The Impact of Corporate Research Labs on Firms' R&D Productivity

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We tested whether the reported demise of corporate research labs has contributed to the 65% decline in firm's R&D productivity. To do so, we first characterized the evolution in the population of corporate research labs, then tested their impact on firms' R&D productivity. Using digitized data from R&D directories from 1975 to 1997, we found no evidence of a decline in the population of corporate labs. Despite that, we continued with the test of their impact. We found the treatment effect of a lab on R&D productivity (RQ) was negative and significant, though of negligible economic impact.

VERY PRELIMINARY. PLEASE DO NOT CITE

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We've known since Solow (1957) that innovation is the primary driver of growth. More recently, Paul Romer was awarded the Nobel Prize in Economics for characterizing how. One of the exciting conclusions from that theory is that the economy will continue to grow in perpetuity, so long as we continue to invest in R&D (Romer 1990). In fact, Romer derives a very specific prediction—that the rate of growth will be proportional to the level of R&D: $g = \delta H_A$, where g is the growth rate, H_A, is the total human capital employed in research, and δ is the productivity per researcher. This has become known as his "scale effects" prediction.

While the prediction held through the mid-1980s in the United States, it no longer holds, as shown in Figure 1, which Jones (1995) first documented. R&D labor has increased by a factor of 2.5, while GDP growth has at best remained constant. If we simply divide nominal GDP growth by the level of R&D labor, it appears that aggregate δ has declined 65% since 1985. While Romer's theory pertains to the economy, the mechanisms really operate at the firm level. Accordingly, it is not surprising, that similar declines in R&D productivity have been documented at the firm-level. Cummings and Knott (2018) report a mean decline in firms' RQ of 1.4% per year, where RQ (short for research quotient, is the revenue elasticity of a firm's R&D). Similarly, Bloom, Jones, VanReenan and Webb (2020) report a decline of 5% per year in firms' *research productivity* where *research productivity* is measured as the decadal average revenue growth divided by R&D.

[Insert Figure 1 Here]

An oft-mentioned contributor to the decline in US productivity growth is the demise of corporate research labs (Corcoran 1994, Corbis 2007, Feldman 2016, Kressel 2017, Hounshell 2017, Arora, Belenzon, Patacconi, Suh 2019), where corporate labs are ones funded and guided by top management, and devoted to higher risk, long-lead projects related to a firm's basic strategy (Rosenbloom and Kantrow 1982).

There is debate about the impact of these labs. On one hand, corporate labs are believed to generate the seeds for future firm diversification and growth; on the other hand, they are perceived to be ivory towers, divorced from the operational activities of the firm and therefore a drag on profits. The debate about the labs' impact hasn't been resolved for two reasons. First, there is only anecdotal evidence of the decline in corporate labs. Second and accordingly, scholars haven't been able to characterize the contribution of a corporate lab to firm performance.

Our goal is to resolve the debate by 1) retrospectively constructing an annual census of corporate labs for all US firms, and 2) quantifying the impact of lab existence on firm R&D productivity for the subset of firms who are publicly traded.

Using data from the Fives Data Project which created digital files from the Directories of Industrial Research and Development[1], we were unable to observe a decline in corporate labs. While a decline may have occurred after the last directory was compiled in 1997, concerns about their demise were first published in 1994. Similarly, the decline in R&D productivity began a decade earlier.

While it is therefore unlikely labs are driving the decline in firms' R&D productivity, the question of their impact on firm performance is still interesting. Our investigation found no significant impact on firm R&D productivity. Thus, it appears neither camp is correct: on average, labs appear to be neither the seeds for diversification and growth, nor a drag on profits.

The paper proceeds as follows. We first review the literature on corporate labs. Next, we present our empirical approach to estimating the contribution of corporate labs to firm R&D productivity. We then present our results. Finally, we summarize and discuss implications.

I. Background on Corporate Research Labs

Industrial research is defined by Leonard Reich as research performed in "industrial laboratories set apart from production facilities, staffed by people trained in science and advanced engineering who work toward deeper understandings of corporate-related science and technology, and who are organized and administered to keep them somewhat insulated from immediate demands, yet responsive to long-term company needs" (Reich 1985:3).

