Firm size and the effect of R&D on Tobin's q

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Significant market value effects of research and development (R&D) are generally apparent, but aggregate evidence has the potential to obscure meaningful differences according to firm size. Consistent with findings reported by Chauvin and Hirschey (1993) for the late 1980s, valuation effects of R&D remain somewhat greater for larger as opposed to smaller firms.

1. Introduction

An enduring theme in the literature on innovative activity is the role of firm size. Since at least Schumpeter's work, the role of firm size in creating knowledge has been recognized. While Schumpeter thought that big firms were likely to be the most important source of innovation, the US experience over the past decade suggests an unusually strong role for smaller firms. The tech boom of the 1990s, the rise of biotechnology, and the changing nature of drug discovery establish clearly that small size may not be a barrier to realizing the market value of innovation (see Hirschey (2003) for a full-length treatment of some of these issues).

Firm size has attracted the attention of researchers in other areas of research, too. In financial economics, the inability of ever-more sophisticated models to explain the unusually high returns to small firm stocks remains an enduring puzzle. Valuing small firms has proven to be a very difficult task. Firm size plays a role in other areas, too. For example, Moeller, Schlingemann, and Stulz (2005) demonstrate that acquisitions by small firms are profitable for their shareholders, but the pattern is reversed for large firms.

Our basic purpose in this paper is to present evidence on the valuation consequences of research and development (R&D) investments by firms of different sizes, controlling for a variety of other factors than can affect company value. The empirical approach we take is not particularly new. Starting with Lindenberg and Ross (1981), a research tradition has grown up in financial economics that uses stock market data as captured by Tobin's q ratio to explore the economic sources of future cash flows, the building blocks of company value. This is not the only measure of firm value, but it has been used extensively in empirical finance and economics research and its attractive properties are well-known among researchers. Our reliance on Tobin's q in this paper also serves to connect the results reported here with the larger literature.

Hirschey (1985) was among the first of a long string of research papers investigating the cross-sectional influences of R&D. In this work, R&D is typically regarded as an indication of 'intangible capital' that gives rise to sustained future cash flows and therefore raises the market value of the firm. In a recent study, Chan et al. (2001) argue that companies with a high ratio of R&D expenditures relative to the market value of equity earn large excess returns.

This purpose of this study is to document the size-related valuation consequences of R&D in a broad sample of US manufacturing and nonmanufacturing companies. To isolate potential differences in the effectiveness of R&D across firm size classes, we control for a number of other determinants of company value. In the next section, we describe the sample and the model we use to evaluate the value consequences of R&D investments. We discuss the results of our empirical investigation in Section 3, and a final section concludes the paper.

2. Data and Methodology

This study focuses on pooled cross-section samples of *Compustat* firms covering the 5-year period from 1997 to 2001. The *Compustat* database, produced by Standard and Poor's, provides a wide range of financial statement-related data on 54,000 publicly traded companies in 80 countries. Its comprehensive nature makes it particularly ideal for research on differences in spending and valuation among publicly traded firms. We identify explicitly the *Compustat* data items used in our work.

Our sample has 15,709 firm-year observations, an average of roughly 3,100 firms per year. The overall sample is comprised of 9,480 (60.3%) nonmanufacturing firm-year observations (SIC <20 or SIC ≥ 40), and 6,229 (39.7%) manufacturing firm-year observations ($20 \geq$ SIC <40). Table 1 presents summary information about aspects of the sample used in our work.

R&D intensity tends to be relatively high in manufacturing industries. Across the manufacturing sector, R&D intensity averages 2.26%, which is nearly 10 times the average 0.29% R&D intensity for nonmanufacturing firms. This may reflect different opportunities for inventive activity across the two broad sectors, but just as readily these differences may stem from financial constraints, growth opportunities, managerial skill sets, and other factors. Regardless of the underlying causes, the sectoral pattern in R&D intensity raises the question as to valuation differences for R&D investments by nonmanufacturing vs. manufacturing firms.

