Birth of a Patent: The Role of Parents, Nursemaids and Constraints[*]

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Abstract:
Recent empirical and theoretical analyses challenge the presumption that either patents or R&D expenditures are reasonable indicators of innovation. This paper presents an integrated theoretical and empirical approach that models the effects of different sources of R&D funding and patent office attributes on the patenting process. Another important contribution is modeling the effect of a random delay in the 'pendency' time as a stochastic process and analyzing its effect on patenting. The empirical estimation is based on four major industries – electronics, chemical and biology, transportation and aeronautics – for the time period 1976-1995. The primary results are: First, the source of R&D funding as well as performer (academic, federal and industry) has a differential effect on patenting. Second, federal R&D has positive spillovers for company R&D. Third, in the short run patenting is heavily influenced by patent office attributes. The results contribute to a better understanding of the shortcomings in the formulation of science indicators. In addition they suggest that the comparative advantage of federal R&D funds lie in improving patent office efficiency, playing nursemaid to company research programs, providing financial resources to university research programs, all of which serve to increase innovative capacity of society.

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INTRODUCTION

Patents have often been used as a proxy for innovations. As a metric for inventive activity, they are far from perfect (Griliches, 1989, Cockburn & Griliches, 1988). Not only are the two influenced by different factors, but different industries have different propensities to patent. Also, within the same industry, different patents have different values. Thus both inter-industry and intra-industry comparisons are fraught with difficulty (Cohen & Levin, 1989; Scherer, 1983). In this paper I attempt to disaggregate the patenting process and look inside the 'black box' to gain a better understanding of what affects the number of corporate patents granted in the U.S.

The complex nature of the patent data, make any clear-cut conclusions difficult. Problems in interpreting the data stem from a number of factors. First, patent application and patent grants do not always follow the same trend. Grants are heavily influenced by the inefficiencies and constraints of the US patent and Trademark Office (USPTO) (Griliches,1989) Second, fluctuations in R&D affect patents, but less than proportionately (Griliches, 1989). Third, current patent applications are strongly correlated with current R&D (Pakes, 1985). Fourth, R&D is not a homogeneous activity and there are substantial differences between the determinants of process and product patents (Lunn, 1986). All these factors make it really difficult to interpret the actual linkage between patents and R&D. Care must be taken to control for these factors when attempting to model this complex relationship.

An important factor determining the rate of innovation, and thus patenting, in a given industry is the level of R&D expenditures. The source through which R&D activities are funded have different impacts on the productivity of innovations and hence the number of patents. Generally, econometric studies have failed to find significant direct productivity effects of federal R&D, whereas company R&D, both past and current, is highly significant. This has led some researchers to hypothesize that the effect of federal R&D on productivity works through indirect channels (Mansfield and Switzer,1984; Lichtenberg,1984, 1987, 1988). Also, research in universities contributes positively to productivity as measured by the number of domestic patent applications (Blumental,1986; Cohen et al., 1997; Feller et al.,1998; Griliches, 1989; Jaffe, 1989; Klevorick 1994; Mansfield (1991); Mowery, 1997; Nelson, 1986;)

The relationship between market concentration, firm size, R&D and innovation is also ambiguous[1]. The Schumpeterian paradigm claims that market concentration reduces uncertainty and thus provides the cash flow required to conduct costly research. The opposite side of this claim has been fueled by Arrow's argument (1962) that a monopolist has less incentive to innovate than is socially optimal. Although a monopolist threatened with entry may behave differently. The empirical evidence on the relationship between concentration and innovation is also inconclusive (Mansfield, 1963, 1968[2]; Scherer, 1965; Williamson, 1965). Unlike the relation between concentration and innovation, there is no controversy about the positive link between firm size, R&D and innovation (Cohen & Levin, 1989; Schmookler, 1972). My model also sheds some light in this regard.

Thus, several salient facts about R&D funding and the nature of patenting need to be considered when formulating any model of corporate patenting activity. First, there is no one to one relationship between innovations and R&D. Second, past and present company R&D has a strong positive influence on corporate patenting activity. Third, federal funding of R&D in the industries does not seem to have any direct influence on patenting. Rather, it influences patents through spillovers. Fourth, university R&D has strong positive spillovers regarding corporate

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[1] For a detailed analysis please refer to Kamien & Scwartz: "Market Structure and Innovation: A Survey", in the Journal of Economc Literature, 1975, vol. 13, no. 1, pp. 1 – 37.

[2] (1963) The author found that during 1919-58 in petroleum refining and bituminous coal the largest four firms did most of the innovating, but this was not true for the steel industry. Thus it is not always the case that the largest firms are the greatest innovators.

patenting. There is evidence of geographic spillovers when industry and university are co-located. Fifth, patenting is influenced by other factors like, market conditions, size and structure of the industry, resources at the patent office, patent fees and law changes that alter the length or breadth of patent protection

With this in mind, the theoretical model incorporates industry characteristics, different types of R&D and US Patent Office variables in explaining corporate patenting. Some important contributions of this paper are to look at the direct and spillover effects of federal R&D on patenting, the importance of past versus present company R&D, the effect of academic R&D, the influence of market structures, US Patent Office resources as determinants of the number of patents granted and the effect of delays in pendency time on patenting by industries. Four major R&D industries, electronics, chemicals and biology, transportation and aeronautics are studied.

SECTION 2: THEORETICAL MODEL

The main purpose of this model is to study the effects of various factors on corporate patenting. Inter-firm rivalry and patent races between firms within the industry is ignored and the number of firms in the industry is normalized to one. The process of obtaining a patent can be broken down into two parts. The first stage deals with actual inventions and innovations. At the end of this stage we observe a number of inventions, each with a different value. The second stage deals with patenting that invention. This involves the application for a patent, the waiting period at the patent office (USPTO) and finally the approval or rejection of the patent application. This model tries to combine the flavors of several earlier works in the literature (Griliches, 1986, 1988, 1989, 1990 & Jaffe, 1986, 1989) and presents a unified approach.

In the first stage, the industry invests in R&D with the aim producing inventions and innovations. The innovations may be cost reducing or quality enhancing, or the industry may discover a new product or process altogether. The objective function of the industry is to maximize the value of the innovations it produces. We assume that each industry engages in 'n' projects, each of which will yield an invention. Thus, inventions can be modeled as a function of the following variables:

$$N_{kt} = f(CRD_{kt}, CRD_{k,t-s}, FRD_{k,t-s}, URD_{kt}, SP_{kt}) \tag{1}$$

where: N =1,…n, and denotes the number of inventions. k denotes the industry and t denotes the time period. CRD_{kt} is the flow of company R&D, i.e. the funds that are invested in R&D from the industry's own resources. FRD_{kt} is that part of total R&D funding in the industry, that is paid for by the federal government. URD_{kt} is the university performed R&D in that industrial category. SP_{kt} is the spillover that the industry receives from past federal R&D and other knowledge spillovers.

Each project N=1,…n, results in an invention. Each invention has a commercial value (V_N) between 0 and ∞, i.e. $V_N \sim [0, \infty)$. In principle, V_N reflects the fact that there is heterogeneity in the value of inventions. The uncertainty in the invention process is reflected by the fact that exante the firm does not know the exact value of the invention that is going to result as a product of R&D investment. It only knows the distribution of values – an exponential in this case.

The Shumpeterian hypothesis of the 'scale effect' and the 'market power effect' are incorporated as shift parameters in this value function. The first effect says that the bigger the firm's market (measured by SIZE) and more diverse the firm's operations, the more inventions it is going to make. The second effect says that the more market power a firm has, (-COMP) the lesser the R&D and inventions. I assume that more inventions (due to a larger market size) mean a higher average value of inventions per se, and that the average value of inventions are greater in a more competitive industry. Thus SIZE denotes the scale of operation, or how ‘big’ the industry is. COMP reflects how competitive the industry is – the more the competition, the less the market power. Thus the density function of V_N is given by:

$$f(V_N) = (COMP_{k,t-r}^{\lambda} * SIZE_{kt}^{\rho}).\frac{1}{b}e^{-V_N/b} \tag{2}$$

where: ‘b’ is the mean and variance of the exponential distribution.

The industry applies for a patent if $E(V_N) > E(C_{kt})$, i.e. the expected cost of patenting (C_{kt}) is less than the expected value of the invention (V_N). We assume that if the industry applies for the patent, it gets the patent with probability one[3]. Therefore the industry obtains the patent if:

$$prob[V_N \geq C_{kt}] = (COMP_{k,t-r}^{\lambda} * SIZE_{kt}^{\rho}).\frac{1}{b}\int_{C_{kt}}^{\infty} e^{-V_N/b}\,dx \tag{3}$$

Therefore, from equation (1) and (3), the expected number of patents in year t is:

$$P_{kt} = \frac{1}{b}N_{kt}.(COMP_{k,t-r}^{\lambda} * SIZE_{kt}^{\rho}).e^{-C_{kt}/b} \tag{4}$$

Section 2.1: Patent Production and Cost Functions

There are two alternative invention production functions that can be studied. One is the more traditional Cobb-Douglas production function that has been studied thoroughly in the literature.

$$N_{kt} = A(CRD_{k,t-s}^{\delta 1}FRD_{k,t-s}^{\delta 2}URD_{kt}^{\delta 3}) \tag{5}$$

The other is a formulation that tries to model the spillovers more directly. I shall outline both model below.

$$N_{kt} = \alpha.CRD_{kt}^{[\beta_k + \gamma_k FRD_{k,t-s}]}URD_{kt} \tag{6}$$

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[3] To simply one layer of the problem, I assume that all patents that are applied for are granted.

where: N is the number of inventions in industry k in year t, A is the technological constant and $\Sigma\delta_i = 1$, i = 1,…3. The FRD term can either be lagged federal R&D or alternatively it can be defined as a spillover term (SP_{kt}).

In recent patent literature, a common finding is that current R&D is significantly correlated with current patent applications (Jaffe, 1986). This cannot be explained by the production function approach because current R&D is not an input for the patents that are being currently issued. The spillover model links current company R&D to current patents. A tentative explanation for this high correlation is given by the fact that a huge amount of money is spent on developing a product once the patents have been issued.

Let the cost of getting a patent be denoted by:

$$C_{kt} = \phi L_t + \varphi T_{kt} + \theta D_t \tag{7}$$

where: L_t is the law change variable. T_{kt} is the commercialization cost of the invention that the industry has to incur. This constitutes the time between the invention happening and the firm actually applying for a patent. This involves the time that goes into researching the 'newness' of the invention before applying for the patent and also other monetary costs. I assume that as the industry gets more competitive, the time between an innovation and patent application decreases.

