

# Privatization and Productivity in China\*

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## Abstract

We study how changes in ownership affect the productivity of firms. Privatization of state-owned enterprises (SOEs) was a major economic reform during China's rapid growth, but its true impact remains controversial. Although private firms seem more productive than SOEs, the government selectively privatized (or liquidated) non-performing SOEs, which complicates the measurement of productivity. We address this selection problem by incorporating endogenous ownership change into a nonparametric estimation method and exploiting a lag structure in data. Results suggest privatization conferred both short-run and long-run productivity gains. The private-SOE productivity gap is larger among older firms and in less economically liberal regions.

*Keywords:* Nonparametric identification, Privatization, Productivity.

*JEL classifications:* D24, L11, L33, O47, P31.

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# 1 Introduction

We study how changes in ownership affect the productivity of firms. Privatization of state-owned enterprises (SOEs) was a major economic reform at the turn of the century in China. More recently, however, the country is showing signs of reversing its economic liberalization policy and advancing “state capitalism” in which the public sector plays key roles in production. Hence, the effect of privatization on productivity is an important theme for our historical understanding as well as contemporary public policy. The true impact of privatization remains controversial. On the one hand, Brandt, Van Biesebroeck, and Zhang (2012, henceforth BVZ) estimate production function by using structural methods and found private firms were more productive than SOEs. On the other hand, Hsieh and Song (2015) show descriptive statistics that suggest the gains from privatization were small. Anecdotal evidence is abundant on the existence of inefficient, loss-making SOEs as well as “super-star” SOEs in innovative industries, and is therefore inconclusive.

A major source of complication is a potential selection problem that arises from the Chinese government’s preference to “grasp the large, let go of the small.” This official slogan was adopted in 1997 when the government announced its restructuring programs for SOEs, which collectively recorded losses in the previous years. To alleviate the fiscal burden, the government tried to keep larger, profitable SOEs in the public sector and either privatize or liquidate smaller, non-performing SOEs. The measurement of firm-level productivity is econometrically involved because of its unobservable nature and endogeneity problems. The government’s preference creates an additional layer of complication by making the privatization and liquidation of SOEs contingent on such unobserved heterogeneity. Even if private firms are more productive than SOEs, *privatized* firms might not appear very productive, because of negative selection.<sup>1</sup> The existing research has not explicitly dealt with this issue, which could explain part of the controversy regarding the relative performances of SOEs and private firms.

We address this problem by augmenting a recently proposed nonparametric method for estimating production functions. Specifically, we extend the frameworks of Gandhi, Navarro, and Rivers (2017, henceforth GNR) and Akerberg, Caves, and Frazer (2015, henceforth

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<sup>1</sup>Our preliminary analysis suggests private firms are more productive than SOEs. Specifically, the average output per worker in private firms is almost three times that of SOEs in 1998. OLS estimates of total factor productivity (TFP) show similar patterns, although the exact size of the TFP gap and whether it tends to shrink over time are sensitive to the inclusion of firm fixed effects. Further investigations (still based on OLS estimates) suggest the least productive SOEs were liquidated and mediocre SOEs were privatized, whereas the most productive SOEs remained state owned. This pattern conforms to the official slogan and selection story. See sections 4.1 and 4.2 for details.

ACF) to incorporate endogenous privatization, in which the firm and/or the government can decide on the firm’s ownership type based on its productivity.<sup>2</sup> Like investment in physical capital, privatization and liquidation take time to implement and register, because state assets in China must go through annual inspections, and any restructuring plan needs to obtain the government’s approval. These procedures typically take a year, which creates a natural lag structure between the planning and implementation of ownership change (or exit). We exploit this lag structure in data to identify production functions and address selection as well as other endogeneity problems, such as simultaneity bias.

Our production functions are identified and estimated nonparametrically and allowed to be heterogeneous across ownership types. Moreover, we separately estimate the short-run and long-run gains from privatization, because organizational changes are not necessarily complete overnight. These features of our model and method add considerable flexibility to the empirical analysis of productivity in the literature.

