Returns to Research and Development?*

William F. Lincoln
Claremont McKenna College

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Abstract

In this study, we consider how financial markets value research and development expenditures. Taking a sample of publicly traded firms over 1998-2015, we find a positive and statistically significant relationship between R&D expenditures and Tobin's Q, consistent with much of the prior literature. When we control for firm and year fixed effects, however, we find statistically insignificant or in some specifications negative effects.

JEL Classification: G12, G18, L25, O31
Keywords: research and development, R&D, innovation, finance, asset pricing.

*Robert Day School, Claremont McKenna College, 500 East Ninth Street, Claremont, CA 91711, Email: wlincoln@cmc.edu. We would like to thank George Batta, Cameron Shelton, and Josh Rosett for helpful comments and suggestions. Wesley Dale and Michali Bahar provided superb research assistance. Any errors are entirely my own.

1 Introduction

We have known at least since the work of Solow (1956) that technological change and research and development (R&D) in particular is crucial for economic growth. Indeed, many of the governments of industrialized nations have policies that subsidize R&D in one way or another. At the same time, how markets would react to firms engaging in research and development is a priori unclear. On the one hand, research and development is quite risky and it therefore may reduce investors' demand for the firms' stock. At the same time, however, R&D is intended to increase the profits of the firm in the long run and has the potential to have large positive impacts on future earnings. In this paper we try to better understand this relationship.

Much of the published studies to date have found positive and statistically significant effects of doing R&D on firm value. Unlike a number of other questions in the finance and economic growth literatures, work on this topic has spanned a number of different countries and financial markets, regulatory regimes, and policy regimes. In this paper we begin by documenting a number of facts about firms that do research and development. One lesson that comes out of this is that firms that do R&D are systematically different than other firms. While having larger sales, profitability, market capitalization, and Tobin's Q, they also have smaller work forces and lower levels of assets. These facts suggest at the least that unobservable differences between firms need to be accounted for when studying this relationship.

We next turn to a set of simple ordinary least squares (OLS) estimations. Consistent with the descriptive statistics, we find results similar to the prior literature in that there is a positive and statistically significant relationship between doing R&D and Tobin's Q. This is true without any controls as well as when using several different control variables that have been suggested in the prior literature. The relationship is also found in each of the main industries in our sample. At the same time, however, we know from descriptive statistics in prior work that firms that do R&D are fundamentally different across a number of dimensions. This raises the possibility that, even while including a variety of covariates, these controls are not sufficient to uncover the true relationship. The estimates in particular may be a function of unobserved firm characteristics that are unrelated to the relationship between R&D and market value.

As an alternate approach, we consider a set of fixed effects estimations in which we are able to control for both firm and year fixed effects. These estimations deliver strikingly different results. In particular, this different estimation approach finds either a negative relationship or fails to find any sort of relationship between performing R&D and firm value. When we look across industries, only two demonstrate a statistically significant relationship and the estimates for these sectors are relatively small and negative.

These results have significant implications. First, they suggest that prior estimates may have been biased by omitted variable bias stemming from a failure to account for permanent unobservable differences across firms. They have further significance for R&D policy, an understanding of how capital markets work, and the relationship between finance and economic growth. Lastly, they have real world implications for individuals who are trying to think about how to best invest their resources.

In the next section we consider prior literature on this relationship and what has been found using different approaches. We then consider a set of simple descriptive statistics in Section 3 to give context to our subsequent econometric estimations. In Section 4 we present our ordinarily squares estimations. Section 5 considers the fixed effects estimations and Section 6 concludes.

2 Literature Review

In this section we review a few of the studies that are most closely related to our own. In pioneering work, Griliches (1981) was one of the first to study this question. He found that past R&D expenditures and the number of patents positively affect a firm's market value. In a recent study, Kanwar and Hall (2017) use a sample of 380 Indian manufacturing firms to study the relationship between market value and innovation in the context of manufacturing firms in a developing country. They find that markets value the R&D investment of Indian firms the same as or more than they do in developed economies like the U.S. and Europe, which potentially suggests a level of investment in developing countries that is not optimal. They further find that this relationship does not vary significantly across industry groups. The authors found these results surprising in that they expected that R&D would not be valued as highly in developing countries, since the human capital to do R&D is concentrated in a small number of developed countries. Hall, Jaffe, and Trajtenberg (2005) find that ratios of R&D to assets stocks, patents to R&D, and citations to patents all have positive effects on a firm's market value. Hall and Vopel (1996) show that the effect of doing R&D on market value is larger for firms with a greater market share.

Tsai (2006) finds that in the US both patent number and patent citation indicators are positively related with firm values, suggesting that the value creations depend on technological improvements not only in quantities, but also in qualities. Chen and Shih (2011) investigate the relationship between patent citations and Tobin's Q in the US pharmaceutical industry, finding a single threshold effect. An increase in the number of patent citations increases Tobin's Q.