D_t reflects the time that the firms expects the USPTO to take to process an application. It is the time between application of a patent and its issue or abandonment. This delay at the USPTO has two parts – a deterministic part already known to the firm before patent application, and a random component. The deterministic part (D^d_t) is termed as the 'pendency time'.It depends on patent office resources, which may include variables like funds at USPTO, number of patent professionals, the degree of automation, the patent processing cost to USPTO income ratio to name a few. D_r denotes the random non-recurrent delay. These are random shocks in the patent office budgeting that result in sudden increases of the pendency time. I shall assume two alternative distributions for the random part of the patent office delay. These are the uniform distribution and the exponential distribution.

Let us first assume that the random delay follows a uniform distribution. This means that there is equal probability of a large and a small random delay. The distribution is defined for the domain [0, D_m]. The probability density function is given by[4]:

$$\begin{aligned} f(D_t^r) &= \frac{1}{D_m} && \text{for} \quad 0 \le D_m \le \infty \\ &= 0 && \text{otherwise} \end{aligned}$$

Therefore the expected cost of patenting (EC_{kt}) is:

$$EC_{kt} = \phi L_t + \varphi T_t + \theta D_t^d + \frac{\theta D_m}{2} \tag{8}$$

Now suppose that D_r follows an exponential distribution. This implies that the probability of a larger delay is less than that of a smaller delay. The probability density function is given as[5]:

$$f(D_t^r) = \frac{1}{a} e^{(-D_t^r/a)}$$

Assuming D_r>0 to guarantee an interior solution, the expected cost of patenting is given by:

$$EC_{kt} = \phi L_t + \varphi\, T_{kt} + \theta\, D_t^d - \theta a \tag{9}$$

Now we have four alternative specifications of the model : (a) Cobb-Douglas production function and D_t^r has a uniform distribution, (b) Cobb-Douglas production function and D_t^r has an exponential distribution, (c)Spillover production function and D_t^r has a uniform distribution and (d) Spillover production function and D_t^r has an exponential distribution.

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[4] The mean is ½.D_m and the standard deviation is $D_m/\sqrt{12}$.

SECTION 3: DATA DESCRIPTION

This section briefly outlines the data that has been used to test the theoretical model. The US data is obtained mainly from two sources. The R&D data for the various industries is obtained from the from the Science and Engineering Indicators (1990 -1996) survey that is published by the NSF. The patent office data is obtained from the US Patent and Trademark Office (PTO). The patent grants in each sector were collected from the online database. The figures about the PTO costs, fees, number of examiners, etc. were obtained from the Annual Report of the Commissioner of Patents and Trademark Office (1976-1996).

The total state-wise industrial R&D, federal R&D funding to industry and university funding data is for alternate years from 1981 to 1995 for the top ten R&D performing states. But this was not broken down by industry. We could only obtain industry specific data for each of the top ten R&D performing states for two years, 1985 and 1995. The following section gives an explanation of the variables used in the empirical estimation. The variables are divided to two sections - the US Patent Office variables and the industry specific variables.

Section 3.1: Patent Office Variables

The dependent variable in the model is log of patents. Patents refer to the number of patents issued by the USPTO to domestic (US) inventors in various categories. For the US data set I use 'inventor-state' as my primary search parameter[6]. As a check of robustness of my results I also use the 'assignee-state' patent data. Table 1 gives a brief summary of the 'patents' variable. Figure 1(a) shows the overall US patent application and issue. It illustrates that while

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[5] The parameter 'a' is the mean and standard deviation of the distribution.

[6] A very important point that should be noted, is the difference between the search parameters by which data was gathered from the patent office. Currently, the USPTO allows a search by either the 'inventor-state' or the 'assignee-state'. These two searches yield dramatically different results. Doing the search by 'assignee-state' understates the amount of inventive activity going on in the US.

patent applications have risen dramatically over the years, the increase in patent issue has been more gradual. The next figure shows the total number of assigned to each state. It shows that other than California, the patent issues have not risen dramatically over the years. Most states show a moderate increase in the number of patents. New Jersey and Ohio show a slight fall in the patent numbers.

For the purposes of this paper, I study four industrial categories – electronics, chemicals/biology, transportation and aeronautics. For detailed sub-classes and exact class codes used by the PTO, please refer to the data appendix. Figure 2 shows the industry specific patent issue. Electronics and chemicals are the high patenting industries. The average patent numbers are much lower for the transportation and aeronautics industry. All four industries show a dip in patents around 1979. Patents issue again rises from 1983.

Patent fee (FEE) is the sum of the filing fee, issuance fee, about 3 independent claim in excess of 3, 1 disclaimer fee, extension fee (sum of 3 petitions), one revival fee, recording fee including printing and total maintenance fee the life for the life an utility patent[7]. It should be noted this is just the official cost of filing a patent. The actual patent process cost (including attorney fees) that firms face is much greater, often running into millions of dollars.

The pendency time is the time that elapses between the application for a patent and its issuance and abandonment. This is a variable that is intricately linked with the resources at the USPTO. Figure 3 illustrates that more resources and more patent examiners mean a shorter pendency time. Before 1982, resources and the number of patent professionals were relatively constant. This, coupled with the increasing number of applications, increased the pendency time. After 1982 both the net funding of the USPTO and the number of patent professionals rose steadily. The pendency time peaked at 1983 and has been falling steadily after that. There was a slight increase in the pendency time around 1991[8].

In the time frame under consideration, there have been two major law changes that have affected the fees collected by the PTO. The first dealt with fee increases[9] and the other altered PTO funding sources. The 1981 law required that the PTO set fees at a rate that will recover 50 percent of the patent process cost, 50 percent of the trademark processing cost and 100 percent of the cost of all other PTO services[10]. This led to a substantial increase in fees in 1981. A dummy variable was used to account for this law change. Another dummy (year 1990 and later set equal to1) was used for the law change that was brought about by "The Omnibus Reconciliation Act of 1990" (Budget Act – Public Law 101-508). This hiked PTO fees by 69 percent and converted the USPTO from a partially user-fee funded agency to an almost fully user-fee funded agency[11].

Section 3.2: Industry Specific Variables

Total, Federal & Company R&D figures are obtained from the Science and Engineering Indicators[12]. The industries were selected based on their SIC codes as seen from the table 2(A). Federal R&D implies the federally funded industry performed R&D funds and company R&D implies industry funded and industry performed R&D. From figure 4, we can observe that

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[7] For the period under consideration, it was 17 years and it was measured from the date of issue. In the recent past a law change has changed the life of the patent to 20 years. But it will be measured from the time of application and not issue.

[8] Although, the pendency time varies by the type of patents, for this paper, I deal with the average pendency time of utility patents.

[9] Before, 1981, the fees charged by the office had been inflexibly set by statute. Patent fees had no changed since 1965 and had declined continuously compared to operating costs.

[10](Public Law 96-517). This provision applied : "Except in the case of design patents, the 50 percent of the patent processing cost will be made up from fees recovering 25 percent of application processing cost and 25 percent of maintenance costs." (Report of the Commissioner of Patents and Trademarks, 1981).

[11] This eliminated public funding for the PTO. This was done in order to produce savings in the federal budget deficit. This was formalized by the "Patent and Trademark Office Authorization Act of 1991".

aeronautics R&D peaked in the mid-eighties mainly due to an enormous increase in federal funding. Total chemical and electronics R&D rose mainly due to an increase in company R&D funding. In these sectors federal R&D funding fell precipitously after the mid-eighties. Transportation shows a mixed trend. A detailed industry specific R&D graph with the funding sources is illustrated in figures 5(a) – (d).

For the US data, there are three ways that the spillover term is constructed. For the Cobb-Douglas model it is an interaction between company R&D and stock of federal R&D both lagged by 4 years. For the spillover model, it is an interaction between federal R&D stock or lagged federal R&D and log(current company R&D). For the state model, the two spillover terms are (i) an interaction between federal intramural R&D stock[13] and total industrial R&D and (ii) an interaction term between the stock of federally funded industrial R&D and current company funded industrial R&D.

The academic R&D funds (university performed R&D) show the total amount of money that the universities and colleges spend in various academic fields[14]. The source of these funds may be federal, company or the university's own resources. Table 2(B) shows the classification of various academic disciplines under the four broad industrial categories. The classification

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[12] 1989(table 6-3, 6-4 & 6-5), 1993 (4-31. 4-32 & 4-33), 1998(table at-04-20...21) (1971.'73 are interpolated). The figures were originally in millions of current dollars. They have been converted to thousands of 1992 dollars using the GDP implicit price deflator (base year 1992 = 100).

[13] The stock of federal R&D is constructed by the following formula:

$FRDSTK_{kt} = FRD_{kt} + FRD_{k, t-1}/(1+r) + + FRD_{k, t-2}/(1+r)^2 + \dots\dots\dots\dots + FRD_{k, t-m}/(1+r)^m$

Here k denotes the industry and t denotes the time period. M is set to 6, for the US data. It was the largest possible value that allowed me to estimate the federal stock over the entire period 1976-1995. For the state data M is set to 4 for lack of detailed historical data. Here r is the depreciation rate of federal R&D and its value is 0.12 following Nadiri and Purcha's report of the social rate of depreciation of R&D capital (1996).

[14] There was a missing data problem in the academia performed R&D. Some years were not reported by the NSF because of confidentiality reasons. Below I outline the procedure undertaken to solve this problem. Materials Engineering : Roughly the share of this class in total engineering R&D is between 10.5 - 9.3% between the period 1990-1998. Therefore we take the average of this number (9.9%) and extrapolate the R&D figures between 1980-1990. Thus the 'other eng' figures also change. They are constructed as (1980-1990) [Total R&D in that class - sum(all 5 subclasses)]. The table below shows the average shares of the various subclasses in the engineering section between 1980-1996. I use this to back-cast the years 1976-1979. The 'other eng' figures are the difference between total and the sum of the 5 subclasses.

loosely follows the classification by Jaffe(1989). Figure 6(a) and (b) show the amount of R&D dollars that the universities spend in each industrial sector. It shows that expenditure in the chemical/biology sector and the transportation fields have doubled between 1984 and 1994. Electronics and aeronautics R&D spending have increased gradually.

