

State Owned Entity Reform in Absence of Privatization: Reforming Indian National Laboratories and Role of Leadership¹

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Abstract

There is relatively less economic scrutiny of performance improvement at state owned entities where privatization may not be a feasible option or may have only been partially implemented. We document evidence of 42 emerging market state-owned laboratories starting from a base of almost no U.S. patenting, collectively being granted more U.S. patents than all domestic private firms combined. The labs are then able to license several of these patents to multinationals to reduce their dependence on government budgetary support. This follows leadership change at labs, an event whose timing is plausibly exogenous being dictated by rigid government employment rules. Also, this commercialization effort does not adversely affect publication quality or quantity. Our empirical analysis is based on hand-collected data from the Council of Scientific and Industrial Research in India from 1993-2006, supplemented by data from CVs of 593 senior scientists.

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I. Introduction

Most of the recent theory and empirical literature on state owned entity (SOE) reform has focused on privatization. However, there is relatively less scrutiny of performance improvement at SOEs where privatization may not be feasible, given that the SOEs are ‘strategic’, loss making, public goods focused, etc. or where privatization may have only been partially implemented. We document evidence of 42 government laboratories in a key emerging market starting from a base of almost no U.S. patenting, collectively being granted more U.S. patents than all domestic private firms combined. The labs are then able to license several of these patents to multinationals and reduce their dependence on government budgetary support. This follows leadership change at labs, an event whose timing is plausibly exogenous being dictated by rigid government employment rules. Though prior literature mentions policy complements and alternatives to privatization like increased competition, performance contracts, corporatization, etc., we could not find prior papers that highlight the role of leadership in reforming state owned entities². Our research is relevant to other public R&D entities crucially dependent on government budgetary support and to state owned firms in emerging markets, who even today, control a large proportion of total industrial assets (31% in the case of India for 2007). More generally, our findings provide insights on how leadership can be effective in resource constrained environments.

The theory literature on SOE reform is focused on privatization and has identified several inefficiencies of state owned entities. Laffont and Tirole (1991) outline several elements of ‘cost’ of public ownership of firms³; Shapiro and Willig (1990) outline a model where a bureaucrat running a state firm maximizes the weighted average of social welfare and his or her personal agenda instead of maximizing profits. Several inefficiencies of state owned firms (principal agent issues; lack of residual claimant; absence of motivation and monitoring; soft budget constraints) have been documented in

² In a recent paper however, Karpoff (2001) attributes the failure of government funded Arctic missions to poor leadership structures, slow adaptation to new information and perverse incentives. Refer Section V for a more detailed discussion

³ In their model, they identify five elements of cost of public ownership: (i) absence of capital market monitoring, (ii) soft budget constraint, (iii) expropriation of investments, (iv) lack of precise objectives and (v) lobbying. They also identify two benefits of public ownership: (i) social welfare and (ii) centralized control.

the agency theory and property rights literature⁴. Given this background, recent theory is focused on the benefits of privatization. Shleifer (1998) points out that private ownership is better than state ownership in most contexts⁵, a key reason being that government employees have very weak incentives with respect to both cost reduction and innovation. Prior research⁶ has also outlined the importance of competition, deregulation and governance change in improving SOE productivity⁷. The recent empirical literature too overwhelmingly supports privatization⁸. In the context of India, Majumdar (1998) documents a significant performance shortfall for government owned firms compared to private firms for the period 1973-1989.

However, privatization may not be a feasible policy option for all state owned entities. In India for example, Kapur and Ramamurti (2002) document the government's stated objective of not privatizing the "strategic" sector⁹. In other cases, only partial privatization may have been implemented: in a sample of share-issue privatizations from 59 countries, Jones, Megginson, Nash, and Netter (1999) found that just 11.5% of the firms sold all of their capital and less than 30% sold more than half of their capital in the initial public offering¹⁰. There is also evidence that governments may choose only certain firms to privatize: Dastidar et al. (2007) point out that governments may not privatize

⁴ The property rights literature (Alchian and Demsetz 1972; Grossman and Hart, 1986) suggests that an entity like a state owned firm, not having a clear residual claimant, will be operated less efficiently than private firms. State owned firms also face several agency issues: (1) principal-agent issues linked to misaligned incentives between the state and bureaucrats; (2) information asymmetry between senior bureaucrats and down the line employees; (3) incentives to free-ride given the lack of monitoring and the absence of penalty and reward systems. Lack of motivation and shirking by employees could also be attributed to the soft budget constraint (Kornai 1986, Maskin 1999), whereby governments often bail out loss making state owned firms. State owned firms also face the issue of agency problems related to politicians. Boycko, Shleifer and Vishny (1996) point out the inefficiencies related to excess employment at state owned firms following directives of politicians. In a related paper, Krueger (1990) suggests that state owned firms are constrained by the fact that they have to hire politically connected people rather than the best qualified for the task

⁵ Shleifer points out that there are a narrow set of circumstances in which government ownership is likely to be superior: (1) opportunities for cost reductions that lead to non-contractible deterioration of quality are significant; (2) innovation is relatively unimportant; (3) competition is weak and consumer choice is ineffective; (4) reputational mechanisms are also weak. Hart, Shleifer and Vishny (1997) use an incomplete contracts based framework to elucidate this point with respect to private owned prisons

⁶ Kay and Thompson, (1986); Bishop and Kay, (1989) and Vickers and Yarrow, (1991)

⁷ An excellent survey of the SOE privatization and reform literature is provided by Megginson and Netter (2001)

⁸ Dewenter and Malatesta (2001) compare net-income based measures for state owned firms and private firms across several countries and multiple years (1399 firm years sampled over 1975, 1985 and 1995) and report that state owned firms are significantly less profitable. Boubakri and Cosset (1996) look at 79 state owned firms across 21 developing countries that experienced full or partial privatization over 1980-1992 and document significant increases in profitability, operating efficiency and total employment, post privatization. Other papers include La Porta et al. (1999)

⁹ Eventually only nuclear power, defense and railroads were left in the "strategic" category. Bardhan (2003) mentions yet another difficulty of privatization in India and highlights the opposition of organized labor to privatization

¹⁰ Gupta (2002) documents the case of staggered and partial privatization of 42 Indian SOEs where the government retained significant control in several post-privatized firms.

firms that are unprofitable or laden with debt or because of political interests¹¹. Finally, success of privatization might be contingent on factors like the type of private owner: Frydman et al. (1999) report that privatization in Central Europe was successful when the new owner was an outsider but not when the new owner was an insider. There are also empirical studies that look at policy alternatives and complements. Groves, Hong, McMillan, and Naughton (1994, 1995) discuss the ways in which incentives and other organizational changes (e.g. selecting managers by auctions) positively affected worker incomes and investment in Chinese SOEs¹². The fact remains that a large proportion of industrial assets remain with state owned firms and in the case of India, 31% of all industrial assets are with SOEs in year 2007, compared to 34% in 1991, when the privatization program was initiated.

Given this evidence, we study the reform of 42 government owned labs in India, a setting where privatization was clearly not an option. A major challenge here is to find the right dataset. Publicly available datasets including those focused on emerging markets¹³ don't track micro-data on emerging market labs or scientists. To address this issue, the researchers work closely with one of the largest emerging market research entities comprising multiple national laboratories – 'The Council of Scientific and Industrial Research' or CSIR in India and hand collect novel data for 42 labs over a fourteen year period (1993-2006). By 2002, collectively these labs had emerged as the single largest emerging market patent applicant¹⁴ and the fact that we have data on 42 laboratories across all major scientific disciplines enables us to exploit cross-sectional variation.

In summary, we find that over 1993 to 2006, CSIR labs collectively emerge with more U.S. patent grants than all Indian private firms combined. In addition, U.S. patents as well as revenue from multinationals increases sharply in response to director changes, whose timing is plausibly exogenous being dictated by rigid government employment

¹¹ A similar result is reported by Gupta, Ham and Svejnar (2000) who report that governments sequence privatization by selecting the most profitable firms first

¹² Other papers in this area include Pinto et al. (1993) who look at Poland's big bang reforms of 1993 and Li (1997) who documents improvements in factor productivity of Chinese SOEs following improved incentives and compensation. Finally, Aivazian et al. (2005) document performance improvement in Chinese SOEs following corporatization.