Turning to the international context, Kim, Kim, and Lee (2011) similarly find a positive impact of innovation on firm values in a sample of Korean firms. They extend this further to find that innovation affects leverage, further impacting firm value. In a different context, Hokkanen (2006) finds a positive effect of R&D in Finnish firms on growth and profitability, but fails to find any effects on stock returns. Lau (2003) investigates the effect of R&D on the market value of firms using UK and Japanese panel data. It shows a positive and significant role of R&D in influencing the market value of the firm. Razaq, Freihat, and Kanakriyah (2017) come to similar qualitative conclusions in a small sample of Jordanian firms.

Taking an even broader view, Gupta, Banerjee, and Onur (2017) use a new comprehensive database covering 2004-2013 spanning 75 countries and find positive effects of R&D expenditures on firm value. Similarly taking a broader view across countries, Hall and Oriani (2006) find positive effects of doing R&D in three separate samples of firms in France, Germany, and Italy. The results for Italy are sensitive to controlling for the ownership structure of the firm, with firms with a large shareholder showing less responsiveness to R&D expenditures.

In "The stock market valuation of research and development expenditures," Chan, Lakonishok, and Sougiannis (2001) argue that the market value of a company's stock depends on its total assets but intangible assets are harder to assess than tangible assets. They use data from 1995 to see if there is a correlation between R&D intensity and future stock returns. They then check if the results are robust, extend the analysis to advertising expenditures, and examine whether stock volatility relates to R&D. Overall, the paper finds that there is no difference in the average return on stocks among companies that do and do not engage in R&D. It also finds that the market gives lack of credit to firms that failed in the past and continue to be R&D-intensive. Such firms could have managers that are confident enough to not fold into pressure to cut R&D and improve earnings. Similar patterns hold for advertising expenditures. But R&D intensity still matters because there is evidence that R&D intensity and return volatility are correlated. Thus, more thorough R&D accounting statements could be beneficial.

In "An examination of long-term abnormal stock returns and operating performance following R&D increases" Eberhart, Maxwell, and Siddique (2004) examine 8,090 cases where 3,099 different firms unexpectedly increased R&D by an economically significant amount over 1951 to 2001 using data from Compustat and the Center for Research in Security Prices (CRSP). Firms experience positive effects during the 5-year period following an unexpected and significant R&D increase. When looking at high-tech firms, low-tech firms, high-growth firms, and low-growth firms separately, the paper finds that while the market is sluggish in recognizing the comprehensive advantage of increased R&D for all firms, it is particularly slow for high-tech firms. This study differs from those examining firm attributes and ensuing abnormal returns because increasing R&D is a managerial decision. Also, unlike stock repurchases, an R&D increase is rarely announced.

Gu (2016) instead uses the real options model developed by Berk, Green, and Naik (2004) for a multistage R&D venture to propose two testable hypotheses: (i) the relationship between R&D and stock returns is larger in competitive industries and (ii) the relationship between competition and returns is larger amongst firms that intensively do R&D. First, using a conventional double-sorting approach shows that the competition and R&D-return relationship are positively correlated. The positive R&D-return relationship is only present in competitive industries, not in concentrated industries. This finding is confirmed by three asset pricing models – Carhart (1997) four-factor model, Hou, Xue, and Zhang (2015) q-factor model, Fama and French (2015) five-factor model – as well as NYSE breakpoints and all-but-micro breakpoints. Second, a positive competition-return relationship is only present for R&D intensive firms. Again, the finding is robust for all three asset pricing models, NYSE breakpoints, and all-but-micro breakpoints. In industries with high competition, firms continuously engage in innovation races. Tests of alternative mechanisms show that financial constraints or innovation ability do not explain the role of competition.

In "The Market Value of Patents and R&D: Evidence From European Firms," Hall, Thoma, and Torrisi (2007) argue that a firm's value of Tobin's Q is positively and significantly related to R&D and patent stocks for European firms. The sample analyzed in the paper is consisted of 1779 observations based on 368 firms headquartered in France, Germany, Great Britain, Switzerland, and Sweden from 1985-2000. Results show that there is a positive effect on firm value of European Patent Office patents on top of the effects of doing R&D. But analysis in the market value of patents specifically in the software field show that software-related patents don't impact firm market value. Perhaps the market is aware that software patents are utilized for strategic reasons, not to indicate real innovation. It could also indicate that the financial market takes note of the fact that it is hard to enforce software patents due to legal ambiguity.