We find private firms are substantially more productive than SOEs at small and medium scales of operations, whereas their performances are indistinguishable from each other among the largest entities. On average, private firms produce more than double the outputs of SOEs in the long run, if endowed with the same amount of inputs, and most of this eventual gain materializes within a few years.

We follow up these main results with several findings concerning heterogeneity in time and space. First, our main analysis focuses on the 1998 cohort of firms, that is, those on record from the beginning of the sample period and therefore potential targets of the government’s restructuring efforts. We conduct the same analysis on the 2003 cohort (i.e., those firms that first appeared on record in 2003) and find relatively small private-SOE gaps. Second, we split the sample in two geographical ways: “North vs. South” and “Inland vs. Coast.” In both cases, economically more liberal regions (i.e., “South” and “Coast”) exhibit smaller TFP gaps between private firms and SOEs. These two findings seem to suggest their performances tend to converge with the progress of economic liberalization.

More detailed analysis at the sector level shows the private-SOE gaps in TFP are larger in “final goods” and “high-tech” sectors than in the “materials” sector. This contrast seems intuitive because the increased managerial freedom under private ownership would make a greater difference in complex environments (e.g., heterogeneous consumer tastes, differenti-

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<sup>2</sup>GNR (2017) show a nonparametric production function is identified under the standard modeling assumptions of ACF (2015) and its predecessors. ACF (2015) clarify the identification of the firm-dynamics model studied by Olley and Pakes (1996, henceforth OP) and Levinsohn and Petrin (2003, henceforth LP). These methods exploit the inherent lag structure in the data-generating process (e.g., investment in capital stock takes time to show up in balance sheets).

ated products, and changing technologies). By contrast, heavy industries with homogeneous goods would be more amenable to the “central planning” style of management.

We also investigate the sensitivity of our findings to the operational definition of SOEs. Our baseline definition follows Yu (2014) and Wang and Wang (2015), to use the firm’s registration type to recognize its ownership status. By contrast, BVZ (2012) use the identity of majority shareholders to define SOEs. Many “SOEs” in our baseline definition become reclassified as “private firms” under this alternative definition, because the government directly owns only a small fraction of firms. Our results remain qualitatively similar, but the reclassification tends to blur the private-SOE gaps in TFP.

Finally, we investigate the mechanism underlying the productivity gains from privatization. The institutional background as well as qualitative case studies suggest the multiplicity of stakeholders and reporting lines (i.e., bureaucracy) tends to add noise and cause delay in decision making at SOEs, playing the role of negative TFP shocks. Privatization seems to reduce such negative shocks and relax managerial constraints. Another channel of productivity improvement would be downsizing, but our data analysis shows inputs (i.e., capital and labor) tend to *increase* after privatization.<sup>3</sup> We also study innovation-related measures, such as the introduction of “new products” and patent applications, but the results are mixed. These measures are policy targets in their own rights and might not simply reflect TFP. Thus we believe the productivity gains primarily stem from the reduction of bureaucratic noise.

This paper aims to contribute to three literatures. First, productivity and its determinants make up a large literature (see Syverson [2011] for an overview), of which the most closely related strand is on ownership and management. Braguinsky, Ohyama, Okazaki, and Syverson (2015) study the sources of TFP growth after mergers and acquisitions (M&As) in the Meiji-era cotton-spinning industry in Japan. They apply the ACF method on extremely high-quality data, but assume M&As are exogenous throughout their analysis, whereas we extend the ACF/GNR framework to incorporate *endogenous* managerial changes and address selection problems.<sup>4</sup> Our extension is not specific to the context of privatization; it may apply to other *discrete* endogenous determinants of TFP as well (e.g., trade and innovation).<sup>5</sup>

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<sup>3</sup>Larger privatized firms are exceptions and tend to reduce inputs, but the magnitude of downsizing is small, and the majority of privatization cases involve small or medium-sized firms anyway.