¹³ Examples include CMIE Prowess for India or FinAsia for China

¹⁴ List of CSIR laboratories and their U.S. patenting rankings in appendix available with authors

rules. We run fixed effects models controlling for government budgetary support (which is fixed ex ante based on historical trends) and a host of control variables. These variables are constructed from CVs of scientists and measure average productivity of labs based on awards received, foreign travel, books published, articles written, processes developed, etc. The period of our study is also significant, given the backdrop of the Indian government launching an ambitious privatization program in the same period¹⁵. The paper is organized as follows. Section II outlines the empirical setting; Section III presents our hypotheses and empirical specifications; Section IV presents the data and results and Section V interprets the results. All figures and tables are presented at the end.

II. Leadership and Policy Change at India's National Laboratories (CSIR)

India's 42 state-owned national laboratories are organized under an autonomous umbrella organization, The Council of Scientific and Industrial Research (CSIR) and collectively have around 12,500 scientific and technical employees¹⁶. The laboratories, covering all major scientific and engineering disciplines were created in the 1940s and 1950s and until the 1980s, the main goal of the labs was to indigenize imported technologies in areas such as tractors, food processing, pharmaceuticals and polymers¹⁷.

Around 1994, the labs started a major transformation process under the leadership of a new Director General, Dr. Raghunath Mashelkar. The 'CSIR 2001 Vision Document', published in January 1996 outlined ambitious goals for 2001 aimed at reducing dependence on government budgetary support¹⁸. In his prior assignment as Director of one of the CSIR labs (National Chemical Laboratory or NCL, based in Pune), Dr. Mashelkar had great success in securing U.S. patents on polymers and then licensing

¹⁵ Starting with the industrial policy resolution of 1991, the Indian government announced a goal to reduce government ownership to 26% in all non strategic firms and until 2002, partial privatization was achieved in 47 state owned firms leading to receipts of around \$5.5 billion (Kapur and Ramamurti 2002). Gupta (2002) reports that a 10% decrease in government ownership increases annual (log) sales and profit by 20% and 13% respectively, post partial privatization.

¹⁶ List of CSIR labs along with their locations and scientific discipline is provided in the appendix

¹⁷ Krishna (2007) provides an exhaustive account of the growth in CSIR laboratories and elucidates a major issue facing the labs in the 1980s. The author quotes Ward Morehouse's (1978: 374) case study of a CSIR laboratory, "one of the major limitations affecting industrial research in India has been the lack of work after the laboratory stage, which is essential if laboratory know-how is to be translated into commercially usable form". Moreover, the 1986 Review Committee on CSIR noted that, "the major failure, perhaps, is its inability to transform scientific results in the laboratory into technologies for industrial production" (CSIR 1986, quoted Jolly 2001).

¹⁸ (1) Move towards the path of self financing by generating over Rs.7 billion from external sources, as against Rs.1.35 billion in 1994-95, of which at least 50% will be from industrial customers (up from 15% in 1994-95); (2) Develop at least ten exclusive and globally competitive technologies in niche areas; (3) Hold a patent bank of 500 foreign patents (up from 50); (4) Realize 10% of operational expenditure from intellectual property licensing (up from < 1%); and (5) Derive annual earnings of \$ 40 million from overseas R&D work and services (up from < \$ 2 million)

these patents to multinationals like GE and in 1995, NCL had an 85% share of all U.S. patents granted to the 42 labs¹⁹. However, replicating NCL's success on a broader scale had significant constraints: for example, on the organizational side, CSIR could not change salaries of scientists which are determined by Indian Central Government rules and there has been no major revision to the salaries during the course of our study²⁰. In this context, there were two major policy changes that were implemented under the new leadership that deserve attention²¹.

A. One Time Change in Employee Level Incentives

Until the 1970s, India's national laboratories had a policy of sharing licensing revenue, with individual inventors; this policy was discontinued in September 1977²². However on June 15, 1994, a committee chaired by Dr. Mashelkar announced that 40% of licensing revenue and fees from corporate R&D projects would be shared among scientists²³. Of the total remuneration, 35% would go to innovators, 35% to other team members, 15% to other staff, 10% would be shared among all employees and 5% would go to the welfare fund²⁴. One could argue that the 1994 incentive reform addressed several of the agency and property rights issues linked to patenting and licensing technologies; it also had a direct impact on the remuneration for a large number of scientists²⁵. This is significant

¹⁹ A more detailed case study of NCL is provided in the appendix

²⁰ From Jan 1, 1996 salaries were determined by the Fifth Central Pay Commission and CSIR Scientists received pay according to the Level they were in (e.g. Scientist B was graded at Level 'Group IV (1)' and Scientist G or senior scientist was graded at Level 'Group IV(6)'). A revision to the pay was announced on 24th March, 2008, when the Sixth Pay Commission recommendations were implemented

²¹ Dr. Mashelkar's involvement with the CSIR reform could be divided into two phases: 1995-1999 and 2000-2006

²² Source: CSIR circular 9/203/92-TU dated 8th May 1992

²³ Source: CSIR Letter 9/203/94-TU, June 15, 1994

²⁴ As a precursor to this policy change, in July 1990, CSIR labs allowed scientists to share revenue of 'consultancy projects'; however, revenue sharing on licensing projects started from January 1994. A few other policy changes are noteworthy in that they support the 1994 policy change; however, discussions with CSIR executives show that the subsequent policy changes have not had as much impact as the 1994 policy change. The subsequent policy change is summarized as follows: in August 1995, with the stated objective of building "organic linkages between the CSIR laboratories and Indian companies", scientists above certain tenure were allowed to join the Boards of Directors of Indian companies and receive external remuneration. The same policy change document also allowed individual laboratories to establish legally distinct 'Section 25 Companies' to "exploit/market its knowledge base, products, databases etc". The condition for labs to do so was that external revenue earnings would have to be at least one third of government budgetary support (however, till date only one lab, NCL, has implemented this). Again, in December 2001, CSIR labs were allowed to appoint 'consultants for business development and marketing'; moreover a 'Scientist Entrepreneur Scheme' was conceived to help scientists commercialize ideas but hasn't really taken off

²⁵ We have data on 156 patents licensed between 2001-2006 and the average remuneration to an individual inventor is around Rs.100000. This works out to around 40% of average senior scientist annual salary in 1999

given that the new leadership was constrained by Indian government pay commission rules and could not revise salaries of scientists.

B. Leadership Change at Individual Laboratories Over the Years

Leadership change at individual labs was also a key event, whose timing was plausibly exogenous, given rigid Indian government employment rules. New directors could only be appointed at the end of the six year contract period of the incumbent director or if the incumbent director had reached the retirement age of 60 years, whichever was earlier. In other words, the new leadership had no control on when lab-directors could be replaced; but had control on who was to be appointed as the new director when the change happened. In all, Dr. Mashelkar was able to implement leadership changes at 36 out of the 42 laboratories; 70% of these changes happened in the first six-year period of his tenure²⁶.

III. Empirical specifications

A. Effect of Director Change on Revenue and Patenting

We first build specifications to test the impact of director changes at individual labs. As discussed earlier, based on director appointment rules at Indian national labs, we conceptualize director change at labs as an event whose timing was exogenous. However, each director change event gave the new leadership an opportunity to replace the existing director with an individual who was potentially more aligned to the new goals of technology commercialization. Hence, our proposition is that new directors at individual labs should strive for higher levels of U.S. patents and higher levels of licensing revenue.

To test this proposition, we collected data on all directorship changes at the 42 labs between 1995 and 2006 and create a dummy variable $post_dir_chn_{it}$ to indicate the first director change at the lab under Dr. Mashelkar's regime. For lab ' i ', the variable takes values of 1 for each year after the first director change and 0 prior to the first change in director. We first analyze the impact of director change on level of U.S. and domestic patents. Given that we are dealing with count data and based on Hausman Hall and Griliches (1984), in the base case, we use a fixed effects Poisson model adjusted for

²⁶Year-wise breakdown of director changes available with authors

quasi-maximum likelihood estimation and robust standard errors as described by Wooldridge (1999). Here,

$$(1) \quad E(Y_{it}|X_{it}) \sim \exp(X_{it} \beta)$$

Where, $X_{it} = post_dir_chng_{it} + post_dir_chng_{it} * Z_i + ecf_govt_{it} + A_{it} + Y$

Here, Y_{it} indicates the dependent count variables (number of US patents granted and number of Indian patents granted to a lab in a year), i indicates an individual laboratory and t indicates the individual year²⁷.

