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# Restructuring China's research institutes[1]

## *Impacts on China's research orientation and productivity*

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## Abstract

Over the past two decades, China's R&D intensity has surged. The institutional arrangements underlying this surge remain unclear. We study the notable restructuring of the country's 5,000 research institutes, begun in 1999. This study first reviews the evolution of China's research institute sector over the period 1995–2010. Then applying OLS, fixed effects, event study and propensity score analysis to institute level data, we find the restructuring programme has accomplished some of its

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goals. The converted Science and Technology enterprises shifted towards a more commercial mission, the institutes converted to non-profit research institutes have focused on a more research-oriented mission.

**JEL classifications:** O31, O32, O33.
**Keywords:** Technological innovation, R&D, invention, research policy.

## 1. Introduction

Over the past two decades, China's R&D intensity has surged from just 0.6 percent of GDP in 1996 to 2 percent in 2012.[2] At least as impressive is the widely reported surge in patent applications.[3] Much of this surge reflects increases in R&D spending and innovation activity across China's diverse enterprise sector. However, the research institute and university sectors have also contributed substantially to China's surge in R&D activity. Throughout China's economy, a key issue is the link between innovation inputs and innovation outputs and the role government has played in financing and incentivizing inputs. This study focuses specifically on the role of China's research institutes as their contributions have evolved following the major restructuring initiative in 1999. That initiative has led to a change in the assigned functions of China's research institutes, their productivity and the nature of their innovation contributions.

China's formal restructuring initiative, administered by the Ministry of Science and Technology (MOST), was designed to clarify the research functions of China's 5,573 organizations that were classified as research institutions in that year.[4] In order to determine the implications of the 1999 restructuring for the productivity, research orientation and patent performance of the institutes, this study examines the overall evolution of the research institute sector during 1995–2010 and then employs a large sample of the institutes spanning 1998, the year prior to the restructuring initiative, to 2005 to assess the impact of various conversions on the research institutes.

Several issues arise from this analysis of MOST's restructuring programme; most notably its impact on the restructured institutes versus those that were not restructured. Because each of the restructured institutes was converted to one of three categories with different degrees of emphasis on commercial versus government-sponsored research and applied versus basic scientific research and public policy-related applications, the conversions raise questions about the restructuring objectives, the restructuring impacts and the role that selection bias might have played in the restructuring process.

China's research institutes constitute a major element of the country's research establishment. In the mid-1990s, 5,000–6,000 research institutes operated as independent accounting units (*duli hesuan danwei*) under the supervision of a wide array of

[2] MOST and NBS (2013, p. 16).
[3] MOST and NBS (2013, p. 712).
[4] MOST and NBS (2006, p. 26).

government agencies, both within the central government and also across China's sub-jurisdictions. Virtually all received direct government subsidies for their research activities. Under the 1999 restructuring programme, specific functions, along with reallocations of government research funding, were assigned to the three types of converted institutes. The three types of conversion were as follows:

1. Science and technology (S&T) enterprises: intended to be commercialized and therefore less reliant on public funds;
2. Non-profit research institutes (NPRs): intended to shift focus towards research, particularly basic research, with government support;
3. Non-profit, non-research institutes: intended to support various economic and social development objectives, primarily through the analysis and transfer of existing technologies.

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 (CAS) and the Chinese Academy of Social Science (CASS). By explicitly commercializing a substantial portion of the nation's state-owned research institutes, the restructuring was intended to enable a shift of the government's administrative and financial resources towards 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 in section 3, which follows. These specific issues include the following:

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, in particular, 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 Statistical Yearbook on Science and Technology*. These data cover a variety of aggregate variables concerning the research sector. Our long-term overview spans the period from 1995 through 2010. 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.

Our analysis concerning the impact of the restructuring programme on China's research institutes employs a balanced sample consisting of 1,813 research institutes for each of the 8 years covered by the 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 institutes from a balanced panel that includes six major sectors. These sectors are agriculture, public service, R&D services and three manufacturing sectors – chemicals, ferrous and non-ferrous metals, and computing and electronic equipment.

The key finding of this study 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 share 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, the S&T conversions more so than their newly converted non-profit research institute counterparts. Given the gestation period for new research to translate into patent filings, particularly invention patents on which the non-profit research institutes are likely to focus, it is premature to draw conclusions concerning the impact of restructuring on patent production. The results do clearly show that resources that relate to the differentiated articulated missions of the S&T enterprises and NPR institutes have been shifted towards the requisite organizations.

The balance of this study consists of seven sections. Section 2 reviews the literature related to the role of MOST (Ministry of Science and Technology) and the research institutes in China's national innovation system; the review also includes the salient publications that relate to the patent production function in China. Section 3 describes the overall organization of China's research institute sector, thus providing a context for the restructuring programme begun in 1999. Section 4 describes the sample of research institutes used to more thoroughly investigate the impact of the restructuring programme. Section 5 describes the modelling and econometric strategy used to conduct this analysis. Section 6 demonstrates the estimated impact of the restructuring programme. Section 7 concludes by noting the programme's robust effect on input reorientation and its qualified effects on output (especially patenting). We discuss how future research examining the long-run impact of the programme may find larger effects.

## 2. Relevant literature

While this study focuses on the restructuring initiative for China's research institute sector, we attempt to place this specific initiative within the larger context of the China's overall R&D programme. In this section, we review the swathe of literature that serves to locate the research institutes within the context of the nation's national innovation system. In addition, because patents are a key output of research institutes, particularly those performing basic research, such as a substantial number of the Chinese research institutes in this study, we search the literature on patent production functions.[5]

### *2.1. 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 programme. According to Sun and Cong (2014), 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 Ministry of Education, CAS and local governments. MOST's funding responsibility is limited to the establishment, annual survey data collection, evaluation and dissolution, as needed, for the relevant units within the SKL program (p. 14).

The academic literature on the evaluation of research institutes is meagre, not only for China, but worldwide. Part of the difficulty is the ambiguity concerning clearly identifying 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,

[5] Jefferson *et al.* (2008) use a similar dataset to provide a preliminary documentation of the data and associated estimation results. The data in this programme have been more carefully sorted and cleaned and the research methodology and estimation methods substantially expanded in relation to the early version.

unlike the conventional commercial corporation, which typically uses a fiscal year to match inputs and outputs for 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 fulfilment generally entails 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.

## 2.2 The patent production function

Following the tradition of Pakes and Griliches (1984), Hausman *et al.* (1984) and Bound *et al.* (1984) we estimate a patent production function. Each of these estimates uses a production function with varying functional forms to relate research inputs with counts of patent applications or patent grants using various 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 US companies analyzing the patent count as a function of current and lagged R&D expenditures. While each of these studies use US 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 towards industries with higher propensities to patent, and enterprise restructuring.

In this study, 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 towards 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 programme, 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 summarizes the survey data for these research institutes collected annually by MOST directly from the population of China's domestically owned research institute. Table 1 shows a profile of changes in China's research institute population over the years 1995–2010. We use 1998, the year prior to the restructuring initiative, as the baseline year. As shown in the table, one obvious substantial change is the abrupt fall off in the number of surviving institutes from 1998 to 2005, during which nearly one-third of the institutes disappeared. That the number of research institutes was relatively stable during the 3 years prior to 1998 and the 5 years following 2005 suggests that the restructuring initiative led to the large surge of exiting research institutes. By and 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', thus causing them to migrate from the statistical system consisting of research institutes under the supervision of MOST to the enterprise statistical system supervized 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 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 3 years of the restructuring programme. 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 S&T personnel, began 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, whereas 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

**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 billions 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***: *Denotes estimates based on 2011 figures.
***Source***: MOST and NBS (2000, 2003, 2008, 2011).

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 towards the overall downsizing of manpower in the research institutes, 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 programme. 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. Notwithstanding the decline in overall research share, largely driven by the surge in

R&D spending by the firm sector, the R&D spending of the average research institute rose from 2.5 million yuan in 1995 to over 32 million yuan in 2010.