Following Chung and Pruitt (1994), we use a simple approximation to the theoretical Tobin's q measure. In this approach, q is measured by the sum of the market value of common (shares outstanding (annual data item #25) times price (#24)) plus the book value of total assets (#6) minus common equity (#60), all divided by the book value of total assets (#6).

The focus of this study is on the role played by R&D as an influential source of intangible capital and a significant determinant of the market value of the firm as measured by Tobin's q. To isolate such influences, the effects of other factors with predictable influences on the current market value of the firm must be constrained. We include current profitability, growth, risk, and advertising intensity. Profitability is measured by the firm's net profit margin, or net income (#172) divided by sales (#12). It is reasonable to expect a positive valuation effects of net profit margins because historical profit margins are often the best available indicator of a firm's ability to generate superior rates of return during future periods. As documented by Hirschey (1985), valuation effects of realized rates of return include both the influences of superior efficiency and/or market power. Because effective R&D investments can be expected to enhance both current and future profitability, the *marginal* effect of R&D intensity on Tobin's q becomes a very conservative estimate of the total short-term plus long-term value of R&D investments when such impacts are considered in conjunction with the valuation effects of current net profit margins. That is, current R&D spending will affect current and future profits (thereby raising Tobin's q), and some of the current profit effect may be obscured by including current profits.

Sales growth is another factor that should affect Tobin's q. Growth is measured by the least-squares estimate of the 3-year compound annual rate of growth in sales for each firm (#12). In their seminal analysis, Miller and Modigliani (1961) argued that growth has a positive effect on market values if future investments are expected to earn above-normal rates of return, and if growth is an important determinant of these returns.

While growth affects the magnitude of anticipated excess returns, highly volatile growth may add less to value than stable sales growth. With an increase in risk, the market value of expected returns is anticipated to fall. Valuation influences of risk are estimated here using financial leverage measured by total assets (#6) minus common equity (#60), all divided by total assets (#6).

Above-normal rates of return are regularly associated with product differentiation efforts by firms. Accordingly, we follow Chauvin and Hirschey (1993) and measure the valuation consequences of R&D while simultaneously control-