Next, we analyze the effect of director changes on revenue from multinationals²⁸ to CSIR laboratories in the period 1995-2006 and run the following fixed effects regression with clustered, robust standard errors:

$$(2) \quad \ln_ecf_foreign_{it} = \beta_0 + \beta_1 * post_dir_chng_{it} + \beta_2 * post_dir_chng_{it} * Z_i + \beta_3 * ecf_govt_{it} + A_{it} + Q_i + Y + \varepsilon_{it}$$

For both (1) and (2), the key independent variable of interest is the *post_director_change_{it}* dummy variable. We also add several control variables to our specifications and the main time variant control variable measures the level of government budgetary support (*ecf_govt*). Inclusion of this variable allows us to control for the size and scale of individual labs, given that government budgetary support is related to the size of a lab and is fixed ex ante, based on historical trends for a lab's budgetary support. In addition, we create several time invariant control variables (Z_i) using data from CVs of 593 scientists across all labs²⁹. These control variables measure various aspects of average scientist productivity across labs and are used in interaction with the *post_director_change_{it}* dummy (leading to the term *post_dir_chng_{it} * Z_i*). The variables included in the set (Z_i) comprises: fraction of scientists that have a PhD

²⁷ Woolridge (1999) shows that the quasi conditional maximum likelihood estimator is consistent under the condition that the conditional mean is correctly specified. We also run alternative models for this specification: given that the dependent variables in these regressions measure the number of patents filed abroad and in India and based on the logic articulated by several prior papers including Jaffe and Lerner (2001) that the patent production function is multiplicative and the fact that there certain labs don't have patents in certain years, we use the logarithm of one plus the number of patents, as the dependent variable and run fixed effects regressions

²⁸ Revenue from multinationals is defined using the "ecf_foreign" variable where 'ecf' stands for external cash flow, using CSIR notation. We take log of 1 added to "ecf_foreign" to account for lab years where revenue from MNCs is equal to zero

²⁹ The 593 CVs comprise all senior scientists at CSIR. We collected CVs for all scientists in the top 4 organizational levels at CSIR (internally defined as Level F, G, H and Director)

(*fraction_PhD*); average number of countries visited by scientists (*avg_countries_visited*); fraction of scientists that have travelled to the U.S. (*fraction_visited_US*); average number of awards received by scientists (*avg_awards*); average number of books (*avg_books*), articles (*avg_articles*) and reports (*avg_reports*) published by scientists, etc. In the set of variables (Z_i), we also include control variables suggested by the public R&D productivity literature. In line with Jaffe and Lerner (2001), we construct a measure of technological focus (*focus*) on individual labs by computing the Herfindahl index of patent classes for patents granted to a lab.

Interviews with scientists across labs also suggest that Dr. Mashelkar aggressively tried to propagate the ‘NCL model’ (of patenting on the USPTO and then using the U.S. patents to pitch for projects from multinationals) across labs. One of the early labs that responded to this effort was IICT in Hyderabad and then gradually other labs joined the process through a program of 55 networked projects where individual labs got a chance to work with NCL and IICT scientists³⁰. To account for this experiment, we created a measure of involvement of individual labs with NCL and IICT and count the number of times individual labs interact with NCL and IICT. Here, the proposition is more number of times a lab (and its scientists) interacted with NCL and IICT on joint projects, the higher was the probability that the lab would file patents on the USPTO. We created a variable *num_interactions_NCLIICT* to measure this interaction and interact the *post_director_change_{it}* variable with *num_interactions_NCLIICT_{it}*. We also control for age of the lab (A_{it}) and add year dummies (Y)³¹.

B. Counterfactual Test: Comparison with Other Public and Private Entities

Next, we compare U.S. patenting at CSIR labs with state owned firms, other public R&D entities and private entities in India, to establish whether or not U.S. patenting trends at CSIR labs were dictated by broader and potentially confounding variables. We code 1640 USPTO patents granted to Indians between 1994 and 2003 and assign each patent an

³⁰ As an example, the filing of U.S. patents requires a much higher level of housekeeping (given that U.S. patents are granted to ‘first to invent’, rather than ‘first to file’); NCL and IICT scientists had prior experience in the U.S. patent filing process and guided other labs in this respect.

³¹ In certain specifications, we also run robustness checks with random effects models where we have 5 dummy variables for the ‘type of science’ pursued, one each for ‘biological sciences’, ‘chemical sciences’, ‘physical sciences’, ‘engineering sciences’ and ‘informational sciences’. In these cases, we also have 19 dummy variables for the lab location based on the 19 Indian states in which CSIR labs are located. These variables are indicated as (Q_i)

‘ownership’ value. The ownership variable can take the following values: CSIR, Indian private, other public R&D (includes University) or state owned firm. In this analysis, we use firm ownership information from the CMIE Prowess database. Here we use both a fixed effects and random effects (difference in difference) regressions to test whether U.S. patenting at CSIR labs was systematically higher than other Indian entities. We use 3 panels (CSIR labs compared to other Indian public R&D/universities, private Indian firms and state owned firms) and use 1996, the first full year of Dr. Mashelkar’s tenure as Director General of CSIR as our baseline year³². Here the specification is:

$$(3) \ln_pat_gr_US_{it} = \beta_0 + \beta_1 * entity_isCSIRlab_t + \beta_2 * post1996_{it} + \beta_3 * entity_isCSIRlab_t * post1996_{it} + \epsilon_{it}$$

In this specification, the key coefficient of interest is β_3 : if CSIR labs show a disproportionate increase in U.S. patents compared to other Indian public and private entities, the coefficient on β_3 should be positive and significant.

IV. Data and Results

A. Data

For 42 CSIR labs and the CSIR headquarters, we hand-collect data on Indian and U.S. patents, lab-earnings from domestic firms, lab-earnings from multinationals, government budgetary support³³ and other laboratory characteristics (like age, location, nature of science pursued, etc.) across 1995-2006 as indicated in Table 1a³⁴. For certain key variables like patents granted, we are able to collect data for 1993-2006 and this resulted in a fairly balanced panel with 571 lab-year observations across 14 years. In addition to data on labs, we also collected micro-data on individual scientists at CSIR and use 593 CVs of scientists across all CSIR labs to construct a dataset with measures of scientist quality (Table 1b) including *fraction of scientists who have PhDs, number of books and*

³² We also repeat the analysis using 1999 as the baseline year. The year 1999 is the beginning of Dr. Mashelkar’s second tenure as Director General, CSIR

³³ A bureaucratic process decides on the level of Government Budgetary support for individual labs, based on past year expenses and size of the lab; this process hasn’t changed significantly from 1993-2006

³⁴ For one of the key variables “pat_gr_US” or patents granted in the U.S., data was collected from 1993-2006 and this additional data helped us in the lagged patents granted effects regression; We also had to match laboratory names across multiple data files and track laboratory name changes, laboratory mergers, etc.

articles published, number of awards won, number of foreign trips and trips to the U.S, number of processes developed, etc.

B. Summary Trends

Figure 1 shows that there was a sharp increase in Indian patents filed by CSIR laboratories starting the policy change year of 1996; however this trend flattened out around year 2000. In contrast, foreign patents filed and granted continued to increase consistently. To augment this analysis, we look at U.S. and Indian patenting by Indian universities, other public research institutes, domestic pharmaceutical companies, other local private companies and state owned firms in India³⁵. Figure 2 shows that CSIR laboratories emerged with a disproportionate share of U.S. patents filed by Indian entities and competed with Indian private firms for the highest share of patents filed in India. We also look at trends in revenue earnings from multinational companies (Figure 3); revenue from multinationals increases from 3% of government budgetary support in 1995 to 15% of government budgetary support in 2006³⁶.

C. Regression Results – Effect of Director Change

In Table 3, we investigate the impact of lab-director change on the level of U.S. and Indian patents³⁷ and find a significant positive relation between director change and number of U.S. patents granted to a lab and a significant negative relation between director change and number of Indian patents granted. Among the interaction control variables, we find a negative (positive) relation between number of U.S. patents (number of Indian patents) and average number of research reports and articles published by a lab.