<sup>4</sup>We also share the view of management as “technology” with Bloom, Sadun, and Van Reenen (2016).

<sup>5</sup>Here we emphasize discreteness, because the application of GNR to continuous changes is trivial. As such, we share the spirit of de Loecker’s (2013) work on “learning by exporting,” and Doraszelski and

Second, privatization has been the centerpiece of market-oriented reforms in many countries. Although politically controversial, empirical studies have found mostly positive effects of privatization on various performance indicators including TFP. However, the identification of the privatization effect faces selection issues.<sup>6</sup> Theories predict selection could be either positive, negative, or nonmonotonic,<sup>7</sup> and hence empiricists cannot impose a simple selection model or other functional-form assumptions a priori. Brown, Earle, and Telegdy (2006) used relatively long panel data from Eastern Europe and the former USSR, with firm fixed effects to control for time-invariant unobserved heterogeneity. In the context of India’s economic reform period (1990–2004), Dinc and Gupta (2011) constructed political IVs for privatization based on local elections, exploiting India’s setting with liberal democracy. Unfortunately, the Chinese political system does not generate comparable data on local elections, and Chinese SOEs’ performance is tightly linked to the local economy, politics, and public finance, which diminishes the validity of these factors as IVs. Instead, we exploit the institutional setting that creates a time lag between the negotiation and implementation of privatization, and allow ownership changes to depend on unobserved heterogeneity (TFP) in a flexible manner.

The third related literature concerns China. For an overview on privatization and other SOE reforms, we refer the reader to general introductions such as Cao, Qian, and Weingast (1999), Bai, Lu, and Tao (2009), Xu (2011), and Zhu (2012).<sup>8</sup> We provide more specific references in sections 2 and 5, in which we explain the institutional background and summarize case studies. Because Chinese firms have gained recognition primarily as exporters of manufactured goods, many studies have focused on the international trade aspect. Roberts, Xu, Fan, and Zhang (2012) analyzed Chinese footwear exports. Yu (2014) and Brandt, Van Biesebroeck, Wang, and Zhang (2017) focused on trade and productivity in China, whereas Pierce and Schott (2016) and Bloom, Draca, and Van Reenen (2016) used Chinese exports as shocks to American and European industries, respectively. Meanwhile, a growing strand of literature has investigated domestic affairs. BVZ (2012) highlighted the contribution of new entrants to aggregate productivity. Huang, Li, Ma, and Xu (2017) studied the political economy of decentralization.

Sections 2 and 3 explain the institutional context and data, respectively. Sections 4 and 5 present our main analysis. Section 6 discusses potential mechanisms. Section 7 concludes.

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Jaumandreu’s (2013) work on R&D.

<sup>6</sup>See Megginson and Netter (2001), Estrin, Hanousek, Kočenda, and Svejnar (2009), and Syverson (2011).

<sup>7</sup>See Yarrow, King, Mairesse, and Melitz (1986), Shleifer and Vishny (1994), Boycko, Shleifer, and Vishny (1996), and Gupta, Ham, and Svejnar (2008).

<sup>8</sup>Sun and Tong (2003) and Jefferson and Su (2006) studied earlier privatization in the 1990s.

## 2 Privatization in China

Our analysis focuses on the period of privatization since 1997, but some background knowledge about the preceding period is necessary to understand the meaning of privatization and the various types of firms that exist in China.<sup>9</sup>