Unlike capital expenditures, R&D investment is often inflexible and determined by regulations and science. If a firm lacks funds and suspends a project, it is more likely that competitor(s) complete an R&D project first. Hence, financial constraints have a large impact on R&D-intensive firms. Therefore, in "Financial Constraints, R&D Investment, and Stock Returns," Li (2011) extends the R&D venture model of Berk, Green, and Naik (2004) to account for financial constraints as the original model does not take this into account. Two predictions are made by the model: (i) the relationship between financial constraints and returns gets stronger as the firm does more R&D and (ii) the relationship between R&D and returns gets stronger as firms face larger financial constraints. These are tested through the Fama-MacBeth (1973) regressions and portfolio stocks. An alternative test is also done using a double sorting approach based on R&D and financial constraint status. Both tests conclude that (i) compared to low R&D firms, the constraints-return relationship is stronger and positive for high R&D firms and (ii) only in financially constrained firms is a positive relationship between R&D and stock returns found. They also find evidence that the positive R&D-return relationship is brought about by increased risks caused by financial constraints.

In "How do country-level governance characteristics impact the relationship between R&D and firm value," Pindado, de Queiroz, and de la Torre (2015) use panel data methods with a sample of 6,170 firm-year observations on 1,199 different non-financial companies located throughout the United States, Japan, and 10 countries from the European Union. There are three main findings. First, there is a positive relationship between investor protection and the market valuation of R&D projects. Second, more sophisticated financial systems are better at assessing R&D. Third, effective corporate governance strengthens the positive impact of R&D on firm value. The findings imply that policymakers can use the legal system, the financial system, and control mechanisms as tools to foster economic growth. This is particularly relevant when there is an economic crisis.

Prior literature argues that excess returns of R&D results from compensation for extra risk that comes with R&D or investors' mispricing. In "The effect of R&D on future returns and earnings forecasts," Donelson and Resutek (2012) develop a different explanation. The paper looks into a sample of firms with fiscal year-ends from January 1976 to December 2006 that appear on the CRSP/Compustat merged data base and have positive R&D expenditures in years t and t-1. Fama-MacBeth regressions and portfolio sorts are utilized throughout the paper to derive results. In the first part, the authors use the empirical design of Daniel and Titman (2006) and sort realized returns into the R&D component and non-R&D component. The results show that the level of and changes in R&D are unrelated to future returns. In the second part, the paper investigates the effect R&D investment has on future earnings. It finds that while R&D is positively associated with future earnings, the non-R&D component of the realized return variation describes a large amount of the variation in future returns.. It's the non-R&D component of realized returns, not actual R&D investment, that is associated with earnings forecast errors that lead to predictable returns in the future. Also, R&D's effect on current earnings does not affect the earnings forecasts of analysts/investors. Overall, R&D firms share characteristics similar to value/growth firms and these characteristics, not R&D itself, is what explains predictable patterns in future returns and forecast errors. Hence, return patterns of R&D firms seem to be part of the broader value/growth picture rather than being a unique pattern of its own. It is evident that investors already appreciate the significance of R&D-related information and capitalizing R&D investment will not improve capital market efficacy. This is important given the possibility of the U.S. switching to international financial reporting standards to capitalize R&D due to investor misunderstanding.

Turning to measurement issues, Hall (2006) critiques several papers in the prior literature. She argues that papers that have made simple assumptions about the depreciation of R&D have yielded biased results. She then discusses a number of issues in measuring the rate of depreciation and shows that differing methodologies do in fact lead to significantly different estimates.

One point to note is that our work is related to but fundamentally different from a separate literature that looks at the value of innovation, such as Pakes (1985) and Bloom and van Reenen (2002). Here we consider the impact of innovative inputs as opposed to innovative outputs such as patents. It's reasonable to think that a patent should raise firm value because it represents a successful effort to innovate. In our work, however, we are considering not the outputs but the inputs into the innovation process and how the uncertain process of engaging in R&D affects firm value.

3 Data and Stylized Facts

Our data comes from one main source: Compustat. This contains information on publicly traded firms in the United States and abroad. We restrict the data set to firms both headquartered and incorporated in the United States, to compare firms operating under the same regulatory regime and tax system. We drop firms with missing values for sales as they often are also missing information on a wide variety of other variables. We further drop observations with missing values for earnings, firm name, NAICS industry code, and each of the variables that are needed to measure Tobin's Q. To restrict the sample to actively operating firms and to measure Tobin's Q, we drop observations with zero or negative sales and those that report zero total assets. One important approximation that we make has to do with the measurement of R&D. Since firms have significant financial incentives to report R&D expenditures in order to qualify for the R&D tax credits, like much of the literature we assume that if a firm does not report R&D expenditures they did not engage in any, or at least did not engage in enough for us to classify them as a firm that does R&D in that year.

While there is a long literature on how to exactly measure Tobin's Q, more recent studies have noted that these measures are all very highly correlated. For our main measure of Tobin's Q, we follow Erickson and Whited (2012) but instead divide by total assets. Formally, we measure Tobin's Q as

$$TobinsQ = \frac{dltt + dlc + (prccf * csho) - act}{at}. \tag{1}$$

Here, dltt represents long term debts, dlc is debt in current liabilities, prccf is the fiscal annual closing price of the firm's shares, csho is common shares outstanding, act is current assets, and at is total assets. Using the second measure of Tobin's Q in Erickson and Whited (2012) loses many more observations but is very highly correlated with the original measure. Lastly, to decrease the influence of outliers and in accordance with much of the asset pricing literature, we winsorize our measure of Tobin's Q at the 5 percent level.