³⁵ We code 83,986 Indian patents between 1991-2004 and assign them an unique ownership value (CSIR labs, private firms or other SOE) using firm ownership information given in CMIE Prowess and searches on several patent databases. We similarly code 1640 U.S. patents granted to resident Indians between 1994-2006 into the same categories (CSIR, private firms and other SOEs)

³⁶The 15% figure is the average of the 2003-2006. Summary data also reveals that while the number of U.S. patents granted and the revenue from multinationals increased by 13 and 29 times between 1995 and 2006, the level of Indian patents granted and government budgetary allocation increased by only 3 times and 1.5 times respectively, in the same period. Revenue from Indian private companies declined by more than half from 1995 to 2006. We also compare the trends to improvements experienced by Indian SOEs that were privatized in the 1991-1998 and look at data presented in Gupta (2002): Table 3 in her paper enables us to compute that for 36 Indian SOEs privatized between 1991-98, the ratio of sales to government borrowing increases by 60%, after converting logs into absolute numbers; on the other hand, the ratio of sales to multinationals to government borrowing increases by 20 times at CSIR labs. We however acknowledge that this is not a comparable estimate and only provides a very rough sense of magnitudes.

³⁷ We also conduct univariate t-tests for patents and revenue for pre and post director change lab years, reported in Table 2

There is a positive relation between the number of joint projects with NCL and IICT and patenting, though this relation is not statistically significant. In Table 4, the dependent variable is *log of revenue from multinationals*³⁸. In the base case, we run a fixed effects regression with the *post_director_change_{it}* dummy, time-variant controls and year dummies (column I) and then run fixed effects regressions with additional interaction terms (columns II and III). Under all models, we find that revenue from multinationals increases after a director change at individual labs. Among the interaction control variables (columns II and III), we find a positive effect among revenue from multinationals and average number of countries visited by scientists. Joint projects with NCL and IICT have a positive relation to revenue from multinationals, though this effect is not statistically significant³⁹. We also repeat the analysis using fraction of revenue from multinationals as proportion of total lab revenue (“MNCshare_tot_rev”⁴⁰) as the dependent variable (Columns IV and V). Here we report that post lab-director change, the share of multinational revenue, as a fraction of total lab revenue increases. Again, we separate out the effect of incentive change, which happened simultaneously for all labs in 1994 and the effect of lab-director change that happens over 1995-2006. In both Tables 3 and 4, the year dummies after 1995 reflect the effect of one time change in incentives; the incremental effect of lab director change across years is measured by the coefficient of the *post_director_change* dummy. We also plot these effects in Figures 4 and 5.

C. Comparing CSIR with other public and private entities in India

Table 5 summarizes the panel regressions comparing U.S. patenting at CSIR with similar patenting at other public R&D entities and Universities in India (columns I and II); private firms in India (columns III and IV) and state owned firms in India (columns V and VI). We use both fixed effects models (columns I, III and V) and random effects difference in difference models (columns II, IV, VI). As summarized earlier, we use 1996 as the baseline and the key coefficient of interest is on the interaction term (*post96*entity_CSIRlab*). For all regressions, we find this coefficient to be positive and

³⁸ Here we add a 1 before taking logs to account for zeros in the data

³⁹ We also analyze impact of director change on revenue from multinationals over years; the effect initially increases and subsequently declines. Analysis available with authors

⁴⁰ This variable is defined as $\frac{\text{revenue from multinationals}}{\text{government budgetary support} + \text{revenue from multinationals} + \text{revenue from Indian private firms}}$

significant indicating that CSIR labs disproportionately increase U.S. patenting at the under the new leadership⁴¹.

D. Robustness checks

CSIR's move towards greater commercialization raises a question of whether or not the labs consequently compromise on their public science and R&D role, that of creating and disseminating scientific knowledge for the public good. We collect data on publications and the quality of publications and show that CSIR labs do not compromise on their public science role during the study period⁴². Results are reported in Table 6 and indicate that publication volume initially declines in the period 1999-2002 but exceeds base levels in the period 2003-2006. Publication quality, measured using average impact factor of publications on the other hand consistently increases over the period of study.

To ensure that our results are not being confounded by any other policy change at Indian laboratories other than that reported, we collate an exhaustive set of internal circulars and memoranda that outlines policy changes at CSIR laboratories in the period 1994-2004 and check for whether any of the other individual policy changes could be driving our results. As part of government rules, CSIR laboratories are mandated to publish each and every policy change as a 'circular'. We collect and analyze 159 circulars in the period of 1994-2004 and find no such confounding effect, in other words we don't find any major policies, implemented on a large scale that could have impacted our results⁴³. We also explore external policy changes that might affect our results and note a major Indian patent law reform in 1999; details of this reform are summarized in the appendix, available with authors. Prior empirical studies that look at the impact of domestic patent reform include Sakakibara and Branstetter (2001), Branstetter, Fisman and Foley (2006) and Lerner (2002); all of these studies report that patenting by domestic residents either declines or remains stagnant post patent reform. The Indian patent reform should have made it more attractive for all entities including CSIR labs to patent in India;

⁴¹ We repeat the analysis with baseline year as 1999. This is the mid-point of Dr. Mashelkar's regime. We get similar results in this case. Results with authors

⁴² In the public R&D literature, publications have been thought as a measure of social impact of the labs and recent papers like Azoulay, Ding and Stuart (2005) classify 'publications' as a measure of "fundamental pursuit of knowledge" as opposed to patents that embody "applied research"

⁴³ Analysis available with authors

however, our analysis shows that CSIR labs move their patent mix towards U.S. patents, post 1999. We also conduct robustness checks that show multinational revenue at labs increasing in response to increasing U.S. patents, but not in response to higher domestic patents⁴⁴.

Our results are also robust to choice of dependent variable (patents filed instead of patents granted; future revenue from multinationals instead of current year revenues, etc.) and choice of specification (for count variables, instead of a fixed effects Poisson specification, we use a fixed effects panel regression with logarithm of normalized patenting as the dependent variable). We also account for additional control variables like type of science being pursued and lab location and the results remain consistent. However, we are aware of limitations of our study - all national labs may not have the same propensity to patent and though we control for science and location dummies in robustness checks, we are also deeply aware of the ‘selecting to patent issue’ that Agrawal and Henderson (2002)⁴⁵ point out.

V. Conclusion

Our paper makes three distinct contributions to the under-researched area of performance improvement at SOEs where privatization might not be feasible. First, a key contribution of this paper is that we highlight the role of leadership in affecting productivity gains within state owned entities. Though prior empirical work in the SOE reform literature has talked about alternatives and complements to privatization including the role of performance contracts (Groves et al., 1994); new entry in transition economies (McMillan and Naughton 1992) and corporatization (Aivazian et al., 2005), we could not find prior papers that document the role of leadership in transforming SOEs. There is

⁴⁴ Results in appendix and available with authors. Also in macro analyses of the impact of the 1999 patent reform, though, we document an increase in domestic patents for both Indian private companies and other Indian SOEs, domestic patenting starts declining around 5 years after the 1999 reform (data with authors); other recent papers have also suggested other causal reasons why domestic patenting (e.g. for pharmaceutical companies) went up in this period. E.g. a recent working paper in this area is Arora et al. (2008); here the authors conclude that the sharp increase in patenting by domestic pharmaceutical companies in India could be attributed to the effect of TRIPs and the opening up of the generics opportunity in the U.S; their paper build on Lanjouw and Cockburn (2001). An excellent survey of the Indian patent reform is also Mueller (2007)

⁴⁵ Other recent papers that study this issue include Azoulay, Ding and Stuart (2006). Additional robustness checks were done to check if Dr. Mashelkar first moved people from his home lab (NCL) to other labs and then selected them as directors. We found no such evidence

however prior work looking at leadership issues within state owned environments: Karpoff (2001) does a cross-sectional analysis comparing 35 government funded and 57 privately funded Arctic expeditions and finds that the government expeditions had higher failure rates, despite being better funded. He then attributes this to poor leadership structures, slow adaptation to new information, and perverse incentives. In contrast, we outline the role of new leadership changing the strategic course across 42 state owned labs over a 14 year period. In our study, we exploit the exogeneity in timing of lab-director changes and find that revenue from multinationals, share of MNC revenue in total lab revenue and U.S. patenting increases after a change in lab director. Anecdotally, we also find that though the new lab directors had no control over the quantum of government budget, they had control in allocation these resources towards more ‘patentable’ projects. These findings are in line with the theory on leadership and incentives in the economics literature. Rotemberg and Saloner (2000) build a model to show how a “visionary” leader affects incentives of employees and implementation of innovative projects within firms⁴⁶. Hermalin (1998) builds a model of leadership, where a leader, with concentrated information and “leading by example” can yield an outcome that is superior to the symmetric information outcome⁴⁷. Komai et al. (2007) extend the Hermalin (1998) model to show that a leader, not revealing all her information can achieve the first best. Our findings are also generally relevant to firms that are resource constrained. We show that in even a resource constrained environment, leaders can be effective by first aligning their overall goals to the incentives of employees and then allocating scarce resources (government budget in this case) to projects that align with the overall goals.