The birth of US industrial research and development is generally pegged at 1900, the year in which General Electric (GE), American Telephone and Telegraph (AT&T), E.I. du Pont de Nemours (DuPont), Eastman Kodak, General Chemical and Dow founded labs. Prior to that time, companies tended to purchase technological innovations from independent inventors (Hounshell 1996). These new internal research programs were developed in response to competitive threats. GE, for example, was concerned that its incandescent lamp business was vulnerable to new lighting technologies, and AT&T was concerned its telegraph business was vulnerable to radio. While originally employed as a defensive strategy, once established, these labs drove an offensive strategy of creating new opportunities to enhance firms' long-term success.

By 1936, approximately 1,150 industrial research laboratories had been established (Hounshell 1996). The formula for the labs seemed to be "Do world-class fundamental scientific research, and you will find important new products that you can then commercialize and profit from enormously because they are completely proprietary" (Hounshell 1996:40). Industrial research grew during World War II, in large part due to military funding of technology to support the war effort, such that by 1950, the military was the largest funder of basic research. This growth continued through the post war period, when companies that previously had no R&D programs began creating them. It accelerated through the Cold War, when federal spending for research was again concentrated in the military.

By the late 1960s however, Hounshell reports that executives began to lose faith in industrial research: "DuPont had no new nylons. Kodak had no radically new system of photography" (Hounshell 1996:50). The general view was that research labs had become too ivory tower. That view in conjunction with new global competition from Japanese firms in the US automobile and consumer electronics markets, produced an environment in which managers placed more pressure on R&D to demonstrate returns. Moreover, equity markets, began to devalue R&D investment, in large part from work by Michael Jensen (1993) asserting that the R&D and capital expenditures of firms such as IBM, Kodak and Xerox exceeded their value to shareholders.

As a consequence of these factors, the National Science Board (NSB) reported in 1992 that effort in large corporations had shifted away from corporate labs toward division-level labs whose R&D tended to be lower risk and more responsive to the customer. Our goal is to characterize the extent of this shift, if any, and determine its impact on companies' R&D productivity, and by extension US economic growth.

To the best of our knowledge, prior research on corporate research labs has comprised rich qualitative accounts, either of the US history generally, (e.g., Rosenbloom and Spencer 1996), or historical accounts of particular companies, e.g., (Hounshell and Smith 1988). While we draw on these accounts, our contribution is primarily quantitative: documenting the evolution of corporate research labs, identifying the factors contributing to their creation and dissolution, and characterizing their impact on R&D productivity. Accordingly, our approach follows that of Steve Klepper in his studies of the evolution of the auto (Klepper

2002), laser (Klepper and Sleeper 2005), tire (Klepper and Simons 2000) and other industries.

II. Empirical Approach

Our empirical approach to characterizing the link between corporate labs and R&D productivity comprises two key elements: 1) Characterizing the evolution of labs' creation and dissolution, and 2) Econometrically modeling factors affecting lab creation and dissolution, as well as the impact of labs on firm R&D productivity.

A. Annual Census of Corporate Labs

Our starting point for the census of corporate research labs was the annual membership lists for the Industrial Research Institute (IRI) (now known as the Industrial Research Interchange). IRI was formed in 1938, under the auspices of the National Research Council (NRC) as an association of industrial research programs and managers "to enhance the effectiveness of technological innovation by networking the world's best practitioners and thought leaders to seek, share, learn, and create." IRI was an integral part of the National Research Council until 1945, when it separated to become a non-profit membership corporation.

Originally IRI members were research directors, and therefore corporate membership over some period (yet to be determined) is presumed to be a good proxy for presence of a corporate research lab. More recently, the organization has broadened its mission to include career and other issues, thus prompting the name change to Industrial Research Interchange. Accordingly, in recent years, membership is less likely to be a proxy for a corporate research lab.

Nevertheless, IRI membership lists allowed us to generate a preliminary characterization of the evolution of corporate research labs. Figure 2 indicates that while IRI membership grew steadily from its founding in 1938, there was a dramatic trend toward dissolution, beginning in the mid 1980s, reaching a peak exodus of 47 firms in 2007, and continuing to exhibit substantial exit since.