In Table 1 we consider a set of descriptive statistics for all firms, firms that engage in R&D, and firms that do not. While firms that do R&D have larger sales, market capitalization, profitability, earnings, and Tobin's Q, they have similar levels of employment, taxes, capital expenditures as well as significantly lower assets. The fact that they pay similar levels of federal taxes despite having larger sales may reflect their ability to take advantage of the R&D tax credit. More broadly, it is clear from the table that firms that engage in R&D are systematically different from firms that don't.

Table 1: Financial Performance By R&D Status

	All Firms	Non-R&D Firms	R&D Firms
Sales	2029	1868	2292
	(9493)	(7791)	(11745)
Employment	9	10	8
	(42)	(48)	(30)
Assets	5371	6756	3115
	(47723)	(58508)	(20066)
Federal Taxes	36	36	35
	(201)	(187)	(218)
Capital Expenditures	128	126	132
	(738)	(544)	(973)
Market Capitalization	2893	2411	3490
	(14423)	(9838)	(18573)
Profitability	0.07	-0.03	0.19
	(27)	(33)	(15)
Earnings	124	106	145
	(1086)	(827)	(1339)
Tobin's Q	2.75	2.11	3.53
	(3)	(3)	(4)

Notes: The table presents descriptive statistics for our sample over 1998-2015. Means are listed with standard deviations below denoted in parentheses.

In Table 2a and 2b we break out these figures across our five main industries. The two tables reveal significant heterogeneity across the different sectors. For example, profitability is larger for firms that do R&D for all industries with the exception of the largest and most important industry, manufacturing. Sales are also larger for R&D firms in only 3 out of the 5 sectors and the magnitudes of these differences vary significantly. In order to reduce the amount of figures, we simply present the means of each variable here.

Table 2a: Financial Performance By Industry

Agriculture, Mining, Construction			
Sales	1987	1708	7500
Employment	4	3	14
Capital to Labor Ratio	1.91	1.97	0.69
Sales to Employment Ratio	594	603	424
Earnings	99	81	458
Market Capitalization	2467	2157	8590
Profitability	-0.68	-0.73	0.22
Observations	5,400	5,140	260
Manufacturing			
Sales	2079	1294	2349
Employment	7	5	8
Capital to Labor Ratio	0.40	0.46	0.38
Sales to Employment Ratio	236	347	201
Earnings	145	72	169
Market Capitalization	3172	1534	3737
Profitability	0.20	0.48	0.10
Observations	21,636	5,547	16,089
Wholesale and Retail			
Sales	4585	4369	9454
Employment	26	27	9
Capital to Labor Ratio	0.31	0.32	0.24
Sales to Employment Ratio	414	409	511
Earnings	143	145	92
Market Capitalization	3197	3141	4465
Profitability	0.39	0.38	0.51
Observations	5,022	4,809	213

Notes: The table presents the average of several firm performance metrics across R&D and non-R&D firms across industries.

Table 2b: Financial Performance By Industry (Continued)

Information & Finance			
Sales	1445	1469	1343
Employment	6	7	6
Capital to Labor Ratio	7.03	8.75	0.37
Sales to Employment Ratio	620	730	195
Earnings	112	109	126
Market Capitalization	2828	2472	4347
Profitability	0.02	-0.07	0.38
Observations	18,818	15,241	3,577
Services			
Sales	1064	1093	788
Employment	19	18	29
Capital to Labor Ratio	0.37	0.39	0.25
Sales to Employment Ratio	211	224	96
Earnings	54	54	52
Market Capitalization	1445	1445	1446
Profitability	0.24	0.22	0.40
Observations	2,774	2,508	266

Notes: The table presents the average of several firm performance metrics across R&D and non-R&D firms across industries.

Figure 1 similarly plots the percentage of firms that do R&D in a given year and over the course of the sampled period across each of the main industries. The two figures track each other fairly closely, reflecting the high degree of persistence in R&D behavior over time. The most notable takeaway from the figure, however, is that R&D activity is highly concentrated in the manufacturing sector with R&D in information and finance as well as services, the second and third most important industries, lagging well behind. In Figure 2 we similarly plot Tobin's Q, the main dependent variable in all of our econometric estimations across industries. It is significantly larger for R&D firms with the exception of the manufacturing industry, where it is larger but not by as substantial a margin.

Figure 3 similarly plots the average values for R&D firms relative to others over time. Firms that do R&D consistently outperform others and the difference is typically substantial. Interestingly, R&D firms show much larger sensitivity to business cycle downturns, perhaps reflecting in part the greater risk that they take on with their innovative efforts.