Secondly, we document that state owned entities might be able to leverage partnerships with private firms, including multinationals in increasing revenue and consequently reducing dependence on government budgetary support. Though the SOE reform literature extensively outlines the role of private sector competition in improving

⁴⁶ In this model, a visionary CEO is biased towards certain kinds of projects and against others. The employees then know that the organization is likely to favor investments that are consistent with this vision and thus, they work hard on such projects, particularly if they can only be rewarded for their efforts when their projects are implemented. One could argue that Dr. Mashelkar and his hand-picked directors created a similar organizational bias towards commercial projects. Also, in a 1993 paper the authors show how leadership style, based on organizational culture or leader personality could affect the incentive contracts that can be offered to subordinates

⁴⁷ In this model, the hidden information problem counteracts free-riding by the team: the need to convince other workers increases the leader’s incentives to work hard, in turn, the followers work hard based on more optimistic beliefs about the leader’s information.

SOE performance⁴⁸, the catalytic role that private firms including multinationals can play in driving up revenue at SOEs hasn't received equal attention.

Finally, we make a contribution by showing that 42 state owned labs were able to leverage their knowledge assets (U.S. patents in this case) rather than physical assets in affecting a turnaround. Specifically, we document that the labs sharply increase U.S. patents and then license many of these patents to multinationals. This result is in line with prior research in the public R&D literature⁴⁹, including Henderson, Jaffe and Trajtenberg (1998), Jaffe and Lerner (2001) and Jensen and Thursby (2001), who all document higher patenting by U.S. public R&D entities in response to incentive and organizational change⁵⁰. Again, barring a few exceptions⁵¹, most of the empirical papers in this literature consider patenting alone; a unique contribution of this paper is the use of data on revenue from multinationals to Indian national labs (as a dependent variable), the use of micro-data from scientist CVs (as control variables) and the use of internal organizational circulars and memoranda (to identify policy changes)⁵². We also document another major insight: the finding that national labs are able to increase revenue from licensing patents to multinationals is significant given that the international IP reform literature (Chin and Grossman 1990, Deardorff 1992, Helpman 1993 and Grossman and Lai 2004) has mostly viewed emerging market R&D entities ('the South') as capable of costless imitation alone and not innovation.

Our findings however need to be studied in context of the overall role of state owned labs and whether focusing on commercial activities is socially optimal. Though we show that the 42 labs were able to commercialize projects without sacrificing publication quality and quantity, a question remains as to why lab directors should even

⁴⁸ Role of privatization versus competition/de-regulation is studied in Yarrow (1986), Lin et al. (1998) and McMillan and Naughton (1992)

⁴⁹ In the context of the U.S., there are several prior papers which have looked at reform of public R&D. Henderson, Jaffe and Trajtenberg (1998) document the impact of The Bayh-Dole Act in assigning property rights of patenting to university researchers, leading to a spike in university patenting. Jaffe and Lerner (2001) look at the transformation of federally funded research and development centers in the U.S. and report that post the 1986 Federal Technology Transfer Act, patenting by government laboratories increased by 50%. Among other incentives, the 1986 law allowed outside collaborators the title to any invention that resulted out of cooperative R&D arrangements (CRADAs). Other papers that look at this issue include Jensen and Thursby (2001).

⁵⁰ This result holds relevance for other emerging market R&D institutions like Embrapa in Brazil

⁵¹ Other papers like Jaffe and Lerner (2001) track the formation of cooperative R&D arrangements (CRADAs)

⁵² Though other researchers like Banerjee et al. (2001) and Jensen (2007) use micro-data to study other government owned sectors in India like sugar cooperatives and fisheries, we could not find any prior papers that uses micro-data for public R&D in an emerging market setting

care about commercialization. Here an important insight is provided by Ramamurti (1987). The author had surveyed senior bureaucrats monitoring SOEs in India and had found that commercial profitability was the most important criterion that explained the subjective evaluations of bureaucrats. The author also mentions that given his results, managers of Indian SOEs could be expected to seek profits not only to reduce financial dependence on the government, but also to gain a measure of external legitimacy.

Finally, we believe that our results are relevant for the large number of state owned firms in emerging markets like India, who continue to lag their private counterparts in performance. As Table 7 suggests, in year 2007, 30% of firm sales in India were with state owned firms; this was in fact an increase from the 27% share of sales that SOEs had in 1991, the year the ambitious privatization program was initiated⁵³. Our analysis also suggests that state owned firms continue to lag their private counterparts in performance (Tobin's q) and R&D investment (R&D to sales ratio). Our finding that CSIR labs were able to increase revenue from multinationals from 3% to 15%, as a fraction of government budgetary support is also relevant for the large number of public R&D entities (universities, other government labs) who are crucially dependent on government budgetary support for survival.

⁵³ Source: CMIE Prowess database

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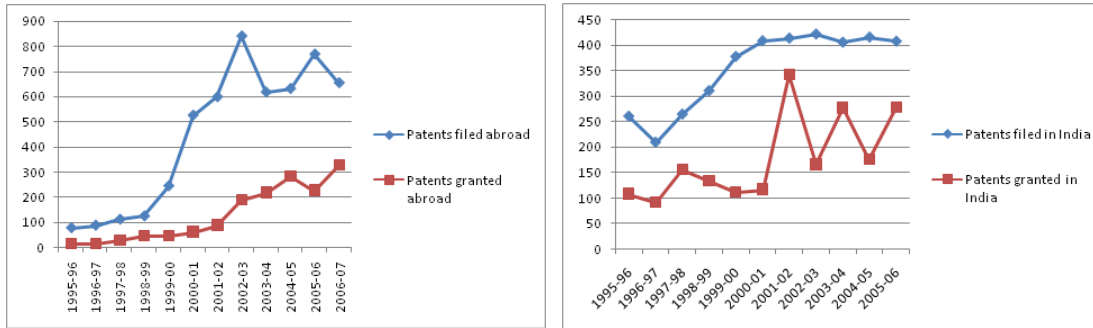
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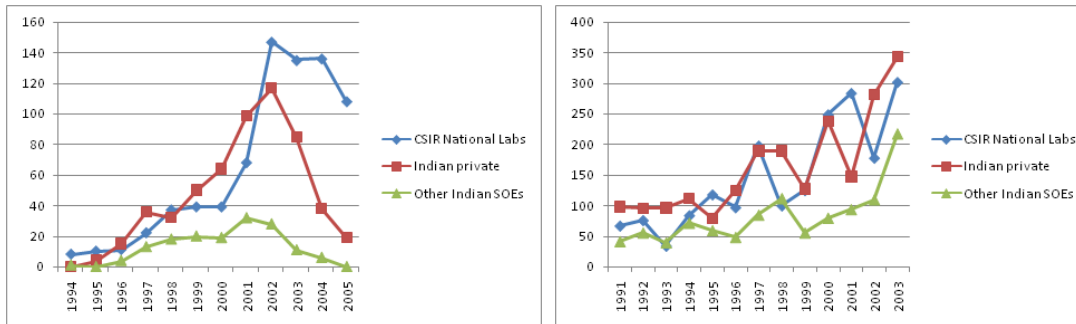
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FIGURE 1 - PATENTING TRENDS AT INDIAN NATIONAL (CSIR) LABS