[Insert Figure 2 Here]

While IRI membership was our starting point for the census of corporate research labs, because we know membership is no longer a good proxy for a corporate lab, we augment the membership list with a second source, *Industrial Research Laboratories of the United States*, and its successor, *Directory of American Research and Technology*. These directories comprise thirty volumes, published on a periodic basis over the period 1920 to 1998. Thus, they precede the rise in labs in the 1930s, and continue beyond the IRI membership decline in the 1980s.

Each directory includes all "known non-government facilities currently active in any commercially-applicable basic and applied research, including development of products and processes". Research programs used exclusively by universities and/ or the government, as well as activities devoted entirely to quality control and testing, are excluded from the directory. Information for each directory is obtained through written questionnaires. Organizations who fail to submit the questionnaire were contacted by phone. For those not reached by phone, information was obtained from secondary sources. The listings based on secondary sources are designated with an asterisk by the organization's name.

The directory entries are at the lab level, but are organized by firm. For each firm with a research laboratory, the directory identifies the firm name, address, phone, and the top executives. Below the firm heading are entries for each lab that include the lab name, address, phone, the name of the lab director, and the reporting structure—whether it is to the corporation or to an operating division (our key variable of interest). The lab listings contain rich data on the number of professional staff, including the number with doctorate degrees and the scientific discipline of those with doctorate degrees, the number of technicians and auxiliary staff, and identification of the fields of the lab's principal R&D activities. It also contains "service codes" designating whom the work is performed for, e.g., parent versus government. See Appendix A for a sample organization listing.

We obtained data for eight editions spanning 1975 to 1997 from Png (2018) as part of the Fives Project. These data documented in Png (2019) included pdfs of each edition, plus a database summarizing key data by firm-year. We merged these data with data from Compustat to identify the universe of public firms conducting R&D.

Figure 3 plots the evolution of US public firms conducting R&D, as well as the subset of those with corporate labs. Looking first at firms conducting R&D, we see that from 1950 (the first year of Compustat data) until 1970, the share of firms conducting R&D hovered around 10%. There was an almost instantaneous rise thereafter, such that the share of firms conducting R&D has hovered around 42% since then.

[Insert Figure 3 About Here]

Looking next at the share of R&D firms with corporate labs, we see that they rose from about 15% of R&D firms in 1975 to 35% in 1995. There is a slight decline in 1997, but unfortunately, we can't tell whether that is noise, or the beginning of a real decline. Nevertheless, our data don't exhibit the decline flagged by Corcoran in 1994.

B. Econometric Analysis

Having compiled the census of corporate labs, we characterize their impact on firms' R&D productivity, for the subset of publicly traded firms. In order to properly characterize the impact of corporate labs on R&D productivity, we need to account for endogeneity in firm choice to create or maintain a lab—factors that jointly increase the likelihood of a lab as well as R&D productivity. We then model the impact of a lab on R&D productivity after controlling for the endogeneity. To do so, we implement propensity score matching, which models the existence of a corporate lab in firm *i* in year *t* as a function of characteristics known to affect firm's R&D decision-making.

$$(1) \qquad P(\text{Corporate lab})_{it} = \Sigma\ \beta_k * \text{firm characteristics}_{ikt-x} + e_{it}$$

These data include firm size (*revenues*), *R&D intensity* (both from Compustat), *patent intensity* and *citation intensity* (from the U.S. patent dataset released by Kogan, Papanikolaou, Seru, and Stoffman (2017) over the period of 1926-2010), *age* and l*everage.* Table 1 provides a data summary of these variables, comparing means for firms with and without corporate labs for the 1997 cross-section. The table indicates that only 20% of firms in our sample (which requires R&D expenditures in 6 of the prior 7 years) have a corporate lab. Ironically, those that do have corporate labs, tend to be smaller (half the size) and younger (by 40%). Those with a lab have very different R&D behaviors, however. They spend twice as much on R&D (as share of assets), and patent at 20% higher rate per dollar of R&D. On average there is little difference in their R&D productivity (4%).

[Insert Table 1 About Here]

After matching firms with and without corporate labs on these characteristics, the model estimates a treatment effect of a corporate lab on firm R&D productivity, measured as RQ (Knott 2008).

