Restructuring China's Research Institutes: Impacts on China's Research Orientation and Productivity

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Abstract

This paper evaluates the impact of the Chinese government's initiative begun in 1999 to restructure the country's approximately 3,500 research institutes. The paper reviews the evolution of China's research sector over the period 1995 to 2010, identifying certain issues that are analyzed using a panel of sample research institutes. The econometric analysis is based on a balanced sample of these institutes, both converted and unconverted, spanning 1998, the year prior to the restructuring initiative, to 2005. In order to control for potential endogeneity and selection bias, the paper employs various econometric methods to evaluate the impact of the restructuring program on the performance of these institutes. We find that the restructuring program appears to have achieved its fundamental goals, that is, shifting the relevant resources toward a more commercial mission for the converted S&T enterprises and a more research-oriented mission, involving the use of government grants, for the non-profit research institutes. The results show modest gains in the efficiency of patent production, but given the lengthy gestation period, a longer duration is needed to assess how the patent production of China's research institutes will adapt to the shift in their missions and reassignment of government resources.

JEL Codes: O31, O32, O33
Keywords: Technological Innovation, R&D, Invention, Research Policy

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1. Introduction

In 1999, China's Ministry of Science and Technology initiated a formal restructuring that was designed to clarify the research functions of China's 5,573 organizations that were classified as research institutions in that year.[1] For the purpose of determining the implications of the 1999 restructuring for the productivity, research orientation, and patent performance of the institutes, this paper examines the impact of conversion on a subset of those organizations. Several issues arise from this analysis of MOST's restructuring program, including its impact on the restructured institutes versus those that were not restructured. Furthermore, the restructured institutes consisted of three categories with different degrees of emphases on commercial versus government-sponsored research and applied versus basic scientific research and public policy-related applications. In order to investigate the direction and magnitudes of the performance impacts of the restructuring, we examine a sample of the research institutes, both restructured and non-restructured.

China's research institutes constitute a major element of the country's research establishment. In the mid-1990s, five to six thousand research institutes operated as independent accounting units (*duli hesuan danwei*) under the supervision of a wide array of government agencies, both within the central government and also across China's sub-jurisdictions. Virtually all received direct government subsidies for their research activities.

In 1999, China's government formally began the implementation of a broad-based program to restructure the nation's research institutes. A key objective of the restructuring program was to assign each of the institutes to a category that represented a particular functional purpose. The three categories were:

1. Science and technology enterprises: Intended to be commercialized, less reliant on public funds;
2. Non-profit research institutes: Intended to shift focus toward research, particularly basic research, with government support;

[1] MOST (2006), p. 26.

3. Non-profit, non-research institutes: Intended to support various economic and social development objectives, primarily through the analysis and transfer of existing research.

With many of the research institutes facing less dependence on government support and more reliance on the market, reformers anticipated that the innovation activities of the research institutes would become increasingly motivated by commercial objectives and as a result become more responsive to the needs of the market. At the same time, the government retained substantial oversight and support for the core of the nation's basic research establishment, such as institutes within the Chinese Academy of Science and the Chinese Academy of Social Science. Explicitly commercializing a substantial portion of the nation's state-owned research institutes was intended to enable a shift of the government's administrative and financial resources toward that subset of research institutes that focused on basic research and other social objectives.

The central purpose of using the sample of research institutes is to more deeply investigate and seek to reconcile certain issues that arise from our review of the overall research institute sector. These include the following questions:

1. Since the restructuring process extended over a substantial period, can we determine how effective the restructuring has been in enhancing the performance of the research institutes?
2. Specifically, has the restructuring improved the overall productivity of the research institutes and, specifically, the patent productivity of the research institutes?
3. Have the institutes classified as S&T enterprises and those classified as non-profit research institutes responded in different ways to the restructuring initiative?

To answer these questions, we use two main sources. One is the aggregate statistical profile of China's research institutes as reported in the annual *Chinese Science and Technology Yearbook*. These data cover a variety of aggregate variables concerning the research sector. Our long-term overview spans the period from 1995 through 2010. In order to examine various specific issues that arise concerning the impact of the restructuring on institute orientation and performance, controlling for selection bias in the restructuring process, we exploit a panel of institute-level data spanning the period 1999-2005. Using these institute level data we estimate various revenue functions to determine how the restructuring shifted the orientation of the restructured institutes relative to those left unrestructured and also the productivity impact of restructuring. In particular, we examine the impact of the restructuring on the patent productivity of restructured institutes. Is there evidence that restructuring affected a shift toward or away from patentable research? In either case, were the institutes using their research-related resources more or less efficiently to produce patents?

This analysis concerning the impact of the restructuring program on China's research institutes employs a balanced sample consisting of 1,813 research institutes for each of the 7-years for our estimation work. The sample represents 33 percent of the 5,573 research institutes that participated in the annual Ministry of Science and Technology survey in 1999 and 46 percent of the 3,901 institutes reporting in 2005, thus accounting for a substantial cross section of China's research institute activity. The sample consists of random selections of institutes from a balanced panel that includes five major sectors. These sectors are agriculture, public service, and three manufacturing sectors – chemicals, ferrous and non-ferrous metals, and computing and electronic equipment.

The key finding of this paper is that the restructuring has achieved some of its hoped-for efficiency gains. The research institutes that were converted to S&T enterprises demonstrate improvements in their ability to generate non-government revenue, controlling for their inputs of S&T personnel and equipment. Institutes that were converted to non-profit research institutes are capturing a substantially larger change of government grants that focus on basic research; their total revenue productivity rose substantially during the conversion period. Both types of conversions exhibit marginal gains in their patent productivity. However, given the gestation period for new research to translate into patent filings, it is likely to be premature to draw conclusions concerning the impact of restructuring on patent production. The results are clear that resources that relate to the differentiated articulated missions of the S&T enterprises and NPR institutes have been shifted toward the requisite organizations.

The balance of this paper consists of five sections. Section 2 describes the restructuring program begun in 1999 and the overall organization of China's research institute sector. Section 3 describes the uses the sample of research institutes used to more thoroughly investigate the impact of the restructuring program. Section 4 describes the modeling and econometric strategy used to conduct this analysis. Section 5 discusses the results. Conclusions and next steps are discussed in the final section, Section 6.

2. Relevant Literature

This paper is specific to the restructuring of China's research institute sector; nonetheless, we attempt to place China's larger research enterprise within a larger context by reviewing some of the related literature. In particular, we have attempted to locate literature that situates research institutes within the context of a nation's national innovation system. In addition, because patents are a key output of research institutes, particularly those perfoming basic research, such as a substantial number of the Chinese research institutes in this study, we search the literature on patent production functions.[2]

The role of MOST and the research institutes. Sun and Cao (2014) provide an extensive account of the role of China's central government in funding and supervising the country's research program. According to Sun and Cao, within China, "MOST is an overarching government agency responsible for China's scientific enterprise. It formulates S&T development plans and policies and organizes and implements S&T programs." (p. 13) At one point during the 1990s, MOST received the largest portion of the central government's S&T appropriations and was the central agency responsible for distributing S&T funds across government agencies. Now, however, the Ministry of Finance (MOF) is responsible for distributing central government S&T expenditures to the secondary funders. In 2011, MOST, the Chinese Academy of Sciences, and the National Science Foundation China accounted for nearly 50 percent of the total central government's total R&D expenditure.

While most of China's domestically-owned research institutes fall within the MOST statistical system, only a portion of their funding comes directly from MOST. For example, in the case of the State Key Laboratory Program (SKL), the relevant research institutes and laboratories are largely based at China's universities and receive most of their funds from the

[2] Jefferson et al (2008) use a similar data set that provides a very preliminary documentation of the data and associated estimation results. The data in this program have been more carefully sorted and cleaned and the research methodology and estimation methods substantially refined relate to the early version.

Ministry of Education, CAS, and local governments. MOST's funding responsibility is limited to the establishment, evaluation, and dissolution, as needed, for the relevant units within the SKLprogram (p. 14).

The academic literature on the evaluation of research institutes is meager, not only for China, but worldwide. Part of the difficulty is the ambiguity concerning the objective function of a research institute. In principle, research institutes produce new knowledge, but new knowledge can be packaged in a variety of ways, for example, as patents, scientific papers, royalties, and consulting revenue. Moreover, there is no common unit, either physical or monetary, to capture a consistent measure of the economic or social value of the output. Furthermore, unlike the conventional commercial corporation, which typically uses a fiscal year to match inputs and outputs or the purpose of measuring productivity or profitability, the time frame within which research inputs are converted to research outputs is ambiguous. While, in principle, a patent application or grant or scientific paper may be produced in a measureable period of time, its fulfillment generally entails a multiple years of uncertain duration. More importantly, the economic and social value of such research outputs may not be measureable, even over long periods. How, for example, would we measure the social value of the invention of calculus or the internet, or even inventions that are more discrete such as the radio or dishwasher?

