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THE LINK BETWEEN RESEARCH EXPENDITURE AND PATENTING

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ABSTRACT

We test patenting and research hypothesis time series data from 1980 to 2007 for the United States. We detail R&D in terms of funds, objectives, and character of work. We divide types of funds into three groups: federal research funds, industry research funds, and academic research funds. We categorize the objectives of funding as defense, space, or other purposes (mostly business-oriented research). In terms of character of work, we test research efforts in the basic, applied, and development phases. We introduce a new measure for patent productivity, which we measure by dividing the number of patents applied for by the number of patents issued; not all patent applications lead to a patent being issued.

Pakes (1985) found that a 1% increase in R&D expenditures will eventually lead to a 1.18% increase in patented innovations. Our result shows that a 1% increase in industrial R&D is associated with an increase of 0.56% in patenting. This finding is consistent with the average fall in productivity since 1985. Neither academic fund nor federal fund is associated with patenting.

Keywords: Patent- Research and Development- Academic- Federal- Industry

INTRODUCTION

The link between patenting and research funds has already been explored in the literature (Kortum & Lerner, 2000; Hellmann & Puri, 2000, 2002; Jaffe, 1989; Pakes, 1985). Our research is different for a number of reasons. First, we test time series data from 1980 to 2007 for the United States, whereas previous research has been industry-, firm-, and region-based (Hellmann & Puri, 2000; Kortum & Lerner, 2000; Jaffe, 1989; Pakes, 1985). Second, we detail R&D in terms of funds, objectives, and character of work. Previous research has explored only corporate or total funding without further categorizing it. In this research, we divide types of funds into three groups: federal research funds, industry research funds, and academic research funds. We categorize the objectives of funding as defense, space, or other purposes (mostly business-oriented research). In terms of character of work, we test research efforts in the basic, applied, and development phases. Third, we introduce a new measure for patent productivity, which we measure by dividing the number of patents applied for by the number of patents issued; not all patent applications lead to a patent being issued. The patent office may reject the patent application due to insufficient contribution.

We aim to answer the following four questions in this research:

1. Is all R&D spending used for patenting?

2. Do defense and space research promote commercial discoveries?
3. Is applied R&D more relevant for patenting?
4. Are R&D activities subject to diminishing returns?

The first question addresses the fact that, in the literature, R&D research is not discussed; the concern is either total R&D or corporate R&D spending. Universities might be active in several areas, such as human capital, funding, and facilities. The human capital aspect and the geographical proximity are already searched, but the impact of funding is omitted. Measuring intellectual outcomes in the form of patents is the common and easy way to measure in the literature (Kortum & Lerner, 2000). Patent protection is equivalent to an R&D subsidy of 5-10% for pharmaceutical and chemical patents and 15-35% for mechanical and electronics patents (Schankerman, 1998). However, a patent is not always the appropriate way to protect intellectual property (Levin et al., 1987; Kremer, 1998). Significant and persistent inter-industry differences between R&D investment and innovative performance indicate that most patents are held by small, technologically-oriented firms. For big companies, lead time, learning curve advantages and secrecy, and sales/service efforts are more relevant ways to protect their comparative advantage (Levin et al., 1987; Whittington et al., 2009). Therefore, corporate funding may not lead to patenting.

Federal funding is a nested bureaucracy; therefore, the procedure may be lasting very long. Additionally, federal funding may be geared more toward social, basic, and defense purposes than toward commercial outcomes. In the old model, the developmental state was portrayed as having a strong relationship with the leading big firms, but in the new approach, growth lies with innovative, research-oriented firms (Breznitz, 2006). Therefore, both universities funds and government funds might play important roles. If innovation were not risky, big firms would engage in it, and they would use their great advantages in finance, marketing, and distribution. This market failure occurs because the significant uncertainties of R&D lead private investors to allocate suboptimal amounts of funds to research (Breznitz, 2006). Therefore, big companies rely on external R&D. Academics and the government in particular may play important roles in R&D efforts due to their decreased concern for commercial success. Talented graduates and professors, high quality libraries, and research laboratories at universities facilitate the process of commercial innovation. University research appears to have a direct impact on through patenting and an indirect impact on local innovation by inducing industrial R&D spending (Jaffe, 1986, 1989).

As for the second question, the transfer of the technology discovered by defense research may have an impact on patenting. In addition, a space research program which is aimed at overcoming tough environmental conditions might lead to many new discoveries.