As shown in Table 1, despite the surge in firm sector R&D spending, the share of basic research in overall R&D remained relatively stable at 5.2–5.7 percent during 1995–2005, before trailing off to 4.6 percent in 2010. Given the mandate of the research institute sector to foster basic research, we should expect that the institute share in overall spending on basic research would not decline as dramatically as it did for its share of overall R&D expenditure. Indeed, Table 1 shows that although the research institute sector's share of overall R&D spending declined, 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. As a result, 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 towards 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 within the research institute sector, 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 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 of 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 total patents in force is 8.9 percent. While this somewhat closes the gap between the share of basic research spending and the share of invention patenting output, the size of the difference is still puzzling.

This overview of China's R&D spending and the role of the research institute sector within it is meant 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 towards 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.

Table 2 shows the initial years of China's restructuring initiative. It shows that in 1999, the first year of restructuring, 114 institutes were reclassified as S&T enterprises and 18 as 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, whereas 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.

## 4. Research institutes: the sample

In this study, we use a sample of the MOST population of research institutes.[6] Table 3 provides a summary description of our sample consisting of 1,813 institutes.

[6] As a condition of the data being used off site at Brandeis, MOST required that we use a sub-sample consisting of the population of institutes within a limited number of sectors. Accordingly, we selected those sectors that we believed were of particular significance to China's economy: agriculture, three industrial sectors – chemicals, metals and electronics – specialized R&D, and public policy. By virtue of having control of a substantial sample we were able to analyze the data from many more different perspectives, using different estimation techniques and robustness checks, than would have been possible using the full population of firms on-site at MOST. The data are collected annually by the Chinese Academy of Science and Technology for Development (CASTED) within MOST. Because the Chinese institutes are required by law and regulation to prepare and submit the relevant data in a timely and accurate manner, the data are typically complete.

**Table 2. Descriptive statistics – total population of Chinese research institutes**

| | 1995 | 1999 | 2001 | 2003 | 2005 | 2007 |
|---|---|---|---|---|---|---|
| Number of institutes | 5,828 | 5,573 | 4,635 | 3,973 | 3,901 | 3,775 |
| Restructured | 0 | 132 | 891 | 1,348 | | |
| Converted to S&T enterprise | 0 | 114 | 821 | 1,087 | | |
| 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 | | |

***Notes*:** Above-county level government research institutes and institutes of scientific information and literature, with an independent accounting system. The variables in this table represent, in the order listed, the cumulative annual number of institutes that were converted to science and technology enterprises, converted to not-for-profit research institutes, converted to not-for-profit, non-research institutes, and the estimated number of institutes that disappeared as a result of mergers and acquisitions or shutdowns. The final entry is 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 (2005); MOST and NBS (2006, 2008).

These institutes are all surviving institutes that comprise a balanced sample. As a result, as shown in Table 1, because the total number of research institutes declined during 1999–2005, our sample, which omits the many exiting institutes and the fewer entering institutes, accounts for a growing share of the institute population. The share of our samples rises from 33 percent to 46 percent during this 6-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, that forms the basis of our empirical analysis.

By 2005, 440 of the 1,813 institutes in our sample (24 percent) 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 distinguish between the unconverted and converted institutes and between two types of the converted institutes,

**Table 3. Summary statistics (MOST sample)**

| | 1995 | 1997 | 1999 | 2001 | 2003 | 2005 |
|---|---|---|---|---|---|---|
| Number of institutes | 1,813 | 1,813 | 1,813 | 1,813 | 1,813 | 1,813 |
| Restructured | 0 | 0 | 96 | 201 | 290 | 440 |
| Converted 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 | 1,813 | 1,813 | 1,717 | 1,612 | 1,523 | 1,373 |
| Total revenue (1,000 Yuan) | 5,642.4 | 7,589.4 | 9,059.8 | 12,196.4 | 16,382.8 | 22,162.1 |
| 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 (persons) | 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) | 2,131.6 | 2,802.2 | 3,553.6 | 4,173.9 | 5,498.0 | 7,383.0 |
| S&T equipment (1,000 Yuan) | 4,388.5 | 5,732.3 | 6,142.9 | 7,816.3 | 10,774.7 | 9,226.7 |
| 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.

that is to say 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 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, most notably towards the NPRs.
- Scientific paper publications: This productivity measure declines for the S&T enterprises, while rising significantly for the unconverted institutes and the NPRs.

**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 | 1,373 | | 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 papers 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 (persons) | 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) | 2,237.1 | 6,767.1 | 8,011.7 | 6,819.7 | 4,909.6 | 17,963.4 |
| S&T equipment (1,000 Yuan) | 4,127.9 | 7,499.0 | 13,060.8 | 12,112.7 | 8,475.2 | 25,630.1 |

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

- 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 dataset does not allow us to distinguish among innovation patents, which are generally of substantially higher quality than the alternative utility and design patents.

Table 4 shows the potential for selection bias. Most of the variables which are smaller or larger for the S&T enterprises and the non-profit research institutes in 2005 exhibit the same relative magnitudes in 1998, the year prior to when the conversions commenced. For example the NPRs, which show larger government grant shares in 2005, also enjoyed a similar clear advantage in 1998; similarly, the larger production and management shares reported by the S&T enterprises in 2005 was already well-established within these institutes in 1998 prior to their conversion. These reflections of differences in 2005 consistent with the restructuring objectives that were already in evidence in 1998 pre-conversion underscore the concern of selection bias that the paper attempts to address in the econometric section through a variety of econometric methods.

Finally, within the summary statistics, Table 5 breaks down the full sample by six different sectors that are included in the dataset. These are agriculture, chemicals, metals, electronics, public policy and specialized R&D. Three of the six sectors are in manufacturing; two in services; one in agriculture. Together the research institutes in manufacturing 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 towards 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. This is likely to be consistent with the function of this sector, and the non-profit, non-research institutes that populate it, the focus on the transfer of science and technology with the Chinese economy.
- The manufacturing sectors show the fastest growing incidence of patents per 100 R&D workers. By 2005, patent productivity in the manufacturing sectors was 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; those are 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 study, the 1,748 research institutes, is hereafter referred to as the 'MOST sample'. The dataset is balanced in the sense that in every year, the same 1,748 institutes are included in the sample. Spanning the years 1997–2005, the sample represents 31 percent of the total population of research institutes in 1997 growing to 44.8 percent in 2005.

**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 papers 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 (persons) | 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) | 1,848 | 3,328 | 4,798 | 4,217 | 20,752 | 11,921 | 2,651 | 2,077 | 3,434 | 12,956 | 2,555 | 6,683 |
| S&T equipment (1,000 Yuan) | 3,450 | 7,120 | 8,779 | 8,565 | 31,702 | 21,549 | 4,806 | 4,612 | 6,155 | 9,693 | 4,376 | 11,552 |

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

The purpose of the econometric section that follows is to clarify the impact of the restructuring programme 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, 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 to obtain consistent estimates of the conversion effect. We outline two methods: standard OLS and fixed effects estimation. Then, to directly control for selection bias, we examine the robustness of these results using an event study methodology and propensity score matching (Cochran, 1968; Rosenbaum and Rubin, 1983).

### *5.1 Model*

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

$$R_{it} = A_{it} f(X_{it}) \tag{1}$$

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, $\alpha$ is a constant term, $s_{it}$ is a conversion indicator equal to one if the institute is converted by time $t$, $\varphi$ is the conversion effect, $u_{it}$ is an unobserved productivity component possibly correlated with $s_{it}$, and $\varepsilon_{it}$ 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 assumption leads to the estimation equation:

$$r_{it} = \alpha + \beta' x_{it} + \varphi s_{it} + u_{it} + \varepsilon_{it}. \quad (2)$$

We now consider each of the three sets of assumptions necessary to obtain a consistent estimate of $s_{it}$. In all these estimation strategies we cluster standard errors by institute.

## *5.2 OLS-FE analysis*

### 5.2.1 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 Equation (2) by ordinary least squares once we include controls for time, industry and region. We do this using year, industry and region fixed effects.

### 5.2.2 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.

## *5.3 Robustness*

Endogeneity of selection is a potential concern with the OLS-FE analysis. Specifically, if converted institutes are on a higher growth path prior to conversion, OLS and fixed effect estimation would find positive conversion effects even absent a true conversion effect. To examine the robustness of our results to this possibility we consider two methods of analysis. The first extension of the main analysis is an event study approach that estimates the conversion effect dynamically, for each year prior to the conversion and after the conversion. This approach allows us to check for pre-trends in the outcome variables. The second extension is a propensity score analysis that matches similar unconverted institutes as a control group when estimating the conversion effect. These institutes are likely to be on the same growth path and therefore serve as a more suitable control group mitigating endogeneity concerns.