Table 1. Summary statistics for sample

2-digit SIC	Industry	Annual average				
		Number of firms	Industry sales	Industry R&D	R&D per firm	R&D/sales (%)
Panel A: nonmanufacturing industries						
01	Agriculture Production-Crops	8.0	10,376	109.5	13.7	1.06
07	Agricultural Services	2.6	5,125	1.3	0.5	0.02
10	Metal Mining	28.6	42,119	327.1	11.4	0.78
12	Coal Mining	2.4	2,701	1.2	0.5	0.04
13	Oil and Gas Extraction	101.4	100,568	922.3	9.1	0.92
14	Mng, Quarry Nonmtl Minerals	7.2	10,993	25.3	3.5	0.23
15	Bldg Cnstr-Gen Contr, Op Bldr	20.2	34,399	0.0	0.0	0.00
16	Heavy Constr-Not Bldg Constr	12.2	24,368	13.1	1.1	0.05
17	Construction-Special Trade	5.8	3,726	1.6	0.3	0.04
40	Railroad Transportation	11.6	47,529	0.0	0.0	0.00
41	Transit and Passenger Trans	2.2	2,611	0.0	0.0	0.00
42	Motor Freight Trans, Warehse	19.0	34,959	0.0	0.0	0.00
44	Water Transportation	15.8	12,942	0.0	0.0	0.00
45	Transportation By Air	28.6	136,954	0.0	0.0	0.00
46	Pipe Lines, Ex Natural Gas	2.2	762	0.0	0.0	0.00
47	Transportation Services	11.0	13,969	0.7	0.1	0.01
48	Communications	123.6	673,786	5,779.3	46.8	0.86
49	Electric, Gas, Sanitary Serv	156.2	528,186	19.2	0.1	0.00
50	Durable Goods-Wholesale	57.8	99,932	104.4	1.8	0.10
51	Nondurable Goods-Wholesale	36.6	213,135	213.8	5.8	0.10
52	Bldg Matl, Hardwr, Gardn-Retl	6.2	53,072	28.7	4.6	0.05
53	General Merchandise Stores	22.2	334,491	0.0	0.0	0.00
54	Food Stores	22.8	226,888	0.4	0.0	0.00
55	Auto Dealers, Gas Stations	9.8	20,468	0.0	0.0	0.00
56	Apparel and Accessory Stores	35.0	65,506	0.0	0.0	0.00
57	Home Furniture, Equip Store	16.4	43,196	0.0	0.0	0.00
58	Eating and Drinking Places	30.6	38,063	5.6	0.2	0.01
59	Miscellaneous Retail	58.0	126,539	40.9	0.7	0.03
60	Depository Institutions	348.4	720,424	0.0	0.0	0.00
61	Nondepository Credit Instn	33.4	105,182	0.0	0.0	0.00
62	Security/Commodity Brokers	41.2	173,584	63.3	1.5	0.04
63	Insurance Carriers	134.2	590,920	0.0	0.0	0.00
64	Ins Agents, Brokers and Service	16.0	27,446	27.7	1.7	0.10
65	Real Estate	22.2	9,570	0.0	0.0	0.00
67	Holding, Other Invest Offices	142.2	43,716	63.6	0.4	0.15
70	Hotels, Other Lodging Places	13.6	28,624	0.0	0.0	0.00
72	Personal Services	10.4	10,325	10.5	1.0	0.10
73	Business Services	340.6	383,899	25,549.8	75.0	6.66
75	Auto Repair, Services, Parking	6.8	14,607	0.0	0.0	0.00
78	Motion Pictures	12.8	41,736	102.7	8.0	0.25
79	Amusement, Recreation Svcs	27.4	21,225	14.4	0.5	0.07
80	Health Services	43.4	68,240	61.5	1.4	0.09
82	Educational Services	11.4	3,074	0.6	0.1	0.02
83	Social Services	7.0	1,634	0.0	0.0	0.00
87	Engr, Acc, Resh, Mgmt, Rel Svcs	45.4	20,404	286.3	6.3	1.40
Nonmanufacturing industry sample averages		46.9	114933	750.6	4.4	0.29
Panel B: Manufacturing industries						
20	Food and Kindred Products	81.0	455,240	2,334.1	28.8	0.51
21	Tobacco Products	6.4	101,295	661.1	103.3	0.65
22	Textile Mill Products	15.0	17,275	55.7	3.7	0.32
23	Apparel and Other Finished Pds	27.8	37,764	29.3	1.1	0.08
24	Lumber and Wood Pds, Ex Furn	20.6	35,836	72.1	3.5	0.20
25	Furniture and Fixtures	21.0	46,339	687.2	32.7	1.48
26	Paper and Allied Products	45.4	164,414	1,828.8	40.3	1.11
27	Printing, Publishing and Allied	49.4	74,396	116.2	2.4	0.16
28	Chemicals and Allied Products	213.6	607,436	53,386.2	249.9	8.79
29	Petr Refining and Related Inds	29.0	784,147	3,258.8	112.4	0.42
30	Rubber and Misc Plastics Prods	28.8	51,978	840.4	29.2	1.62

Table 1. (Contd.)