Academic research that focuses on the research enterprise typically focuses on specific research projects that entail the application of resources to achieve a specific research objective, such as the cure of a disease or mitigation of a social problem, such as pollution or respiratory illness. Again, little research focuses on individual research organizations and the efficiency with which they convert research inputs into measureable research outputs. Perhaps the most typical or sought-after objective of the research institute is the creation of patentable research. One research method that has become formalized and useful is the patent production function. We review its function and use.

The patent production function. Following the tradition of Pakes and Griliches (1984), Hausman, Hall and Griliches (1984), and Bound et al. (1984) we estimate a patent production function. Each of these uses a production function with varying functional forms to relate research inputs with counts of patent applications or patent grants and varying estimation strategies, such as the Poissant estimator, which corrects for the non-normal distribution of patents within their samples, often involving a preponderance of firms without patents. In their seminal article, Pakes and Griliches (1984), for example, use an 8-year panel of patent data for 121 U.S. companies analyzing the patent count as a function of current and lagged R&D expenditures. While each of these studies use U.S. firm data to estimate their functions, Hu and Jefferson (2009) extend the methodology to a large panel of large and medium-size Chinese firms. They use these data and a zero-Poissant estimator to test among five factors that may have been responsible for the patenting surge in China: the pro-patent amendments to the Patent Law in 1992 and 2000, the surge in R&D intensity, the rise in foreign direct investment, shifts toward industries with higher propensities to patent, and enterprise restructuring.

In this paper we utilize patent production functions, although rather than using the patent count approach, we address the problem of non-normality by using an approach in which we group research institutes by various ranges of patent production. We also use a more standard revenue production function approach to test for changes in overall productivity gains following the 1999 restructuring, including whether research institutes that were classified in different ways shifted toward and expanded their research output in ways that were consistent with the government's restructuring objectives.

3. China's Research Institutes: Restructuring

In 1999, the Chinese government began its restructuring of the 5,705 research institutes operating in that year. The program, administered by MOST, was motivated by the objective of commercializing that sector of the research establishment that seemed to be potentially responsive to market incentives while at the same time concentrating the government's administrative capabilities and financial support on a smaller number of research institutes that would be more explicitly dedicated to basic research and policy analysis.

Table 1 shows a profile of changes in China's research institute population over the years 1995 to 2010. We use 1998, the year prior to the restructuring initiative, as the baseline year. One obvious substantial change is the abrupt falloff in the number of surviving institutes from

1998 to 2005, during which approximately one-quarter of the institutes disappeared. That the number of research institutes was relatively stable during the three years prior to 1998 and the five years following 2005 suggests that the restructuring initiative led to the large surge of exiting research institutes. By in large, these institutes exited through one of four potential channels. Some simply shut down; still others merged with other research institutes so as to achieve economies of scale and/or scope. Other research institutes dropped their formal status as research institutes acquiring the new formal designation of "enterprises" and causing them to migrate from the statistical system consisting of research institutes under the supervision of MOST to the enterprise statistical system supervised by the National Bureau of Statistics. The research institutes migrating into the enterprise system did so either because they were absorbed by commercial enterprises for the purpose of augmenting individual firm R&D capabilities or they migrated as a result of having shed research, and various science and technology (S&T) activities, as their principal locus of operation.

Data on the total number of employees in the research institute sector show a significant reduction in total S&T employment, having fallen from 644,000 in 1995 to 588,000 in 1998 the year prior to the restructuring initiative and then declining precipitously by nearly 30 percent to 415,000 during the first three years of the restructuring program. The decline in personnel was also reflected, albeit not as dramatically, in the decline in the full-time equivalent R&D personnel. As shown in Table 1, the total numbers of S&T personnel and the full-time equivalent R&D personnel, a component of the S&T personnel figure, begin to rebound by 2005, further rising by 2010. By 2010, the number of R&D personnel had substantially exceeded those of previous years including 1995, while the broader measure of S&T personnel continued to be less than those of 1995 and 1998, the year prior to the restructuring initiative. We also see in Table 1, a steady increase in the proportion of S&T personnel reported as scientists and engineers. Together these statistics convey subsequent to 1998 a trend toward the overall downsizing of manpower in the research institute, albeit with growing concentrations of R&D staff and scientists and engineers.

Table 1 also shows during 1995-2010 a substantial shift in the levels and composition of China's overall R&D program. Overall, during this 15 year period, national R&D spending rose by a factor of more than 20, in nominal terms. Significantly, however, the share of the nation's total R&D spending controlled by the research institute sector declined significantly from 42.5 percent in 1998 to just 16.8 percent in 2010. Given the mandate of the research institute sector to foster basic research, we focus on that component of overall R&D. Table 1 shows that as a fraction of total national R&D, China's overall spending on basic research remained relatively stable at 5.2-5.7 percent during 1995-2005, before trailing off to 4.6 percent in 2010, most likely reflecting the surge in overall applied and development R&D spending, particularly within China's enterprise sector. Notwithstanding the decline in the research institute sector's share of overall R&D spending, its share of national spending on basic research remained relatively robust, declining from near 60 percent in 1998 to 40 percent in 2010, a reduction of one-third. At the same time, within the research institute sector, spending on basic research rose from 7.5 percent of its total R&D spending in 1997 to 11 percent in 2010. Hence, in 2010 the share of basic R&D spending in the research institute sector was about 2.4 times that of the share in the nation's overall R&D spending.

This relative downsizing of China's research institute sector, with its commensurate shift toward the nation's basic research mission, leads naturally to the question of how effective the research institute sector has been in generating S&T outputs, particularly basic research outputs. While publications and S&T consulting revenue may result from a focus on basic research, the summary descriptive statistics in Table 1 focus on patent applications as a key measure of research efficiency. Table 1 shows a dramatic increase in the total number of applications generated per thousand S&T workers, rising from 0.6 in 1998, the year before the restructuring initiative, to 2.1 in 2005 and 5.6 in 2010. While research productivity, measured in terms of patent applications per S&T employee, has risen within the research institute sector, the sector's share of invention patent applications has declined. Table 1 shows that the decline in the share of the nation's basic research from 1998 to 2010 and the decline in the share of invention patent applications are proportional – about one third. However, the levels of the shares of basic R&D spending and invention patents are strikingly different. In 2005, while the research institute's share of the nation's basic research is 44.2 percent, the sector's share of domestic invention patent applications rises only to 7.2 percent, about one-sixth the share of basic research spending. In 2010, the respective shares decline to 40 and 6.2 percent. In 2010, the share of invention patents granted is 8.2 percent and the share of the total in force is 8.9 percent. While this somewhat closes the gap between the share of basic research spending and the size of the difference is still puzzling.

The purpose of this overview of China's R&D spending and the place of the research institute sector within it is to provide a perspective on the evolution of the research institutes within a broader framework. This review leads to the following conclusions: i) The number of research institutes and the size of its S&T personnel were significantly reduced as a result of the restructuring initiative begun in 1999; ii) Within the research institute sector, resources have shifted more toward a research orientation, particularly a basic research orientation. Nonetheless, within the research institute sector, basic research accounts for only about 11 percent of total R&D resources; and iii) With respect to invention patents as a measure of basic research output, given its share of total basic research funding, the research institute appears to be under performing.

We use our panel of research institutes spanning 1998-2005 to examine the contribution of the restructuring initiative to these changes. In particular, the yearbook data do not distinguish among the research institutes that have been restructured and those that have not. Given that only a minority of research institutes has been restructured, we might expect that the overall descriptive statistics in Table 1 may not give an accurate and complete account of the impact of restructuring. Also, we know from our sample of institutes that the restructured institutes have been reassigned to different categories of institutes, some with a focus on more basic research; others with a focus on commercializing their S&T activities. We will examine this sample of research institutes to identify the differential impacts that China's restructuring initiative has had on the research institute sector.

4. Research Institutes: the Sample

Table 2 shows the initial years of China's restructuring initiative. It shows that in 1999, the first year of restructuring, 132 institutes were reclassified as S&T enterprises and 114 to non-profit research institutes By 2003, the number of institutes converted to S&T enterprises had grown to 1,087, nearly one-quarter of the total institutes, while 127 institutes had been reclassified as non-profit research institutes and 134 as non-profit, non-research institutes. These so-called non-profit, non-research institutes are largely focused on technology transfer or S&T consulting; some have been assigned to independent university or hospital supervision. In any event, their function is largely to serve as intermediaries to process and transfer research rather than to produce it.

In 1999, there were actually 205 research institutes that were restructured. In addition to the 132 institutes accounted for above, 73 institutes exited from the research institute sector. Most of these were merged into enterprises outside the formal research sector; otherwise they were liquidated.