### 5.3.1 Event study

For an event study approach we modify Equation (2) so that:

$$r_{it} = \alpha + \beta' x_{it} + \varphi S_{it} + u_{it} + \varepsilon_{it}. \quad (3)$$

Here, $S_{it}$ is a set of dummies indexed by $j$ which represents years to conversion. $J$ can be negative which would represent years until conversion. Therefore, $S_{it} = \{c_i * I$

$[(year - conyear) = j]\}$, where $c_i$ is an indicator variable for ever being converted and $I[(year - conyear) = j]$ is an indicator variable for years to conversion equalling $j$. We estimate the equation using institute fixed effects, hence $u_{it}$ represents year and institute fixed effects.[7]

### 5.3.2 Propensity score estimation

In this section, we outline the method of propensity score estimation we use to obtain a sample of similar institutes. We use the propensity score methodology to find institutes with similar probabilities of being selected for conversion.

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

$$p(X) = P(s_{it} = 1|X) = \left(1 + \exp[-(\alpha + \beta' x_{it})]\right)^{-1}. \tag{4}$$

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. As a result, 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 ($\varphi$) using the formulas from Imbens and Rubin (2015):

$$\phi = \frac{1}{N}[N_1\phi_1 + \cdots + N_5\phi_5] \tag{5}$$

$$se(\phi) = sqrt\left[\left(se(\phi_1)\frac{N_1}{N}\right)^2 + \cdots + \left(se(\phi_5)\frac{N_5}{N}\right)^2\right]$$

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 $\varphi$ we require that:

[7] OLS estimation without fixed effects yielded very similar results. The one exception was the effect of NPRI conversion on total revenue. The OLS estimate in this one case shows less of a pre-trend and an immediate, short-lived effect.

$$E[E(u_{it} - s_{it})|region, year, industry, p(X) = 0]. \quad (6)$$

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 $\varphi$ we require that:

$$E[E(u_{it} - \eta_i|s_{it})|region, year, industry, p(X) = 0] \quad (7)$$

where $\eta_i$ 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 each institute's mean productivity.

## 6. Estimation results

This section presents results from our various estimation methods. First we present the main results from OLS and fixed effects estimation. We then examine our event study and propensity score analysis.

### *6.1 OLS and fixed effects 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 is statistically significant at the 10 percent level. Since the outcome variable is log of total revenue the fixed effect estimate indicates that conversion results in an 8 percent increase in revenue, somewhat less than the 39 percent increase suggested by the OLS estimate. The next three sets of results, columns (3) through (8) show shifts in

**Table 6. Effect of 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*** |
| | (0.048) | (0.042) | (0.022) | (0.025) | (0.018) | (0.012) | (0.019) | (0.016) |
| Total personnel | 0.754*** | 0.586*** | −0.042*** | −0.019 | −0.010 | −0.045*** | 0.043*** | 0.040*** |
| | (0.020) | (0.047) | (0.007) | (0.021) | (0.008) | (0.013) | (0.006) | (0.014) |
| R&D personnel share | 0.278*** | 0.102*** | −0.004 | 0.004 | 0.124*** | 0.038*** | −0.019* | −0.008 |
| | (0.034) | (0.032) | (0.014) | (0.012) | (0.019) | (0.013) | (0.010) | (0.009) |
| P&M personnel share | 0.145** | −0.039 | −0.354*** | −0.175*** | −0.289*** | −0.029 | 0.381*** | 0.162*** |
| | (0.067) | (0.066) | (0.031) | (0.036) | (0.028) | (0.019) | (0.027) | (0.026) |
| Intermediate inputs | 0.289*** | 0.124*** | 0.016*** | 0.022*** | −0.038*** | −0.012*** | −0.017*** | −0.018*** |
| | (0.010) | (0.008) | (0.003) | (0.005) | (0.004) | (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 |
| | (0.006) | (0.005) | (0.003) | (0.003) | (0.003) | (0.002) | (0.002) | (0.002) |
| No. of observations | 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*** |
| | (0.031) | (0.036) | (0.048) | (0.042) | (0.072) | (0.059) |
| Total personnel | 0.624*** | 0.442*** | −0.268*** | −0.443*** | −0.293*** | −0.295*** |
| | (0.015) | (0.036) | (0.020) | (0.048) | (0.040) | (0.080) |

**Table 6. (Continued)**

| | S&T expenditure | | Productivity | | Non-gov. productivity | |
|---|---|---|---|---|---|---|
| | (9) | (10) | (11) | (12) | (13) | (14) |
| R&D personnel share | 0.212*** | 0.033 | 0.273*** | 0.100*** | −0.184** | −0.047 |
| | (0.025) | (0.031) | (0.034) | (0.032) | (0.094) | (0.082) |
| P&M personnel share | −0.406*** | −0.310*** | 0.145** | −0.037 | 0.967*** | 0.096 |
| | (0.046) | (0.065) | (0.067) | (0.066) | (0.130) | (0.120) |
| Intermediate inputs | 0.360*** | 0.257*** | 0.289*** | 0.124*** | 0.399*** | 0.151*** |
| | (0.009) | (0.009) | (0.010) | (0.008) | (0.020) | (0.013) |
| S&T equipment | 0.049*** | 0.009* | 0.051*** | 0.004 | 0.040*** | −0.002 |
| | (0.004) | (0.005) | (0.006) | (0.005) | (0.013) | (0.010) |
| No. of observations | 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 |

***Notes*:** This table shows the impact of conversion on the dependent performance variables. 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 and 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. Asterisks indicate significance at the 10 (*), 5 (**) and 1 (***) percent levels. We report robust standard errors clustered by institute.

**Table 7. Effect of 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 |
| | (0.044) | (0.035) | (0.010) | (0.009) | (0.019) | (0.017) | (0.011) | (0.007) |
| Total personnel | 0.715*** | 0.528*** | −0.035*** | 0.002 | −0.001 | −0.036** | 0.036*** | 0.028*** |
| | (0.020) | (0.047) | (0.007) | (0.017) | (0.009) | (0.014) | (0.006) | (0.011) |
| R&D personnel share | 0.247*** | 0.096*** | 0.004 | 0.002 | 0.134*** | 0.039*** | −0.025** | −0.006 |
| | (0.033) | (0.032) | (0.013) | (0.011) | (0.019) | (0.013) | (0.010) | (0.009) |
| P&M personnel share | 0.080 | −0.159*** | −0.319*** | −0.132*** | −0.302*** | −0.017 | 0.345*** | 0.102*** |
| | (0.066) | (0.057) | (0.032) | (0.036) | (0.030) | (0.020) | (0.028) | (0.025) |
| Intermediate inputs | 0.311*** | 0.142*** | 0.013*** | 0.015*** | −0.043*** | −0.015*** | −0.014*** | −0.01*** |
| | (0.011) | (0.008) | (0.004) | (0.006) | (0.004) | (0.002) | (0.003) | (0.002) |
| S&T equipment | 0.056*** | 0.009* | 0.005** | −0.001 | 0.001 | 0.002 | −0.005** | −0.001 |
| | (0.006) | (0.005) | (0.003) | (0.002) | (0.003) | (0.002) | (0.002) | (0.002) |
| No. of observations | 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 |

**Table 7. (Continued)**

| | 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 |
| | (0.042) | (0.036) | (0.044) | (0.035) | (0.125) | (0.119) |
| Total personnel | 0.620*** | 0.422*** | −0.308*** | −0.503*** | −0.359*** | −0.334*** |
| | (0.015) | (0.038) | (0.020) | (0.047) | (0.044) | (0.090) |
| R&D personnel share | 0.205*** | 0.027 | 0.242*** | 0.094*** | −0.255*** | −0.064 |
| | (0.025) | (0.031) | (0.033) | (0.032) | (0.096) | (0.085) |
| P&M personnel share | −0.359*** | −0.239*** | 0.080 | −0.158*** | 0.972*** | −0.034 |
| | (0.046) | (0.064) | (0.066) | (0.057) | (0.140) | (0.128) |
| Intermediate inputs | 0.363*** | 0.246*** | 0.311*** | 0.142*** | 0.443*** | 0.181*** |
| | (0.010) | (0.010) | (0.011) | (0.008) | (0.023) | (0.016) |
| S&T equipment | 0.051*** | 0.009** | 0.055*** | 0.009* | 0.048*** | 0.007 |
| | (0.004) | (0.005) | (0.006) | (0.005) | (0.014) | (0.011) |
| No. ofobservations | 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 |

***Notes*:** This table shows the impact of conversion on the dependent performance variables. 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. Asterisks indicate significance at the 10 (*), 5 (**) and 1 (***) percent levels. We report robust standard errors clustered by institute.

revenue composition, such that S&T conversions increase their P&M shares of total revenue at the expense of revenue shares associated with S&T activity and government grants. With the outcome variable being revenue share and ranging from 0 to 1, according to the fixed effects estimator, 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 P&M personnel share are strongly positively associated with the P&M revenue share, whereas the P&M personnel share is 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, 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 in columns (11) and (12) and non-government revenue per worker in columns (13) and (14). Consistent with declines in the government grant share, the results also 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 towards the production and management functions. 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 towards 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. However, while the conversion has seemed to result in the S&T conversions becoming more focused on commercial development and production, as we will see in Table 8, in relation to China's standard industrial enterprise, they would appear to be more focused on S&T development.