To make the context of our estimations more concrete, in Table 3 we list the firms that report the largest R&D expenditures in our sample. The list contains a variety of firms, from Covid-19 vaccine makers Pfizer and Johnson and Johnson to tech companies Microsoft and Intel, to car companies Ford and General Motors. The overall skewness of the distribution of R&D expenditures is evident here, with the top performer Pfizer spending more than twice as much as even the tenth firm on the list, Bristol-Myers Squibb. The pattern of the results is consistent with the descriptive evidence in Figure 2 from Section 3.

Fig. 1: Percentage of Firms that do R&D in a Given Year or Over the Course of the Entire Sample

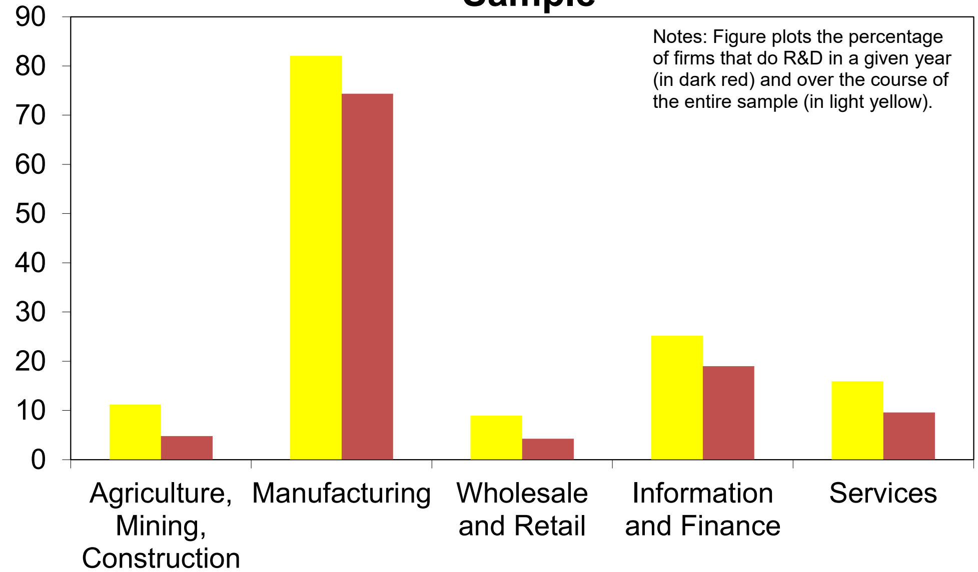


Fig. 2: Tobin's Q Across Industries for Firms That Do and Do Not Do R&D

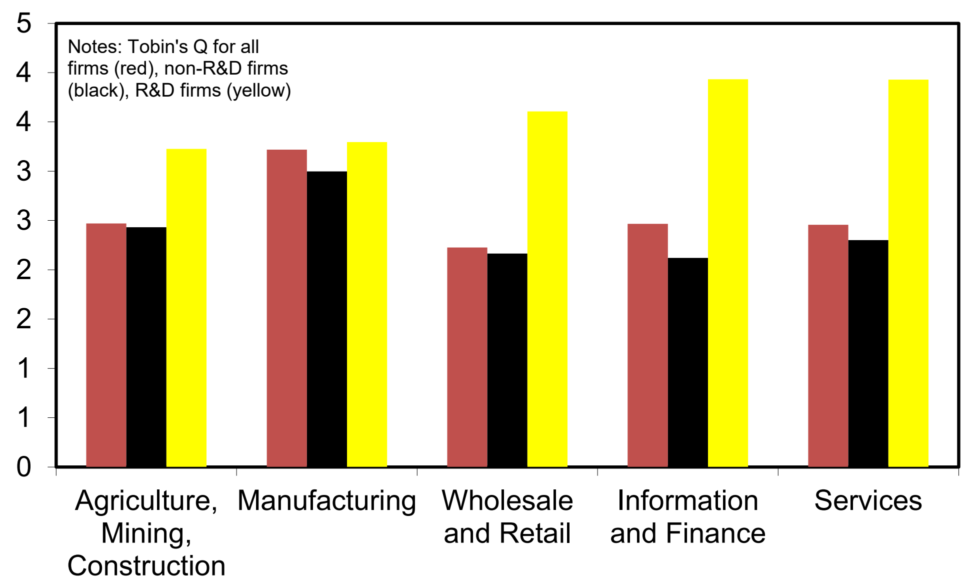


Fig. 3: Tobin's Q for R&D and non-R&D Firms Across Years

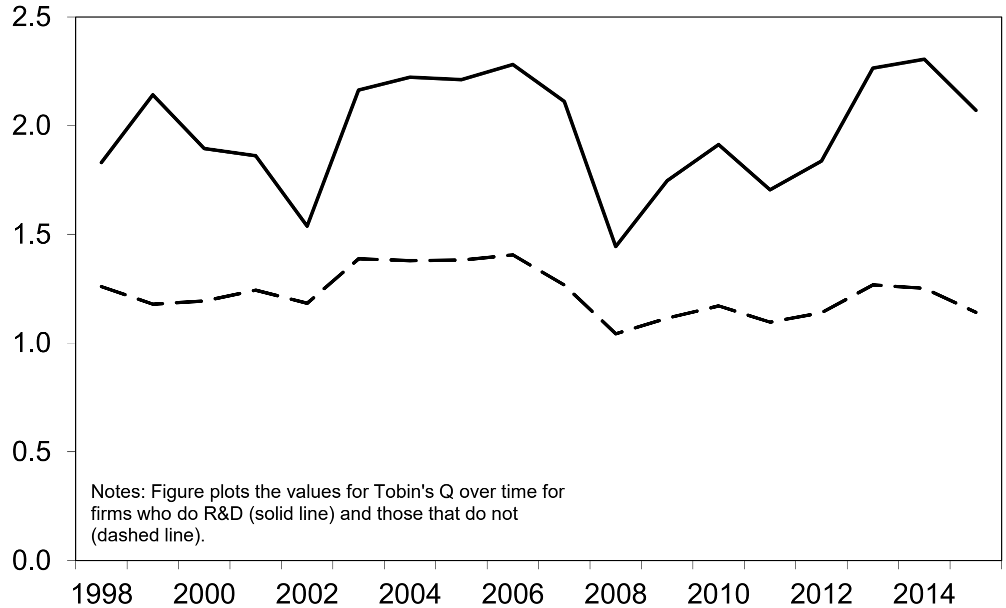


Table 3: Top R&D Firms

Rank	Company Name	Total Spent on R&D 1998-2015 ($m)
1	Pfizer Inc.	97,747
2	Ford Motor Company	93,782
3	Microsoft	87,221
4	Johnson & Johnson	82,531
5	Intel	82,505
6	General Motors	72,762
7	IBM	72,232
8	Merck	66,111
9	Cisco Systems	58,595
10	Bristol-Myers Squibb	44,128

Notes: The table presents the firms that account for the largest amount of R&D expenditures in our sample.

4 Econometric Estimations

In this section we begin our econometric analysis with a set of ordinary least squares estimations. Here we consider specifications of the form:

$$TobinsQ_{it} = \delta_0 + \delta_1 \cdot R\&D_{it} + X_{it}\beta + \varepsilon_{it}. \quad (2)$$

Here $TobinsQ_{it}$ is a measure of firm i's value in year t, $R\&D_{it}$ is an indicator function for whether the firm did R&D in the given year, X_{it} refers to a bevy of firm specific control variables that vary over time, and ε_{it} is the error term.