Table 3 provides a summary description of our sample consisting of 1,813 institutes. Because these institutes are all surviving institutes that comprise a balanced sample while, as shown in Table 1, the total number of research institutes declined during 1999-2005, our sample accounts for a growing share of the institute population, rising from 33 percent to 46 percent during this six-year period. As Table 3 shows, by 2005, 440 research institutes representing 24 percent of our sample had been restructured. Among the 440 restructured institutes, 60 percent had been reclassified as S&T enterprises, 25 percent as non-profit research institutes, and 15 percent as non-profit, non-research institutes. This is the panel, spread over the period 1998-2005.

By 2005, 440 of the 1,813 institutes in our sample (i.e. 24%) had been converted, a proportion virtually identical to the 23 percent conversion rate for population of research institutes in that year. Table 4 highlights some of the changes in institute performance over the period 1998, the year before the conversion initiative to 2005, the last year of our sample. The changes distinguished between the unconverted and converted institutes and among the converted institutes, between the S&T enterprise conversions and the non-profit research institute conversions. Notable changes in the output and performance measures of the sample include:

- Revenue per worker and revenue composition: Total revenue per worker rises for all three groups, but it rises most robustly for the converted enterprises. The composition of the changes differs notably among the three groups. S&T rises most for the NPRs and the least for the S&T enterprises. The S&T enterprises are the only group for which the revenue share fell substantially. In its place, the converted S&T enterprises exhibited a substantial increase in its production and management revenue share, suggesting that for S&T enterprises, a substantial portion of their activity shifted to manufacturing production. Simultaneously, over the 7-year period, the share of revenue from government grants shifted away from the S&T revenues and most notably toward the NPRs.

- Scientific paper publications: This productivity measure declines for the S&T enterprises rising significantly for the unconverted institutes and the NPRs.
- Patent production: Patents per 100 R&D workers rise by a factor of two or more for all three groups. While the largest proportional increase is for the NPRs, the S&T enterprises show the most productive output, exceeding that of the NPRs by more than a factor of three. Unfortunately, our data set does not allow us to distinguish among innovation patents, which are generally of substantially higher quality than the alternative utility and design patents.

Finally, among the stylized facts, Table 5 breaks down the full sample by six different sectors that are included in the sample. These are agriculture, chemicals, metals, electronics, public policy, and specialized R&D. These show that three of the six sectors are in manufacturing. Together they constitute only 13.2 percent of the sample. However, they also exhibit a substantially higher rate of conversion approaching two-thirds or more for each of the three manufacturing sectors. Other notable aspects of the table include:

- The three manufacturing sectors show the largest increases in the shares of P&M revenue; again this is consistent with the apparent shift away from S&T activity and toward production in the S&T enterprise sector.
- While scientific paper productivity fell in the three manufacturing sectors, it rose in the three non-manufacturing sectors; the public policy sector shows the highest and fastest growing incidence of scientific papers per R&D employee.
- The manufacturing sectors show the fastest growing incidence of patents per 100 R&D workers. By 2005, patent productivity in the manufacturing sectors were multiples of their levels in the other sectors.
- Among the sectors, the metals industry stands out for its level and increase in total revenue per worker and for the level and increase in patents per R&D worker. Among all

the industries, it also has the lowest S&T revenue share and the largest P&M revenue share.

- The government grant revenue share is substantially larger in the non-manufacturing sectors than the manufacturing sectors.

From the sample described above, for the purposes of our research, we use only the research-oriented research institutes, i.e. the S&T enterprises and the non-profit research institutes. From our sample of 1,813 research institutes, we drop the 65 non-profit, non-research institutes, leaving a sample of 1,748 institutes. The empirical foundation of this paper, the 1,748 research institutes, is hereafter referred to as the "MOST sample." The data set is balanced in the sense that in every year, the same 1,748 institutes are included in the sample. Spanning the years 1997 to 2005, the sample represents 31 percent of the total population of research institutes in 1997 growing to 46.5 percent in 2005.

The purpose of the econometric section that follows is to clarify the impact of the restructuring program on China's research institutes. In particular, we do two things. The first is to control for selection bias as we examine the impact of the restructuring, concerning how the converted inputs, outputs, and change in productivity differed among the converted and non-converted institutes. A second major focus of the econometric analysis is to use the patent production function methodology described in Section 2, the Literature Review, to determine how the restructuring affected the patent productivity of the various institute types.

5. Econometric Methodology

In this section we describe the main model we estimate and the various methods used to estimate the main model equation. Our goal is to estimate the effect of converting an unrestructured institute to an S&T enterprise or to a non-profit research institute on the functional orientation and performance of the organization. We do this by evaluating the impact of conversion on the changes resulting from conversion, on the nature of the institute's revenue stream, on its productivity, and specifically on its post-conversion patent production. Because selection for conversion is likely to be non-random, we pay particular attention to the assumptions we need to make in order to obtain consistent estimates of the conversion effect. We outline three methods: standard OLS, fixed effects estimation, and propensity score matching; each of these will be consistent under increasingly weak assumptions concerning the nature of selection.

5.1 Model

We assume that our various outcomes can be related to conversion and inputs via a production function relationship. Let $R_{i,t}$ be the outcome of interest for institute i at time t (e.g. revenue) then we write:

$$R_{i,t} = A_{it} f(X_{it}), \quad (1)$$

where A_{it} is a productivity parameter and X_{it} is a vector of inputs. The vector includes total personnel as well as the shares of personnel engaged in R&D and in production and management, S&T intermediate inputs, and S&T equipment.

We take productivity in logs a_{it} as: $a_{it} = \alpha + \varphi s_{it} + u_{it} + \varepsilon_{it}$. Here α is a constant term, s_{it} is a conversion indicator equal to one if the institute is converted by time t, φ is the conversion effect, u_{it} is an unobserved productivity component possibly correlated with s_{it}, and ε_{it} is a productivity shock uncorrelated with conversion. Assume that $f(X_{it})$ is a log-linear function $f(X_{it}) = \beta' ln(X_{it}) = \beta' x_{it}$. This leads to the estimation equation:

$$r_{i,t} = \alpha + \beta' x_{it} + \varphi s_{it} + u_{it} + \varepsilon_{it} \quad (2)$$

We now consider each of the three sets of assumptions necessary to obtain a consistent estimate of s_{it}.

5.2 *Ordinary least squares estimation*. First we assume that u_{it} is a function of observable variables. Specifically we assume that u_{it} is a function only of time, the industry of the institute, and the region where the institute is located. There are no unobservable, omitted variables. In this case, we can consistently estimate (2) by ordinary least squares once we include controls for time, industry and region. We do this using year, industry and region fixed effects.

5.3 *Fixed effects estimation*. Second, we assume that u_{it} can be separated into a time component that does not vary by institute and an institute component that does not vary over time. In this case, $u_{it} = \xi_t + \eta_i$. Now we can consistently estimate the selection effect once we allow for time effects and institute fixed effects.

5.4 *Propensity score estimation*. Since u_{it} may vary over time in a way correlated with selection, for example if the government selects institutes they believe to be best poised for growth, we want to consider the case where neither the assumptions of section 5.2. nor 5.3 hold. We will assume that they hold only for institutes which look similar based on our available observables. In order to obtain a sample of similar institutes we use propensity score methods to find institutes with similar probabilities of being selected for conversion.

To calculate the propensity score we estimate the following logit regression:

$$p(X) = P(s_{it}=1|X) = (1+exp[-(\alpha + \beta' x_{it})])^{-1} . \qquad (3)$$

We then use the fitted value to calculate the propensity score. We run this regression using observations on all unconverted institutes and all institutes converted up through the time of conversion. However, we obtain a propensity score even for post-conversion observations, since we can still calculate the fitted value for these observations.

Since x_{it} varies over time, the propensity score will vary over time as well. Therefore, the propensity score will vary within each institute. To match institutes we first calculate the mean propensity score for each institute. Then we sort the institutes by this mean propensity score and run the above regressions (adding the propensity score as an additional control) within five equally sized blocks. Therefore, the first block will contain those institutes in the lowest propensity score quintile, the second block in the second lowest quintile and so on. We obtain estimates of the overall conversion effect (φ) using the formulas from Imbens and Rubin (2005):

$$\varphi = (1/N)*[N_1\varphi_1 + ... + N_5\varphi_5]$$

$$se(\varphi) = sqrt[(se(\varphi_1)(N_1/N)]^{\wedge}2 + ... + [se(\varphi_5)\ (N_5/N)]^{\wedge}2)]$$

where N_i is the number of observations in block i and N is the total overall number of observations.

For the standard OLS regression to obtain a consistent estimate of φ we require that:

$$E\ [\ E(u_{it\,|}\, s_{it})\ |\ region, year, industry, p(X)] = 0$$

This condition says that conditional on region, year, industry controls and the propensity score, selection is uncorrelated with other variables that affect productivity. In other words, among institutes with similar propensity scores, selection is random once we control for region, year and industry effects.