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 percent increase in total revenue. Scanning columns (3) through (8), the results across the OLS and fixed effects estimates show uneven results, with the OLS estimates yielding the anticipated increases in the S&T and government grant shares, whereas the fixed effects estimates indicate only marginal impacts. In fact, as suggested by Table 4, the share shifts for the NPR conversions were not nearly as great as those for the S&T conversions. For the NPRs, the pre-conversion P&M shares were already small, so that substantial increases in the *levels* of S&T and government grants may have had little impact on the P&M share, and in fact may have required some near proportional increases simply to manage the additional S&T expenditures and government grants.

The results in columns (7) and (8), showing at most a marginal reduction in the P&M share, may be 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 explanation of the marginal impact of conversion on the P&M shares is the fact that the P&M shares in the non-profit research institutes are quite small both in 1995 and in 2005. Hence, the converted NPRs may have already exhibited relatively small P&M shares prior to conversion, so that conversion did not result in substantial declines in either P&M shares or productivity measured in terms of non-government revenue.

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 principally centred on increases in government grant revenue. These results are largely consistent with the restructuring goal of shifting the NPRs more towards a pure research function. In conclusion, based on the estimation results in Tables 6 and 7, we find affirmative evidence that during the immediate years following the introduction of China's research institute restructuring programme, the programme made substantial progress towards achieving its goals – shifting the S&T enterprises towards commercial applications and the NPR towards government-supported research.

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. To minimize or avoid estimation bias resulting from a fat zero tail when using 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 behind this approach is that a fixed effects estimator only uses within-variability to estimate the parameters; the conditional logit model drops the institutes for which the observations are all 0 or all 1 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 during the sample period. Column (4) is the same regression with institute fixed effects. 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 to 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.

## Table 8. The effect of 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** |
| | (0.144) | (0.233) | (0.711) | (0.416) | (0.006) | (0.011) | (0.052) | (0.073) | (0.961) | (0.579) |
| Total personnel | 0.437*** | 1.193*** | 1.046*** | 0.562** | 0.004*** | 0.016** | 0.014 | 0.088 | 1.598*** | 1.007** |
| | (0.070) | (0.218) | (0.219) | (0.275) | (0.001) | (0.008) | (0.016) | (0.087) | (0.332) | (0.486) |
| R&D personnel share | 1.935*** | 0.908*** | 1.786*** | 0.774*** | 0.015*** | 0.014* | 0.033 | 0.048 | 2.701*** | 1.060** |
| | (0.166) | (0.254) | (0.348) | (0.256) | (0.005) | (0.008) | (0.044) | (0.115) | (0.626) | (0.447) |
| P&M personnel share | −0.457* | −0.454 | −2.889** | −0.320 | −0.006 | 0.006 | 0.077 | 0.088 | −3.752* | −0.488 |
| | (0.254) | (0.449) | (1.236) | (0.848) | (0.005) | (0.010) | (0.078) | (0.209) | (1.919) | (1.446) |
| Intermediate inputs | 0.195*** | −0.007 | 0.164*** | 0.024 | 0.000 | −0.001 | 0.003 | 0.002 | 0.160** | −0.013 |
| | (0.034) | (0.039) | (0.048) | (0.036) | (0.001) | (0.001) | (0.009) | (0.016) | (0.074) | (0.070) |
| S&T equipment | 0.175*** | 0.090** | 0.075 | 0.017 | 0.001** | 0.001 | −0.003 | 0.006 | 0.143 | 0.005 |
| | (0.034) | (0.039) | (0.063) | (0.047) | (0.000) | (0.001) | (0.008) | (0.021) | (0.136) | (0.093) |
| No. of observations | 14,683 | 4,806 | 5,601 | 5,601 | 10,551 | 10,551 | 1,294 | 1,294 | 2,838 | 2,838 |
| 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 | −0.087 | 0.319 | 0.394 | 0.754 | 0.005 | 0.004 | 0.120 | 0.157 | 0.188 | 0.730 |
| conversion | (0.229) | (0.322) | (0.545) | (0.618) | (0.012) | (0.017) | (0.126) | (0.174) | (0.841) | (0.938) |
| Total personnel | 0.385*** | 1.247*** | 0.491*** | 0.656** | 0.005*** | 0.010 | 0.025 | 0.132 | 0.774*** | 1.301** |
| | (0.080) | (0.269) | (0.111) | (0.291) | (0.001) | (0.007) | (0.019) | (0.098) | (0.183) | (0.525) |
| R&D personnel share | 1.890*** | 1.002*** | 1.427*** | 0.647*** | 0.017*** | 0.020** | 0.016 | −0.008 | 2.013*** | 0.927** |
| | (0.169) | (0.261) | (0.268) | (0.220) | (0.005) | (0.008) | (0.045) | (0.118) | (0.441) | (0.380) |

## Table 8. (Continued)

| | 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) |
| P&M personnel share | −0.326 | −0.112 | −1.059*** | −0.242 | −0.009* | 0.000 | 0.064 | 0.231 | −1.607*** | −0.696 |
| | (0.271) | (0.500) | (0.346) | (0.429) | (0.005) | (0.010) | (0.075) | (0.219) | (0.550) | (0.723) |
| Intermediate inputs | 0.206*** | 0.005 | 0.119*** | 0.042 | −0.000 | −0.001 | −0.001 | −0.007 | 0.146*** | 0.037 |
| | (0.041) | (0.050) | (0.029) | (0.037) | (0.001) | (0.001) | (0.011) | (0.023) | (0.052) | (0.069) |
| S&T equipment | 0.160*** | 0.060 | 0.086*** | 0.064** | 0.001 | 0.001 | −0.005 | −0.001 | 0.122** | 0.093 |
| | (0.039) | (0.040) | (0.027) | (0.028) | (0.000) | (0.001) | (0.008) | (0.022) | (0.058) | (0.066) |
| No. of observations | 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 |

***Notes*:** This table shows the impact of conversion on various patent outcomes. 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 refer to total applied patents. Given are results for four different samples: those institutes who patent at least once in the dataset 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+. Asterisks indicate significance at the 10 (*), 5 (**) and 1 (***) percent levels. We report robust standard errors clustered by institute.

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)–(4) show interesting results concerning the relative contribution of the inputs to patent production. The most dramatic – and predictable – is 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, whereas 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 in the R&D personnel shares clearly enhance patent production.

For columns (5) though (10), as with the earlier columns in Table 8, 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 while the estimation signs are positive for columns (5) through (10), 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 results in columns (9) and (10) indicate an increase in the number of institutions with two or more patents per year.

Consistent with the increase in the incidence of 4+ patents, we see for this patent-active group 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 into 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 towards moving their prior research work towards sale or production. This may have given the S&T enterprises an incentive to accelerate backlogged patents in process in the pipeline to patent applications, a response to conversion that would be clearly unsustainable.

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, not a single one exhibits any statistical significance, even at the 10 percent 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 patent production for 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 (1)–(10) and (10)–(20). This pattern suggests that R&D personnel have similar level effects on patent applications, even as conversion exhibits less of a favourable impact for the NPR institutes compared with the S&T enterprises.