(2) $$RQ_{it} = \beta_1 * \text{Corporate Lab}_{\,it\text{-}x} + e_{it}$$

RQ (short for research quotient) is the firm-specific revenue, *Y*, elasticity of R&D, *R*, holding all other inputs (capital, *K*, labor, *L*, spillovers, *S* and advertising, *A*) and their elasticities fixed. It is the estimate for γ_i in firm i's production function. The exponent, γ_i, represents the percentage increase in revenues from a 1% increase in R&D, when other inputs are held constant.

(3) $$Y_{it} = K_{it}^{\alpha_i} L_{it}^{\beta_i} R_{it}^{\gamma_i} S_{it}^{\delta_i} A_{it}^{\xi_i}$$

The way to interpret RQ is a firm's ability to generate revenue from its R&D investment. Thus, a firm can have high RQ either by generating a large number of innovations and being reasonably effective exploiting them, or by generating a reasonable number of innovations and being extremely effective exploiting them.

We chose RQ over other measures of R&D productivity and innovative efficiency, because it is the only innovation measure that robustly predicts firm value (Cooper, Knott and Yang 2021).

Before estimating the matching model, however, we estimate simple OLS and firm fixed effects models of the impact of a corporate lab on firm RQ. Because the work in corporate labs typically has long horizons, we examine multiple lags to determine the duration of a lab's impact on performance.

III. Results

Results for estimating a simple model of the lagged impact of corporate labs are presented in Table 2. Models 1 through 6 use OLS, while models 7 through 12 employ firm fixed effects. In all models we control for revenues and year effects. We only obtain a positive and significant effect for labs on R&D productivity in

OLS models with two to four-year lags. This effect goes away in the presence of firm fixed effects. This implies that firms with corporate labs have higher performance, but that the performance is due to something other than the lab. The coefficient of 0.003 in the OLS models, is similar to the difference in RQ for the two sets of firms from Table 1.

[Insert Table 2 About Here]

The result that a corporate lab has a negligible effect on firms' R&D productivity may mean labs truly have no effect. However, it may also mean that weaker firms are more likely to have labs, and for those weaker firms, a corporate lab enhances productivity.

To assess the treatment effect of having a corporate lab on R&D productivity, we use a logistic model to predict each firm's propensity to have a lab using the following covariates: size (*revenues*), *R&D intensity, patent intensity* and *age*. We evaluated other variables shown elsewhere to affect R&D behavior, such as *citation intensity*, *leverage* and *R&D tax shield*, but none was significant in predicting presence of a lab. The logistic regression indicates that the main predictors of a firm having a corporate lab are R&D intensity and patent intensity. Size and age reduce the likelihood of having a corporate lab.

After matching firms on these covariates, we find that the treatment effect of having a lab is -0.004, as shown in Table 3. This means that the average RQ of firms if all of them were to have a corporate lab, would be 0.004 lower than the average would be if no firms had corporate labs. This is a negligible effect. It represents only 3.5% of mean RQ.

[Insert Table 3 About Here]

This result in conjunction with the earlier result that labs are only positively and significantly correlated with RQ in OLS regressions, suggests that stronger firms have labs, but that the lab is mildly degrading performance

IV. Discussion

R&D is the primary driver of economic growth. Accordingly, a likely culprit for stagnant economic growth in the US is a 65% decline in R&D productivity since 1985. One proposed explanation for the decline is the demise of corporate research labs, where corporate labs are ones funded and guided by top management, and devoted to higher risk, long-lead projects related to a firm's basic strategy. However, to date, we have only anecdotal evidence of the demise of corporate labs, and accordingly we have not been able to test the impact of their demise on R&D productivity.

This study attempted to fill that gap. We began by characterizing the evolution in the population of corporate research labs. While we found a rise and decline in IRI membership, suggesting a decline in labs, further investigation using R&D directories failed to confirm that. Instead, we saw only a rise in the population of corporate labs. Note that our sample was restricted to US public firms, so there may be a decline in private firms. However, public firms conduct the bulk of US R&D, so if there was a decline, we should see some evidence in our sample. Similarly, our data only extend to 1997, so it is possible a decline in the population of corporate labs occurs after that. However, concerns about the demise in labs precede that.