For the US data, I use several proxies to control for the size of the industry[15]. In theory, size can measured in several ways. The number of firms in the industry, the amount of output or value added and the total employment in the sector can all be used to proxy size. In this paper, I use three measures alternative measures for size – all of which yield essentially the same result[16]. First, I use the annual estimates of gross output by detailed industry for 1976-95[17]. Gross output represents the market value of an industry's production, including commodity taxes, and it differs from GPO, which represents an industry's contribution to GDP[18]. Second I use the share of GDP that is attributed to each industry for the same period. This is the traditional 'value added' measure. Third, I use the total employment in the different industries to serve as a proxy for size. For the state data I use the industrial gross state product as a share of US GDP. This is done to control for the differing industrial sector sizes in the various states.

The competitive term a proxy for how private the industry is in terms of its R&D funding This term is defined as follows:

$$COMP_{k,t-s} = 1 - FEDSH_{k,t-s} \qquad\qquad 0 \le COMP_{k,t-s} \le 1$$

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[15] This is important because the electronics and chemical/biology and transportation group are taken to be the 2 digit SIC code industry, aeronautics has a 3 digit codes. In the case of patent classes, electronics and chemicals form the main categories, whereas transportation and aeronautics are just small subclasses. For both the industrial and patent classification, aeronautics is a part of the transportation category. To avoid double counting, the aeronautics figures are subtracted from the total transportation figures to arrive at the numbers for the transportation class.

[16] Total employment works a little better than the other measures.

[17] The 1977-95 figures are obtained from the Bureau of Economic Analysis data on Industry (Series Go7787 & Go7797). (The 1976 figures are extrapolated).

[18] The aeronautics class contains some extra SIC codes other than 372 and 376. Since there was no precise aeronautics class in the table, I have proxied it by the 'other transportation equipment' class. This increases the size of gross output, but the effect on industry size is minor.

where: FEDSH denotes the share of federal R&D in that industry in a year. It shows how private the industry is. In terms of this measure, the chemical industry is the most private in terms of R&D. Competition in the electronics industry has been increasing since the nineties. Aeronautics is the least competitive. The next section deals with the estimation results.

SECTION 4: ESTIMATION RESULTS

Section 4.1: US Results

This section presents the estimation results obtained from the two models outlined earlier in the paper. I estimate two reduced form regression models. The first relates current patents (P_{kt}) to lagged company R&D ($CRD_{k,t-s}$), lagged federal R&D or spillover from federal R&D ($FRD_{k,t-s}$), lagged academic R&D ($URD_{k,t-s}$), competitiveness ($COMP_{kt-r}$), size ($SIZE_{kt}$), law change (L_t) and deterministic and random pedency times (D^d_t, a). The specific form used is given by:

$$\begin{aligned}\log P_{kt} &= \log(\frac{A}{b}) + \beta_1 \log CRD_{k,t-s} + \beta_2 \log FRD_{k,t-s} + \beta_3 \log URD_{kt} \\ &\quad + \gamma_1 \log COMP_{k,t-r} + \gamma_2 \log SIZE_{kt} - \frac{\phi}{b} L_t - \frac{\theta}{b} D^d_t - \frac{\theta a}{b} + \varepsilon_{kt} \qquad (10)\end{aligned}$$

The difference in the second model is that it relates current patents, to current company R&D, and spillover from federal R&D ($FRD_{k,t-s}$ * log(CRD_{kt})).The specific form used is given by:

$$\begin{aligned}\log P_{kt} &= \log\alpha + \delta_1 \log CRD_{kt} + \delta_2 (FRD_{k,t-s}.\log(CRD_{kt})) + \delta_3 \log URD_{kt} \\ &\quad + \lambda_1 \log COMP_{k,t-r} + \lambda_2 \log SIZE_{kt} - \frac{\phi}{b} L_t - \frac{\theta}{b} D^d_t + \frac{\theta a}{b} + \varepsilon_{kt} \qquad (11)\end{aligned}$$

The error component is assumed to be: $\varepsilon_{kt} = \delta_k + \varepsilon'_{kt}$, where δ_k is the industry specific random component and ε'_{kt} is the idiosyncratic error. I use an error components model to estimate these equations.

For the purposes of econometric estimation certain modifications had to be made to the theoretical model. As we observe, all the patent office variables could not be used. For the law change variable, the dummy for 1981, dummy for 1991 and fee, all turned out to be highly collinear. Thus, I use the dummy for 1990 because it heralded one of the biggest law changes coupled with a fee increase. The variable (T_{kt}) that denoted the time between invention and patent application within a firm was dropped due to lack of available data. The 'number of employees in the industry' is used to measure industry size. The choice of the lag structure was determined by the timing of decisions taken by the firm. Models using both the exponential random delay and the uniform random delay were estimated. Exponential random delay was used in all the models.[19] as the exponential function seems to be a better mirror of reality[20]. The results for the 4 month delay are presented in the paper.

Section 4.1.1: CobbDouglas Model

Model 1 in Table 3(A) outlines a Cobb-Douglas type production function approach to patents (equation 10). It explains how inputs such as different types of R&D are turned into output, i.e. patents. It also shows how factors such as market conditions affect the production. The choice of lag structure is influenced by the production process timing. The application for the patents being issued today must have been made about one and a half or two years earlier (as seen from the pendency time). Plus the product must have been under research for at least one or

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[19] The uniform distribution says that a longer delay and a shorter delay are equi-probable. But the exponential function says that the occurrence of a shorter delay is greater than that of a longer delay.

[20] I estimated the model for random delays of 2, 4 6 and 8 months. The coefficients of the other regressors did not change sign or significance in the process.

two years. Thus a lag of 4 years has been imposed on the R&D figures. The ‘competition’ variable has a two year lag on it. The reason is that market conditions during the time of application for a patent determine the expected value of the patent.

There are two different versions of this model. The first uses lagged federal R&D as one of the regressors (i(a) & ii(a)). The second uses a spillover term instead of the federal R&D directly (i(b) & ii(b)). This second proposition tries to test, the often asserted hypothesis, that although federal R&D is not very productive by itself, its productivity lies elsewhere. It is assumed that it plays nursemaid to company R&D and helps to increase its productivity through spillovers. These alternatives are estimated to see whether federal R&D directly affects the number of patents or whether it influences the number of patents through positive spillovers.

As seen from Table 3(A) - the difference between the two models i(a) and i(b), lies in their treatment of federal R&D. Model i(a) has a 4 year lagged federal R&D as a regressor. The coefficient is significant at the 15 percent level. So there is very weak evidence that federal R&D directly contributes to patenting in the four industries under consideration. Model i(b) tests whether federal R&D works more through spillovers than through direct channels. The spillover function is an interaction term[21] between federal R&D stock (lagged 4 years) and company R&D (lagged 4 years). But I fail to find any evidence of such spillovers. The coefficient, though positive, is not significant and is even weaker than the direct effect. Therefore it seems that federal R&D does not have any spillovers on contemporaneous company R&D.

The other coefficients from model i(a) & i(b) are not significantly different from each other. Lagged company R&D is positive and strongly significant. This implies that company R&D is one of the major determinants of the number of patents an industry obtains. Current university R&D is also positive and significant at the 1 percent level. Universities spend more money in those fields where technological opportunities are the greatest. Thus, this could be interpreted as a variable that reflects the current technological opportunity in the industry. The R&D variables are singly and jointly significant.

The size variable is positive and significant, lending support to the hypothesis that bigger the size of the industry the more inventions it makes. The 'competition' variable is positive and significant implying that the less federal 'soft funds' a firm has to fall back on, the more inventions it makes, as evidenced from the patents. The law change dummy (for the Omnibus Act, 1990) is highly significant in both the models. Two changes took place under the Omnibus Act. On one hand, the USPTO was converted from a government funded to a user-fee funded organization. This may have made the USPTO more efficient and had a positive effect on patenting. On the other, patent fees went up. This should have had a negative effect on patenting. But the coefficient on the law change dummy is positive. This implies that after the Omnibus Act of 1990 the number of patents issued increased. This in turn may imply that turning the USPTO into a fully user-fee funded organization may have increased its efficiency.

The 'pendency time' variable is significant and negative. The greater the delay in processing a patent, the lesser the number of patents issued. This supports Griliches's claim (Griliches, 1989) that in the short-run patents are very heavily affected by patent office variables. Another interesting observation that emerges from these models is that, not only does the actual pendency time matter, but the random variance also has a significant negative effect (at the 10 percent level) on patenting. This is important because so far none of the papers on patents have focussed on how such random delays at the USPTO affects patenting.

Comparing the models we find that the coefficient of company R&D is lower when the dependent variable is patents issued by assignee state. This is expected as the 'patents by

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[21] Spillover = FEDSTK (k, t-4) * CRD (k, t-4)

assignee state' numbers are smaller than the 'patents by inventor state', and so using the former would introduce a downward bias in the estimates. But the federal, spillover and university R&D coefficients are higher. But none of the coefficients are significantly different from each other. Thus using either measure of patent counts give approximately the same results and proves the robustness of the model.

Section 4.1.2: Spillover Model

The second model (Table 3(B)) attempts to directly capture the spillover from federal R&D. This model explores the relationship between current company R&D, federal R&D spillovers and patents. The spillover term in this model captures the effect of past federal R&D on current company R&D - unlike the spillover in the basic model[22], In this model the spillover term is constructed in two different ways to test the robustness of the specification.

$$(a) \qquad SPILL1_{kt} = FRD_{k,t-4} * \log(CRD_{kt})$$

$$(b) \qquad SPILL2_{kt} = FRDSTK_{k,t-4} * \log(CRD_{kt})$$

From Table 3(B) models i(a) &(b) I find that current company R&D, the spillover terms, university R&D, competitive term and the law change dummy are all positive and significant. The pendency time coefficient is negative and significant. The random delay coefficient is negative but not significant. When two different dependent variables are used (model (i) v/s model (ii)), the results are not significantly different. Most of the coefficients are singly and jointly significant. Comparing Tables 3(A) and 3(B) three things attract attention. First, current R&D has a much more stronger effect on patents than past R&D. Jaffe(1986) also noted this correlation between current R&D and patents. A plausible explanation for this strong correlation may be the huge sums of money that is needed to develop a product and make it commercially viable once the patent is granted. Second, the spillover term is much stronger in model 2 than in model 1. From the way the spillover terms are constructed in the two models, the estimation results suggest several things. First, although federal R&D has no significant spillover on contemporaneous company R&D, past federal R&D has significant positive spillover on current company R&D. Second, this spillover effect from past federal R&D positively affects the number of patents in the industry. Last, past federal R&D stock has a stronger spillover effect than past federal R&D flow.