2-digit SIC	Industry	Annual average				
		Number of firms	Industry sales	Industry R&D	R&D per firm	R&D/sales (%)
31	Leather and Leather Products	8.2	5,646	2.7	0.3	0.05
32	Stone, Clay, Glass, Concrete Pd	25.2	35,680	151.1	6.0	0.42
33	Primary Metal Industries	58.8	135,783	1,586.2	27.0	1.17
34	Fabr Metal, Ex Mach, Trans Eq	41.8	58,700	632.0	15.1	1.08
35	Indl,Comml Mach,Computer Eq	196.8	553,775	32,496.8	165.1	5.87
36	Electr, Oth Elec Eq, Ex Cmp	237.4	554,739	42,731.1	180.0	7.70
37	Transportation Equipment	73.8	1,029,680	36,415.0	493.4	3.54
38	Meas Instr; Photo Gds; Watches	149.2	143,662	9,963.0	66.8	6.94
39	Misc Manufacturng Industries	21.2	19,308	602.7	28.4	3.12
Manufacturing industry sample averages		67.5	245655	9392.5	79.5	2.26
Full sample averages		53.2	155155	3409.6	27.5	0.90

ling for the valuation influences related to advertising expenditures (#45). Because it is relatively rare to find firms and industries that employ both methods in tandem, there is little reason to fear a commingling of such influences. In all cases, both R&D and advertising are normalized by sales (#12) to eliminate size-related influences.

Finally, there are undoubtedly other, industry-related factors that affect valuation of firms. We control for these industry factors with a set of two-digit SIC industry dummy variables.

3. Effects of R&D on Tobin's *q*

3.1. Manufacturing vs. nonmanufacturing

After allowing for potentially important simultaneous influences, Connolly and Hirschey (1990) find no significant endogenous influences among relations describing market value and other important elements of market structure. Therefore, we estimate the effects of net profit margin, growth, risk, advertising, and R&D on Tobins's q through straightforward application of ordinary least squares (OLS). We discuss first the results for the model estimated across size classes using the manufacturing vs. nonmanufacturing sample split and then consider how the model estimates are affected by partitioning the sample further according to firm size.

In Table 2, we report estimates of the marginal impact of R&D spending on market value. We find a persistently positive and statistically significant influence of R&D intensity on the market value of the firm across both the manufacturing and nonmanufacturing sectors. Using an F-test, we note a statistically significant difference in the valuation model fit across the manufacturing and nonmanufacturing sectors ($F = 3.29$).

Across all 15,709 *Compustat* firm-year observations, we find positive and statistically significant effects on Tobin's q from profit margins, growth, advertising intensity and R&D intensity. The predicted negative influence of risk on valuation is also evident in the estimates. Recall that in the case of R&D intensity, both short- and long-run profitability effects are undoubtedly present. This means that at least some of the effects of R&D intensity on Tobin's q are reflected in the statistically significant positive estimate for profit margins. The statistically significant and positive coefficient estimates for the R&D intensity variable are better regarded as a lower bound on the marginal economic impact of R&D on the market value of the firm.

Despite some obvious differences in explanatory power between the manufacturing and nonmanufacturing sectors, it is clear from Table 2 that this very simple model describes a meaningful share of the firm-by-firm variation in Tobin's q. In the manufacturing sector, roughly one-quarter of the variation in Tobin's q can be attributed to variation in profit margins, growth, risk, advertising intensity, and R&D intensity. In the nonmanufacturing sector, roughly one-third of the variation in market values can be similarly attributed. Given the relative consistency of valuation effects because of advertising and R&D in the manufacturing and nonmanufacturing sectors, it appears safe to argue that both types of expenditures give rise to valuable intangible capital.

While both advertising and R&D generally appear to constitute alternative forms of profitable investment intangible assets, the estimate