We next examined the impact of corporate labs on firms' R&D productivity. To do so, we created a matching model that paired firms on covariates predicting the likelihood of a corporate lab. After doing so, we found the treatment effect of a lab was negative and significant, though of negligible economic impact.

The fact that the population of corporate labs was increasing over the period of the decline, combined with the fact that labs have a negative effect on firms' R&D productivity, suggests that their rise (rather than their demise) may have contributed to the decline in aggregate R&D productivity.

While we lack the data to explain why R&D productivity is only negligibly affected by the presence of a lab, it seems possible that labs have become "ivory towers" divorced from the central operations of their respective firms, as detractors have argued.

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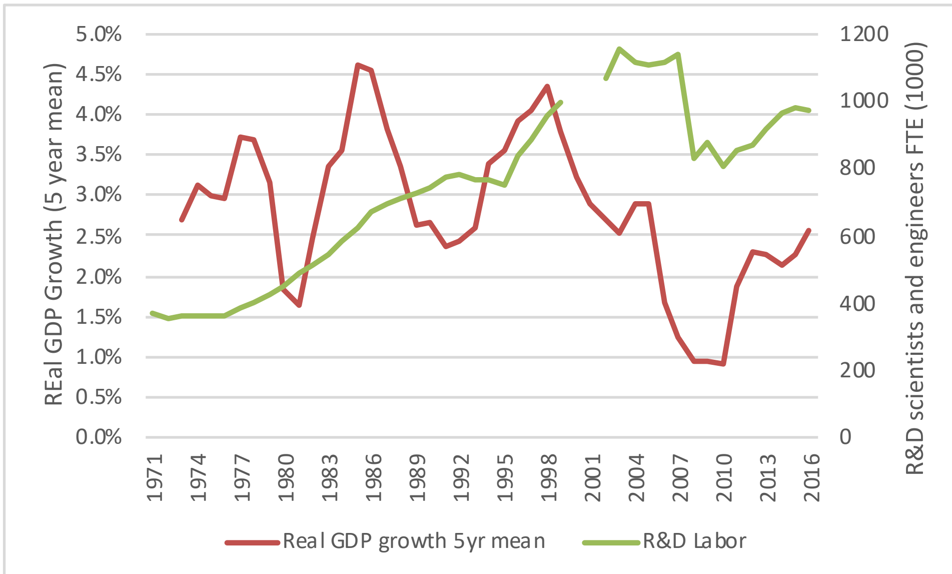
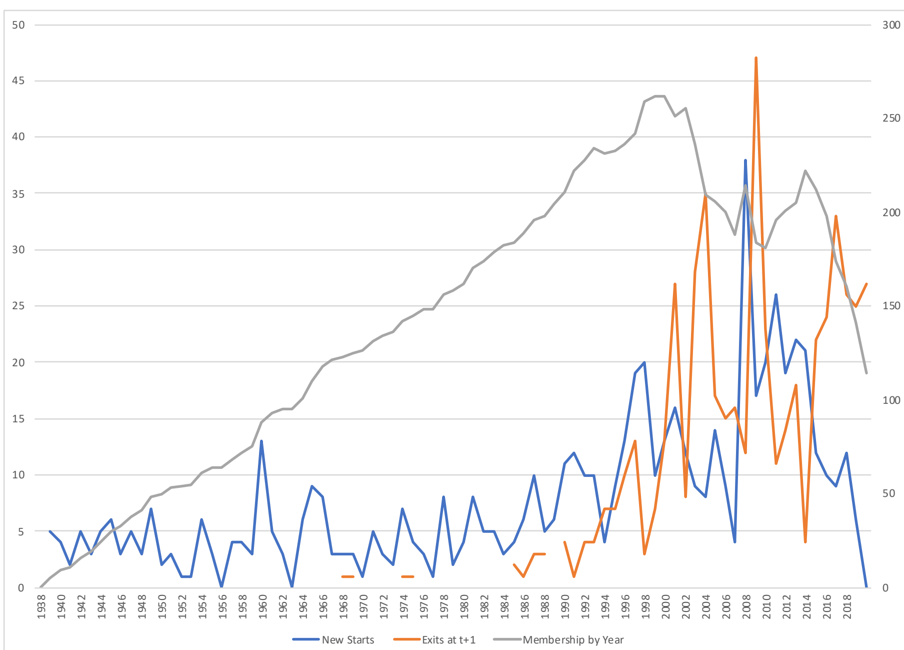


FIGURE 1. TRENDS IN R&D AND GDP GROWTH

Notes: These are the notes applicable to the figure. The style is named Figure Notes.