Table 1: Historical Background of SOEs and Privatization in China

Year	Event
<b>I. Central Planning: The Birth of SOEs</b>	
1949	People's Republic started
1950–53	Korean War
1953	Soviet-style central planning began (first Five-Year Plan): All private enterprises reorganized into the public sector by the end of the 1950s
1958	Delegation of control over most SOEs to local governments (i.e., decentralization of fiscal revenues)
1958–60	Great Leap Forward policy and famine
1960	Withdrawal of Soviet technical assistance
1969	Sino-Soviet border conflict
1971	Henry Kissinger visits Zhou Enlai: Rapprochement
1976	Mao Zedong died
<b>II. Economic Liberalization: Decentralization of SOEs and the Entry of Private Enterprises</b>	
1978	Deng Xiaoping starts economic liberalization policy
1980	Decentralization of budgetary control to local governments
1986	Legalization of private enterprises (with 8+ employees)
1991	Soviet Union dissolved
1992	Deng's Southern Tour Speech endorsed private enterprises
1994	Liberalization of prices and commerce complete Modern corporate law and labor law became effective
1995	SOEs started making losses collectively; Restructuring and layoffs at SOEs permitted
1996	Last Five-Year Plan with production quantity targets
<b>III. Restructuring and Privatization of SOEs</b>	
1997	Private sector endorsed as an "important part of socialist market economy" Privatization of SOEs endorsed under the slogan "Grasp the large, let go of the small"
2002	Privatization of small and medium local SOEs (and layoffs at large SOEs) mostly complete Accession to World Trade Organization
2006	"Indigenous innovation" set as new policy target

*Source:* Marukawa (2013), Naughton (2007), Xu (2011), Yuan (2009), and Zhu (2012).

### 2.1 Disappearance and Re-emergence of Private Enterprises<sup>10</sup>

**Central Planning** China's first Five-Year Plan started in 1953. Both the supply of inputs and the sale of outputs came under state control. Bureaucrats joined the board of private firms and took control of management. The original owners of these firms became minority

<sup>9</sup>For a general background, see Naughton (2007), Xu (2011), and Zhu (2012), among others.

<sup>10</sup>This subsection draws on Marukawa (2013) and Yuan (2009).

shareholders without controlling stakes, and gradually disappeared from ownership and operations. Smaller manufacturers were grouped into collectives. All of the private businesses were reorganized and integrated into the public sector by the end of the 1950s.

**Decentralization of the SOEs** However, Mao’s policy diverged from the Soviet-style “orthodox” central planning. In 1958, he delegated the control of most of the centrally managed SOEs (i.e., fiscal revenue sources) to local governments, along with the authority to design and implement economic plans, although the full delegation of budgetary control had to wait until 1980. The movement toward decentralization was temporarily reversed after the disasters of the Great Leap Forward (1958–60), but only approximately 500 SOEs remained under the central government’s control after 1970.

**SOEs as Fiscal-Revenue Generator** Almost all of the government revenue stemmed from SOEs at the peak of socialist economic management. For example, 40.02 billion RMB of the total fiscal revenue of 81.56 billion in 1975 came from SOEs’ profits, and additional 34.80 billion from “industrial and commercial taxes,” which were also paid by SOEs. Their sum accounts for 91.7% of the government income.

**Private Firms’ Comeback** Deng Xiaoping made economic liberalization an official policy in 1978. Reforms were gradualist, but many small businesses sprang up and eventually “grew out of the planning” (Naughton 1995, 2007). These businesses were typically family owned and founded for subsistence, or were “township” enterprises, which were managed like private firms but meant to raise fiscal revenues for local governments in rural areas (Bei 2014). Despite the nominal legalization in 1986 of private enterprises with eight or more employees, the very existence of private businesses was in an institutional gray zone (Marukawa 2013). Some private firms coped with the unfriendly institutional environment by obtaining a cover of SOE officialdom through joint venture with local governments or other means: so-called private enterprises with “red hats.”