Table 2. Firm size and the effects of R&D on Tobin's q, 1997–2001

Firm size class	Intercept	Profit margin	Growth	Risk	Adv./sales	R&D/sales	R^2 (%)	F	Sample size
Panel A: Compustat firms from the manufacturing sector ($20 \leq SIC < 40$)									
Smallest third	2.288	−0.460	0.788	−1.418	1.581	0.074	25.1	25.1	2,120
	(8.20)[1]	(−5.04)[1]	(8.69)[1]	(−8.36)[1]	(1.02)	(0.58)			
Central third	2.899	0.378	1.061	−2.539	0.797	1.132	27.9	27.1	1,993
	(8.44)[1]	(1.99)[2]	(8.49)[2]	(−12.3)[1]	(0.42)	(5.32)[1]			
Largest third	2.924	3.210	2.072	−3.366	7.332	4.212	37.8	45.2	2,116
	(6.10)[1]	(10.32)[1]	(10.66)[1]	(−12.2)[1]	(4.31)[1]	(11.88)[1]			
All manufacturing firms	2.525	0.526	1.175	−2.071	5.608	1.147	22.8	65.4	6,229
	(11.46)[1]	(5.72)[1]	(15.06)[1]	(16.30)[1]	(5.43)[1]	(9.64)[1]			
Panel B: Compustat firms from the nonmanufacturing sectors ($SIC < 20$, or $SIC \geq 40$)									
Smallest third	2.283	0.037	0.127	−1.235	1.450	0.930	25.8	18.3	3,118
	(18.48)[1]	(0.89)	(2.61)[1]	(−10.1)[1]	(1.37)[1]	(5.30)[1]			
Central third	3.421	0.252	0.135	−2.572	1.068	2.155	41.8	39.5	3,243
	(23.96)[1]	(2.87)[1]	(2.55)[1]	(−19.3)[1]	(0.86)	(9.61)[1]			
Largest third	3.601	0.499	0.621	−2.931	−0.808	3.810	45.1	43.4	3,119
	(18.99)[1]	(7.32)[1]	(8.03)[1]	(−16.1)[1]	(−0.40)	(8.27)[1]			
All nonmanufacturing firms	2.878	0.320	0.295	−2.032	0.960	1.720	32.6	78.6	9,480
	(31.52)[1]	(8.93)[1]	(8.20)[1]	(−23.2)[1]	(1.15)	(11.54)[1]			
Panel C: All compustat firms									
Smallest third	2.250	−0.094	0.353	−1.284	1.394	0.545	26.1	23.4	5,238
	(20.57)[1]	(−2.31)[2]	(7.64)[1]	(−12.7)[1]	(1.53)[3]	(7.14)[1]			
Central third	3.385	0.332	0.403	−2.617	1.183	1.246	34.6	34.9	5,236
	(24.92)[1]	(3.79)[1]	(7.39)[1]	(−22.5)[1]	(1.09)	(10.97)[1]			
Largest third	4.003	0.825	1.037	−3.608	5.001	2.583	40.5	45.1	5,235
	(22.88)[1]	(10.80)[1]	(13.00)[1]	(−23.2)[1]	(4.00)[1]	(13.21)[1]			
All nonmfg. firms	2.837	0.381	0.564	−2.007	3.553	1.123	27.8	78.5	15,709
	(34.13)[1]	(10.28)[1]	(15.76)[1]	(−28.6)[1]	(5.44)[1]	(17.52)[1]			

Note: We estimated, but do not report, coefficients on industry and annual dummy (binary) variables.[1]Statistical significance at the 0.01 level (one-tail test).[2]Statistical significance at the 0.05 level (one-tail test).[3]Statistical significance at the 0.10 level (one-tail test).

suggest the valuation effects of R&D are more consistent and uniformly positive than for advertising. In the nonmanufacturing sector, the weakly positive effect of advertising intensity on Tobin's q is not statistically significant by conventional criteria. In terms of consistency and statistical significance, R&D appears to be more important than advertising as a positive long-term influence on Tobin's q. In contrast with some popular assumptions that stock-market investors are myopic in their focus on short-run performance, these findings are also consistent with investors applying a long-term perspective to evaluate the advertising and R&D efforts of firms.

Across all 6,229 manufacturing firm-year observations, and among 9,480 nonmanufacturing firm-year observations, positive and statistically significant effects on Tobin's q are noted for profit margins, growth, advertising intensity and R&D intensity. Risk continues to have a negative impact on firm value. R&D clearly emerges as an important determining factor for Tobin's q in the overall sample, and among both manufacturing and nonmanufacturing firms. As such, the empirical results reported in Table 2 offer strong evidence in support of the hypothesis that R&D is an important source of intangible assets with predictably positive effects on future cash flows.