These dissimilar conversion 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 the 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 R&D 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. While the differences in conversion effects substantially favour the S&T enterprises, 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. Specifically, the long lag time for patent production, probably more so for quality patents, such as invention patents, may mean that for patent production in the NPR institutes, the conversion impacts may outrun the duration of our sample.

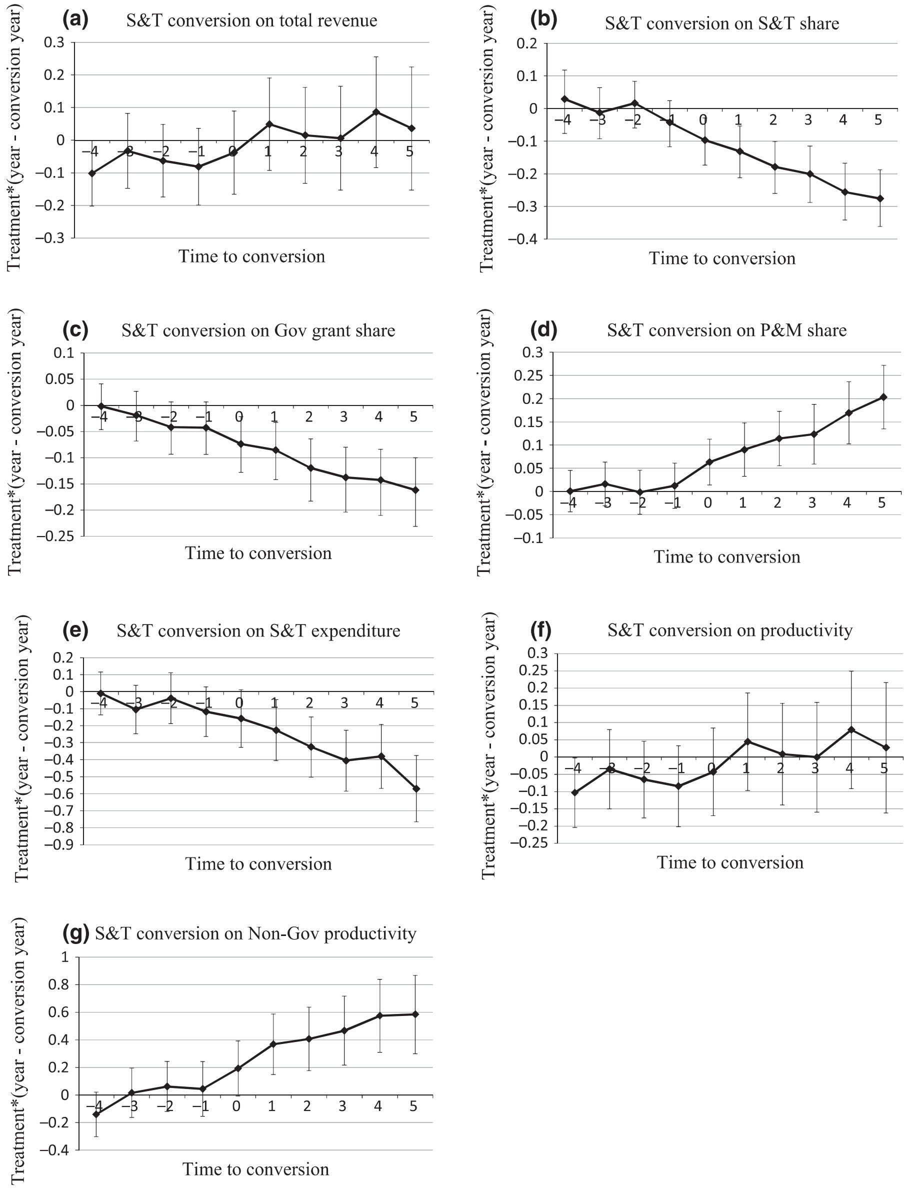
### 6.2 Event study approach

Figures 1–3 present the event study results. We report graphically the coefficients on $S_{it}$ along with two standard deviation error bands. The omitted group from the set of binary variables is greater than 4 years to conversion. For the S&T converted institutes we group together the conversion effect for 5 or more years past conversion and for the NPRI converted institutes we group together the conversion effect for 3 or more years past conversion.[8]

Turning our attention to Figure 1(a), the dynamic effect of S&T conversion on total revenue, we see a positive effect on revenue consistent with our main results. In addition, we see no evidence of a pre-trend. Revenue at years −4 to −1, (4 to 1

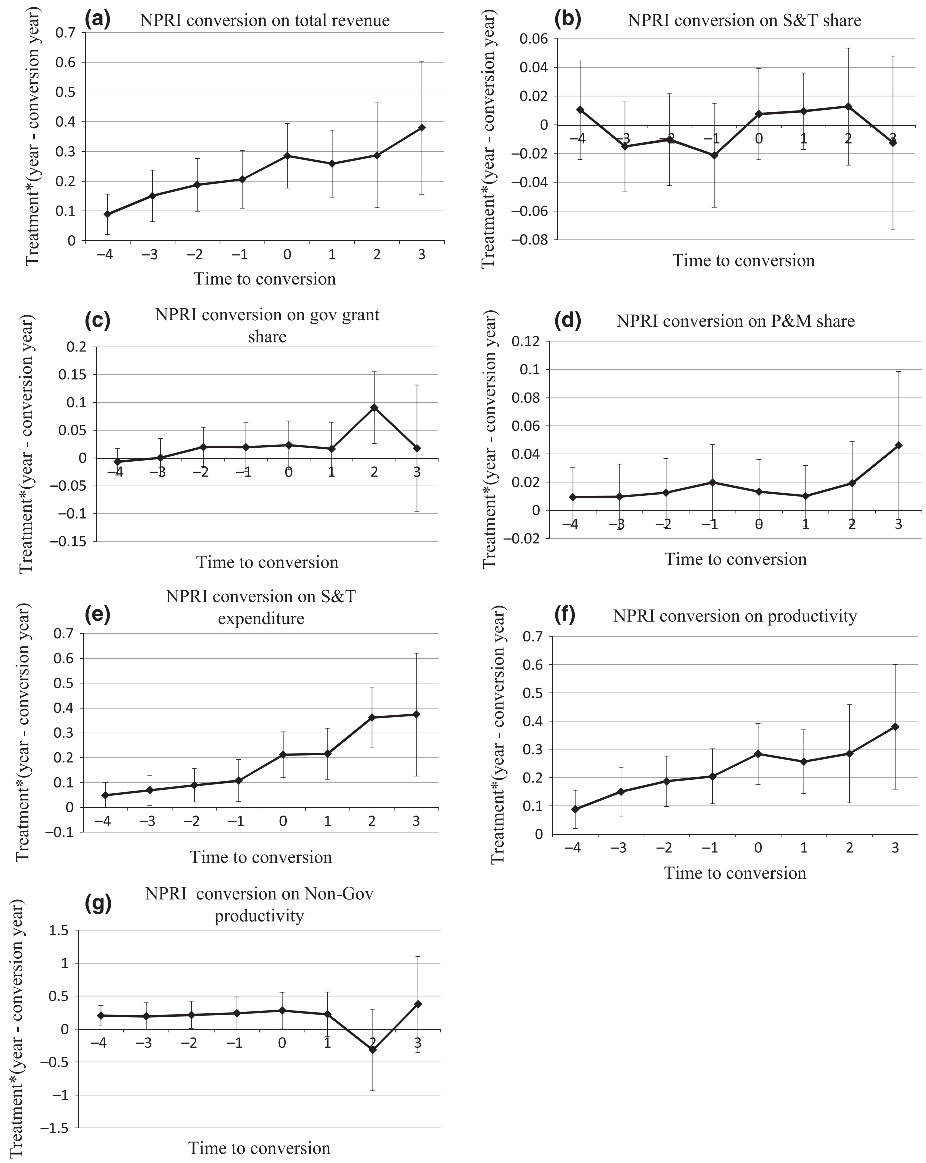
[8] These groupings are necessary because the small number of observations at the tail of the years to conversion distribution prevents precise estimation of effects this far into the future. The NPRI cut-off occurs earlier because NPRI conversions on average begin later.