In Table 4 we use controls along the lines of Denis, Denis, and Yost (2002), which considered a different but related context. This includes firms' sales, employment, assets, relative debt, relative capital expenditures, and relative earnings. In column (1), we begin by estimating the specification with only our indicator function for whether the firm engaged in R&D in the given year or not. Consistent with the prior literature, we find a positive and statistically significant effect. Adding in the control variables in column (2) does not appreciably affect the magnitude of our main coefficient of interest. In columns (3) – (7) we estimate the specification in column (2) across industries. The coefficient of interest here is positive and statistically significant for each sector. The quantitative magnitudes, however, vary significantly, ranging from 0.63 in the manufacturing sector to 1.91 in the information and finance sector.

Table 4: R&D Financial Performance I, OLS

			NAICS Industry				
	Entire Sample	Entire Sample	Agriculture, Mining, Construction	Manufacturing	Wholesale and Retail	Information and Finance	Services
R&D Firm	1.08	1.12	1.28	0.63	1.36	1.91	1.56
	(0.03)	(0.03)	(0.16)	(0.05)	(0.16)	(0.05)	(0.15)
Sales		-0.000016	0.000009	-0.000005	-0.000005	-0.000021	0.000019
		(0.000002)	(0.000008)	(0.000003)	(0.000005)	(0.000005)	(0.000030)
Employment		0.000195	-0.014116	-0.014797	0.003183	-0.000652	0.002449
		(0.000386)	(0.004446)	(0.001368)	(0.000660)	(0.000816)	(0.001226)
Assets		-0.000001	-0.000033	0.000008	-0.000043	0.000000	-0.000090
		(0.000000)	(0.000006)	(0.000002)	(0.000008)	(0.000000)	(0.000026)
Relative Debt		-0.000186	-0.001764	-0.000010	0.010556	0.000048	-0.030969
		(0.000187)	(0.000609)	(0.000235)	(0.001976)	(0.000497)	(0.020649)
Relative Investment		-0.002542	0.005405	-0.004739	0.068302	0.021015	0.050163
		(0.000400)	(0.001108)	(0.000547)	(0.055085)	(0.008395)	(0.033399)
Relative Earnings		-0.001200	-0.004232	-0.001252	-0.002357	-0.001641	0.000251
		(0.000058)	(0.000373)	(0.000083)	(0.000310)	(0.000134)	(0.000415)

Notes: The table presents estimates from ordinary least squares (OLS) estimations with a set of control variables motivated by the work of Denis, Denis, and Yost (2002). Relative investment more precisely refers to relative capital expenditures. Standard errors are in parentheses.