The third question addresses the fact that applied research may be more patentable than basic research, since the goal of the latter is to make fundamental discoveries, whereas in development research the discoveries are supplementary and there are less resources available for patenting.

Finally, regarding the fourth question, many discoveries were realized in the past and R&D lost its edge. Evenson (1984, 1993) claims that research productivity has declined sharply over the last 40 years in many different industries and countries. By 1990, the number of patents produced in the United States by scientists and engineers had fallen to just 55% of its 1970 level, with even steeper declines in Europe. A process of technological exhaustion would directly lower innovative output and, by reducing the private returns to R&D, it would also decrease the equilibrium of private R&D investments (Lanjouw & Schankerman, 2001).

The rest of this paper is organized as follows: the next section presents the empirical methodology, which is followed by the results. Finally, there is a concluding discussion.

EMPIRICAL METHODOLOGY AND DATA

We consider time series data from 1980 to 2007 in the United States (U.S. Census Bureau, 2010; U.S. Patent Office, 2010) (see Tables 1 and 2 in the Appendix for descriptive statistics). The major explanatory variable for patent discoveries is R&D expenditures (Kortum & Lerner, 2000; Hellmann & Puri, 2000; Jaffe, 1989; Pakes, 1985). In our research, we divide R&D expenditures into the following categories: industrial, academic, and federal.

Our dependent variable is the number of patents issued in the United States (Graph 1). When patent disbursements are viewed according to the resource of funds (Graph 2), it is shown that 70% goes to industrial R&D ($250 billion), 27% is spent by federal states ($100 billion), and only 3% comprises funds for universities ($10 billion). In the early 1980s, expenditures for federal and corporate R&D were equal, but after the 1990s, a sharp increase in corporate R&D took place. The pro-patent shift in the U.S. legal environment in the 1980s may have caused this increase (Hall & Ziedonis, 2001). Stronger patent rights are especially critical to these firms in attracting venture capital funds and securing proprietary rights in niche product markets. Spending for academic R&D remains relatively low, even though the total expenditure in the 1980s was $1 billion and reached $10 billion in 2007 (Graph 2).

When patent disbursements are viewed according to research objectives, it is shown that 16% goes to defense R&D ($60 billion), 2% is spent by federal states on space R&D ($7 billion), and 82% goes toward other R&D ($300 billion). In the early 1980s, the expenditure percentages for defense, space, and other R&D were 24%, 5%, and 70%, respectively. IN 2007, defense and space R&D fell to 16% and 2%, respectively, but other R&D (mostly commercial) jumped to 82% (Graph 3).

When patent disbursements are viewed according to character of work, it is shown that 58% of R&D funding goes toward development ($222 billion), 23% toward applied research ($80 billion), and 17% toward basic research ($65 billion). Since the 1980s, all stages have consistently increased, but considerable augmentation occurred in the developmental phase (Graph 4).

In the literature, research productivity is measured by the ratio of patents to R&D. However, in this research, R&D is our explanatory variable. Therefore, we have developed a new concept for measurement. Each year, the U.S. Patent Office reports the number of patent applications received and the number of patents issued. By dividing the latter number into the former, we are able to measure the productivity of research efforts to analyze the fourth question in the introduction section. Graph 5 is consistent with other findings in the literature (Everson, 1984, 1993; Lanjouw & Schankerman, 2004), since the ratio of patents issued to patent applications fell from 60% to 40% over the course of 27 years Clearly, the patent acceptance ratio has sharply fallen.

EMPIRICAL RESULTS

In Table 1, we consider the research funds (searching the results for the first question in the introduction). The first column shows that only industrial R&D is statistically significant. A $1 billion increase in corporate R&D is associated with an increase of 840 patents. Academic and federal R&D are not statistically significant. The major problem of the time series is the autocorrelation. Based on an OLS estimation, for a sample size of 28 and 3 explanatory variables, the critical d_L and d_U of Durbin Watson's critical values are 1.65 and 1.104, respectively. The estimated Durbin-Watson d value is shown to be 1.43, thus suggesting that there is a positive serial correlation in the residuals (since the value is less than 1.65).

For the remedial measure, in column 2 we test the regression using Newey-West (NW) heteroscedasticity and autocorrelation consistent standard errors. With Newey-West, the coefficients remain the same but the t-values change. According to NW, the t-value of the coefficient of industrial R&D has slightly increased.