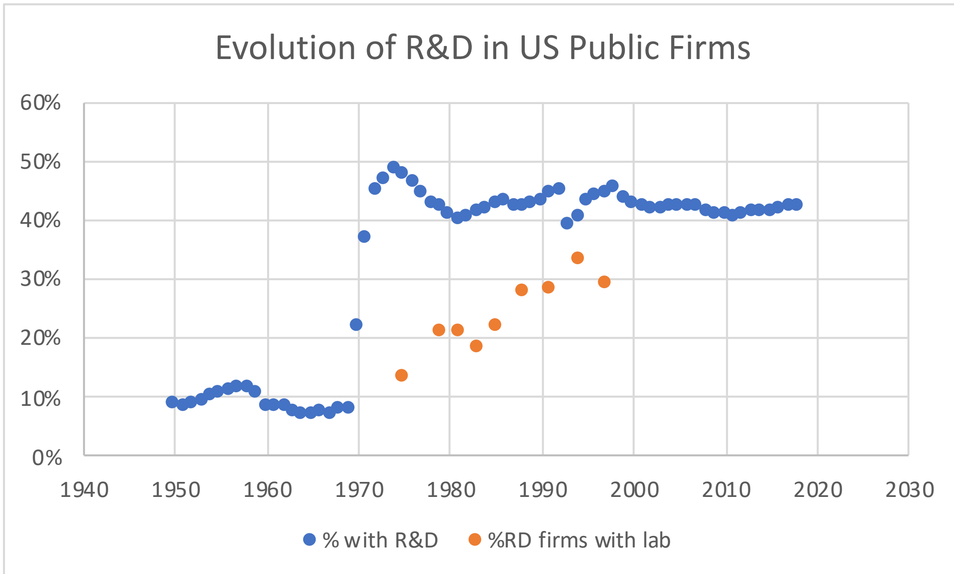


FIGURE 3. EVOLUTION OF R&D AND CORPORATE RESEARCH LABS IN US PUBLIC FIRMS

TABLE 1. Firm Summary Statistics 1997

	Without Corporate Lab	With Corporate Lab
Observations	834	203
Revenues ($million)	4479 (13846)	2263 (7755)
R&D Intensity (R&D/Assets)	0.060 (0.058)	0.134 (0.172)
Patent intensity*	0.186 (0.185)	0.221 (0.307)
Age	28.9 (14.9)	17.3 (13.9)
RQ	0.112 (0.047)	0.117 (0.050)

*(patents_(i,t))/((R&D_(i,t-2)+0.8R&D_(i,t-3)+0.6R&D_(i,t-4)+0.4R&D_(i,t-5)+0.2R&D_(i,t-6)))

TABLE 2. Impact of Corporate Lab on Firm R&D Productivity (RQ)