Section 4.2: State Results

The state analysis is done for the top ten R&D states in the US. Between them, these states accounted for 64 percent of the total US R&D and 62 percent of the issued patents in 1995. In the US data, the main purpose of the models was to explain what drives patenting in the United States. For the state data I ask a slightly different question - how do the state share of patents change when various factors change. Therefore the dependent variable in the state models is the share of patents in each state. All the independent variables are also in shares. It is interesting to study the state shares because it gives us an idea about the how and why the relative position of the states change. This model does not distinguish between the various industries[23]. Therefore, unlike the US model all patents assigned to the state are taken into account (not just the industry ones). Therefore, I introduce another explanatory variable in this model – federal R&D funding going to intramural performers. Figure 7 shows how the share of patents has changed for each state over the years.

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[22] The interaction between federal and company R&D were contemporaneous in the basic model.

[23] This is due to severe data constraint. The state-wise breakdown of R&D funding by industry is extremely hard to come by.

Table 4 gives the results of the basic state-share model. I estimate three alternative specifications of the model. The common coefficients are robust to different specification. For all the five models, the share of industrial GSP in the state is significant at the 5% level. This implies that larger the size of the industrial sector in the sate, compared to the other sectors, the greater will be its share of patents. The pendency time is insignificant and does not affect the patent shares. The time trend is negative and significant, implying that over the years, the patents share of the top 10 R&D states is decreasing. The data shows that their patent share dropped from 64 percent in 1981 to 62 percent in 1995. The overall R-square of the models is around 0.93.

The main difference between the models is the way they treat the various R&D terms. Model (i) breaks up R&D into three broad groups viz. state share of total federal R&D funds, state share of company funded industrial R&D and company funded academic R&D. Model (ii) deals with the R&D expenditure of performing agency. It breaks up R&D into share of federal funds for intramural performers, share of total industry performed R&D in the state and the share of university and college performed R&D in the state. Model (iii) disaggregates the share of total industrial R&D by the source of funds.[24] The estimates show that the share of company funded industrial R&D in the state has a strong positive on state patent shares. In models (i) and (ii) the state share federal R&D funds seem to have a weak positive effect on the state patent shares. Academia performed R&D, irrespective of the source of funds, do not affect the state patent shares.

Figure 8 illustrates how R&D shares and patents shares are related. It shows that in terms of both patent shares and industrial R&D shares California is an outlier. We observe, that compared to the other states, California’s share of patents is much less compared to its share of R&D. It gets about 22% of the US industrial R&D but accounts for only 16% of the patents. The bias is even more pronounced for federal R&D. Compared to this, a state like New York, accounts for roughly 8 percent of the US industrial R&D and patents.

The results for the spillover specification is shown in models (iv) and (v). Two alternative specifications of spillovers are outlined.

$$SPILLOVER\ \ TERM\ \ 1 = FEFEDSTK_{i,t} * INTOT_{i,t}$$

$$SPILLOVER\ \ TERM\ \ 2 = INFEDSTK_{i,t} * ININD_{i,t}$$

where i stands for the state and t for the year. FEFEDSTK is the current stock of federal intramural R&D in the state. It has been constructed from the past 4 years[25]. INTOT is the total current industrial R&D in the state, INFEDSTK is the stock of federal funding that goes to industry and ININD is the current total company funding in the state. In the regression, these spillover terms have been turned to shares, because we are interested in knowing what happens to patent share when the share of spillovers in the state increase[26].

Table 4, Model (iv) shows that the state share of federal funds for intramural R&D performers has no effect on the patent shares. This may be because the federal intramural performers are not a very great source of patents. Even premier research agencies like NASA do not take out a large number of patents, as commercialization of research is not their aim. The share of company funded industrial R&D has a significant positive effect on patent shares. The spillover term is positive and significant at the 10 percent level. This shows that the share of

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[24] Two other models were also estimated. One broke down R&D by the source of funds and the R&D performer, and the other, took into account, only that portion of R&D funds that is spent by the industry. It ignores the R&D performed by federal intramural agencies.

[25] The discount rate is 10%.

[26] Therefore I use: State share of spillover = Total state spillover/Total US spillover.

federal funds for industrial R&D has an indirect positive effect on the share of patents. It works by enhancing the productivity of company funded R&D. A good example of this would be in the electricity industry. After deregulation, EPRI (the collaborative R&D organization) is using the ‘public’ part of the research money to conduct the earlier part of the research when results are still uncertain. Once the project seems commercially viable, the utility companies step in with their own funding. Thus spillovers from federal R&D share increase patent share through subsidizing commercial research. The other coefficients have not changed in significance from the previous table.

Model (v) drops the federal intramural funding as a regressor. It is substituted by a spillover term which shows the interaction between the share of federal intramural R&D and share of current total industrial R&D. This model shows that the state share of federally funded industrial research has no direct effect on patent shares. As before, the share of company funded industrial R&D has a strong positive coefficient. Also, the spillover term is stronger than in Model (iv). It is positive and significant at the 5 percent level. This implies the interaction between the share of federal intramural R&D and share of total industrial R&D is stronger than that between the share of federally funded industrial R&D and company funded R&D.

Comparing across the two different specifications, we observe some similar trends. The state share of current company funded R&D and the state share of industrial GSP are strongly positively correlated with state patent shares. The difference in the two specifications lies in their treatment of the federal R&D term. From the basic model, we see that when the state share of federal R&D funds are broken down by R&D performers they lose their significance. But over all, the state share of total federal R&D is positive and significant. This would seem to suggest that there are spillovers that table 5 is not capturing. The spillover models alter this flaw and show the existence of positive R&D spillovers.

An important thing that should be kept in mind while drawing conclusions about state level results is the dominance of California. It accounts for 16 percent o the US patents and 20 percent of total US R&D funds. Of the top 10 R&D states, it accounts for 27 percent of the patents, 32 percent of the total R&D and 41 percent of the total federal R&D. In the models above if we introduce a California specific dummy (Table 4(B)) it turns out to be highly significant. Also, state share of federal R&D and the spillover terms lose their significance. [27] We can conclude that there is a significant California effect.

SECTION 5: POLICY IMPLICATIONS & CONCLUSIONS

Based on the empirical findings of the model some preliminary policy recommendations can be advanced. First, any government policy that seeks to directly increase patents through federal funding of industrial R&D may not be very successful in the short run. The effect of federal R&D on patents, although positive, is not significant. Evidence of positive spillover effects from federal R&D to contemporaneous company R&D is also weak. On the other hand, there are strong positive spillovers from past federal R&D to present company R&D. Therefore, the aim of federal policy should be to play a nurse-maid to company R&D and increase its productivity. Second, the government should create incentives, like tax cuts, so that the companies themselves invest more in their research. This would greatly enhance innovations and patents. Third, more financial resources should be provided to university performed R&D. In the long run, this would increase the innovative capacity of society. Fourth, the government should not appropriate any resources for the USPTO and divert it elsewhere. Decreasing resources at the patent office will adversely affect the number of patent issued. The patent office should aim at reducing its ‘pendency time’. Fifth, random fluctuations in the ‘pendency time’ should be

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[27] Please refer to Appendix Table 2

avoided as this has a negative effect on patents. The USPTO should announce the expected ‘pendency time’ at the beginning of the year and maintain that through the year. This would reduce the uncertainly of the timing of patent isssue and would help the companies plan better. This would have a positive influence on patenting. Last, subsidizing any agency hampers its efficiency. From the time that the USPTO was turned into a fully user-fee funded agency, its efficiency increased and more patents were issued. Thus the empirical results point to a limited but important role for the government. Rather than just directly investing in industrial R&D, the federal government should formulate to urge the companies to invest more themselves and see to the efficient working of the USPTO.

As the US economy matures, exhaustion of technological opportunities and the eventual slowdown of the economy, has been a concern among many. To some economists, the productivity slowdown and declining patents in the 1980’s heralded the approach of this static phase in economic growth. But the eighties slowdown eventually gave way to enormous technical advances in the nineties, revival of productivity, and tremendous increase in domestic patenting activity. Mokyr (1990)[28] observed that there is no historical indication that “creation of new technological opportunities – as opposed to their exploitation – is subject to diminishing returns, fatigue, old age or exhaustion”.

This paper shows that patents are related to various types of R&D expenditure, structure of the market and patent office resources. A decline or increase in the number of patents has more to do with fluctuations in the above variables than with a decline in inventive opportunity. Empirical results show that the number of domestic patents issued are strongly affected by the amount of R&D in the industry. An important contribution of the paper is to break down R&D performed by the industry into two sources – federal and company- and study their effects on patenting. Company R&D, both past and present, are positively correlated with patents issued. A curious fact that emerges, is that present company R&D has a stronger effect on current patents than past company R&D. Past federal R&D has a fairly significant direct positive on patents. But the spillover effect of federal R&D is much greater than its direct effect. Therefore we can conclude that although federal R&D may not directly affect patenting as company R&D, it works by enhancing the productivity of company R&D.

Also, the propensity to patent across years appears to be sensitive to the extent to which the public sector dominates R&D activities of an industry. The more ‘private’ the R&D is, the patenting the industry does. Also, the bigger the size of the industry, the greater the number of patents. Lastly, an important contribution of the paper is to show the strong negative effect that the patent office ‘pendency time’ has on patenting. It also shows that random fluctuations of ‘pendency time’ adversely affect patents. Thus, controlling for other factors, the changes in patenting behavior in the four major US industries studied here can be attributed to the shift of industrial R&D from the public to the private sector.

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[28] Mokyr (1990) – “Lever of Riches”, pp.301.

Table 1(A)

SUMMARY OF THE DEPENDENT VARIABLE

	Mean	Std. Dev.	Min	Max	Obs.
Log (Patent Issued _ By Inventor State)					
Overall	8.10	1.69	5.23	10.01	N = 77
Between		1.92	5.65	9.70	n = 4
Within		0.19	7.68	8.49	
Log (Patent Issued _ By Assignee State)					
Overall	7.83	1.76	4.93	9.87	N = 77
Between		2.00	5.39	9.55	n = 4
Within		0.18	7.37	8.23	

Note: The 'between' and 'within' refer to between group and within group. Here group refers to the four industries: electronics, chemical/biology, transportation and aeronautics.