In column 3, we modify the data based on the Durbin-Watson d test. We take the first difference equation and use the dependent and explanatory variables as inputs in the regression analysis. As it is noticed one number of observation is lost due to the first difference equation. The results based on the Durbin-Watson transformation are consistent with our previous findings. The industrial R&D is still statistically significant, but the strength of the coefficient falls from 840 patents to 680 patents for each billion dollars. After the modification, the Durbin-Watson d becomes 1.93, which is above the critical values.

In column 4, we test the log form of the equation. The log form is a common form in the literature, and this time none of the explanatory variables is significant. As in the linear form, there is an autocorrelation based on the Durbin-Watson d test (1.61). In column 5, we run the regression with Newey-West heteroscedasticity and autocorrelation consistent standard errors, and both the academic and industrial categories become statistically significant. However, when we use the first difference equation, the academic coefficient loses its significance. The log form result suggests that a 1% increase in industrial R&D is associated with an increase of 0.56% in patenting. Pakes (1985) found that a 1% increase in R&D expenditures will eventually lead to a 1.18% increase in patented innovations. This finding is consistent with the average fall in productivity since 1985.

In column 7, our dependent variable is patents issued/patent applications. We suggest this ratio as a productivity indicator, since patent applications can be rejected due to insufficient contribution. In column 8, we test the lag values because most contributions may come from previous R&D spending. In column 9, we test the corporate patenting. It has been claimed that the real effect of academic research is its impact on corporate patenting (Jaffe, 1989). To test the validity of this claim, we regressed our research variables on corporate patenting.

In all regressions, the industrial regressions are statistically significant. The academic and federal research fund variables are not statistically significant in terms of patenting. Kortum and Lerner (2000) found that increases in both corporate research funds and venture capital in an industry are associated with significantly higher patenting rates. Thus, a plausible explanation for Jaffe's (1989) claim is that corporations put more pressure and spend more time in pursuit of results, hence they discipline their researchers to follow the target in a timely manner. In addition, the academic world is not as competitive as the business world, so academics may work under less time pressure. Another reason might be that academics try to publish papers as a result of their work rather than merely focusing on patenting. Some research in academia may deal with basic science rather than aim toward patenting and innovation, and this is contrary to the goal of corporations. In other words, an academic research project may have a purely theoretical purpose.

Another explanation for Jaffe's (1989) claim is explored by Owen-Smith and Powell (2001). They recognize that the success rate for converting high quality basic science into commercial development changes across U.S. research universities. These researchers discuss elite private universities and big state universities in particular. Private universities combine academics with a highly successful technology transfer and licensing operation. In contrast, state universities have been less able to convert their high quality basic science, even though private and public universities have comparable numbers of researchers and spend approximately the same amount of funds on R&D. According to Owen-Smith and Powell, there are two main reasons for this. First, private universities focus more on engineering which is suited to commercialization. In contrast, state universities' research areas are less likely to develop patentable innovations. Second, the institutional environment (e.g., entrepreneurial culture) and the effectiveness of technology transfer offices differ between the two types of university.

Our empirical results show that academic funding has a weak association with patenting, but federal research funding has no link with patenting at all; this suggests that the return in terms of patenting is very low under federal funding. Federal funds can be used for a variety of different purposes. They can be dedicated for a patent buyout program to spread knowledge rather than monopolize it (Kremer, 1998). Or, to ensure the effectiveness of federal research funding, the research can be associated with patenting (payment can be adjusted based on patenting).

Tables 3, 4, 5, and 6 follow a similar regression strategy as Tables 1 and 2. In Tables 3 and 4, we consider the objectives of research (searching the answers for the second questions in the introduction). The first column shows that only other R&D is statistically significant. "Other" consists mostly of business-oriented research. Neither defense nor space R&D has any link with patenting. The estimated d value is shown to be 1.45, suggesting that there is a positive serial correlation in the residuals. For the remedial measure, in column 2 we test the regression using Newey-West heteroscedasticity and autocorrelation consistent standard errors. According to NW, the t-value of the coefficient of "other" has slightly decreased. In column 3, we modify the data based on the Durbin-Watson d test. The results based on the Durbin-Watson transformation are consistent with our previous findings. Other R&D is still statistically significant, but the strength of the coefficient fell from 4.92 to 0.63, suggesting than a $1 billion increase in other R&D is associated with an increase of 630 patents. After the modification, the Durbin-Watson d becomes 2.03, which is above the critical values.