**Figure 1. Event study of S&T conversion effect. S&T conversion on: (a) Total revenue, (b) S&T share, (c) Gov grant share, (d) P&M share, (e) S&T expenditure, (f) productivity, (g) non-gov productivity**



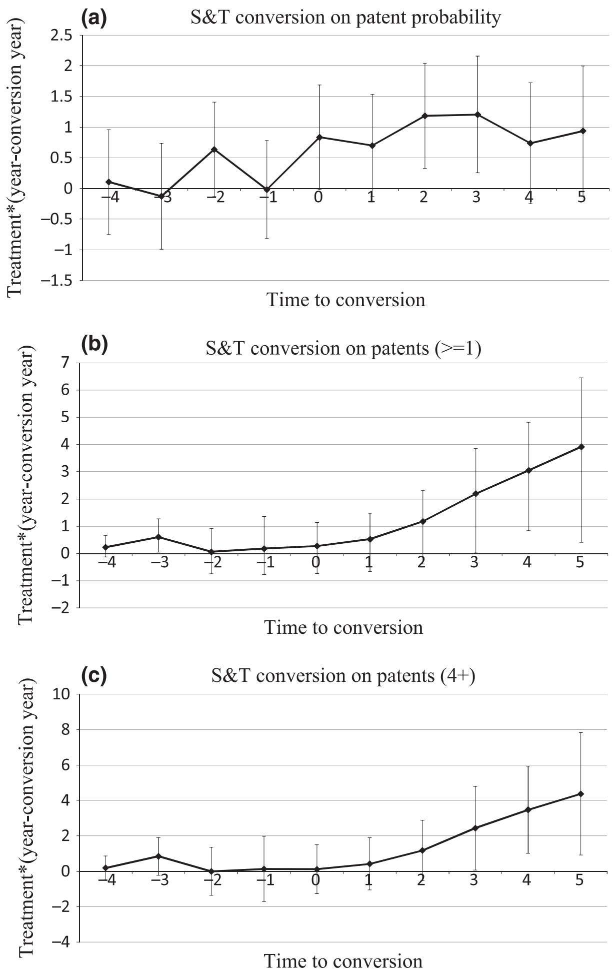

***Note*****:** Graphs give coefficients on event study binary variables for the stated outcomes. Vertical bars represent two standard error bands.

**Figure 2. Event study of NPRI conversion effect. NPRI conversion on: (a) Total revenue, (b) S&T share, (c) Gov grant share, (d) P&M share, (e) S&T expenditure, (f) productivity, (g) non-gov productivity**




***Note*:** Graphs give coefficients on event study binary variables for the stated outcomes. Vertical bars represent two standard error bands.

**Figure 3. Event study of S&T conversion effect on patenting. S&T conversion on: (a) patent probability, (b) patents (≥1), (c) patents (4+)**




***Note*****:** Graphs give coefficients on event study binary variables on patenting. Vertical bars represent two standard error bands.

years until conversion) is roughly the same; it is not until year 0 (the conversion date) that revenue begins to rise. We find that by 1 year after the conversion most of the revenue gains have been achieved, thereafter reaching a permanently higher level.

Figure 1(b) examines the conversion impact on share of S&T revenue. We find little evidence of a falling S&T share in the 4 to 2 years prior to conversion. There is no consistent trend prior to conversion. After conversion, S&T revenue falls consistently year by year.

Figure 1(c) plots the same results for the share of revenue coming from government grants. Again, this share declines substantially year-by-year post conversion, with little evidence of a pre-trend. Similarly, in Figure 1(d) the P&M share of revenue begins to rise year-by-year beginning with the date of conversion. There is no trend in P&M share prior to conversion.

Figure 1(e) plots the effect on S&T expenditure. The results are similar to the results on share of S&T revenue, with no consistent pre-trend prior to conversion but then decreasing S&T expenditure year-by-year post-conversion.

Finally we turn our attention to the effects on productivity and non-government productivity in Figures 1(f) and 1(g). In neither case do we see any trends prior to conversion. Post conversion we see a small uptick in productivity, with most of the gains coming by 1 year after conversion. However, for non-government productivity we see a much larger increase and we see larger and larger effects as time from conversion increases.

To summarize, the event study methodology for the S&T conversion effect yields results of similar sign and magnitude as the OLS-FE results. Consistent with the changes highlighted by the OLS-FE analysis, the event study shows the principal changes coming post conversion with little evidence of trends prior to conversion.

Next, we examine Figure 2 which plots the dynamic effect of conversion for the non-profit research institutes. In Figure 2(a), we see a positive effect of conversion on total revenue. While there is some evidence of a positive trend prior to conversion, the estimated coefficients indicate a substantial jump in revenue at the time of conversion and large effects on revenue at 3 plus years of conversion. In Figure 2(b), we find a positive effect of conversion on the S&T share of revenue, though the standard errors on the estimated coefficient are quite large. This is consistent with the positive but not statistically significant effect we found in the OLS-FE analysis. In Figure 2(c), we see a positive conversion effect, though only 2 years post conversion. Again this is consistent with the positive but statistically insignificant effect found in the previous econometric analysis; it then drops off during the following year. In the OLS-FE analysis we found no effect on the P&M share of revenue, that result is consistent with the estimates in Figure 2(d), though there appears to be a substantial positive effect 3 or more years after conversion.

Turning to the effect on S&T expenditure in Figure 2(e) we see an immediate jump in S&T expenditure at the year of conversion and an additional and substantial increase 2 years after conversion. This increase is much larger than the small increases in the year prior to conversion. The effects on productivity in Figure 2(f) are similar to the effects on total revenue. While slowly rising prior to conversion, there is a substantially increase in productivity the year of conversion and an additional increase 3 plus years out. Finally, consistent with the OLS-FE results, we find no conversion effect on productivity when revenue is measured only using non-governmental sources.

Non-profit research institute conversion appears to create substantial increases in revenue, productivity and S&T expenditure. While there are small pre-trends in these variables, there are substantial increases post-conversion that are notably much more than the pre-trend.

Finally Figure 3 plots the effect on patenting. For clarity, we show only figures for which we found a significant conversion effect in the OLS-FE specification; those are the effect of S&T conversion on patent probability and number of patents for institutes which patented at least once in the sample and four or more times in sample. We omit results for the NPRIs since we found no effect of conversion in the OLS-FE results.

In Figure 3(a), we see that S&T conversion has a positive effect on the probability of applying for a patent beginning in the conversion year. There is no pre-trend in this variable. Examining Figure 3(b), (c) we see no evidence of a pre-trend in the number of patents. However, post-conversion patenting increases and continues to increase in every year post conversion.

To conclude, the event study approach supports the finding that we reported in the previous section using OLS-FE regression analysis. There is little evidence of pre-trends in these variables and with substantial changes during the post-conversion periods. The results are largely consistent with the stated objectives of the restructuring programme.

### *6.3 Propensity score analysis*

Tables 9–13 report our Propensity Score Estimation results. Table 9 consists of two logit regressions. Each estimates the propensity for conversion, the first for S&T enterprise conversions; the second for the conversion of non-profit research institutes. To estimate the propensity scores, 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 into 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, 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 be more extensively specialized, employs intermediate inputs more than does the

**Table 9. Propensity score estimation**

| | S&T conversion year (1) | NPRI conversion year (2) |
|---|---|---|
| Total personnel | −0.046 | 0.065 |
| | (0.121) | (0.174) |
| R&D personnel share | −0.511 | 0.821** |
| | (0.385) | (0.347) |
| P&M personnel share | 2.159*** | −0.599 |
| | (0.392) | (0.654) |
| Intermediate inputs | 0.164*** | 0.003 |
| | (0.049) | (0.079) |
| S&T equipment | 0.063 | 0.254** |
| | (0.046) | (0.119) |
| Constant | −5.827*** | −6.046*** |
| | (0.516) | (0.664) |
| Observations | 11,074 | 8,621 |

***Notes*:** This table contains the logit results used to estimate 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. We include year, region and industry fixed effects. Asterisks indicate significance at the 10 (*), 5 (**) and 1 (***) percent levels. We report robust standard errors clustered by institute.

R&D enterprise. By-and-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 which are S&T enterprise and NPR institute conversion. The robust tilt of large P&M personnel shares towards S&T conversions and the contrasting tilt of large R&D shares towards NPR conversions underscore the importance of controlling our regression analysis for selection criteria.