Table 1(B)

SUMMARY OF THE MAIN REGRESSORS

Variable	Mean	Std. Dev.	Min	Max
Log (Total Funding for Industrial R&D) in thousands of $	16.39	0.374	15.69	17.20
Log (Company Funding for Industrial R&D) in thousands of $	15.90	0.361	14.97	16.58
Log (Federal Funding for Industrial R&D) in thousands of $	14.74	1.42	11.79	16.92
Log(University Performed R&D in Industry Field) in thousands of $	13.55	1.65	10.99	16.28
Log(Competitive Term)	-0.488	0.501	-1.51	-.009
Log(Size)	6.93	0.341	6.31	7.53
Pendency Time	20.80	2.30	18.2	25.5
Log (Spillover Term) Log($frd_{k,t-4} * crd_{k,t-4}$)	1.03e+14	1.03e+14	7.35e+12	3.98e+14
Log(Spillover1)	9.05e+07	9.36e+07	3655745	3.47e+08
Log(Spillover2)	2.44e+08	2.49e+08	1.09e+07	8.83e+08

Table 2(A)

Matching Up Industrial Classifications and SIC Codes

Industry	SIC Code	Sub-Classes
Electronics	36	Radio and TV receiving equipment, Communication equipment, Electronics components, Other electrical equipment.
Chemical/Biology	28	Industrial chemicals, Drugs and medicine, Other chemicals.
Transportation	37(except 372 & 376)	Motor vehicles and equipment, Other transportation equipment.
Aeronautics	372, 376	Aircrafts and missiles.

Table 2(B)

Matching Up Industrial Classification and Academic Disciplines

Industry	Academic Discipline
Electronics	Electrical Engineering, Astronomy, Physics, Other Physical sciences, Math and Computers.
Chemical/Biology	Chemical Engineering, Materials Engineering, Chemistry, Life Sciences.
Transportation	There was no transportation category. So it was proxied by the Mechanical Engineering sub-class.
Aeronautics	Aerospace Engineering

Table 3(A)

MODEL 1

COBBDOUGLAS MODEL WITH RANDOM DELAY

Random Effects Estimation

(standard errors in parentheses)

Dependent Variable	Log(Patents Issued _ By Inventor State)		Log(Patents Issued _ By Assignee State)	
Independent Variable	Model i(a)	Model i(b)	Model ii(a)	Model ii(b)
Log (Company Funding for Industrial R&D Lagged 4 Years) in thousands of $	0.584 ** (0.285)	0.511* (0.292)	0.511 * (0.313)	0.425 (0.319)
Log(Federal Funding for Industrial R&D Lagged 4 Years) in thousands of $	0.119 (0.084)	-	0.133 (0.092)	-
Log (Spillover Term)	-	0.102 (0.083)	-	0.121** (0.091)
Log(University Performed R&D in Industry Field) in thousands of $	0.465 ** (0.041)	0.457 ** (0.040)	0.570 ** (0.045)	0.562 ** (0.044)
Log(Size)	1.45 ** (0.251)	1.48 ** (0.255)	1.54 ** (0.275)	1.56 ** (0.279)
Log(Competitive Term)	1.28 ** (0.213)	1.24 ** (0.208)	1.05 ** (0.233)	1.02 ** (0.227)
Dummy (For 1990 PTO Law Change)	0.312 ** (0.143)	0.323 ** (0.143)	0.360 ** (0.157)	0.369 ** (0.157)
Pendency Time for Each Patent	-0.045 ** (0.018)	-0.043** (0.018)	-0.040 ** (0.020)	-0.038 ** (0.020)
Random Delay in Patent Process: Exponential Distribution (s.d.=4 mths.)	-0.020 * (0.011)	-0.020 * (0.011)	-0.021* (0.012)	-0.021* (0.012)
Constant	63.69 ** (28.28)	65.93 ** (28.68)	58.61** (30.99)	61.52 * 31.39
σ^2_ε	0.122	0.122	0.130	0.130
Overall R-Square	0.975	0.974	0.972	0.972

Note: $\sigma^2\varepsilon$ is the estimated variance of the idiosyncratic component. The sample size is 77. The exponential distribution is given by $f(D_r)= (1/b)e^{(-Tr/b)}$ and s.d. = b. The regression also contains a time trend. All dollar terms are in 1992 constant dollars. The spillover term is constructed by interacting the federal R&D stock lagged 4 years with the company R&D flow lagged 4 years ($frd_{k,t-4} * crd_{k,t-4}$.) Size is denoted by the total employment in the industry. The competitive term shows how private the industry is.Dummy_1990=1 if year>1990 and 0 otherwise.

Appendix Table 3(B)

MODEL 2

SPILLOVER MODEL WITH RANDOM DELAY

Random Effects Estimation

(standard errors in parentheses)

Dependent Variable	Log(Patents Issued _ By Inventor State)		Log(Patents Issued _ By Assignee State)	
Independent Variable	**i(a)**	**i(b)**	**ii(a)**	**ii(b)**
Log (Current Company Funding for Industrial R&D) in thousands of $	2.18 ** (0.337)	2.37 ** (0.333)	2.17 ** (0.362)	2.39 ** (0.357)
Log(Spillover Term 1)	0.004 ** (0.002)	-	0.005** (0.002)	-
Log(Spillover Term 2)	-	0.002** (0.0006)	-	0.002 (0.0007)
Log(University Performed R&D in Industry Field) in thousands of $	0.520** (0.054)	0.50** (0.053)	0.631** (0.058)	0.606** (0.057)
Log(Competitive Term)	1.24 ** (0.340)	1.43 ** (0.325)	1.09 ** (0.366)	1.31** (0.348)
Dummy (For 1990 PTO Law Change)	0.637** (0.235)	0.583 ** (0.229)	0.688** (0.253)	0.624** (0.245)
Pendency Time for Each Patent	-0.079** (0.029)	-0.082** (0.028)	-0.071** (0.031)	-0.075** (0.030)
Random Delay in Patent Process: Exponential Distribution (s.d.=4 mths.)	-0.025 (0.018)	-0.024 (0.018)	-0.026 (0.020)	-0.025 (0.019)
Constant	211.59 ** (45.08)	231.01** (44.71)	215.53** (48.48)	237.78** (47.87)
σ^2_ε	0.121	0.122	.130	0.132
Overall R-Square	0.929	0.933	0.924	0.929

Note: $\sigma^2\varepsilon$ is the estimated variance of the idiosyncratic component. The sample size is 77. The exponential distribution is given by $f(D_r)= (1/b)e^{(-Tr/b)}$ and s.d. = b. The regression also contains a time trend. All dollar terms are in 1992 constant dollars. The competitive term shows how private the industry is.Dummy_1990=1 if year>1990 and 0 otherwise. Spillover Term 1=frd-flow $_{k,t-4}$ * log(crd $_{kt}$) and Spillover Term 2 = frd-stock $_{k,t-4}$ * log(crd $_{kt}$)

Table 4(A)

STATE SHARE MODEL

Dependent Variable is the Share of Patents in each State
Random Effects Estimation
(standard errors in parenthesis)

	Basic Model			Spillover Model	
	(i)	(ii)	(iii)	(iv)	(v)
State Share of Total Federal R&D Funds (Lagged 4 years)	0.123 ** (0.060)	-	-	-	-
State Share of Total Federal Intramural R&D Funds (Lagged 4 years)	-	0.101 * (0.057)	0.038 (0.059)	0.031 (0.059)	-
State Share of Current Total Industrial R&D Funds	-	0.309 ** (0.071)	-	-	-
State Share of Federally Funded Industrial R&D (Lagged 4 years)	-	-	0.046 (0.031)	-	-0.034 (0.049)
State Share of Current Company Funded Industrial R&D	0.201 ** (0.047)	-	0.210 ** (0.047)	0.164 ** (0.057)	0.179 ** (0.048)
State Share of Total Academic R&D Funds	-	-0.131 (0.131)	0.064 (0.125)	0.082 (0.123)	0.076 (0.122)
Spillover Term 1	-	-	-	-	1.75 ** (0.811)
Spillover Term 2	-	-	-	0.431 * (0.251)	-
State Share of Company Funded Academic R&D	-0.029 (0.074)	-	-	-	-
State Industrial GSP as a Share of US GDP	0.468 ** (0.124)	0.505 ** (0.141)	0.459 ** (0.143)	0.416 ** (0.148)	0.365 ** (0.146)
Constant	95.29** (49.77)	83.19** (50.35)	91.04 ** (50.18)	96.95 ** (49.52)	95.21 ** (48.59)
σ^2_ε	0.278	0.323	0.251	0.246	0.247
Overall R-Square	0.928	0.924	0.929	0.924	0.928

Note: σ^2_ε is the estimated variance of the idiosyncratic error component. The sample size is 80. The panel consists of 10 states and 8 years for each state. A time trend is also included in the regressors and is negative and significant in all formulations. The regressors also contain 'pendency time' – it is insignificant in all formulations. Everything is in terms of shares, i.e. the state magnitude as a percentage of the US magnitude. Spillover Term 1 = Intramural federal R&D stock interacted with current total industrial R&D. Spillover Term 2 = Stock of federal funds for industry research years interacted with current company funds for industry R&D. For e.g.: pat_sh=(total patents issued in state i / total patents issued in the US). '**' denotes significnce at 5% and '*' denotes significance at 10%.

Appendix Table 4(B)

STATE SHARE MODEL: THE CALIFORNIA EFFECT

Dependent Variable is the Share of Patents in each State
Random Effects Estimation
(standard errors in parenthesis)

	(i) **With CA**	**(ii)** **With CA Dummy**	**(iii)** **Without CA**
State Share of Total Federal R&D Funds (Lagged 4 years)	0.123 ** (0.060)	-0.038 (0.083)	-0.012 (0.108)
State Share of Current Company Funded Industrial R&D	0.201 ** (0.047)	0.208 ** (0.046)	0.166 ** (0.069)
State Share of Company Funded Academic R&D	-0.029 (0.074)	0.022 (0.074)	-0.084 (0.099)
State Industrial GSP as a Share of US GDP	0.468 ** (0.123)	0.246 * (0.142)	0.085 (0.166)
Time Trend	-0.047 ** (0.025)	-0.052** (0.024)	-0.057 ** (0.023)
California Dummy	-	6.30 ** (2.28)	-
Constant	95.29** (49.77)	105.63 ** (47.47)	116.82** (46.54)
σ^2_ε	0.278	0.280	0.193
Overall R-Square	0.928	0.891	0.346
Sample Size	80	80	72

Note: σ^2_ε is the estimated variance of the idiosyncratic component. Everything is in terms of shares, i.e. the state magnitude as a percentage of the US magnitude. For e.g.: pat_sh=(total patents issued in state i / total patents issued in the US). The equation also includes the patent pendency time – the coefficients of which are all insignificant – as common sense would suggest. There is no reason why the pendency time would affect the state share of patents.'**' denotes significance at 5% and '*' denotes significance at 10% level.