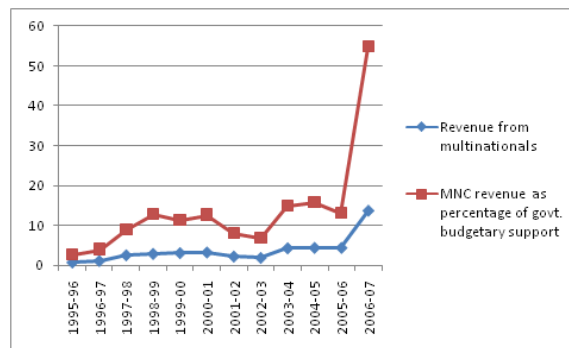
Notes: Here, we trace U.S and Indian patent filings and patents granted to CSIR laboratories. Source: CSIR

FIGURE 2 – COMPARISON OF CSIR PATENTING TO OTHER INDIAN ENTITIES



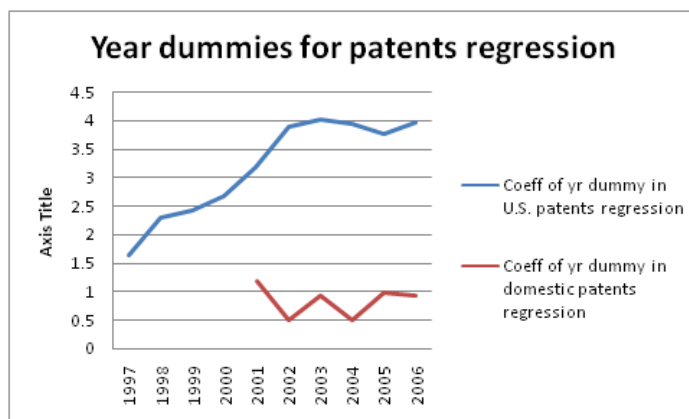
Notes: Here, we trace U.S and Indian patent filings by CSIR laboratories, domestic private firms and other state owned enterprise (other public R&D entities, state owned firms and universities). For each patent, we code the variable 'ownership' (the variable can take the following values: CSIR, Indian private or Other SOE). In this analysis, we use firm ownership information from the CMIE Prowess database. We code 83,986 Indian patents (1991-2003) and 1640 U.S. patents (1994-2005). Foreign patent filings include filings on the USPTO, EPO and other global patent systems. Source: *Ekaswa* Indian patent database for Indian patents; EPO patent dataset for U.S. patents

FIGURE 3 – TREND OF REVENUE FROM MULTINATIONALS AT CSIR LABS



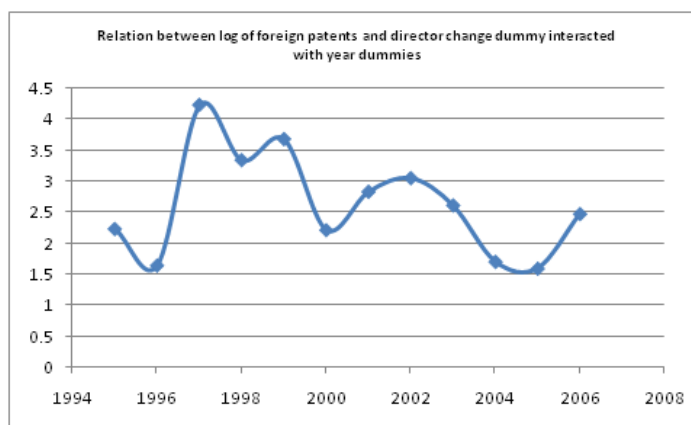
Notes: Revenue from multinationals expressed in millions of 1995 dollars; inflation indices obtained from consumer price index series from International Monetary Fund (IMF) data; MNC revenue as percentage of government budgetary support expressed as percentage. Source: CSIR

FIGURE 4 – EFFECT OF 1994 INCENTIVE CHANGE



Notes: This graphic plots the effect of the 1994 incentive change on patenting in subsequent years. In 1994, all the labs were simultaneously affected by the decision to share revenue from IP licensing with scientists. The point estimates on the year dummy variables captures the general trend of increase in patenting (and revenue from multinationals, which is not shown here). For the U.S. patents regression, we get a positive and significant level shift for years starting 1997; for the Indian patents regression, we get a positive and significant coefficient for years starting 2001. These coefficients are however not ‘net’ of other effects that might affect patenting. However in Table 5, we show that U.S. patenting by CSIR labs is disproportionately higher than other Indian entities

FIGURE 5 – EFFECT OF LAB DIRECTOR CHANGES OVER TIME



Notes: This graphic plots the effect of lab director change over time. Lab director changes happened across multiple labs across 1995-2006, the timing of individual change being plausibly exogenous. Here we interact the *post_director_change* dummy variable with the year dummies to show the effect of lab director change over time

TABLE 1a - SUMMARY STATISTICS OF LAB LEVEL VARIABLES

Variable	Description	Obs	Mean	Std. Dev.	Min	Max
age _{it}	Age of lab 'i' in year 't'	484	39.69	14.7	0	65
Year	Year	564	1999.4	4.03	1993	2006
pat_gr_US _{it}	U.S. patents granted to lab 'i' in year 't'	498	1.77	4.64	0	44
pat_uscum _{it}	Cumulative U.S. patents granted to lab 'i' in year 't'	564	7.62	24.05	0	242
pat_gr_ind _{it}	Indian patents granted to lab 'i' in year 't'	438	5.02	9.29	0	90
pat_indcum _{it}	Cumulative Indian patents granted to lab 'i' in year 't'	438	27.41	52.58	0	512
ecf_foreign _{it}	Revenue from multinationals to lab 'i' in year 't'	328	100.62	181.53	0	1310
ecf_govt _{it}	Budgetary support from government to lab 'i' in year 't'	478	473.99	672.54	14.06	6935.1
ecf_indpvt _{it}	Revenue from Indian private firms to lab 'i' in year 't'	406	74.05	130.72	-17.8	1070.5

Notes: The variable (*age_{it}*) represents age of the lab measured from the year of incorporation; (*ecf_foreign*), (*ecf_govt*) and (*ecf_indpvt*) measure revenue from foreign companies, budgetary support from the government and revenue earnings from Indian private companies. The term “*ecf*” stands for “external cash flow” in CSIR terminology. Source of all data is CSIR. All monetary variables are in Rs. crore where crore represents 10 million

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TABLE 1b - SUMMARY STATISTICS OF VARIABLES FROM SCIENTIST CVs

Variable	Description	Obs	Mean	Std. Dev.	Min	Max
<i>fraction_Phdi</i>	For lab 'i', fraction of scientists with a PhD	42	0.75	0.24	0.00	1.00
<i>num_countries_visitedi</i>	For lab 'i', average number of countries visited by scientists	42	3.08	1.52	0.50	7.08
<i>fraction_visited_USi</i>	For lab 'i', fraction of scientists who visited the U.S.	42	0.45	0.23	0.00	1.00
<i>avg_papersi</i>	For lab 'i', average number of papers published by scientists	42	50.54	25.62	0.50	110.83
<i>avg_scientific_booksi</i>	For lab 'i', average number of books authored by scientists	42	0.89	1.82	0.00	11.25
<i>avg_patentsi</i>	For lab 'i', average number of patents published by scientists	42	2.95	3.79	0.00	18.21
<i>avg_processes_i</i>	For lab 'i', average number of processes developed by scientists	42	2.49	2.50	0.00	10.75
<i>avg_articlesi</i>	For lab 'i', average number of articles published by scientists	42	10.56	47.64	0.00	311.00
<i>avg_reportsi</i>	For lab 'i', average number of reports published by scientists	42	0.01	0.05	0.00	0.31
<i>avg_awardsi</i>	For lab 'i', average number of awards won by scientists	42	1.07	0.93	0.00	3.78
<i>fraction_SSB_awardeei</i>	For lab 'i', fraction of scientists who are SS Bhatnagar awardees	42	0.05	0.11	0.00	0.50
<i>fraction_INSAfellowi</i>	For lab 'i', fraction of scientists who are fellows of Indian Science Association	42	0.03	0.08	0.00	0.33