To deepen our understanding of how the observable variables differ between the converted and unconverted institutes, Tables 10 and 11 present differences in means for the converted and unconverted institutes. The tables present means in 1998, prior to conversion, and for the full sample and by propensity score quintile. Here, quintile 1 is the least likely to be converted; quintile five is most likely to be converted.

First, in Table 10, we see that S&T converted institutes have almost twice the level of revenue per worker, and have a lower share of revenue coming from S&T and government grants. They also have a higher share of revenue coming from P&M sources. They are larger with about 160 more employees, and have more

**Table 10. S&T converted vs. unconverted: Difference in pre-conversion means**

| | Revenue per worker | S&T Rev. Share | Gov. Grant Rev Share | P&M Rev Share | Total Per. | P&M Per. | S&T Per. | S&T Input | S&T Exp. | Patent Apps. |
|---|---|---|---|---|---|---|---|---|---|---|
| S&T con. | 65.82 | 0.83 | 0.28 | 0.28 | 268.01 | 92.61 | 138.62 | 8,011.67 | 13,060.82 | 1.00 |
| Uncon. | 38.89 | 0.97 | 0.64 | 0.08 | 107.36 | 25.13 | 66.41 | 2,237.12 | 4,127.94 | 0.16 |
| Diff. | 26.93*** | −0.14*** | −0.35*** | 0.20*** | 160.64*** | 67.48*** | 72.22*** | 5,774.55*** | 8,932.90*** | 0.83** |
| Quintile 1 | | | | | | | | | | |
| S&T con. | 68.93 | 0.81 | 0.35 | 0.32 | 132.00 | 16.00 | 101.00 | 734.50 | 2,730.50 | 1.00 |
| Uncon. | 28.67 | 1.00 | 0.74 | 0.04 | 63.64 | 9.39 | 45.51 | 711.67 | 1,504.06 | 0.10 |
| Diff. | 40.26*** | −0.20 | −0.19*** | 0.27 | 68.36*** | 6.61 | 55.49* | 22.83 | 1,226.40*** | 0.90 |
| Quintile 2 | | | | | | | | | | |
| S&T con. | 27.91 | 0.90 | 0.52 | 0.10 | 59.33 | 7.78 | 45.00 | 441.89 | 1,447.33 | 0.11 |
| Uncon. | 33.00 | 0.98 | 0.73 | 0.06 | 82.04 | 15.39 | 55.22 | 1,283.30 | 2,449.42 | 0.06 |
| Diff. | −5.08 | −0.09 | −0.21 | 0.05 | −22.71 | −7.61 | −10.22 | −841.41* | −1,002.09 | 0.05 |
| Quintile 3 | | | | | | | | | | |
| S&T con. | 80.49 | 0.87 | 0.54 | 0.18 | 80.71 | 15.86 | 51.86 | 3,480.93 | 5,327.14 | 0.21 |
| Uncon. | 45.44 | 0.98 | 0.63 | 0.07 | 124.80 | 28.06 | 76.66 | 2,027.38 | 4,040.86 | 0.27 |
| Diff. | 35.05* | −0.11 | −0.09 | 0.11 | −44.08** | −12.21 | −24.80** | 1,453.55 | 1,286.28 | −0.06 |

**Table 10. (Continued)**

| | Revenue per worker | S&T Rev. Share | Gov. Grant Rev Share | P&M Rev Share | Total Per. | P&M Per. | S&T Per. | S&T Input | S&T Exp. | Patent Apps. |
|---|---|---|---|---|---|---|---|---|---|---|
| Quintile 4 | | | | | | | | | | |
| S&T con. | 47.42 | 1.00 | 0.35 | 0.16 | 131.11 | 42.80 | 72.81 | 2,854.13 | 4,929.48 | 0.06 |
| Uncon. | 45.14 | 0.92 | 0.53 | 0.11 | 136.26 | 33.39 | 80.25 | 4,108.52 | 7,072.53 | 0.21 |
| Diff. | 2.28 | 0.08 | −0.17*** | 0.05 | −5.15 | 9.41 | −7.44 | −1,254.39 | −2,143.05 | −0.15* |
| Quintile 5 | | | | | | | | | | |
| S&T con. | 71.42 | 0.78 | 0.23 | 0.34 | 333.76 | 117.92 | 169.36 | 10,306.92 | 16,696.21 | 1.37 |
| Uncon. | 52.79 | 0.91 | 0.39 | 0.17 | 177.21 | 62.21 | 93.88 | 4,989.78 | 8,865.70 | 0.21 |
| Diff. | 18.63** | −0.13 | −0.16*** | 0.16*** | 156.55*** | 55.71** | 75.48*** | 5,317.14* | 7,830.50* | 1.16** |

***Notes*****:** This table presents differences in means for the variables listed above. Means are given for the unconverted firms and those eventually converted to S&T institutes. Means are given in 1998 before conversions took place. The first row block gives means for all institutes, the following rows give means for institutes in the lowest propensity score quintile to the highest quintile. Asterisks indicate significance at the 10 (*), 5 (**) and 1 (***) percent level. We report robust standard errors clustered by institute.

employees engaged in both P&M work and in S&T work. They use more S&T intermediate inputs and spend more on S&T. Finally, they produce more patent applications.

Examining the difference in means across propensity score quintiles, we see that the matching helps create similar control groups. While the matching is not perfect, we do see the differences in means tending to be smaller in the propensity score blocks and less likely to be statistically significant. In a majority of the cases we see that the gap between the converted and unconverted has closed and differences become statically insignificant. Since the matching is not perfect, we include additional controls in our propensity score regressions. We control for the level of the propensity score and we use institute fixed effects as well.

Table 11 repeats this analysis comparing the NPR converted institutes to the unconverted. We first see that the converted institutes have higher levels of revenue per worker, more revenue coming from government grants and less from production and management. They tend to have more workers, largely resulting from more S&T personnel. They use more S&T intermediate inputs and spend more on S&T. There is no significant difference in their S&T revenue shares or government grant shares; however, as shown in the last column, as with the S&T conversions, their incidence of patent applications is significantly higher than for the institutes in the lower quintiles.

For the variables where we see significant differences, we also see that the propensity score matching helps create more similar control groups. In the majority of the cases the differences are smaller and no longer significant within the propensity score quintiles. The only exception is for the revenue share variables where the matching provides little help in narrowing the differences.

Table 12 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 12 reports two tiers of results – those which include only industry and regional fixed effects, as do the odd-numbered columns in Tables 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 whereas 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 the initial regression results in Tables 6 and 7.

**Table 11. NPRI converted vs. unconverted: difference in pre-conversion means**

| | Revenue per worker | S&T rev. share | Gov. grant rev share | P&M rev share | Total personnel | P&M per. | S&T per. | S&T input | S&T exp. | Patent apps |
|---|---|---|---|---|---|---|---|---|---|---|
| NPRI con. | 49.78 | 1.00 | 0.70 | 0.04 | 168.77 | 20.06 | 122.96 | 4,909.63 | 8,475.20 | 0.27 |
| Uncon. | 38.89 | 0.97 | 0.64 | 0.08 | 107.36 | 25.13 | 66.41 | 2,237.12 | 4,127.94 | 0.16 |
| Diff. | 10.88* | 0.03 | 0.07** | −0.04*** | 61.40** | −5.07 | 56.56*** | 2,672.50** | 4,347.30** | 0.11 |
| Quintile 1 | | | | | | | | | | |
| NPRI con. | 29.84 | 1.07 | 0.71 | 0.01 | 42.71 | 8.29 | 30.14 | 507.29 | 1,227.57 | 0.00 |
| Uncon. | 22.58 | 0.94 | 0.69 | 0.07 | 55.32 | 14.13 | 34.39 | 464.51 | 1,054.18 | 0.03 |
| Diff. | 7.25 | 0.13* | 0.03 | −0.06** | −12.61 | −5.84 | −4.25 | 42.77 | 173.40 | −0.03 |
| Quintile 2 | | | | | | | | | | |
| NPRI con. | 17.45 | 0.99 | 0.82 | 0.02 | 73.50 | 14.67 | 40.58 | 473.92 | 1,274.25 | 0.08 |
| Uncon. | 29.92 | 0.96 | 0.66 | 0.09 | 85.47 | 22.89 | 52.63 | 788.66 | 1,785.14 | 0.08 |
| Diff. | −12.47*** | 0.03 | 0.15** | −0.07*** | −11.97 | −8.22 | −12.05 | −314.75 | −510.89 | 0.01 |
| Quintile 3 | | | | | | | | | | |
| NPRI con. | 22.90 | 0.92 | 0.67 | 0.11 | 58.27 | 11.82 | 42.09 | 413.00 | 1,126.55 | 0.00 |
| Uncon. | 32.79 | 1.01 | 0.69 | 0.05 | 93.44 | 22.77 | 55.85 | 1,203.80 | 2,504.55 | 0.09 |
| Diff. | −9.89** | −0.09* | −0.01 | 0.05 | −35.17*** | −10.96* | −13.76 | −790.80*** | −1,378.00*** | −0.09*** |
| Quintile 4 | | | | | | | | | | |
| NPRI con. | 37.67 | 0.95 | 0.75 | 0.07 | 127.83 | 18.13 | 92.74 | 2,377.22 | 5,043.70 | 0.09 |