For the fixed effect regression to obtain a consistent estimate of φ we require that:

$$E\ [\ E(u_{it} - \eta_i \,|\, s_{it})\ |\ year,\ p(X)] = 0$$

where η_i is the institute specific productivity level. This condition says that conditional on year effects and the propensity score, productivity shocks distributed about the institute productivity means are uncorrelated with selection. In other words, among similar institutes as measured by the propensity score, selection is uncorrelated with deviations from the institutes mean productivity.

6. Estimation Results

Each of the seven pairs of regressions in Table 6 consists of two estimation methods: the first is OLS; the second is fixed effects. As a first attempt to control for selection bias in the conversion process, Table 6 includes only the firms that were converted to S&T enterprises and the non-converted firms; it omits the non-profit research institutes. The regressions include a dummy variable for the S&T conversion effect. Table 7 shows the comparison for firms that were converted to non-profit research institutes; the results there are based on a sample of non-converted institutes and NPRs; that sample excludes the S&T enterprises. Using this approach, we are able to estimate the conversion effect of each type of converted institute in relation to only the non-converted institutes.

The first column in Table 6 shows that relative to the unconverted institutes, S&T conversion is associated with increases in total revenue. While the magnitude of the increase diminishes significantly with the fixed effect results, the result remains statistically robust. The outcome variable is log of total revenue indicating that conversion results in an 8% increase in revenue. The next three sets of results, columns (3) through (8) show shifts in the revenue composition, such that the S&T conversions increase their P&M share of total revenue at the expense of revenues associated with S&T activity and government grants. Here the outcome variable is share, ranging from 0 to 1. Therefore, S&T conversion results in a 12 percentage point increase in the P&M share of revenue. The R&D and P&M personnel estimates indicate that R&D personnel are closely associated with government grants as a share of total revenue. By comparison, increases in the personnel and management share are strongly positively associated with the P&M revenue share P&M shares and negatively associated with the S&T revenue and government grant shares.

In column (10) we see a robust decline in S&T expenditure among the S&T conversions. The remaining four columns, i.e., columns (11) – (14), measure per-worker productivity. Consistent with the total revenue regressions, these per worker regressions show a significant rise in the overall productivity of the S&T conversions, measured in terms of total revenue per worker. Also consistent with declines in the government grant share, columns (13) and (14) show an increase in the productivity of the S&T enterprises in producing non-government grant revenue. Overall, the results show the increased importance of P&M activity and revenue for the S&T conversions, involving internal shifts in personnel toward the P&M function. This shift is consistent with the intent to encourage the S&T conversions to commercialize their research, including that of moving some of their innovations into production. The apparent shift toward P&M activity and away from S&T expenditures and revenue, suggest that, at least for this subset of S&T conversions, the category "S&T enterprise" may be somewhat of a misnomer.

The regressions in Table 7 mimic those in Table 6, except that they are run with the sample that omits the S&T conversions and includes the observations for the converted non-profit research institutes along with the relevant control dummies. As with the S&T enterprises, we see from columns (1) and (2) that the converted NPRs exhibit enhanced overall productivity in relation to the non-converted enterprises as total revenue increases controlling for the inputs. The fixed effect estimate indicates an 18% increase in total revenue. Additionally, scanning columns (3) through (8), the results across both the OLS and fixed effects estimates show increases in the S&T and government grant revenue shares of about two percentage points. These changes are consistent with the increase in R&D personnel for the NPR conversions shown in Table 4. That we see a simultaneous increase in the relative shares of government grant revenue and R&D personnel most likely reflects the fact that virtually all the funds that flow to the NPRs for R&D activity originate with the government. The results do show different degrees of robustness for the OLS and fixed effects results, with the latter, in Column (8), showing no significant reduction in the P&M share. Looking ahead, this difference in the OLS and fixed effects results is consistent with the results reported in Columns (13) and (14) in which the OLS result shows a robust decline in non-government productivity, whereas the fixed effect result shows little effect. One possible implication of these differences is the possibility of selection bias, whereby the converted NPRs may have had relatively small P&M shares prior to conversion.

Also in Table 7, columns (9) and (10) show an increase in S&T expenditure per worker, controlling for the relevant inputs. At the same time, columns (11) and (12) show a substantial relative increase in overall productivity, which, in combination with Columns (13) and (14), indicates that the gains in productivity were largely centered on increases in government grant revenue. These results are largely consistent with the restructuring goal of shifting the NPRs more toward a pure research function. In conclusion, based on the estimation results in Tables 6 and 7, we find clear evidence that the conversion goals of the Chinese government entailing a reorientation of the converted organizations – the S&T enterprises toward commercial applications and the NPR toward government-supported research - have been substantially achieved.

Table 8 focuses exclusively on patent production; the top tier of results reports on the impact of S&T conversion on the efficiency of patent production; the lower tier reports on the impact of NPR conversion on patent efficiency. In order to minimize or avoid estimation bias associated with the fat tail zero tail associated with OLS or other estimation methods that assume a normal distribution, we use logit estimators. Column (1) uses a logit procedure to test whether an institute has (1) or has not (0) filed a patent application during each year within the sample period. Column (2) is similar, except that the conditional logit drops any institutes that never patent, as well as those that patent in every period. The intuition is that a fixed effects estimator only uses within-variability to estimate the parameters; the conditional logit model drops the observations for which there is no within variability in outcomes. Column (3) is an OLS model with the number of patents applied for that year as the outcome variable. However, we use only the sample of firms that patented at least once in the sample. Column (4) is the same regression with institute fixed effects. In Columns (5) through (10) we consider firms that only patent 0-1 times in the sample, 2-3 times in the sample, or more than 4 times in the sample.

The key result in Columns (1) – (4) is that, controlling for the inputs, S&T conversions appear to significantly enhance patent production efficiency. This result holds with and without fixed effects. Columns (1) to (4) show interesting results concerning the relative contribution of the inputs to patent production. The most dramatic – and predictable – is that the contribution that R&D personnel make to patent production as compared with the negative, or mixed, impact that the P&M personnel share has on patent production. While the positive contribution of R&D personnel remains robust across both OLS and fixed effects estimates, that of the P&M personnel, while strongly negative for the OLS estimates becomes negligible for the fixed effects estimates. Changes in the within P&M personnel shares have little impact compared with those across institutes; by comparison increases (or decreases) in the R&D personnel shares clearly enhance R&D patent production.

In Columns (5) through (10), we have grouped three different types of institutes, each based on the number of patent applications the institute filed over the sample period. The institutes included in regressions reported in columns (5) and (6) reported 0 or 1 patent over the life of the sample period, from 1995-2005. Columns (7) and (8) are based on the institutes that reported filing 2 or 3 patent applications; columns (9) and (10) reported four or more. The S&T conversion dummy tests whether after conversion, the S&T converted institutes exhibited a statistically different incidence of patent filing than the relevant control sample. We see that much of the conversion-related patent action among the S&T enterprises appears to have resulted from the high-incidence patenters, with a cumulative patent record of four or more filings. The S&T conversions exhibit a significantly higher incidence of patenting relative to the unconverted institutes. The outcome variable here is number of patents, so the significant results indicate an increase of one to two patents per year.

Consistent with the increase in the incidence of 4+ patents we see a very robust contribution of R&D personnel, far higher than for the less active patenters. The robust string of estimates on patent production for the S&T conversions is somewhat of a surprise. Two matters come to mind; neither of which can be resolved with our data. The first is that we do not know the quality level of the patent production – whether they are higher quality invention patents or lower quality design and utility patents. The second issue is that the conversion to S&T enterprises with the mandate to commercialize their research may have motivated institutes to push their research in progress out the door in the form of patent applications with a view toward moving their prior research work toward sale or production.

What stands out from these results is the substantial impact that S&T conversion appears to have had on both the propensity to patent and the incidence of patenting. Specifically, as well as observing a significant increase in the propensity to patent for converted S&T enterprises, we also see an increase concentrated among the converted S&T enterprises who produce four or more patents in the sample period

The estimates in the 10 columns of the lower tier of Table 8 relate to the impact of conversion for the non-profit research institutes. While 9 of the 10 conversion estimates for the converted non-profit research institutes are positive, only one exhibits any statistical significant; that is only at the 10% level. While conversion seems to have substantially affected the propensity and incidence of patenting among converted S&T enterprises, it seems to have had little impact on the quantitative dimension of its patent production fot the NPRs. Nonetheless, we note that the elasticity of patenting with respect to total personnel and the R&D personnel share seems to be comparably robust across columns (10) and (20).

These results are somewhat consistent with the figures shown in Table 4 comparing the patents per 100 R&D workers for the S&T enterprises and non-profit research institutes. While both show significant proportional increases – 3½ fold for the S&T conversions and 5 fold for the NPR conversions – the rate of patent production for the S&T enterprises in 1998, at the beginning of restructuring period, was already at the level achieved by the NPR conversions in 2005, at the end of the sample period. One change that appears to happen is that, as shown in Table 4, the S&T enterprises experienced a substantial reduction in R&D personnel, whereas the NPRs experienced a substantial increase. As a consequence, assuming that the annual patent flows were determined by the availability of R&D workers in prior years, for the S&T conversions, the reduction in S&T workers would lead to a statistical up-tick in patents per R&D worker, whereas for the NPRs, the substantial increase in R&D workers would result in the appearance of a decline in productivity in 2005. Even controlling for the change in the numbers of R&D workers in the enterprises and institutes, the surge in patenting in the S&T enterprise sector is impressive. Again, controlling for quality and sustainability of patent production between the S&T enterprises and NPR's could lead to a different set of results than that shown in the upper and lower tiers of Table 8.