In column 4, we test the log form of the equation. In the log form, contrary to the linear form, there is no autocorrelation based on the Durbin-Watson d test (1.71). In column 5, we run the regression with Newey-West heteroscedasticity and autocorrelation consistent standard errors. Defense R&D becomes significant with a wrong sign (negative). Hence, we cannot find statistical evidence that defense and space R&D expenditures are associated with patenting. The "other" category is still significant, suggesting that a 1% increase in other R&D is associated with an increase of 0.79% in patenting

In column 6, our dependent variable is patents issued/patent applied. In column 7 we test the lag values, and in column 8 we run the corporate patenting. Out of all of the regressions, those under the category of "other" are statistically significant.

The third research question in the introduction concerned the impact of applied R&D on patenting. In Tables 5 and 6, we consider the character of works. The first column (linear), the second column (NW), and the third column (DW) show that only development R&D is statistically significant. Our findings suggest that a $1 billion increase in development R&D is associated with an increase of 920 patents. Basic and applied R&D are not statistically significant. The log form result suggests that a 1% increase in development R&D is associated with an increase of 0.65% in patenting.

In column 7, our dependent variable is patents issued/patent applied. In column 8 we test the lag values, and in column 9 we run the corporate patenting. In all regressions, the coefficients of development are statistically significant.

CONCLUSION

We aim to answer the following four questions in this research:

1. Is all R&D spending used for patenting?
2. Do defense and space research promote commercial discoveries?
3. Is applied R&D more relevant for patenting?
4. Are R&D activities subject to diminishing returns?

As for the first question, not all R&D spending is associated with patenting. The academic and federal research fund variables are not statistically significant in terms of patenting. Our result suggests that a 1% increase in industrial R&D is associated with an increase of 0.56% in patenting. Pakes (1985) found that a 1% increase in R&D expenditures will eventually lead to a 1.18% increase in patented innovations. This finding is consistent with the average fall in productivity since 1985. Corporations put more pressure and spend more time in pursuit of results; hence they discipline their researchers to follow the target in a timely manner. The academic world is not as competitive as the business world, so academics may work under less time pressure. Another reason might be that academics try to publish papers as a result of their work rather than merely focusing on patenting. Some research in academia may deal with basic science rather than aim toward patenting and innovation, and this is contrary to the goal of corporations. In other words, an academic research project may have a purely theoretical purpose. Federal funds can be used for a variety of different purposes. They can be dedicated for a patent buyout program to spread knowledge rather than monopolize it (Kremer, 1998). Or, to ensure the effectiveness of federal research funding, the research can be associated with patenting (payment can be adjusted based on patenting).

Regarding the second question, our findings suggest that neither defense nor space R&D have an association with patenting during this time interval (1980-2007). Since business research is the main source in the "other" category, we may conclude that research for commercial purposes produces patents.

As for the third question, only development R&D is statistically significant. O that a 1% increase in development R&D is associated with an increase of 0.65% in patenting.

Regarding the fourth question, each year, the U.S. Patent Office reports the number of patent applications received and the number of patents issued. By dividing the latter number into the former, we are able to measure the productivity of research efforts. The ratio of patents issued to patent applications fell from 60% to 40% over the course of 27 years Clearly, the patent acceptance ratio has sharply fallen.