Notes: Source for this data is CVs of 593 Scientists (in grade F, G and H) of all 42 CSIR labs and CSIR HQ. Values of variables in this table are original values prior to any scaling. SS Bhatnagar Award is a prestigious award named after an ex-Director of CSIR; patents include patents filed in India and abroad. Given that the CVs were collected around year 2000, we only get a one-time measure of these variables

TABLE 2 - UNIVARIATE TESTS: PRE AND POST DIRECTOR CHANGE LAB YEARS

	Pre-director change average	Observations	Post-director change average	Observations	t-statistic for difference
U.S. patents granted	0.68	219	2.63	279	-4.77***
Indian patents granted	3.34	154	5.94	284	-2.82***
Government budgetary support	349.58	195	559.71	283	-3.39***
Revenue from multinationals	48.81	109	126.4	219	-3.72***
Revenue from Indian private companies	84.04	159	67.62	247	1.24

Note: This table provides comparisons of U.S. patents, Indian patents, government budgetary support, revenue from multinationals, revenue from Indian companies and government budgetary support for pre-director change and post-director change lab years

*Denotes significance at the 10-percent level

**Denotes significance at the 5-percent level

***Denotes significance at the 1-percent level

TABLE 3 – REGRESSION RESULTS: RELATING LAB DIRECTOR CHANGE TO PATENTING

Explanatory variables	Dependent Variable			
	(I) pat_gr_US	(II) pat_gr_US	(III) pat_gr_ind	(IV) pat_gr_ind
post_dir_chng	3.94** (1.64)	6.68** (3.33)	-1.74** (0.81)	-2.20** (0.93)
ln_ecf_govt	0.23 (0.17)	0.17 (0.22)	-0.06 (0.15)	-0.15 (0.18)
post_dir_chng*focus	-3.81*** (0.95)	-3.82** (1.73)	0.29 (0.50)	0.39 (0.43)
post_dir_chng*fraction_phd	-1.38 (1.25)	-4.57 (4.04)	1.18 (0.73)	0.76 (0.51)
post_dir_chng*num_countries_visited	-1.31 (1.14)	-1.53 (1.58)	1.96*** (0.61)	2.08*** (0.55)
post_dir_chng*fraction_visited_us	-0.03 (1.95)	-1.14 (2.31)	0.73 (0.80)	1.17 (0.95)
post_dir_chng*avg_books	11.80* (6.40)	15.17 (9.73)	-0.76 (0.56)	-1.05 (0.80)
post_dir_chng*avg_processes	-2.04 (0.88)	-6.38* (3.81)	0.03 (0.47)	-0.06 (0.64)
post_dir_chng*avg_articles	-76.67* (42.64)	-110.27** (49.63)	44.51*** (14.55)	42.95*** (11.33)
post_dir_chng*avg_reports	-1.47*** (0.39)	-1.85*** (0.62)	-0.90*** (0.19)	1.02*** (0.23)
post_dir_chng*avg_awards	-0.63 (1.15)	-1.43 (1.49)	-1.87*** (0.63)	-1.54*** (0.51)
post_dir_chng*num_projects_NCLIICT	-	0.14 (0.27)	-	0.07 (0.05)
1996	0.02 (0.41)	0.72 (0.94)	-0.16 (0.24)	-0.32 (0.29)
1997	0.60* (0.34)	1.63** (0.80)	0.34* (0.19)	0.36 (0.26)
1998	1.10*** (0.38)	2.30** (1.01)	0.22 (0.16)	0.13 (0.23)
1999	1.17*** (0.43)	2.43** (0.99)	0.05 (0.19)	-0.02 (0.30)
2000	1.04** (0.51)	2.68*** (0.97)	0.11 (0.20)	-0.13 (0.27)
2001	1.52** (0.71)	3.18*** (1.09)	1.18*** (0.18)	1.01*** (0.25)
2002	2.23*** (0.61)	3.91*** (1.04)	0.51** (0.21)	0.35 (0.30)
2003	2.15*** (0.80)	4.03*** (0.95)	0.94*** (0.30)	0.93** (0.46)
2004	2.08*** (0.72)	3.95*** (0.98)	0.51 (0.37)	0.50 (0.57)
2005	1.81** (0.79)	3.77*** (0.95)	0.97** (0.39)	0.88 (0.55)
2006	1.93** (0.78)	3.97*** (0.97)	0.94*** (0.35)	0.86* (0.49)
Observations	359	335	383	359

Notes: This table reports results of regressions of U.S. patenting (*pat_gr_US*) and Indian patenting (*pat_gr_ind*) on a dummy variable distinguishing lab-years after the first director change from lab-years prior to the first director change under Dr. Mashelkar’s tenure. The variable (*post_dir_chng_{it}*) is set equal to 1 after the first director change at the lab post 1995. We use a Fixed-effects Poisson (Quasi-ML) regression with robust standard errors (based on Wooldridge 1999 and Simcoe 2007). We also interact the (*post_dir_chng_{it}*) variable with a host of lab level control variables like number of countries visited, fraction of scientists who have visited the U.S., average number of books written by scientists, average number of processes, articles, reports and awards measured at the level of a lab. The variable *focus* measures the patenting focus of a lab measured by Herfindahl index of patent classes. The variable (*num_interactions_NCLIICT_{it}*) measures the number of joint projects a lab has with the two pioneer labs, NCL and IICT. *Denotes significance at the 10-percent level; **Denotes significance at the 5-percent level; ***Denotes significance at the 1-percent level

TABLE 4 –RELATING LAB DIRECTOR CHANGE TO REVENUE FROM MULTINATIONALS

Explanatory variables	Dependent Variable			
	(I)	(II)	(III)	(IV)
	ln_ecf_foreign	ln_ecf_foreign	MNCshare_tot_rev	MNCshare_tot_rev
post_dir_chng	3.50*** (0.92)	3.18*** (0.97)	0.22*** (0.08)	0.15* (0.08)
ln_ecf_govt	-0.24 (0.17)	-0.33* (0.16)	-0.07*** (0.02)	-0.08*** (0.02)
post_dir_chng*focus	-0.24 (1.06)	0.61 (1.28)	0.04 (0.10)	0.05 (0.11)
post_dir_chng*fraction_phd	-3.36*** (0.93)	4.13*** (1.08)	-0.15* (0.08)	-0.07 (0.09)
post_dir_chng*num_countries_visited	3.01*** (1.02)	3.43*** (0.95)	0.23*** (0.08)	0.23*** (0.08)
post_dir_chng*fraction_visited_us	-4.16*** (1.50)	-3.63** (1.55)	-0.27** (0.11)	-0.23* (0.12)
post_dir_chng*avg_books	6.89 (5.92)	0.61 (6.40)	0.37 (0.41)	0.14 (0.40)
post_dir_chng*avg_processes	0.92 (0.93)	-1.53 (1.51)	-0.16** (0.07)	-0.07 (0.12)
post_dir_chng*avg_articles	20.76 (39.42)	57.44 (45.09)	-0.11 (2.64)	1.09 (2.79)
post_dir_chng*avg_reports	-1.24*** (0.29)	-1.41*** (0.26)	-0.12 (0.03)	-0.12*** (0.02)
post_dir_chng*avg_awards	-0.27 (0.71)	-0.30 (0.79)	-0.11 (0.04)	-0.06 (0.04)
post_dir_chng*num_projects_NCLICT	-	0.12 (0.09)	-	-0.00 (0.01)
1996	0.45 (0.42)	0.91** (0.38)	0.02 (0.03)	0.05 (0.03)
1997	0.50 (0.53)	0.53 (0.60)	0.07 (0.05)	0.05 (0.05)
1998	0.64 (0.59)	0.55 (0.66)	0.06 (0.05)	0.03 (0.04)
1999	0.70 (0.52)	0.52 (0.56)	0.07 (0.05)	0.03 (0.04)
2000	0.31 (0.52)	0.09 (0.58)	0.05 (0.04)	0.01 (0.04)
2001	0.88* (0.48)	0.69 (0.53)	0.07 (0.04)	0.03 (0.04)
2002	1.00** (0.48)	0.92* (0.53)	0.08* (0.04)	0.06 (0.04)
2003	1.56*** (0.51)	1.57** (0.59)	0.15*** (0.05)	0.13** (0.05)
2004	1.56*** (0.55)	1.55** (0.61)	0.14*** (0.05)	0.13** (0.05)
2005	1.71*** (0.51)	1.72*** (0.58)	0.15*** (0.04)	0.14*** (0.05)
2006	3.15*** (0.53)	3.17*** (0.60)	0.26*** (0.05)	0.23*** (0.06)
Observations	269	246	244	221