FIGURES

Figure 1(a): Total Patent Application and Patent Issue to US Residents (US totals)

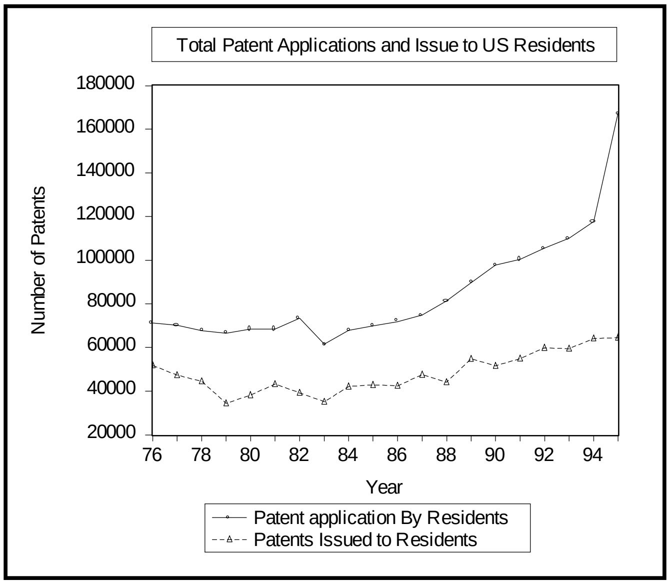


Figure 1(b): Total Number of Patents in Each State

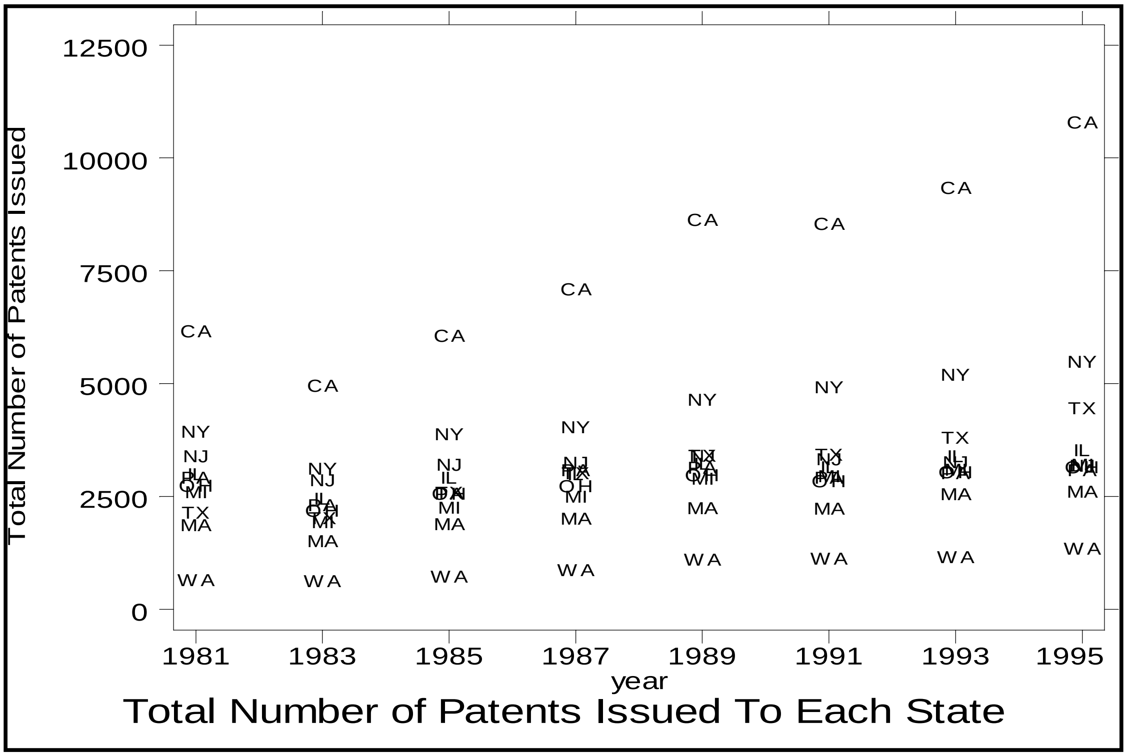


Figure 2: Patents Issued in Four Industries: US Data

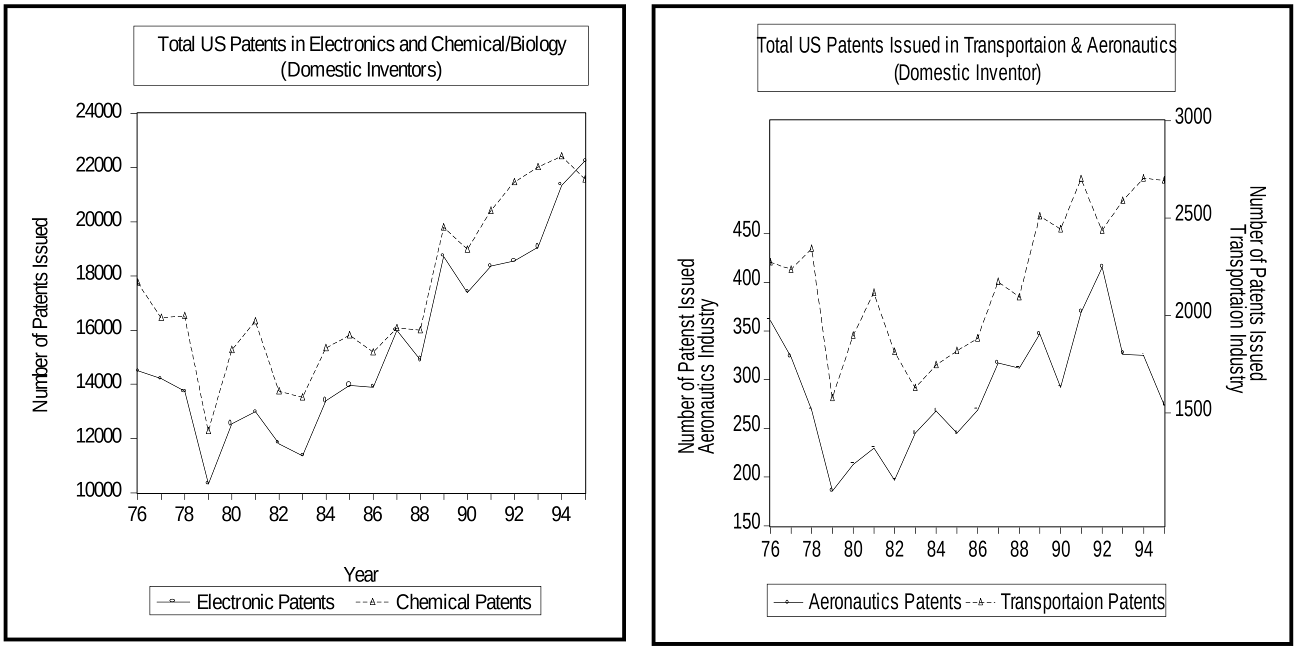


Figure 3: Pendency Time

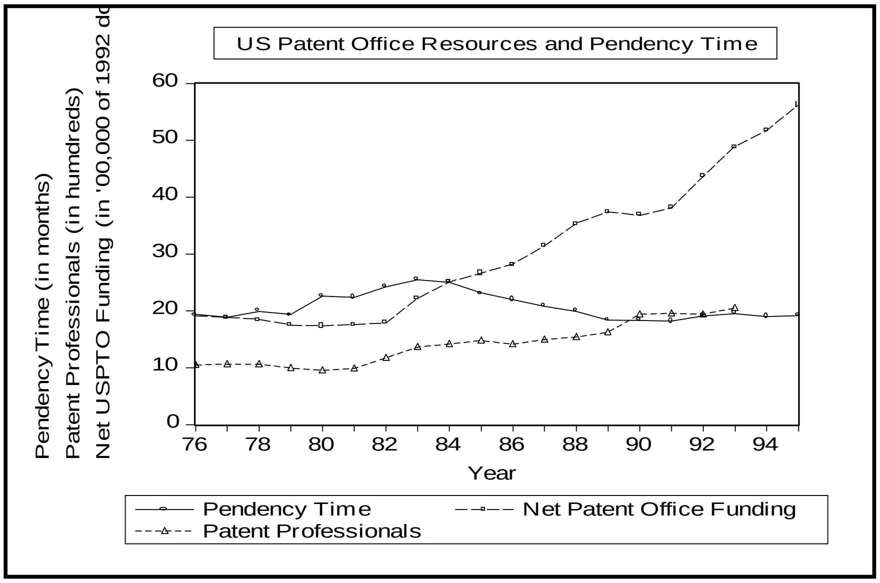


Figure 4: Total R&D Expenditures, US Data)