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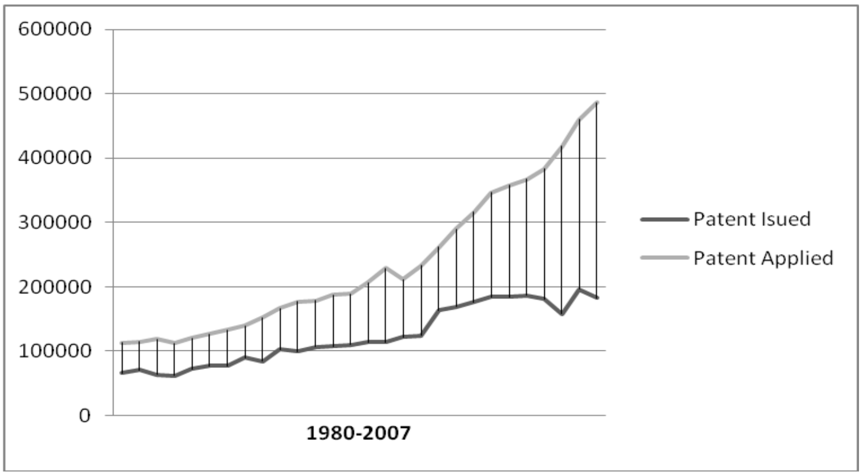
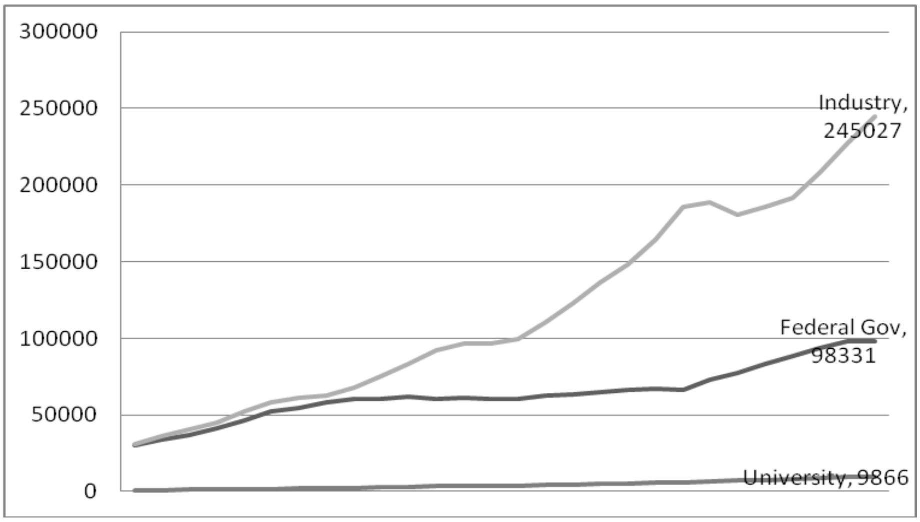
APEENDIX



Source: U.S. Patent Office (2010)

Graph 1. Patent Issued and Patent Applied



Graph 2. Research by Resource of Funds(1980-2007)

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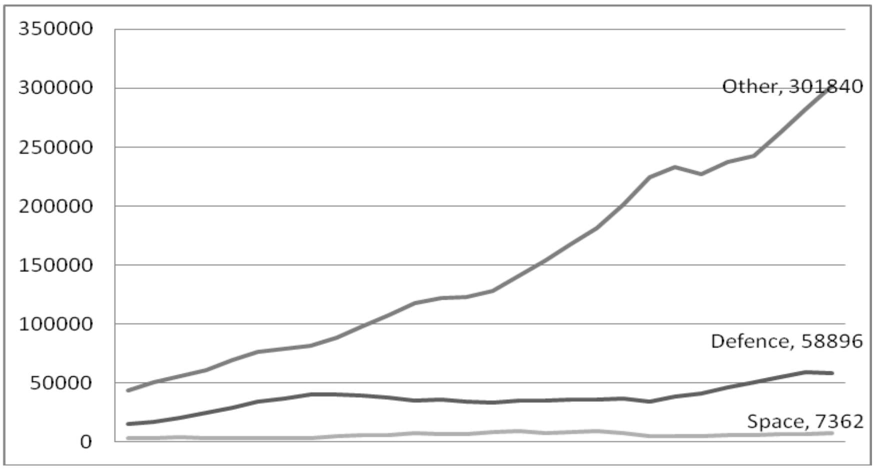
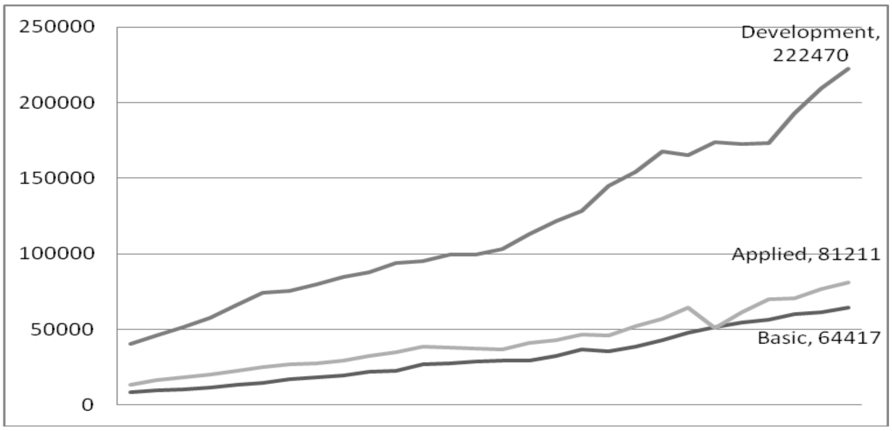
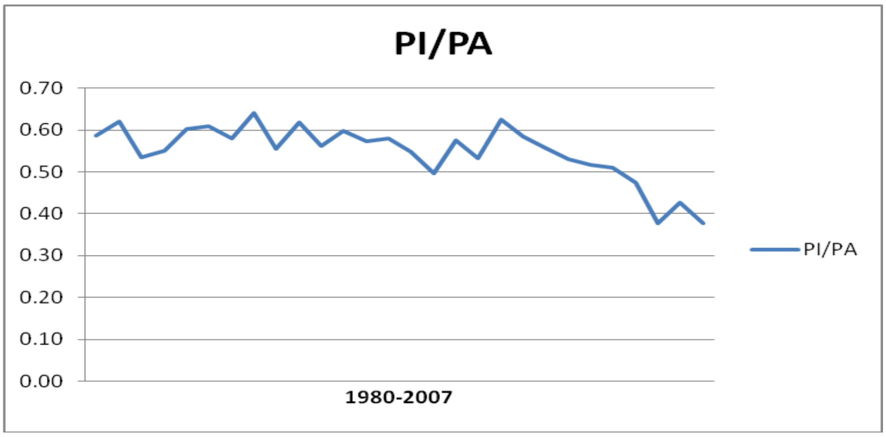


