D capital depreciates at the same rate it always has (which may be an untenable assumption), then a coefficient of .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! More careful measurement of the actual rates of return experienced by these firms would help in testing this hypothesis. The effects of the changes in the corporate tax system on the valuation of capital needs to be investigated also, especially given the timing of the decline observed here and the Tax Reform Act of 1986.

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. But this seems implausibly high; it says that two-thirds of the capital becomes nonproductive in one year. Capital of this type would have to earn a very high return on the margin to cover the depreciation rate plus the rate of interest.

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 .95, the implied discount for R&D capital is .19 (that is, an interest rate of .81!). This is really the same as the second possibility, since 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 nineteen-eighties. Since 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 towards 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, since the buyout wave really began in about 1984, and the real changes in valuation happen more in 1986-1987, but the idea seems worth exploring further using a more detailed industry-level examination. I plan to pursue this in future work.

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