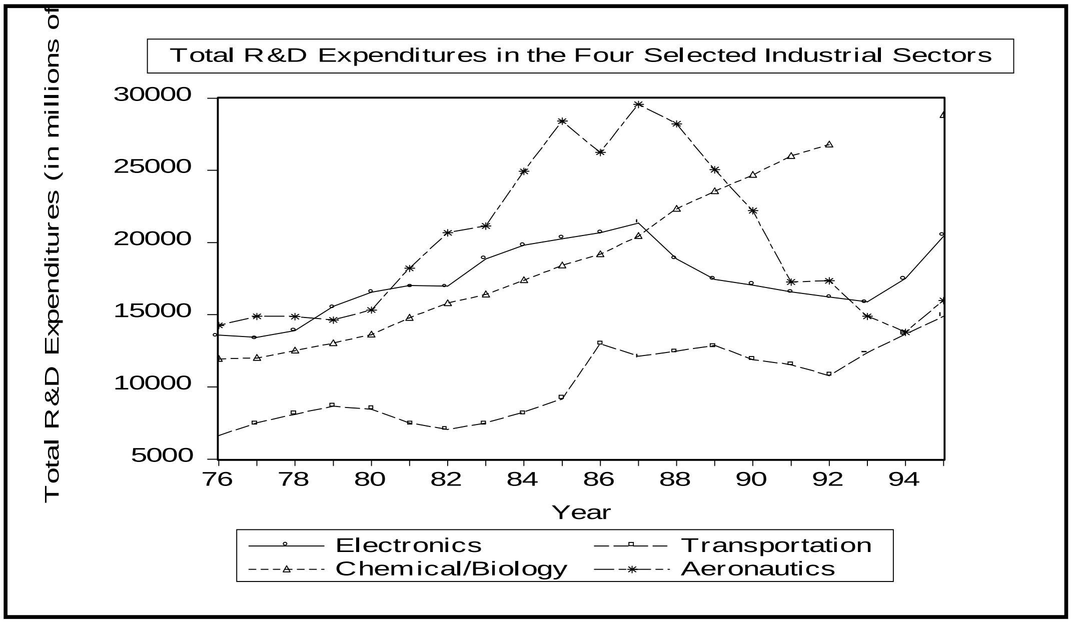


Figure 5: US R&D Expenditure and Patents in the Four selected Industries

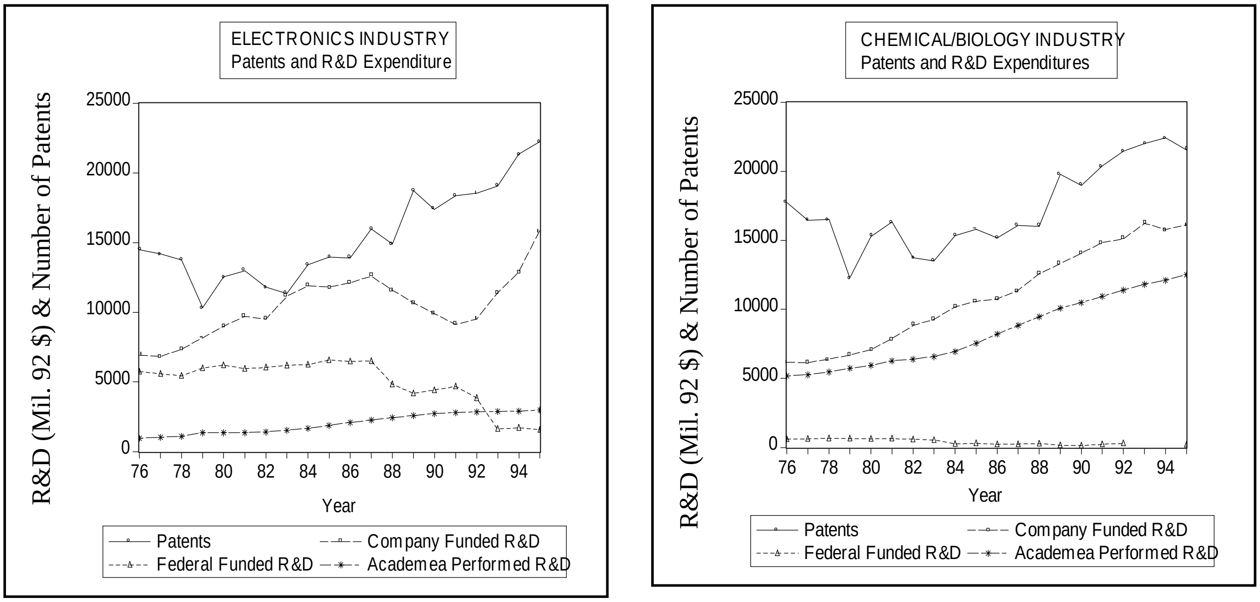


Figure 5(a): Electronics Industry

Figure 5(b): Chemical/Biology Industry

Figure 5(c): Transportation Industry

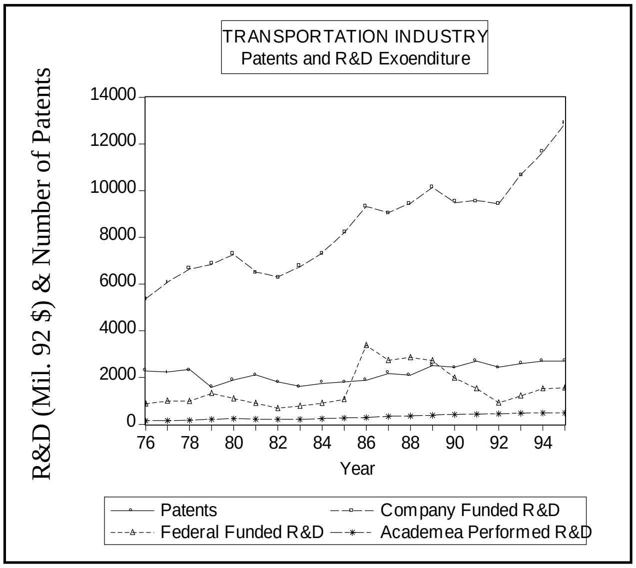


Figure 5(d): Aeronautics Industry

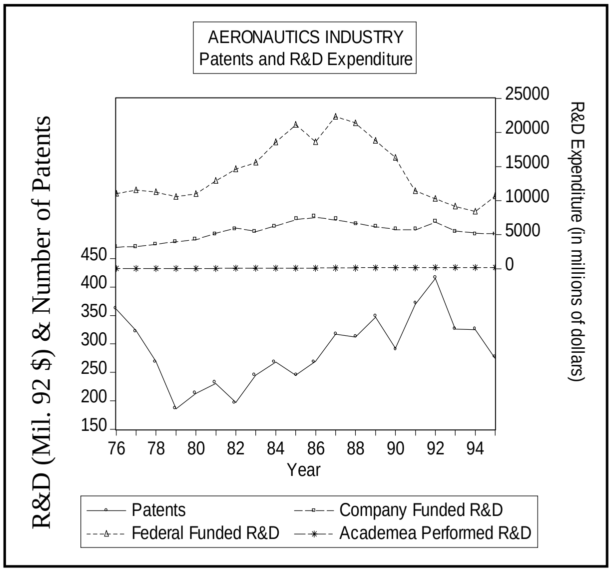


Figure 6: University and College R&D Expenditures, US Data

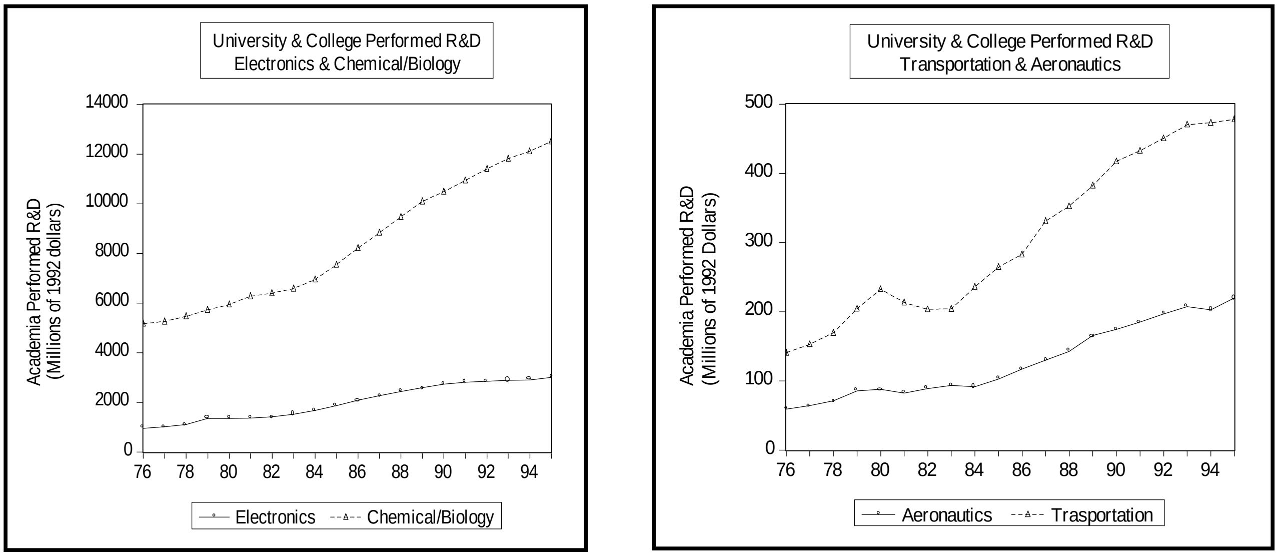


Figure 7: State Share of Patents

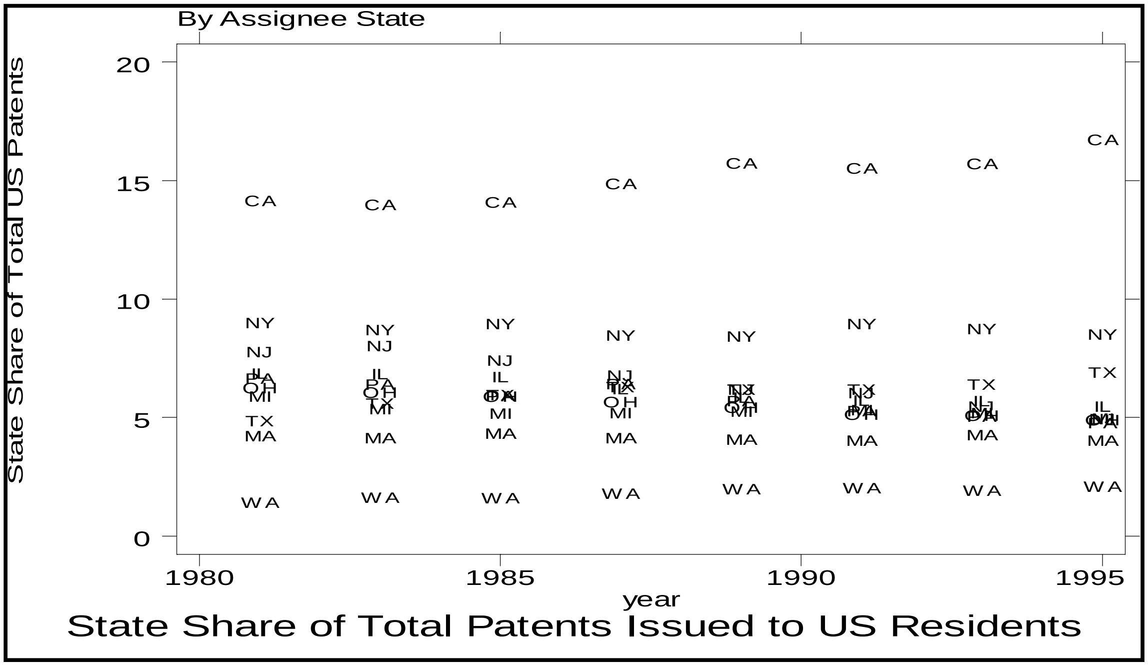
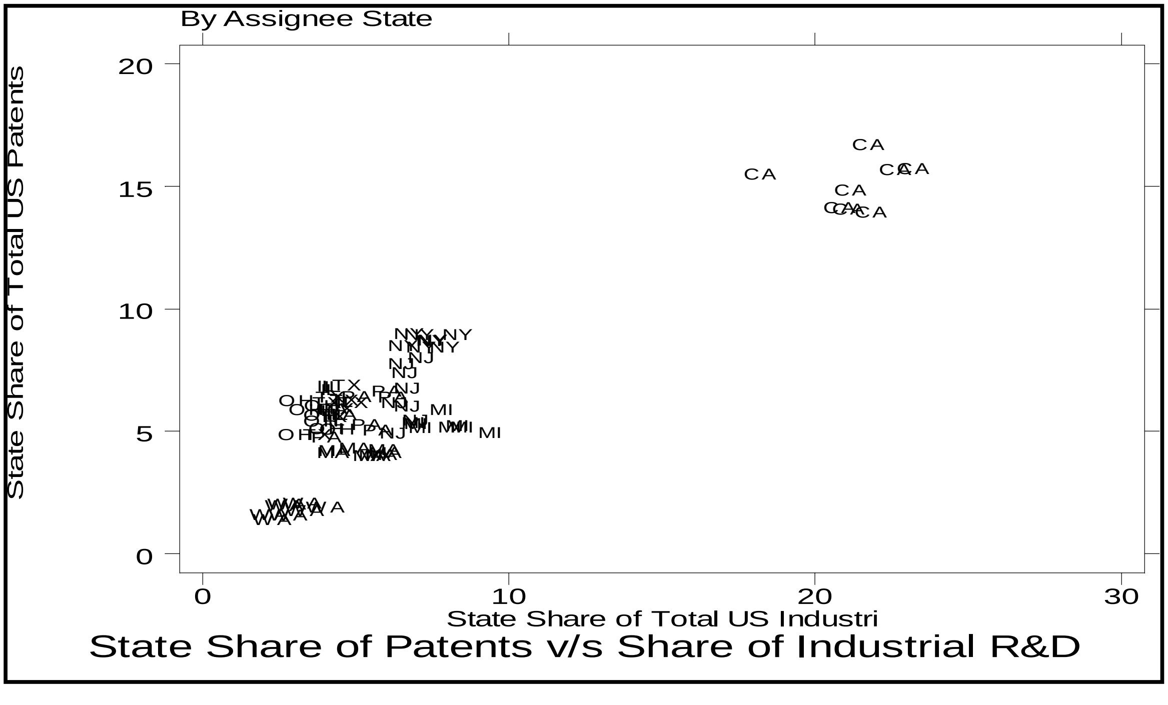