Source: U.S. Census (2010)

Graph 3. Research by Objectives (1980-2007)



Graph 4. Research by Character of Work (1980-2007)



Source: U.S. Patent Office (Total Patent Number in the U.S. is 77,793)

Graph 5. Productiviy of Patenting (1980-2007): Patent Issued/Patent Applied

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Table 1: Full Sample Regressions, Dependent Variable is Patent Issued (1-3) Patent Issued in Log Form (4-6), Patent Issued/Patent Applied (column 7)

	(1 linear)	(2 linear NW)	(3 linear DW)	(4 log)	(5 log) NW)	(6 log) DW)	(7 PI/PA)
Constant	55244*** (2.82)	55244*** (3.32)	63154. (1.85)*	9.79*** (4.29)	9.79*** (4.32)	3.52*** (3.41)	54.29*** (8.22)
Fed_R&D	-0.41 (-0.86)	-0.41 (-1.03)	-0.52 (-0.66)	-0.54 (-2.75)	-0.54 (-2.69)	0.36 (0.84)	0.00015 (0.99)
IND_R&D	0.84** (2.84)	0.84** (3.09)	0.68*** (1.71)	0.38 (1.47)	0.38* (1.82)	0.57** (1.96)	0.000261 (2.61)
ACA_R&D	-1.12 (-0.12)	-1.12 (-0.12)	2.74 (0.21)	0.42 (1.57)	0.42* (1.77)	0.079 (0.31)	-0.009146 (-3.07)
R^2	0.94	0.94	0.88	0.96	0.96	0.93	0.69
No. of obs	28	28	27	28	28	27	28
Durbin-Wattson	1.43	1.43	1.93	1.61	1.61	1.94	1.89

Table 2. Full Sample Regressions, Dependent Variable is Patent Issued (8), Corporate Patent in log form (9)

	(8)	(9)
Constant	36231.98 (2.59)	3.39 (1.19)
Fed_R&D	-0.252282 (-0.27)	-0.64 (-2.68)
IND_R&D	0.214894 (0.64)	0.75 (2.9)
ACA_R&D	-31.04420 (-1)	0.13 (0.46)
Fed_R&D (t-1)	0.289026 (0.31)	
IND_R&D (t-1)	1.238605 (5.37)	
ACA_R&D (t-1)	14.77922 (0.55)	
R^2	0.95	0.95
No. of obs	28	28
Durbin-Wattson	1.91	1.4

Note: Newey-West HAC Standard Errors & Covariance (lag truncation=2)