In Table 5, we consider a related set of estimations where we instead consider a set of control variables motivated by the work of Fillat and Garetto (2015). This includes the sales to employment ratio, capital to labor ratio, profitability as constructed by Novy-Marx (2013), and firm leverage. Like above column (1) estimates the specification without any controls, column (2) adds the controls, and columns (3) – (7) consider the specification across industries. The pattern of the effects is similar to that found in Table 6 both qualitatively and quantitatively. The main coefficient of interest is positive and statistically significant in column (1), retains the same magnitude when adding the controls in column (2), and the estimates are all similar across the columns. The results suggest that the relationship between R&D and firm value is robust to the control variables used and is robust across industries within the framework of an OLS estimation approach.

Table 5: R&D and Financial Performance II, OLS

			NAICS Industry				
	Entire Sample	Entire Sample	Agriculture, Mining, Construction	Manufacturing	Wholesale and Retail	Information and Finance	Services
R&D Firm	1.08	1.20	0.83	0.57	1.37	1.95	1.67
	(0.03)	(0.03)	(0.19)	(0.05)	(0.17)	(0.05)	(0.15)
Sales/Employment		-0.00007	-0.00029	-0.00034	-0.00007	0.00000	-0.00001
		(0.000011)	(0.000046)	(0.000041)	(0.000024)	(0.000012)	(0.000043)
Capital/Labor		0.00166	-0.03522	0.03588	-0.08761	-0.00048	-0.11452
		(0.000367)	(0.014539)	(0.021286)	(0.024855)	(0.000394)	(0.032365)
Profitability		-0.00932	-0.00662	-0.06239	-0.21061	-0.03168	-0.24480
		(0.001120)	(0.001120)	(0.004780)	(0.024506)	(0.012302)	(0.043223)
Leverage		0.07306	0.01858	0.11862	1.01865	0.10684	0.490094
		(0.003948)	(0.005765)	(0.008378)	(0.158525)	(0.006707)	(0.054949)

Notes: The table presents estimates from ordinary least squares (OLS) estimations with a set of control variables motivated by the work of Fillat and Garetto (2015). Standard errors are in parentheses.

In this section we enrich the econometric approach considered previously to include a set of firm and year fixed effects, leveraging the panel nature of our data. The specification that we estimate is thus extended to

$$TobinsQ_{it} = \delta_0 + \delta_1 \cdot R\&D_{it} + X_{it}\beta + \mu_i + \mu_t + \varepsilon_{it}. \tag{3}$$

All variables are defined as above. μ_i are firm fixed effects and μ_t are year fixed effects.

The results here are significantly different when using the OLS approach. In Table 6 we begin like we did in Tables 4 and 5 and simply regress the firm's level of Tobin's Q against an indicator function for whether the firm was doing R&D. The results are negative and strongly statistically significant. When we add a set of controls in column (2), the main coefficient of interest drops by roughly two thirds and is no longer as well measured as it was previously, with the p value now much larger than it was previously. When we break the results out by industry, the results are statistically significant only for the agriculture, mining, and construction, and services industries. Contrasting with all of the results in this table that are statistically significant suggest a negative rather than positive relationship between firm value and doing R&D. The control variables here are the same as they were in Table 4.

In Table 7 we run a similar set of fixed effects regression as in Table 6 but with a different set of control variables. The pattern of effects across the different estimations is similar. Importantly, when we go from column (1) to column (2) in adding the control variables, the main coefficient is still estimated to be negative, but the results are now statistically insignificant. This suggests a cautious approach in interpreting the results. It does, however, suggest that the OLS and fixed effects results generally are not robust, shedding doubt on the reliability of prior studies on this topic. When we break out the results by industry, it is still the case that the effects are only statistically significant for the agriculture, mining, and construction industry as well as the services industry. The p values are not exceptionally strong here either, however.

In order to demonstrate this change more intuitively, in Figure 4 we plot the estimated coefficients across industries. Here we plot the coefficients across each of the industries in Table 5 and 7. It demonstrates how much adding fixed effects changes the coefficients. With the OLS specifications the coefficients are all large and positive. Once we add in the fixed effects, however, the coefficients are mostly negative and overall substantially smaller.