Tables 9-11 report our Propensity Score Estimation results. Table 9 consists of two logit regressions, the first for S&T enterprise conversions; the second for the conversion of non-profit research institutes. To estimate the propensity score, we use observations only on institutes converted to the type indicated and the unconverted and only observations up until the year converted. The regressors consist of the regressors used in Tables 6-8, including industry and regional dummies. Comparing the two sets of results in Table 9, we see that high R&D personnel shares affect the probability of conversion very differently – showing a weak negative effect for the S&T conversions and a robustly strong effect for the NPRs. Conversely, the P&M personnel share substantially increases the probability of conversion to an S&T enterprise while weakly depressing the likelihood of a NPR conversion. Concerning the non-personnel inputs, intermediate inputs increase the probability of an S&T conversion with no effect on NPR conversions; S&T equipment raises the probability of a NPR conversion with little impact on the probability of an S&T conversion. The latter result, i.e., reliance on S&T equipment for the R&D operation, accords with our intuition. For intermediate inputs, it may be that production activity, in which the S&T enterprises are intended to more extensively specialize, employs intermediate inputs more than does the R&D enterprise. By-in-large, the propensity score results shown in Table 9 confirm our expectations concerning the types of pre-restructuring enterprises that are likely to be chosen for the different conversion outcomes, i.e. S&T enterprise vs. NPR institute. The robust tilt of large P&M personnel shares toward S&T conversions and the contrasting tile of large R&D shares toward NPR conversions underscores the importance of controlling our regression analysis for selection criteria.

Table 10 applies the propensity score analysis to the full samples – excluding the NPR conversions for the S&T enterprises and excluding the S&T enterprises for the NPR institutes. These results, which for each set of regressions have blocked together institutes with similar characteristics, yield some notable changes in relation to Tables 6-8. First, we note that Table 10 reports two tiers of results – those which include only industry and regional fixed effects, as do the odd-numbered columns in Table 6-8; the second tier includes institute FE as does each of the even-number columns in these earlier tables. We first examine the results with industry and regional dummies only. These results, both for the S&T conversions and the NPR institutes, generally match up with both the OLS and fixed effects results in Tables 6 and 7. For both types of conversion, restructuring imparts a substantial boost to overall revenue productivity. For the S&T enterprises, the P&M revenue share rises while the S&T and government grant shares decline. Non-government productivity rises. For the NPR institutes, as in Table 7, the government grant share rises, and the P&M share falls as does non-government productivity. Again, these results align with those previously reported for Tables 6 and 7.

However, when we look at the PSA results blocked by similar institutes and with institute fixed effects, we see some notable differences. These differences suggest that when the population of institutes is not clustered by industry and region, the selection bias becomes more evident. Alternatively, the inference is that much of the selection bias materialized within individual industries and regions. When institutes with similar characteristics across industries and regions were held up side-by-side, we tend to see that the selection outcomes were different nationwide than they were within the individual industries and regions. This is not surprising.

First, for the S&T conversions, the total revenue and productivity impacts are no longer robustly positive. Furthermore, while the P&M share rises, the increase is not as robust as shown in Table 6. The decline in the government grant share remains robust as does the rise in non-government productivity. However, the increase in non-government productivity now seems to have resulted exclusively from the shift in the composition of revenue income, rather than from an overall productivity increase. Overall, the PSA institute FE results compared with those of other tables, suggest that the S&T enterprise process may have exhibited a systematic selection bias toward choosing the candidate institutes that were relatively more productive than their otherwise comparable counterparts that were not selected. Nonetheless, once converted, as the S&T enterprises lost substantial government grant revenue, they were able to compensate with non-government revenue, so that their overall revenue productivity seems to have been only mildly adversely affected.

For the NPR conversions, the positive total revenue results are sustained with institute fixed effects; moreover the robust positive estimate of productivity (total revenue per worker) remains intact. Perhaps the single most striking difference is that the reduction in the P&M

personnel share and increase in the government grant share were not as large and robust as suggested by the earlier estimation results slight. Together with the negligible reduction in non-government productivity suggests that the shift toward a pure research model was not as robust as some of the previous results would have suggested.

Table 11 reports the PSA estimates for patenting outcomes. For most of the results, both the OLS and FE estimates in Table 8, and the PSA estimate with industry-region FE results in Table 11, we find a substantial degree of concurrence. Overall, these results indicate substantial gains in patent productivity for the S&T enterprises with little or no gain for the NPR institute conversions. However, the results with institute FE show notable differences. For the S&T enterprise conversions, the results show no overall increase – only an increase in the enterprises that are producing one patent during the years following their conversion. One possible interpretation of the selection bias implicit in the earlier results, but controlled for in this result, is that institutes converted to S&T enterprises may have been selected for having had a backlog of potentially patentable knowledge that, with the proper mission and incentivization, could be patented and exploited for commercial gain. Hence these institutes were moved to the front of the conversion queue.

The institute FE estimates for the NPR institutes show one significant difference with the prior results. That is, none of the prior results, neither in Table 8 nor for the industry-region results in Table 11, indicate that conversion increased the incidence of patenting institutes among the NPR institute conversions. The Table 11 NPR institute FE estimates, however, do show a robust increase in the incidence of patenters. Again, we observe an inconsistency between the PSA industry-region FE results and the institute FE results. In this case, with the industry-region pools of institutes, officials may have selected for conversion institutes that exhibited a relatively high incidence as patenters. Relative to the unselected institutes, the converted subsample exhibited little increase in the propensity to patent subsequent to conversion. Most were already patenting. However, when the distinctive characteristics of these converted institutes were controlled for relative to their unconverted counterparts, the institute FE results show that during the post conversion period, as a group, the converted institutes exhibited a tendency to increase their incidence of patenting. Unfortunately, this set of industry FE results in Table 11 does not yield a companion estimate that shows a robust increase in the incidence of patenting in a particular group. The new patenters are breaking into the patent lineup with but one or few patents during the post-conversion period; thus, they are most likely to appear in the 0-1 or 2-3 groups for total sample period patents. Both of these columns show weak positive estimates for NPR conversions. The robust results showing converted NPR institutes graduating to patenter status may not be apparent when spread between those graduating to one patent over the conversion period versus those graduating to 2-3 patents during the same period. It is somewhat curious that candidate conversion institutes that had had no history of patenting had been selected into the non-profit research institute category.

To conclude this section it may be helpful to contrast the conventional estimation results with the propensity score results. All methods showed that S&T conversion increased the share in revenue coming from P&M activities while decreasing the share which came from government grants. Consequently, S&T conversion consistently resulted in an increase in non-government productivity (revenue from non-government sources per worker). However, while the conventional estimation strategies indicated an increase in total revenue and patenting, the propensity score analysis did not find consistent results for this variable particularly with the most stringent test, the propensity score with fixed effects analysis.

Results for NPR conversion were more robust across the various methods. We saw robust increases in total revenue and revenue coming from government grants. Productivity and expenditure on S&T inputs also rose across all methods. Finally, no specifications consistently found an increase in patent production.

7. Conclusions and Next Steps

This paper uses both conventional and innovative methods to identify the impact of China's research institute restructuring program initiated in 1999 on the performance of the converted enterprises. The central challenge of the paper is to control for the bias arising from the selection or treatment of the converted institutes in a non-random manner. To address the issue of selection bias, the paper uses several estimation techniques, including OLS with fixed effects and propensity score analysis, as well as various combinations of these techniques.

A central objective of the conversion program was to encourage one set of research institutes to more aggressively commercialize their research while also eliminating their reliance on government grants and subsidies; these institutes were converted to S&T enterprises. Yet another group, those converted to non-profit research institutes, were intended to strengthen their focus on research, in part through the use of a larger share of government grants. Finally, a third group of institutes, those converted to non-profit, non-research institutes, were expected to narrow their focus to supporting public service activity, such as that in the areas of public health and the environment. Due to some ambiguity concerning the relevant outcome variables for the third public-service group, we focus our research on the first two groups – institutes converted to S&T enterprise and those converted to NPR institutes. The pattern of results using the methods highlighted in the paper indicates that through 2005 the Chinese government substantially moved the orientation of the nation's institutes toward their intended directions. However, once we apply the propensity score analysis to control for selection bias, we see that the shift toward a commercial orientation for the S&T enterprises and toward government-supported research for the NPR institutes was not as decisive as it might appear to have been.