Table 3. Full Sample Regressions, Dependent Variable is Patent Issued (1-3), Patent Issued in log form (4-5) Patent Issued/Patent Applied in log form (column 6)

	(1)	(2)	(3)	(4)	(5)	(6)
Constant	-0.71*** (4.92)	-0.71*** (4.23)	55636 (3.39)	5.3 (9.15)	5.3 (9.15)***	185.7358 (2.68)
Defense R&D	0.36 (-2)**	0.36 (-1.7)	-0.76 (-1.48)	-0.23 (-2.84)***	-0.23 (-2.73)***	-6.45 (-0.76)
SPACE_R&D	0.64 (0.24)	0.64 (0.3)	0.29 (0.16)	-0.064 (-1.07)	-0.064 (-1.25)	2.11 (0.65)
OTHER_R&D	4.92 (12.44)	4.92 (10)	0.63 (9.1)***	0.791 (14.86)	0.791 (14.64)***	-8.23 (-1.55)
R2	0.94	0.94	0.89	0.96	0.96	0.382

Table 3. Full Sample Regressions, Dependent Variable is Patent Issued (1-3), Patent Issued in log form (4-5) Patent Issued/Patent Applied in log form (column 6) (Contd.…)

	(1)	(2)	(3)	(4)	(5)	(6)
No. of obs	28	28	27	28	28	27
Durbin - Wattson	1.45	1.45	2.03	1.71	1.71	1.89

Table 4. Full Sample Regressions, Dependent Variable is Patent Issued (8), Corporate Patent in log form (9)

	(7)	(8)
Constant	55818 (5.75)	0.81 (1.68)
Defense R&D	-1.47 (-1.51)	-0.37 (-5.43)
SPACE_R&D	-1.49 (-0.95)	-0.14 (-3.1)
OTHER_R&D	-0.09 (-0.28)	0.89 (21.56116)
Defense R&D (t-1)	0.76 (0.67)	
SPACE_R&D (t-1)	1.91 (0.87)	
OTHER_R&D (t-1)	0.76 (2.53)	
R^2	0.95	0.96
No. of obs	27	28
Durbin-Wattson	1.758	2.05

Note: Newey-West HAC Standard Errors & Covariance (lag truncation=2)

Table 5. Full Sample Regressions, Dependent Variable is Patent Issued (1-6),

	(1)	(2)	(3)	(4)	(5)	(6)
Constant	-22099 (3.29)***	220996 (3.042)***	23142 (1.89)	4.0 (3.66)	4.016 (2.38)***	2.762830 (2.12)
Basic R&D	-0.032 (-0.25)	-0.032 (-0.24)	0.44 (0.37)	0.48 (1.86)	0.48 (1.46)***	0.189375 (0.69)
Applied R&D	-0.51 (-0.66)	-0.51 (-1.02)	-0.1 (-0.51)	-0.52 (1.55)	-0.52 (-1.75)	-0.057826 (-0.19)
Develop-ment R&D	1.1 (3.38)***	1.1 (3.89)***	0.92 (2.16)***	0.7 (2.16)**	0.709 (1.922374)**	0.655522 (2.07)
R^2	0.95	0.92	0.85	0.94	0.94	0.9
No. of obs	27	28	27	28	28	27
Durbin-Wattson	1.41	1.28	1.99	1.36	1.36	2.01

Table 6. Full Sample Regressions, Patent Issued/Patent Applied (column 7), Dependent Variable is Patent Issued (8), Corporate Patent in log form (9)

	(7)	(8)	(9)
Constant	63.48 (16.21)	20013.46 (1.490916)	22099.16 (3.042)
Basic R&	-0.000505 (1.3)	-2.38 (-1.1)	-0.032053 (-0.24)
Applied R&D	-0.000141 (-0.51)	-1.39 (-2.89)	-0.510339 (-1.02)
Development R&D	0.000114 (0.96)	-0.00095 (-0.0027)	1.103956 (3.89)
Basic R&D (t-1)		1.884 (1.18)	
Applied R&D (t-1)	0.53	-0.93 (-1.19)	
Development R&D(t-1)	27	1.96 (5.25)***	
R^2	2.03	0.95	0.92
No. of obs		27	28
Durbin-Wattson		1.41	1.16

Note: Newey-West HAC Standard Errors & Covariance (lag truncation=3)