Table 6: R&D and Financial Performance I, Fixed Effects

			NAICS Industry				
	Entire Sample	Entire Sample	Agriculture, Mining, Construction	Manufacturing	Wholesale and Retail	Information and Finance	Services
R&D Firm	-0.30	-0.11	-0.37	-0.04	0.14	-0.08	-0.86
	(0.05)	(0.05)	(0.14)	(0.08)	(0.17)	(0.09)	(0.23)
Sales		-0.000002	0.000001	0.000014	0.000004	-0.000015	0.000081
		(0.000003)	(0.000007)	(0.000006)	(0.000009)	(0.000008)	(0.000046)
Employment		-0.005831	-0.004270	-0.007675	-0.006715	-0.006959	0.005470
		(0.001024)	(0.007901)	(0.002306)	(0.001706)	(0.001945)	(0.002360)
Assets		0.000000	-0.000005	-0.000011	-0.000020	0.000001	-0.000115
		(0.000001)	(0.000007)	(0.000003)	(0.000011)	(0.000001)	(0.000041)
Relative Debt		-0.000094	-0.001918	0.000169	0.007749	-0.001030	-0.081404
		(0.000159)	(0.000387)	(0.000254)	(0.001295)	(0.000311)	(0.014832)
Relative Investment		-0.000615	0.003992	-0.001246	-0.027811	0.008718	0.131606
		(0.000264)	(0.000821)	(0.000360)	(0.042840)	(0.005322)	(0.023999)
Relative Earnings		-0.000288	-0.002941	-0.000246	-0.000221	-0.000426	0.000950
		(0.000045)	(0.000218)	(0.000065)	(0.000222)	(0.000114)	(0.000317)
Firm Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes

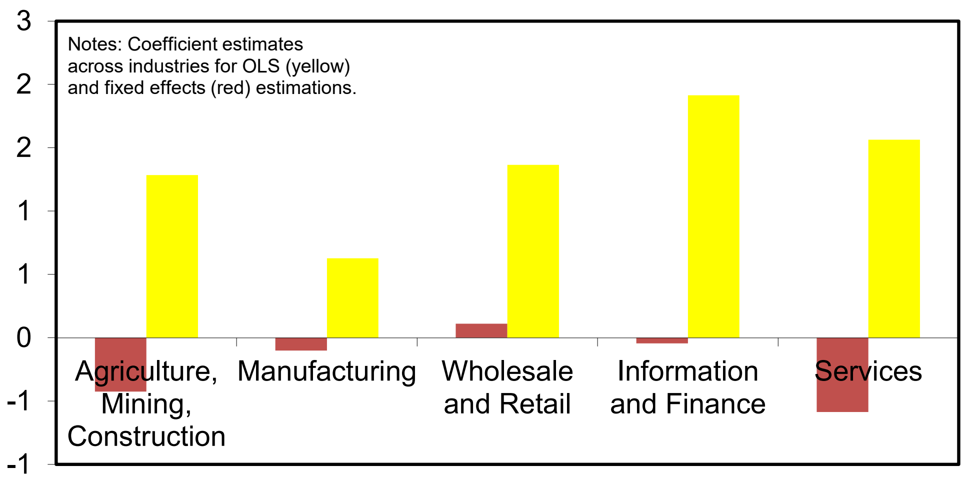
Notes: The table presents estimates from fixed effects estimations with a set of control variables motivated by the work of Denis, Denis, and Yost (2002). Relative investment more precisely refers to relative capital expenditures. Standard errors are in parentheses.

Table 7: R&D and Financial Performance II, Fixed Effects

			NAICS Industry				
	Entire Sample	Entire Sample	Agriculture, Mining, Construction	Manufacturing	Wholesale and Retail	Information and Finance	Services
R&D Firm	-0.30	-0.09	-0.43	-0.10	0.11	-0.05	-0.59
	(0.05)	(0.05)	(0.17)	(0.08)	(0.17)	(0.10)	(0.24)
Sales/Employment		-0.00003	0.00002	0.00015	-0.00009	-0.00001	0.00002
		(0.000011)	(0.000047)	(0.000033)	(0.000051)	(0.000013)	(0.000035)
Capital/Labor		0.00063	-0.08818	-0.16501	-0.28784	0.00037	-0.22345
		(0.000455)	(0.011780)	(0.015774)	(0.071388)	(0.000487)	(0.046587)
Profitability		-0.00513	-0.00215	-0.01497	-0.17372	-0.02707	-0.14681
		(0.000679)	(0.001103)	(0.003170)	(0.015348)	(0.008299)	(0.040260)
Leverage		0.03894	0.28591	0.04061	1.75356	0.03253	0.32303
		(0.003559)	(0.110580)	(0.006016)	(0.106664)	(0.004502)	(0.041365)
Firm Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Notes: The table presents estimates from fixed effects estimations with a set of control variables motivated by the work of Fillat and Garetto (2015). Standard errors are in parentheses.

Fig. 4: Effect of Doing R&D on Tobin's Q Across Estimation Approaches



5 Conclusion

In this study we have considered the effect of research and development on firm market values. We show that while simple OLS specifications agree with much of the prior literature, when a more stringent set of controls is added the effect becomes difficult to identify in terms of statistical significance or, in several specifications, entirely reverses sign. Our results suggest that the results in the prior literature may not be as robust as previously suggested.

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