**SOEs as (Messy) Profit Maximizers** Meanwhile, SOEs became increasingly decentralized after local governments were given full control over both revenues and expenditures in 1980. Political scientists emphasize the local governments’ autonomy, competition, and “corporatism” (i.e., government-orchestrated cooperative pursuit of net revenues, in this context) as an important source of economic growth during the reform period (Granick 1990; Oi 1992; Montinola, Qian, and Weingast 1995). Thus, Chinese SOEs do not appear conceptually too far from the canonical notion of profit-maximizing firms, except that their decision making tended to be messier, slower, less informed about market demand, and subject to random government interventions that hindered overall productivity (Marukawa 2013, Bei

2014). This characterization seems to apply to the large SOEs that belong to the central government as well. Despite the official *raison d'être* of SOEs “for the benefit of the society,” researchers found their behaviors more consistent with profit maximization than as a policy instrument to address market failures (Kato, Watanabe, and Ohashi 2013, ch. 3–4). Even the Communist Party’s media criticized SOEs for abusing access to power and exploiting the governments’ political agenda to entrench their vested interests, instead of conducting commercial activities for public purposes (*People’s Daily Online*, September 14, 2006).

**Deng’s Approval of Private Enterprises** The Soviet Union dissolved and the Cold War ended in 1991. Deng’s Southern Tour speech in 1992 changed the obscure legal status of private enterprises by declaring the private sector an important part of the socialist economy, thereby officially approving it. The modernization of corporate law and labor law became effective in 1994. In the same year, the liberalization of prices and commerce was completed. The 1996–2000 version became the last Five-Year Plan with production targets.

## 2.2 Privatization since 1997

**Grasp the Large, Let Go of the Small** Despite earlier restructuring efforts, SOEs as a whole experienced a loss in 1995. SOEs were no longer contributing to fiscal revenues; they now represented a net fiscal burden. In the same year, the central government permitted layoffs at SOEs, effectively allowing SOEs to treat labor as variable inputs rather than fixed ones (Asuyama and Yamaguchi 2014). The party adopted a new privatization policy with a slogan “grasp the large, let go of the small” in 1997, which meant the policymakers prioritized the off-loading (i.e., liquidation, forced merger, or privatization) of small, loss-making SOEs. By the same token, the party declared the private sector an “important element of socialist market economy,” thereby finally giving it official approval (Marukawa 2013, pp. 211, 274, 334).

**Privatization by Management Buy-Out (MBO)** The number of SOEs decreased by more than half from approximately 238,000 in 1998 to 116,000 in 2007 (Jin 2013).<sup>11</sup> The largest, centrally administered SOEs were kept under the state control, but most of the local SOEs including township enterprises were sold to private hands. According to a survey of 3,012 small and medium-size private enterprises in 2004 commissioned by the Party, most of the new owners of the privatized firms were the managers of the same SOEs before privatization (Bei 2014, Marukawa 2013). Whether a given SOE becomes the target

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<sup>11</sup>These numbers include non-manufacturing firms and are therefore larger than the number of *manufacturing* SOEs in our sample.

of off-loading is decided by the government and therefore outside the control of the SOEs' managers. For example, both Huajing Electronics and Northeast Pharmaceutical were large SOEs, but part of the former was privatized in the form of joint venture with a private firm, whereas the latter managed to turn around as an SOE and became one of the world's top makers of vitamin C (Yuan 2009, ch. 4; Igami and Sugaya 2017, Appendix A.2).

**The Process of Privatization** However, the exact mode and outcome of restructuring were often negotiable. Bei (2014) conducted systematic in-depth interviews of the owners and managers of seven newly privatized firms, six of which went through privatization by management buy-out (MBO) despite the governments' initial inclination to shut them down.<sup>12</sup> The prevalence of MBO among those successfully privatized firms does not mean the managers of SOEs could freely choose to privatize. Wu (2008) chronicles the history of 38 famous firms between 1978 and 2007, 24 of which belonged to the public sector, according to Watanabe's (2013) analysis. Only one of them was successfully privatized by MBO, whereas eight others experienced some sort of conflict with the authority and often ended with the arrest of managers and liquidation. The governments have the upper hand.