**Table 11. (Continued)**

| | Revenue per worker | S&T rev. share | Gov. grant rev share | P&M rev share | Total personnel | P&M per. | S&T per. | S&T input | S&T exp. | Patent apps |
|---|---|---|---|---|---|---|---|---|---|---|
| Uncon. | 43.15 | 0.98 | 0.64 | 0.07 | 105.29 | 23.32 | 66.00 | 1,667.18 | 3,359.75 | 0.27 |
| Diff. | −5.47 | −0.03 | 0.12* | 0.00 | 22.54 | −5.19 | 26.74 | 710.03 | 1,683.95 | −0.19 |
| Quintile 5 | | | | | | | | | | |
| NPRI con. | 67.85 | 1.02 | 0.67 | 0.02 | 235.70 | 25.00 | 173.32 | 7,726.00 | 12,954.32 | 0.47 |
| Uncon. | 70.77 | 0.97 | 0.56 | 0.09 | 203.16 | 40.04 | 129.39 | 7,917.07 | 13,330.50 | 0.36 |
| Diff. | −2.92 | 0.06* | 0.11** | −0.06*** | 32.54 | −15.04 | 43.93 | −191.07 | −376.19 | 0.11 |

***Notes*:** This table presents differences in means for the variables listed above. Means are given for the unconverted firms and those eventually converted to NPR institutes. Means are given in 1998 before conversions took place. The first row block gives means for all institutes; the following rows give means for institutes in the lowest propensity score quintile to the highest quintile. Asterisks indicate significance at the 10 (*), 5 (**) and 1 (***) percent levels. We report robust standard errors clustered by institute.

**Table 12. 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 | 0.344 *** | −0.201 *** | −0.285 *** | 0.203 *** |
| | (0.065) | (0.029) | (0.039) | (0.028) |
| Year and institute FE | −0.098 | −0.062*** | −0.073 *** | 0.076 *** |
| | (0.070) | (0.023) | (0.021) | (0.019) |
| | S&T expenditure | Productivity | Non-gov. productivity | |
| Year, region and industry FE | 0.064 | 0.347 *** | 1.158 *** | |
| | (0.055) | (0.065) | (0.114) | |
| Year and institute FE | −0.109 | −0.099 | 0.233 *** | |
| | (0.084) | (0.070) | (0.098) | |
| | **Non-profit research conversion** | | | |
| | **Total revenue** | **S&T share** | **Gov. grant share** | **P&M share** |
| Year, region and industry FE | 0.106 * | 0.019 | 0.100 *** | −0.018 |
| | (0.061) | (0.014) | (0.022) | (0.013) |
| Year and institute FE | 0.084 *** | 0.009 | 0.026 | 0.003 |
| | (0.037) | (0.019) | (0.019) | (0.011) |
| | S&T expenditure | Productivity | Non-gov. productivity | |
| Year, region and industry FE | 0.184 *** | 0.102 * | −0.298 * | |
| | (0.049) | (0.060) | (0.165) | |
| Year and institute FE | 0.191 *** | 0.082 *** | −0.108 | |
| | (0.042) | (0.037) | (0.152) | |

***Notes*:** This table gives conversion effects estimated by the propensity score measure. Regressions are as in Tables 6 and 7, but run by dividing observations into five 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. Asterisks indicate significance at the 10 (*), 5 (**) and 1 (***) percent levels. We report robust standard errors clustered by institute.

However, when we look at the PSA results blocked by similar institutes and with institute fixed effects, we also 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 are 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 results with institute FE, compared with those of other tables, suggest that the S&T enterprise process may have exhibited a systematic selection bias towards 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 revenue share and increase in the government grant share were not as large and robust as suggested by the earlier estimation results. Together with the negligible reduction in non-government productivity this suggests that the shift towards a pure research model was not as robust as some of the previous results would have suggested.

Table 13 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 13, indicate that among the NPR institute conversions there is any robust increase in the incidence of institutes reporting patenting. The Table 13 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

**Table 13. Conversion effect on patenting (block propensity score)**

| | Patenter | Patents Group (≥1) | Patents Group (0–1) | Patents Group (2–3) | Patents Group ≥4 |
|---|---|---|---|---|---|
| S&T enterprise conversion | | | | | |
| Year, region and industry FE | 0.929 *** | 0.817 *** | 0.022 * | 0.033 | 0.901 |
| | (0.347) | (0.357) | (0.013) | (0.049) | (0.566) |
| Year and institute FE | 0.677 | 0.088 | 0.044 ** | 0.028 | −0.278 |
| | (0.535) | (0.341) | (0.019) | (0.077) | (0.434) |
| Non-profit research conversion | | | | | |
| Year, region and industry | 0.412 | −0.351 | 0.003 | 0.124 | −0.737 |
| FE | (0.375) | (0.317) | (0.011) | (0.131) | (0.527) |
| Year and institute FE | 1.091 *** | −0.013 | 0.012 | 0.154 | −0.202 |
| | (0.316) | (0.297) | (0.013) | (0.178) | (0.520) |

***Notes*****:** 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 blocks (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 refer to total applied patents. Given are results for four different samples: those institutes patenting at least once in the dataset 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. Asterisks indicate significance at the 10 (*), 5 (**) and 1 (***) percent levels. We report robust standard errors clustered by institute.

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 vs. 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 yielded an increase in patent production. The effect which resulted from the most active patenters among the S&T conversions failed to sustain their robustness under the test of the PSA approach with institute fixed effects. That the other estimation methods did show a robust effect for the most patent-active S&T enterprises suggests that these institutes may have been chosen for conversion precisely because they had a backlog of patents that might have near-term commercial application. That restructuring seemed to have little effect on patenting, may simply reflect the lag between R&D inputs and incentivization and the time when such changes yield measurable results in the relevant patent office.

## 7. Conclusions and next steps

Over the past two decades, China has reported a striking surge in R&D expenditure and in patenting. Questions arise concerning the quality of the institutions that are shaping the effectiveness of this surge in innovation activity. In this study, we have focused on the contributions of the research institute sector to China's overall innovation effort and changes in the institutional structure of that sector that affect its ability to transform R&D inputs into measurable innovation outputs.

To achieve these research goals, we have used detailed yearbook data that provide an overview of the changing role of China's research institutes within the nation's innovation system. To more deeply understand institutional aspects of the research institute sector, we use a substantial sample of the research institutes, both those that were converted pursuant to the 1999 restructuring initiative as well as a control group that was not converted. Using this set of converted and unconverted institutes, we examine the impact of restructuring to two conversion types – S&T enterprises and non-profit research institutes – on the revenue composition, overall productivity and patent production across these institutes.

A central objective of the conversion programme 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.

We use a variety of analytical methods to investigate the impact of the conversion, including estimating revenue, productivity and patent production functions with OLS and fixed effects. The central challenge of the study 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, in addition to using OLS and fixed effects, the paper uses event study methods and propensity score analysis.

The pattern of results using the methods highlighted in this study indicates that through 2005 the Chinese government substantially moved the orientation of the nation's institutes towards their intended directions. Once we apply the propensity score analysis to control 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 be 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 programme. The puzzle that emerged from Table 8, suggesting that this shift towards 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 generate more patents relative to their pre-conversion condition.

Overall, the shift in emphasis intended by the research institute restructuring programme seems to have exhibited some success during the initial years of the restructuring programme. 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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