After we filter for selection bias, we find that the S&T enterprises did shift away from their reliance on government grants and did robustly increase the productivity in generating non-government revenue per worker. These firms also appear to have marginally increased their patent productivity. Since we expect they had a stock of patentable research prior to their conversion, we will need over time to test whether this sustained, perhaps enhanced patent productivity turns out to the sustainable or simply transitional.

Relative to the S&T conversions, the converted NPR institutes seem to have been more successful in increasing their total revenue productivity. All of this increase appears to have resulted from a gain in the productivity of government-grant related activity, a central objective of the restructuring program. The puzzle that emerged from Table 8, suggesting that this shift toward government-supported research had not increased the patent productivity of these converted institutes was somewhat addressed by the PSA estimate that shows some increase in the propensity to patent, although principally at the low end of the patenting distribution. Some of the converted research institutes appear to be beginning to generated patents relative to their pre-conversion condition.

Overall, the shift in emphasis intended by the research institute restructuring program seems to have exhibited some success during the first 5 years of the restructuring program. The success is more evident in terms of a shift in resources and the composition and focus of the personnel. On the patenting front, we find less of a notable change and differentiation between the S&T conversions and NPR conversion with respect to advances or retreats in the incidence of patenting. Given the lag in patent production, the decade subsequent to 2005 will be critical in determining whether the new directions shown by the converted institutes in this sample expand and become more evident of the restructuring goals of the Chinese Government.

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Table 1: Descriptive Statistics – R&D activity of China's Research Institutes

	1995	1998	2002	2005	2010
Number of Institutes	5,841	5,778	4,372	3,901	3,696
Intramural R&D expenditure (total national in billion of yuan)	34.9	55.1	128.8	245	706.3
Of which: research institute share (%)	42	42.5	27.3	20.9	16.8
Basic research:					
Expenditure share of total national R&D (%)	5.2	5.3	5.7	5.4	4.6
Of which: research institute share (%)	56.5	59.2	55.2	44.2	40
Of which: share within research institutes (%)	7	7.5	11.6	11.3	11
Research institutes only					
Full-time equivalent R&D personnel (1,000 man years)	245	227	206	215	293
Of which: share of total employment (%)	24.3	24.2	34.9	38.4	44.9*
S&T Personnel (thousands)	644	588	415	456	478
Scientists and engineers as percent of S&T personnel (%)	59	62.4	64.8	70	74.5
Total patent applications per thousand S&T personnel	0.4	0.6	1.3	2.1	5.6
Share of domestic invention patent applications (%)	8.6	9.1	8.6	7.2	6.2

Note: Source is China Statistical Yearbook on Science and Technology (2000), (2003), (2008); * denotes estimates based on 2011 figures.

Table 2: Descriptive Statistics -- Total Population of Chinese Research Institutes

	1995	1999	2001	2003	2005	2007
Number of Institutes	5828	5573	4635	3973	3901	3775
Restructured	0	132	891	1348		
coverted to S&T enterprise	0	114	821	1087		
converted to Non-Profit Research Institute	0	18	70	127		
converted to Non-Profit Non-Research Institute	0	0	0	134		
Merged or closed institutes	0	73	147	371		
S&T Personnel (thousands)	644	535	427	398	456	478
Scientists and Engineers as percent of S&T personnel	59.0%	62.4%	64.8%	66.0%	70.0%	74.5%
Patents per thousand S&T personnel			8	14		

Note: Above-country level government research institutes and institutes of science information and literature, with an independent accounting system, but not including restructured research institutes. The number in 2004 is estimated. The cumulative annual number of the institutes that were successfully converted to enterprises or converted to not-for-profit non-research institutes B1 = b1+b2. The number of institutes that still remains as government not-for-profit research institutes. It's a cumulative number. The estimated number of research institutes that disappeared as a result of mergers and acquisitions or shut-downs. The average number of patents owned per 1,000 S%T personnel in all research institutes that have non-zero S&T personnel for that year. Sources: MOST, "S&T Technological Index of China, 2004", August 2005, S&T Publishing, Beijing. MOST, "National Survey of S&T institutes", 1995-2004

Table 3: Summary Statistics (MOST Sample)

	1995	1997	1999	2001	2003	2005
Number of Institutes	1813	1813	1813	1813	1813	1813
Restructured	0	0	96	201	290	440
coverted to S&T enterprise	0	0	92	182	230	264
converted to Non-Profit Research Institute	0	0	0	2	25	111
converted to Non-Profit Non-Research Institute	0	0	4	17	35	65
Not-Restructured	1813	1813	1717	1612	1523	1373
Total Revenue (1,000 Yuan)	5642.4	7589.4	9059.8	12196.4	16382.8	22162.1
S&T Revenue Share	92%	90%	93%	92%	91%	87%
Government Grant Revenue Share	59%	60%	60%	60%	62%	63%
Production and Management Revenue Share	13%	12%	11%	12%	13%	13%
Total Personnel	144.9	138.5	128.5	120.0	114.7	113.6
R&D Personnel	--	24.6	25.2	21.2	23.2	24.9
P&M Personnel	33.8	34.2	32.8	29.6	28.3	23.5
S&T Intermediate Input (1,000 Yuan)	2131.6	2802.2	3553.6	4173.9	5498.0	7383.0
S&T Equipment (1,000 Yuan)	4388.5	5732.3	6142.9	7816.3	10774.7	9226.7
Patents per 100 R&D Workers	--	1.3	1.2	1.7	2.6	3.1

Note: This table provides summary statistics for the MOST sample. R&D Personnel variables are missing for 1995.

Table 4: Performance Measures by Conversion Type, 1998--2005 (MOST Sample)

	Unconverted		S&T Enterprise		Non-Profit Research	
	1998	2005	1998	2005	1998	2005
Number of Institutes	1373		264		111	
Total Revenue (1,000 Yuan) per worker	38.9	103.7	65.8	241.8	49.8	183.6
S&T Revenue Share	96.9%	92.8%	83.3%	49.5%	99.6%	96.4%
Government Grant Revenue Share	63.6%	69.2%	28.1%	23.6%	70.2%	78.2%
Production and Management Revenue Share	8.0%	7.3%	28.0%	51.4%	4.0%	3.6%
S&T Revenue (1,000 Yuan) per S&T employee	53.4	136.5	93.2	122.0	66.1	224.7
Scientific paper per 100 R&D workers	59.7	77.7	39.6	30.1	130.0	158.0
Patents per 100 R&D workers	1.2	2.3	2.5	8.8	0.5	2.5
Total Personnel	107.4	97.7	268.0	190.0	168.8	147.6
R&D Personnel	21.1	21.4	37.8	30.7	46.6	60.1
P&M Personnel	25.1	15.8	92.6	69.3	20.1	19.1
S&T Intermediate Input (1,000 Yuan)	2237.1	6767.1	8011.7	6819.7	4909.6	17963.4
S&T Equipment (1,000 Yuan)	4127.9	7499.0	13060.8	12112.7	8475.2	25630.1

Note: This table provides summary statistics by conversion type for the MOST sample.

Table 5: Performance Measures by Industry, 1998--2005 (MOST Sample)

	Agriculture		Chemicals		Metals		Electronics		Public		Spec. R&D	
	1998	2005	1998	2005	1998	2005	1998	2005	1998	2005	1998	2005
Number of Institutes	617		143		43		55		593		362	
Number Restructured	78		94		38		34		84		112	
Total Revenue (1,000 Yuan) per worker	35.7	84.2	53.2	170.5	86.4	424.0	46.1	137.6	45.2	131.6	43.3	145.4
S&T Revenue Share	100.3%	93.4%	79.8%	52.3%	75.2%	37.3%	88.0%	57.8%	93.8%	93.9%	97.7%	88.2%
Government Grant Revenue Share	72.8%	81.0%	28.8%	30.1%	23.4%	17.0%	35.3%	40.5%	61.0%	61.0%	52.6%	58.1%
Production and Management Revenue Share	8.4%	6.8%	33.4%	48.2%	35.3%	63.2%	21.5%	42.5%	7.0%	6.1%	6.6%	12.2%
S&T Revenue (1,000 Yuan) per S&T employee	55.4	115.3	61.8	103.2	150.8	114.9	57.9	86.8	59.8	180.7	54.9	144.1
Scientific paper per 100 R&D workers	70.0	83.5	19.6	16.3	47.4	25.4	6.4	4.2	79.9	115.3	44.3	46.2
Patents per 100 R&D workers	0.6	2.1	2.0	6.8	1.7	14.1	1.2	10.8	1.6	2.4	2.3	2.6
Total Personnel	114.4	100.8	251.5	152.9	462.5	346.6	173.7	117.4	122.9	116.0	93.9	87.3
R&D Personnel	26.9	28.3	40.3	26.6	71.5	71.4	9.3	8.5	24.4	26.7	13.6	12.6
P&M Personnel	32.8	23.7	88.2	55.3	155.8	139.7	64.4	45.6	23.2	13.4	14.8	10.1
S&T Intermediate Input (1,000 Yuan)	1848	3328	4798	4217	20752	11921	2651	2077	3434	12956	2555	6683
S&T Equipment (1,000 Yuan)	3450	7120	8779	8565	31702	21549	4806	4612	6155	9693	4376	11552

Note: This table provides summary statistics by industry for the MOST sample.