**The Timeline and Procedures** More formally, the restructuring of an SOE proceeds in three stages. Stage 1 involves the proposal and discussion of potential restructuring plans among the interested parties. If the final plan is acceptable to the government, it issues an official approval in stage 2. The new owners/managers have 30 days after the approval to register the enterprise under the new ownership/management, which is stage 3.

This timeline does *not* mean an ownership change can start and be completed within 30 days. Our investigation into the registration record and the report of restructuring suggests the privatization process takes approximately 12 months on average, with the median of 15.5 months, from planning to execution.<sup>13</sup> This time lag is related to the need to go through the official inspection of property-rights registration, which takes place at an annual frequency. The violation of the registration requirements could lead to fines and, in serious cases, criminal charges.<sup>14</sup> Our econometric method is agnostic about the exact mechanism of privatization, but the time-consuming nature of the decision-making process becomes important in our empirical analysis.

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<sup>12</sup>The seventh case involved a former assistant professor of philosophy who became a serial entrepreneur, developed and patented a laser-based machine-repairment technology, and acquired a small SOE near bankruptcy. See Bei (2014), pp. 76–77.

<sup>13</sup>We investigated a random subsample of 500 privatization cases.

<sup>14</sup>See “Management Methods for the Registration of State-owned Assets of Enterprises” and other official documents for the regulatory details.

## 3 Data

### 3.1 Source

We use the Annual Survey of Industrial Enterprises (ASIE) from 1998 to 2007. This dataset contains financial statements and other basic firm-level information (e.g., the firms' names, addresses, registration types, industry classifications, and the number of employees) for all SOEs as well as private firms above the revenue threshold of 5 million RMB in the manufacturing sector. We show its descriptive statistics in section 4.1 and further details in Appendices A.1 and A.2.

We investigate the mechanism of productivity gains in section 6, part of which analyzes patent data. For this purpose, we match the ASIE data with all patents filed with China's State Intellectual Property Office from 1985 to 2013. The matching is based on the names and addresses of firms and patent assignees (see Appendix C.2 for details).

We focus on domestic firms, including SOEs, collective firms, and private firms, but exclude foreign firms and firms based in Hong Kong, Macau, and Taiwan, because privatization in China mostly took the form of MBOs rather than sales to foreigners. Moreover, foreign firms could be operating in a different product space from that of domestic Chinese firms.

### 3.2 Definition of Ownership Type

Two approaches coexist in the literature for the operational definition of ownership types. The first approach uses the registration types of firms (e.g., Yu 2014), and the second approach uses shareholder information (e.g., BVZ 2012). Each has its own merits and limitations. The main benefit of using registration types is clarity and transparency, as well as relevance according to Yu (2014), whereas Hsieh and Song (2015) emphasize the importance of using the majority (50%) shareholding threshold to determine SOEs. We are aware of diverse anecdotal evidence in favor of both. *The Economist* reports that no firm in China can avoid the government's influence and that state control is a matter of degree.<sup>15</sup> Given the hazy nature of ownership type in China, we have chosen not to take any original stand on this issue. Our baseline analysis uses the former, registration-based definition to ensure comparability of our results with the majority of the literature, but we find qualitatively similar results using the latter definition (section 4.6).

Another issue is that privatization in China frequently involves a change in registration

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<sup>15</sup> "Back to business: Special Report on Business in China," September 12, 2015.

type, which in turn triggers a change in firm identifier. That is, a new firm ID is created and assigned to the privatized entity. If a researcher does not reconnect these multiple IDs across years, the raw data would wrongly suggest “many SOEs exited” and “new private firms entered,” creating a false appearance of massive turnovers. We manually checked and reconnected firm IDs over time by using firms’ other ID information, including (but not limited to) their names, addresses, managers’ names, main products, and industries.

### 3.3 Revenue TFP and Physical TFP

Other ground work involved the deflation of revenues and expenditures using the industry-level price index, as well as the construction of a capital-stock variable using the perpetual inventory method. Labor input is recorded as the number of employees and does not require deflation. We follow the detailed instructions by BVZ (2012) and their price-index data. Some limitations exist. Although we deflate revenues by using industry-specific price indices, firms within the same industry could still face different prices (e.g., by location).