Dependent Variable: RQ												
	Lag=5	Lag=4	Lag=3	Lag=2	Lag=1	Lag=0	Lag=5	Lag=4	Lag=3	Lag=2	Lag=1	Lag=0
Has Corporate Lab	0.0013	0.0037**	0.0030**	0.0034**	0.0050	0.0010	0.0000	0.0020	0.0005	-0.0013	-0.0029	-0.0021*
	0.0016	0.0015	0.0015	0.0014	0.0014	0.0013	0.0014	0.0013	0.0132	0.0013	0.0013	0.0011
Revenues	2.59E+07***	2.49E+07***	2.27E+07***	1.94E+07***	1.53E+07***	1.35E+07***	3.96E+07***	4.04E+07***	3.34E+07***	2.93E+07***	2.81E+07***	2.47E+07***
	3.48E+08	3.54E+08	3.64E+08	3.90E+08	4.09E+08	4.28E+08	9.22E+08	9.14E+08	9.07E+08	9.53E+08	9.38E+08	9.26E+08
Year effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Firm Fixed effects	No	No	No	No	No	No	Yes	Yes	Yes	Yes	Yes	Yes
Constant	0.156***	0.167***	0.173***	0.150***	0.127***	0.156***	0.157***	0.167***	0.176***	0.153***	0.132***	0.161***
	0.003	0.004	0.004	0.004	0.004	0.005	0.003	0.003	0.003	0.003	0.003	0.004
Observations	10392	11667	13117	14862	16948	19687	10392	11667	13117	14862	16948	19687
Firms							1329	1457	1611	1864	2104	2440
R-squared	0.114	0.118	0.122	0.117	0.102	0.080						
Adjusted R-squared	0.112	0.116	0.120	0.110	0.100	0.079						
Within							0.201	0.202	0.203	0.185	0.180	0.151
Between							0.035	0.041	0.041	0.049	0.033	0.024
Overall							0.110	0.114	0.118	0.107	0.096	0.075

*** Significant at the 1 percent level
** Signficant at the 5 percent level
* Significant at the 10% level

TABLE 3. Propensity Score Matching

Dependent Variable: RQ	
ATE Has Corporate Lab (t)	-0.004*
	0.002
Logit Match: p(Has corporate lab)	
Revenues ($million)	-7.21E-06
	4.76E-06
R&D Intensity (R&D/Assets)	4.751***
	0.573
Age	-0.260***
	0.003
Patent intensity*	0.210*
	0.121
Constant	-1.438***
	0.120
observations	7081
log likelihood	-2807
psuedo R2	0.0471

*** Significant at the 1 percent level
** Signficant at the 5 percent level
* Significant at the 10% level

Appendix A. Sample Entry

SAMPLE ENTRY

[1]C351 [2]**COMMUNICATIONS SYSTEMS CORPORATION,**
[3]107 L'Enfant Plaza SW, Washington, DC 20023.
[4]Tel: 202-864-5000; WATS: 800-303-7030
[5]*Chmn & Chief Exec Officer* Jerry Goldin; *Pres & Chief Operating Officer* Laurence Lawson

[6].1 [7]—[8]**CSC Laboratories,** 2000 Brooks Dr, Forestville, MD 20747. [9](pi)
Tel: 305-427-4000; Telex: 77-9667
VPres & Dir of Lab Dr John James
[10]**Professional Staff:** 408 (Doctorates:56) - [11]Computer science, electrical engineering, mathematics, physics. [12]Technicians & Auxiliaries: 174
[13]**Fields of R&D:** Research in satellite communications, spacecraft technology and network technology

.2 ——**Environmental Division,** 696 N Wayne St, Arlington, VA (pg)
22201. Tel: 703-369-8910
Dir Vernon Sampson
Fields of R&D: Air quality modeling research for basic and applied technology

1. This code consists of the letter under which the company is alphabetized and a number indicating its position within the letter grouping. This identifying code is used in the Geographic, Personnel and Classification Indexes to refer the user to the appropriate text entry in the main section.
2. Name of the parent organization.
3. Address.
4. Telephone numbers.
5. Personnel. Personnel listed for the parent company consist of officers of the company, while divisional listings include major research personnel.
6. Decimal number identifying each facility's sequential location in the company's listing. The decimal number is used in the three indexes following the parent company's code to refer to specific facility listings in the main section.
7. Reportage - each dash indicates what division of the parent company the facility reports to. One dash indicates reportage to the parent company. A facility preceded by two dashes reports to the division with one dash found above it in the entry, etc.
8. Name of the division, laboratory, or subdivision.
9. R&D services codes. These letter codes appear in each R&D facility's entry to indicate for whom research work is performed. The following codes are used:

   (p) for parent (own) organization
   (g) on contract for government
   (i) on contract for industry
   (c) consultation for others
10. Number of professional staff. Included in parentheses is the number of staff possessing doctoral degrees.
11. Scientific disciplines represented by doctorates.
12. Number of laboratory and technical support staff working at the facility.
13. Statement of chief R&D activity. Detailed information does not appear in every entry since all organizations are not structured identically and some have policies which restrict publication of certain research activities.