Table 6: Effect on S&T Conversion on Revenue, Expenditure and Productivity

	Total Revenue		S&T Share		Gov. Grant Share		P&M Share	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
S&T Conversion	0.389***	0.079***	-0.192***	-0.155***	-0.196***	-0.076***	0.178***	0.121***
	(0.028)	(0.025)	(0.013)	(0.016)	(0.009)	(0.008)	(0.010)	(0.011)
Total Personnel	0.754***	0.586***	-0.042***	-0.019	-0.010**	-0.045***	0.043***	0.040***
	(0.012)	(0.027)	(0.004)	(0.015)	(0.004)	(0.009)	(0.003)	(0.009)
R&D Personnel Share	0.278***	0.102***	-0.004	0.004	0.124***	0.038***	-0.019***	-0.008
	(0.020)	(0.024)	(0.010)	(0.010)	(0.010)	(0.009)	(0.006)	(0.007)
P&M Personnel Share	0.145***	-0.039	-0.354***	-0.175***	-0.289***	-0.029**	0.381***	0.162***
	(0.036)	(0.047)	(0.018)	(0.027)	(0.013)	(0.014)	(0.013)	(0.018)
Intermediate Inputs	0.289***	0.124***	0.016***	0.022***	-0.038***	-0.012***	-0.017***	-0.018***
	(0.007)	(0.005)	(0.002)	(0.004)	(0.002)	(0.002)	(0.002)	(0.002)
S&T Equipment	0.052***	0.004	0.006***	0.001	0.003**	0.003***	-0.006***	-0.002
	(0.004)	(0.003)	(0.002)	(0.002)	(0.001)	(0.001)	(0.001)	(0.001)
# of obs	15,640	15,640	15,640	15,640	15,640	15,640	15,640	15,640
R-squared	0.856	0.947	0.148	0.442	0.340	0.822	0.356	0.734
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Region and Industry FE	Yes	No	Yes	No	Yes	No	Yes	No
Institute FE	No	Yes	No	Yes	No	Yes	No	Yes

	S&T Expenditure		Productivity		Non-Gov. Productivity	
	(9)	(10)	(11)	(12)	(13)	(14)
S&T Conversion	-0.014	-0.226***	0.392***	0.075***	0.891***	0.350***
	(0.022)	(0.027)	(0.028)	(0.025)	(0.041)	(0.037)
Total Personnel	0.624***	0.442***	-0.268***	-0.443***	-0.293***	-0.295***
	(0.011)	(0.026)	(0.012)	(0.028)	(0.022)	(0.048)
R&D Personnel Share	0.212***	0.033	0.273***	0.100***	-0.184***	-0.047
	(0.017)	(0.028)	(0.020)	(0.024)	(0.053)	(0.061)
P&M Personnel Share	-0.406***	-0.310***	0.145***	-0.037	0.967***	0.096
	(0.030)	(0.050)	(0.036)	(0.047)	(0.070)	(0.089)
Intermediate Inputs	0.360***	0.257***	0.289***	0.124***	0.399***	0.151***
	(0.007)	(0.008)	(0.007)	(0.005)	(0.013)	(0.010)
S&T Equipment	0.049***	0.009**	0.051***	0.004	0.040***	-0.002
	(0.003)	(0.004)	(0.004)	(0.003)	(0.007)	(0.007)
# of obs	15,798	15,798	15,640	15,640	13,570	13,570
R-squared	0.889	0.936	0.588	0.847	0.391	0.793
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Region and Industry FE	Yes	No	Yes	No	Yes	No
Institute FE	No	Yes	No	Yes	No	Yes

Note: This table gives the results from regressing various outcomes on conversion. S&T conversion is a binary variable indicating the institute was converted in the current year or a previous year. All variables are in logs except the revenue share variables are personnel share variables which are fractions. Productivity is total revenue/total personnel and Non-Gov productivity is total revenue excluding revenue from government grants per total personnel.

Table 7: Effect on Non-Profit Research Conversion on Revenue, Expenditure and Productivity

	Total Revenue		S&T Share		Gov. Grant Share		P&M Share	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Non-Profit Research Conversion	0.136***	0.178***	0.028***	0.014*	0.130***	0.020*	-0.020***	0.006
	(0.037)	(0.027)	(0.008)	(0.008)	(0.014)	(0.011)	(0.007)	(0.005)
Total Personnel	0.715***	0.528***	-0.035***	0.002	-0.001	-0.036***	0.036***	0.028***
	(0.012)	(0.028)	(0.004)	(0.015)	(0.004)	(0.009)	(0.003)	(0.008)
R&D Personnel Share	0.247***	0.096***	0.004	0.002	0.134***	0.039***	-0.025***	-0.006
	(0.019)	(0.024)	(0.010)	(0.009)	(0.010)	(0.010)	(0.006)	(0.006)
P&M Personnel Share	0.080**	-0.159***	-0.319***	-0.132***	-0.302***	-0.017	0.345***	0.102***
	(0.035)	(0.046)	(0.019)	(0.029)	(0.014)	(0.015)	(0.014)	(0.018)
Intermediate Inputs	0.311***	0.142***	0.013***	0.015***	-0.043***	-0.015***	-0.014***	-0.010***
	(0.008)	(0.006)	(0.003)	(0.004)	(0.002)	(0.002)	(0.002)	(0.002)
S&T Equipment	0.056***	0.009***	0.005***	-0.001	0.001	0.002	-0.005***	-0.001
	(0.003)	(0.003)	(0.002)	(0.002)	(0.002)	(0.001)	(0.001)	(0.001)
# of obs	14,525	14,525	14,525	14,525	14,525	14,525	14,525	14,525
R-squared	0.861	0.948	0.065	0.397	0.258	0.802	0.225	0.716
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Region and Industry FE	Yes	No	Yes	No	Yes	No	Yes	No
Institute FE	No	Yes	No	Yes	No	Yes	No	Yes

	S&T Expenditure		Productivity		Non-Gov. Productivity	
	(9)	(10)	(11)	(12)	(13)	(14)
Non-Profit Research Conversion	0.153***	0.183***	0.136***	0.176***	-0.278***	0.088
	(0.034)	(0.027)	(0.037)	(0.027)	(0.093)	(0.078)
Total Personnel	0.620***	0.422***	-0.308***	-0.503***	-0.359***	-0.334***
	(0.011)	(0.026)	(0.012)	(0.029)	(0.025)	(0.056)
R&D Personnel Share	0.205***	0.027	0.242***	0.094***	-0.255***	-0.064
	(0.017)	(0.027)	(0.019)	(0.024)	(0.055)	(0.063)
P&M Personnel Share	-0.359***	-0.239***	0.080**	-0.158***	0.972***	-0.034
	(0.029)	(0.050)	(0.035)	(0.046)	(0.075)	(0.101)
Intermediate Inputs	0.363***	0.246***	0.311***	0.142***	0.443***	0.181***
	(0.007)	(0.008)	(0.008)	(0.006)	(0.015)	(0.012)
S&T Equipment	0.051***	0.009***	0.055***	0.009***	0.048***	0.007
	(0.003)	(0.003)	(0.003)	(0.003)	(0.008)	(0.008)
# of obs	15,798	15,798	15,640	15,640	13,570	13,570
R-squared	0.889	0.936	0.588	0.847	0.391	0.793
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Region and Industry FE	Yes	No	Yes	No	Yes	No
Institute FE	No	Yes	No	Yes	No	Yes

Note: This table gives the results from regressing various outcomes on conversion. Non-Profit Research Conversion is a binary variable indicating the institute was converted in the current year or a previous year. All variables are in logs except the revenue share variables are personnel share variables which are fractions. Productivity is total revenue/total personnel and Non-Gov productivity is total revenue excluding revenue from government grants per total personnel.