Figure 8



DATA APPENDIX

Appendix Table 1

DIFFERENCES IN PATENT NUMBERS

The following table provides a detailed outline of the magnitude of difference between the patent issued numbers when two different search criterion are used on the USPTO data base.

Industry	**Electronics**			**Chemical/Biology**		
Year	Pat_IS	Pat_AS	% Difference	Pat_IS	Pat_AS	% Difference
1976	14502	12529	15.75	17749	15937	11.37
1977	14208	11955	18.85	16449	14428	14.01
1978	13746	11516	19.36	16525	14598	13.20
1979	10324	8477	21.79	12278	10618	15.63
1980	12542	10381	20.82	15270	12965	17.78
1981	12984	10709	21.24	16325	14057	16.13
1982	11807	9973	18.39	13744	11842	16.06
1983	11363	9896	14.82	13512	11836	14.16
1984	13397	11669	14.81	15340	13515	13.50
1985	13957	12260	13.84	15815	13794	14.65
1986	13887	12210	13.73	15180	12876	17.89
1987	15991	14040	13.90	16080	13525	18.89
1988	14915	12935	15.31	15997	13462	18.83
1989	18727	16019	16.90	19794	16588	19.33
1990	17389	14743	17.95	18971	15834	19.81
1991	18371	15650	17.39	20408	16998	20.06
1992	18557	15923	16.54	21466	17916	19.81
1993	19062	16530	15.32	22020	18571	18.57
1994	21342	18588	14.82	22417	18764	19.47
1995	22251	19328	15.12	21555	17962	20.00
1996	24309	21182	14.76	23122	19126	20.89
Industry	**Transportation**			**Aerospace**		
Year	Pat_IS	Pat_AS	% Difference	Pat_IS	Pat_AS	% Difference
1976	2273	1444	57.41	361	280	28.93
1977	2236	1356	64.90	323	256	26.17
1978	2343	1429	63.96	269	194	38.66
1979	1576	975	61.64	186	138	34.78
1980	1896	1123	68.83	213	170	25.29
1981	2116	1304	62.27	230	175	31.43
1982	1813	1111	63.19	197	147	34.01
1983	1629	1061	53.53	245	202	21.29
1984	1746	1147	52.22	268	204	31.37
1985	1817	1156	57.18	245	207	18.36
1986	1883	1093	72.28	269	213	26.29
1987	2172	1270	71.02	317	235	34.89
1988	2093	1201	74.27	312	246	26.83
1989	2510	1376	82.41	347	263	31.94

1990	2441	1366	78.70	292	231	26.41
1991	2701	1499	80.19	369	280	31.79
1992	2435	1386	75.69	415	310	33.87
1993	2588	1503	72.19	326	245	33.06
1994	2703	1569	72.28	325	259	25.48
1995	2692	1614	66.79	274	210	30.48
1996	3086	1923	60.48	253	195	29.74

Note: Pat_IS: # of Patents Issued when search criterion was "Inventor State"
Pat_AS: # of Patents Issued when search criterion was "Assignee State"
% Difference = [(Pat_IS-Pat_AS)/Pat_AS]*100. It shows how much bigger the 'inventor state' numbers are.

But both the above criteria (assignee state v/s inventor) are fraught with problems when dealing with state data within the US. The ‘assignee-sate’ data under-reports the inventive activity in states like California and over estimates it for New York and New Jersey. The ‘inventor-state’ data involves a huge amount of double counting. So, a recent convention, while dealing with patent data is to take the country or state of the ‘first-inventor’. For example consider three inventors – residing in California, New York and New Jersey, and working for a company with headquarters in Texas. If the search is done just by ‘assignee-state’ then the patent goes to Texas and misrepresents the amount of inventions in the three states. If the search is done by ‘inventor-state’ then this patent will be listed thrice – once for each state. There would be a huge amount of double counting. But if the search is done by first inventor then the ‘inventor-state’ on the patent will be California. It should be noted that there is nothing sacrosanct about the first inventor. The USPTO does not list inventors according to their contribution in the invention. Thus this data too has some amount of bias in it. But, in the absence of a better search parameter, and following the general convention, I use the ‘first-inventor state in analyzing the state data. The differences between the patent numbers using different search criteria, are outlined in the table above.

Appendix Table 2

PATENT CLASSES

The **electronics patents** category includes the following subclasses:
Computing And Data Processing: 380, 377, 371, 364, 395, 901, 902, 235, 347, 360, 365, 369
Electricity And Electric Power: 505, 318, 320, 322, 323, 324, 361, 218, 219, 392, 373, 290, 388, 307, 333, 363, 310, 313, 314, 315, 335, 336, 337, 200, 174, 191, 136
Electronics & Electronic Components: 437, 216, 257, 116, 326, 327, 330, 331, 333, 338, 361, 336, 174, 377, 439, 445, 505, 136
Radiant Energy/Optics/Photography: 250, 351, 352, 353, 354, 355, 503, 356, 359, 378, 372, 385, 362
Communications: 340, 341, 342, 343, 348, 358, 382, 370, 381, 379, 178, 375, 455, 367, 334, 332, 329
Others / Measurement / Nuclear: 181, 204, 345, 346, 368, 374, 376, 429, 430, 431, 976, 33, 177, 73, 968
Music / Education / Amusement: 434, 446, 40, 472, 473, 273, 124, 84, 281, 462, 984

The **chemical/biology patents** category includes the categories:
Biochemistry: 127, 800, 435, 436, 930, 935, 514, 424
Chemical Engineering: 427, 502, 210, 205, 201, 202, 203, 494, 422, 95, 96, 55, 261, 159, 588, 23, 8, 184, 148, 366, 44, 196, 208, 134, 34
Organic Chemistry: 71, 512, 260, 518, 520, 521, 522, 523, 524, 525, 526, 527, 528, 530, 532, 534, 536, 540, 544, 546, 548, 549, 552, 260, 552, 554, 556, 558, 560, 562, 564, 568, 570, 585, 987
Surgery / Body Care / Cosmetics: 482, 433, 128, 600, 602, 604, 606, 607, 601, 623, 132, 63, 27, 512
Materials / Compositions / Explosives: 65, 252, 505, 428, 156, 420, 75, 507, 106, 117, 501, 423, 71, 419, 102, 149, 86, 89, 42, 34, 148, 366
Agriculture / Farming: Plt, 99, 426, 111, 166, 449, 452, 43, 47, 119, 54, 56, 59, 168, 231, 131, 239, 426, 504, 147, 71, 256

The **aeronautics patents** come from a subclass of the broad engineering patent class:
Vehicles and Transportation category - *Aeronautics*: 244

The **transportation patents** are also a part of the broader engineering class
It comprises the following sub-class: *Vehicles And Transportation*:187, 244, 114, 440, 441, 191, 104, 105, 246, 238, 278, 280, 298, 180, 296, 301, 305, 295, 152, 213, 293, 410, 258, 404, 14, 405, 291, 44.

For our data set we subtract the aeronautics patents (sub-class 244) from the transportation patents to prevent double counting.

Appendix Table 3

	Year	1976	1981	1991
	Patent Fees (in current dollars)			
1.	Filing Fees : Charged for each original application or reissue (except plant or design)	100	300	670
2.	Claim: (a) Each independent claim in excess of 3	-	30	60
	(b) Each independent claim in excess of 20	-	10	20
	(c) Dependent Claim(for each application containing multiple dependent claim)	-	100	210
3.	Patent Issue Fees (except plant or design)	150	500	1120
4.	Disclaimer Fee: For each disclaimer filed	-	50	110
5.	Extension Fee: For petitions for 1 month extension of time to take action required by the commissioner in an application			
	(a) On filing a first petition	25	50	110
	(b) On filing a second petition	50	100	210
	(c) On filing a third or subsequent petition	125	200	460
6.	Revival Fee: On filing each petition of an unintentionally abandoned application for a patent or for the unintentionally delayed payment of the issuance fee.	150	500	1120
7.	Recording Fee: for recording each document affecting the title of the patent	-	40	40
8.	Total Maintenance Fee:	1200	2400	5360

Note: total maintenance fee is the sum of the fee that must be paid to keep the patent in force after 3.5, 7.5 and 11.5 years. For 1976 the breakdown in patent fees is unavailable, but the gross numbers are available.

This table denotes the average fees paid by the utility patent applicants in the life of the patent. ‘Life’ of a patent denotes the length of time that the patent holder is protected and has the sole right to his product..

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