3.2. Firm size effects

To the extent that economies of scale or other size advantages in R&D are present, the market value effect of a dollar in R&D expenditures will be greater for larger as opposed to smaller firms. Conversely, to the extent that diseconomies of scale or other size disadvantages in R&D are present, the market value effect of a dollar of R&D expenditures may be smaller for relatively larger firms.

Table 2 illustrates the influence of firm size on the market-value effects of R&D intensity using a simple three-part breakdown of each sample according to stock market capitalization. Cut-off points for each size class are calculated on an annual basis. Small firm size cut-off points are \$330.3 million (1997), \$334.9 million (1998), \$343.4 million (1999), \$400.0 million (2000), and \$399.9 million (2001). Large firm size cut-off points are \$1,236.8 million (1997), \$1,270.8 million (1998), \$1,370.8 million (1999), \$1,767.0 million (2000), and \$1,613.2 million (2001). By definition, the medium firm size class falls between these size cut-off points during each period.

From Table 2, it is clear that the valuation effects of various fundamental determinants of Tobin's q vary according to firm size class. Profit margin is important within each sample of manufacturing and nonmanufacturing firms, and for the overall sample, but its positive impact on Tobin's q is most consistently important for relatively large firms. While growth has a uniformly positive market-value influence on small, medium and large firms within each sample, this positive influence appears to increase with firm size. In the case of advertising, almost all of the significant positive impact on Tobin's q appears to originate among large manufacturers. Little, if any, positive effect of advertising on Tobin's q is detected among small to medium-size manufacturers, and among nonmanufacturers.

Of primary interest to this study is the relative impact of R&D on Tobin's q across firm size classes. After controlling for other important valuation effects, evidence reported in Table 2 suggests that the market-value influence of R&D intensity does indeed depend upon firm size. For the 1997–2001 time period of our sample, the effect of R&D intensity on market value appears positively related to firm size. In the manufacturing sector, using a t-test of the difference in coefficient estimates, the marginally larger impact of R&D on Tobin's q for medium-size firms over small firms is statistically significant ($t = 4.26$), and the same relationship holds for large firms relative to medium-sized firms ($t = 7.45$). Similarly, in the nonmanufacturing sector, the superior value effects of R&D in medium-size firms over small firm is statistically significant ($t = 4.30$), and the same relationship holds for large firms relative to medium-sized firms ($t = 3.23$). These strong findings testify to the importance that size advantages in determining the valuation effects of R&D investments. Especially when the R&D-intensive manufacturing sector is considered, large firm advantages in R&D are unmistakable.

4. Conclusions

Much of the original work relating R&D with firm size was based on data samples that predate some of the changes in many R&D-intensive industries during the 1990s. Most of this work also focuses on the manufacturing sector. In this paper, we report estimates of the marginal impact of R&D spending on firm value using data for the 1997–2001 period. Further, we partition our sample along the lines of firm size and for the manufacturing vs. nonmanufacturing sectors. (We also include industry dummy variables to capture fixed effects that vary by two-digit SIC industry.)

The findings reported here suggest important differences in the *effectiveness* of R&D expenditures according to firm size. A dollar's worth of R&D spending adds significantly more to Tobin's q for large firms than smaller firms. This result holds for both manufacturing and nonmanufacturing firms. When comparing across the two broad sectors, the market value effect of a dollar in R&D spending tends to be greater for manufacturing firms than nonmanufacturing companies.

The interesting, ongoing research question revolves around the exact sources of these differential valuation effects. Large firms may enjoy scale economies in production and/or marketing of R&D-intensive goods, geographic scope, or have superior financial resources at their disposal compared with small firms. Given the difficulty of identifying measures of these potentially relevant phenomena, we expect that this question may persist for some time.

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