Table 8: Effect on Conversions on Patenting

	Patenter		Patents - Group (>=1)		Patents - Group (0 - 1)		Patents Group (2-3)		Patents Group (>=4)	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
S&T Conversion	0.870***	0.700***	2.255***	1.150***	0.007	0.012	0.085	0.116*	2.508***	1.194***
	(0.092)	(0.233)	(0.355)	(0.295)	(0.006)	(0.010)	(0.058)	(0.069)	(0.489)	(0.417)
Total Personnel	0.437***	1.193***	1.046***	0.562***	0.004***	0.016**	0.014	0.088	1.598***	1.007***
	(0.048)	(0.218)	(0.097)	(0.193)	(0.001)	(0.007)	(0.023)	(0.076)	(0.159)	(0.352)
R&D Personnel Share	1.935***	0.908***	1.786***	0.774***	0.015***	0.014*	0.033	0.048	2.701***	1.060***
	(0.108)	(0.254)	(0.192)	(0.187)	(0.005)	(0.008)	(0.054)	(0.105)	(0.346)	(0.331)
P&M Personnel Share	-0.457***	-0.454	-2.889***	-0.320	-0.006	0.006	0.077	0.088	-3.752***	-0.488
	(0.165)	(0.449)	(0.545)	(0.494)	(0.005)	(0.010)	(0.108)	(0.184)	(0.883)	(0.834)
Intermediate Inputs	0.195***	-0.007	0.164***	0.024	0.000	-0.001	0.003	0.002	0.160***	-0.013
	(0.025)	(0.039)	(0.029)	(0.027)	(0.001)	(0.001)	(0.010)	(0.014)	(0.051)	(0.052)
S&T Equipment	0.175***	0.090**	0.075**	0.017	0.001**	0.001	-0.003	0.006	0.143*	0.005
	(0.025)	(0.039)	(0.038)	(0.030)	(0.000)	(0.001)	(0.009)	(0.020)	(0.081)	(0.062)
# of obs	15,798	5,446	6,270	6,270	11,081	11,081	1,382	1,382	3,335	3,335
R-squared			0.157	0.712	0.006	0.111	0.018	0.063	0.185	0.712
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Region and Industry FE	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No
Institute FE	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes
	Patenter		Patents - Group (>=1)		Patents - Group (0 - 1)		Patents Group (2-3)		Patents Group (>=4)	
	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)	(20)
Non-Profit Research Conversion	-0.087	0.319	0.394	0.754*	0.005	0.004	0.120	0.157	0.188	0.730
	(0.178)	(0.322)	(0.414)	(0.406)	(0.013)	(0.016)	(0.119)	(0.138)	(0.643)	(0.623)
Total Personnel	0.385***	1.247***	0.491***	0.656***	0.005***	0.010	0.025	0.132	0.774***	1.301***
	(0.055)	(0.269)	(0.070)	(0.194)	(0.002)	(0.006)	(0.025)	(0.087)	(0.123)	(0.376)
R&D Personnel Share	1.890***	1.002***	1.427***	0.647***	0.017***	0.020**	0.016	-0.008	2.013***	0.927***
	(0.110)	(0.261)	(0.158)	(0.169)	(0.005)	(0.008)	(0.054)	(0.106)	(0.275)	(0.298)
P&M Personnel Share	-0.326*	-0.112	-1.059***	-0.242	-0.009*	0.000	0.064	0.231	-1.607***	-0.696
	(0.180)	(0.500)	(0.234)	(0.361)	(0.005)	(0.009)	(0.113)	(0.209)	(0.394)	(0.629)
Intermediate Inputs	0.206***	0.005	0.119***	0.042	-0.000	-0.001	-0.001	-0.007	0.146***	0.037
	(0.029)	(0.050)	(0.022)	(0.028)	(0.001)	(0.001)	(0.012)	(0.019)	(0.041)	(0.054)
S&T Equipment	0.160***	0.060	0.086***	0.064***	0.001	0.001	-0.005	-0.001	0.122***	0.093*
	(0.028)	(0.040)	(0.018)	(0.022)	(0.001)	(0.001)	(0.009)	(0.021)	(0.044)	(0.051)
# of obs	14,683	4,806	5,601	5,601	10,551	10,551	1,294	1,294	2,838	2,838
R-squared			0.120	0.558	0.006	0.120	0.021	0.065	0.151	0.557
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Region and Industry FE	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No
Institute FE	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes

Note: This table gives the results for patent outcomes on conversion. Patenter is an indicator for patents > 0. The first column gives the results of a logit regression, the second of a conditional (fixed-effects) logit model. For the logit regression the outcome variable is the log odds ratio, ln(p/(1-p)) where p is the probability of patenting. For the remaining columns the first column is standard ols, the second column is fixed effects regression. Patents refers to total applied patents. Given are results for four different samples: Those institutes who patent at least once in the data set Group 1+, those who patent 0 to 1 times, Group (0-1), those who patent 2 to 3 times Group (2-3) and those who patent 4 or more times Group 4+.

Table 9: Propensity Score Estimation

	S&T Conversion Year	NPRI Conversion Year
	(1)	(2)
Total Personnel	-0.046	0.065
	(0.116)	(0.172)
R&D Personnel Share	-0.511	0.821**
	(0.377)	(0.348)
P&M Personnel Share	2.159***	-0.599
	(0.366)	(0.647)
Intermediate Inputs	0.164***	0.003
	(0.048)	(0.078)
S&T Equipment	0.063	0.254**
	(0.048)	(0.119)
Constant	-5.827***	-6.046***
	(0.508)	(0.663)
Observations	11,074	8,621

Note: This table contains the logit results used to estimated the propensity score. The dependent variable is the log odds ratio ln(p/(1-p)) where p is the probability of being converted. To estimate the propensity score we use observations only on institutes converted to the type indicated and the unconverted and only observations up until the year of conversion. All independent variables are in logs except for Personnel Share variables which are fractions. I include year, region and industry fixed effects.

Table 10: Conversion Effect on Outputs and Inputs (Block Propensity Score)

S&T Enterprise Conversion

	Total Revenue	S&T Share	Gov. Grant Share	P&M Share
Year, Region and Industry FE	0.343 ***	-0.202 ***	-0.288 ***	0.204 ***
	(0.055)	(0.04)	(0.025)	(0.038)
Year and Institute FE	-0.107	-0.062	-0.076 ***	0.076 *
	(0.066)	(0.045)	(0.021)	(0.045)

	S&T Expenditure	Productivity	Non-Gov. Productivity
Year, Region and Industry FE	0.062	0.346 ***	1.163 ***
	(0.059)	(0.055)	(0.076)
Year and Institute FE	-0.117	-0.109 *	0.235 ***
	(0.092)	(0.066)	(0.084)

Non-Profit Research Conversion

	Total Revenue	S&T Share	Gov. Grant Share	P&M Share
Year, Region and Industry FE	0.101 **	0.02 **	0.102 ***	-0.019 **
	(0.051)	(0.011)	(0.017)	(0.01)
Year and Institute FE	0.083 ***	0.009	0.025 *	0.002
	(0.0320)	(0.017)	(0.014)	(0.008)

	S&T Expenditure	Productivity	Non-Gov. Productivity
Year, Region and Industry FE	0.184 ***	0.097 *	-0.32 ***
	(0.042)	(0.051)	(0.126)
Year and Institute FE	0.192 ***	0.081 ***	-0.124
	(0.033)	(0.0330)	(0.1110)

Note: This table gives conversion effects estimated by the propensity score measure. Regression are as in Tables 6 and 7, but run by dividing observations into 5 blocks by propensity score. Statistics are calculated by averaging across blocks as explained in section 5. Control variables are as in Tables 6 and 7, but omitted here for simplicity. All outcome variables are in logs except the revenue share variables which are fractions. Productivity is total revenue/total personnel and Non-Gov productivity is total revenue excluding revenue from government grants per total personnel.

Table 11: Conversion Effect on Patenting (Block Propensity Score)

S&T Enterprise Conversion

	Patenter	Patents - Group (>=1)	Patents - Group (0-1)	Patents - Group (2-3)	Patents - Group >=4
Year, Region and Industry FE	0.913 ***	0.817 ***	0.017	0.043	0.813 ***
	(0.278)	(0.211)	(0.013)	(0.084)	(0.295)
Year and Institute FE	0.579	0.074	0.033 **	0.036	-0.276
	(0.540)	(0.27)	(0.016)	(0.082)	(0.349)

Non-Profit Research Conversion

	Patenter	Patents - Group (>=1)	Patents - Group (0-1)	Patents - Group (2-3)	Patents - Group >=4
Year, Region and Industry FE	0.402	-0.341	0.003	0.124	-0.743 *
	(0.37)	(0.27)	(0.011)	(0.125)	(0.435)
Year and Institute FE	1.408 ***	-0.013	0.012	0.154	-0.204
	(0.315)	(0.245)	(0.012)	(0.154)	(0.412)

Note: This table gives the results for patent outcomes on conversion estimated with the propensity score. Regressions are run as in table 8, but by dividing observations into five block (by propensity score) and averaging statistics across blocks. The control variables are the same as in Table 8, and are omitted here for simplicity. Patenter is an indicator for patents > 0. The patenter effect is estimated with a logit regression, and in the row below a conditional (fixed-effects) logit model. For the logit regression the outcome variable is the log odds ratio, ln(p/(1-p)) where p is the probability of patenting. For the remaining columns the first row is standard ols, the second row is fixed effects regression. Patents refers to total applied patents. Given are results for four different samples: Those institutes who patent at least once in the data set Group >=1, those who patent 0 to 1 times, Group (0-1), those who patent 2 to 3 times Group (2-3) and those who patent 4 or more times Group >=4.