Notes: This table reports results of regressions of revenue from multinationals (*ln_ecf_foreign*) and share of multinational revenue in total earnings of a lab, including government budgetary receipts (*MNCshare_tot_rev*) on a dummy variable distinguishing lab-years after the first director change from lab-years prior to the first director change under Dr. Mashelkar’s tenure; the variable (*post_dir_chng_{it}*) is set equal to 1 after the first director change at the lab post 1995. We use a fixed effects regression here. The variable (*MNCshare_tot_rev*) is defined as (revenue from multinationals)/(government budgetary support+ revenue from multinationals + revenue from Indian private firms). We interact the (*post_dir_chng_{it}*) variable with a host of lab level control variables like number of countries visited, fraction of scientists who have visited the U.S., average number of books written by scientists, average number of processes, articles, reports and awards measured at the level of a lab. The variable *focus* measures the patenting focus of a lab measured by Herfindahl index of patent classes. The variable (*num_interactions_NCLICT_{it}*) measures the number of joint projects a lab has with the two pioneer labs, NCL and IICT

*Denotes significance at the 10-percent level

**Denotes significance at the 5-percent level

***Denotes significance at the 1-percent level

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TABLE 5 - REGRESSION RESULTS: COMPARING U.S PATENTING OF CSIR LABS TO OTHER INDIAN ENTITIES

Explanatory variables	Sample: CSIR labs, all other public R&D labs and public Universities		Sample: CSIR labs and all private Indian firms		Sample: CSIR labs and all state owned firms	
	Dependent Variable					
	(I)	(II)	(III)	(IV)	(V)	(VI)
	<i>ln_US_patents</i>	<i>ln_US_patents</i>	<i>ln_US_patents</i>	<i>ln_US_patents</i>	<i>ln_US_patents</i>	<i>ln_US_patents</i>
post_1996	-04 (0.05)	-0.04 (0.09)	-00 (0.01)	-00 (0.02)	1.12** (0.41)	-0.19 (0.39)
entity_is_CSIRlab	-	1.75** (0.81)	-	1.75* (1.02)	-	1.71** (0.87)
post96*entity_CSIRlab	1.84*** (0.02)	1.84** (0.89)	1.83*** (0.02)	1.83** (0.89)	1.73*** (0.10)	1.73** (0.82)
Year dummies	Yes	Yes	Yes	Yes	Yes	Yes
N	533	533	2041	2041	117	117
Base year	1996	1996	1996	1996	1996	1996
Model	Fixed effects	Random effects	Fixed effects	Random effects	Fixed effects	Random effects

Notes: This table reports results of regressions that compare U.S. patents at CSIR labs to other Indian entities. Models I and II compare CSIR labs to other Indian public R&D labs and universities; models III & IV compare CSIR labs to Indian private firms; models V & VI compare CSIR labs to Indian state owned enterprise. The analysis is done for baseline year 1996 (first full year of Mashelkar’s tenure as Director General CSIR). Similar results, not reported here are obtained for dummy year 1999 (mid point of Mashelkar’s regime). Models I, III and V are fixed effects and models II, IV and VI are random effects/difference in difference models. For each patent, we code the variable ‘ownership’ and we code 1640 U.S. patents (1994-2005). Heteroscedasticity consistent standard errors reported within parentheses.

*Denotes significance at the 10-percent level

**Denotes significance at the 5-percent level

***Denotes significance at the 1-percent level

TABLE 6 - REGRESSION RESULTS: TRENDS OF PUBLICATION VOLUME AND QUALITY

Explanatory variables	Dependent Variable		
	(I) Pub	(II) ln_pub	(III) Impact_Factor_Perpub
period2 (1999-2002)	-0.13** (0.05)	-0.23*** (0.08)	0.25*** (0.05)
period3 (2003-2006)	0.30*** (0.05)	0.33*** (0.09)	0.62*** (0.05)
ln_ecf_govt	0.14* (0.07)	0.01 (0.06)	0.03 (0.03)
ln_pub	-	-	-0.09** (0.04)
Observations	465	466	442
Method	Fixed Effects Poisson adjusted for QML	Fixed Effects	Fixed Effects

Notes: This table reports regressions results of how publication quality (measured by *pub* and *ln_pub*) and publication quality (*impact_factor_Perpub*) changes over time. The baseline period is 1995-1998 and the independent regressors are two period dummies (period 2 for 1999-2002 and *period3* for 2003-2006). In the public R&D literature, publications have been thought as a measure of social impact of the labs and recent papers like Azoulay, Ding and Stuart (2005) classify ‘publications’ as a measure of “fundamental pursuit of knowledge” as opposed to patents that embody “applied research”. The dependent variable publication quality (*Impact_Factor_Perpub*) is measured using Thomson indices. Publication quality consistently improves over time; publication volume dips in period 2 but pick up in period 3. Results robust to choice of specification

*Denotes significance at the 10-percent level

**Denotes significance at the 5-percent level

***Denotes significance at the 1-percent level

TABLE 7 - COMPARISON OF INDIAN SOEs AND DOMESTIC PRIVATE FIRMS, 1991 & 2007

	1991		2007	
	SOE	Private domestic	SOE	Private domestic
Number of firms	176	2630	244	5074
Percentage of total sales	27%	73%	30%	70%
Percentage of total assets	34%	66%	31%	69%
R&D to sales ratio	0.02%	0.02%	0.18%	0.52%
q ratio	0.25	0.7	2.12	14.44

Notes: This table compares number of firms, R&D to sales ratio and Tobin’s (*q-ratio*) for Indian state-owned firms (SOEs) and domestic private firms in year 1991 and year 2007. The table also compares the percentage of total industry sales (*Percentage of total sales*) and percentage of total industry assets (*Percentage of total assets*) in the SOE and domestic private sector in years 1991, 2007. The year 1991 is chosen to indicate the beginning of the Indian government disinvestment/privatization program. Year 2007 indicates the end of the time period of the current study

Appendix Case Study: The CSIR-GE Partnership

Here, we document a motivating example⁵⁴ that suggests that foreign patenting at CSIR was instrumental in attracting business from GE. In 1989, Dr. Mashelkar took over as Director of the National Chemical Laboratory (NCL), one of the CSIR labs. Prior to this, CSIR filed for less than 5 foreign patents every year. Around 1989, NCL scientists under the new leadership prioritized research in the area of polymer preparation, condensation and poly carbonates and filed for the first U.S. patents in this area⁵⁵

Around 1991, NCL started interacting with GE, the firm being a large purchaser of THPE⁵⁶, and Hoechst Celanese USA, was the only supplier of THPE to the global market. In 1994, NCL initiated a program, funded by GE aimed at developing a proprietary process for THPE. In parallel, NCL started aggressively patenting in the USPTO system and filed several U.S. patents in the area of polymers between 1994 and 2000⁵⁷. In interviews, Dr. Mashelkar and other NCL scientists have stressed on the *role played by the first few USPTO patents on polymers in “getting a foot in the door at GE”*. The GE-NCL alliance successfully worked for 9 years and was successful in breaking the global monopoly of Hoechst in the area of THPE. NCL earned revenues of around USD 8.5 m over this period from GE.

⁵⁴ Based on interviews with Dr. Mashelkar and other CSIR executives

⁵⁵ e.g. patent number 5,080,121 filed in August 1990 that claimed to create a "novel polymer useful for drag reduction in hydrocarbon fluids in exceptionally dilute polymer solutions"

⁵⁶ 1,1',1''-Tris(4'-hydroxyphenyl) ethane; a branching agent used in the synthesis of high grade polycarbonates

⁵⁷ e.g. U.S. patents 5,780,578, 5,851,546, 6,379,599, 6,420,487, 6,605,714, 6,689,836, 6,794,467 and 6,867,268