In the presence of such heterogeneity, our TFP measure could contain both physical TFP and firm-specific markup.<sup>16</sup> Fortunately, this issue does not defeat our purpose. Our identification method is robust to the existence of measurement error in prices/markups (see Appendix B.2 for proof). Moreover, we are interested in knowing whether privatization made firms more profitable as well as more productive. For example, if privatized SOEs successfully cultivated a new demand base with higher willingness to pay, their profitability would increase, and our measure of TFP *should* and would capture this improvement. We expect the short-run TFP gains from privatization to reflect such changes on the demand/markup side, whereas the long-run TFP gains are more likely to involve supply-side/technical changes. We discuss this point further when we interpret our estimates.

## 4 Empirical Analysis

### 4.1 Basic Data Patterns

Table 2 shows the number of SOEs decreased from 17,313 to 4,440 between 1998 and 2007. More than 1,000 firms were privatized in every year except 1999, and many SOEs exited

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<sup>16</sup>A series of papers demonstrate the importance of this distinction, including Foster, Haltiwanger, and Syverson (2008), de Loecker (2011), de Loecker and Warzynski (2012), Braguinsky, Ohyama, Okazaki, and Syverson (2015), and de Loecker, Goldberg, Khandelwal, and Pavcnik (2016).

(i.e., disappeared from record). In the meantime, the number of private firms grew 30-fold, as some SOEs were privatized and new firms appeared (especially after 2002).

Table 2: Number of Firms, Privatization, and Labor Productivity (Full Sample)

Year	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
(A) Number of firms										
SOE	17,313	13,931	11,826	9,235	7,866	11,185	9,136	7,449	6,204	4,440
Collective	30,988	28,971	28,003	27,541	27,398	49,040	53,719	55,656	56,827	60,571
Private	4,856	6,460	9,659	15,849	21,719	56,618	92,729	104,631	125,881	147,946
(B) Privatization										
Privatized	–	927	1,087	1,800	1,548	2,551	8,072	4,240	5,042	3,042
Collectivized	–	742	747	682	418	468	884	448	384	204
(C) Exit										
SOE	–	3,080	3,196	3,352	1,941	1,988	3,592	1,929	1,486	2,075
Collective	–	6,383	6,471	7,871	5,057	5,416	13,604	5,410	6,922	6,391
Private	–	906	1,341	3,067	2,732	3,573	15,382	7,487	11,659	11,568
(D) Entry										
SOE	–	1,221	769	1,294	965	5,768	2,048	503	493	391
Collective	–	4,595	5,601	8,054	5,601	28,299	20,463	8,160	10,180	10,718
Private	–	1,827	3,773	8,163	7,614	36,854	49,425	18,328	30,541	33,434
(E) Output/worker										
SOE	63.5	72.8	91.2	99.1	118.9	142.7	163.0	205.4	256.2	373.4
Collective	158.0	165.0	217.5	200.3	223.8	257.5	298.6	349.5	415.8	460.3
Private	178.9	186.4	229.3	204.6	223.7	261.4	276.9	323.9	383.5	430.2

*Note:* Full sample including new entrants during the sample period. Panel (E) is in 1998 constant RMB in thousands.

The last three rows (Panel E) of Table 2 compares labor productivity in terms of the average revenue per employee. Private firms were almost three times more productive than SOEs in 1998. This gap had narrowed to a double score by 2002, and collectively owned firms had caught up with private ones.

## 4.2 Suggestive Evidence from Preliminary OLS Estimates

Labor productivity, although simple and suggestive, does not account for the use of other inputs, such as capital and materials, and hence does not show the whole picture. Let us incorporate these other inputs and estimate the following Cobb-Douglas production function with OLS:

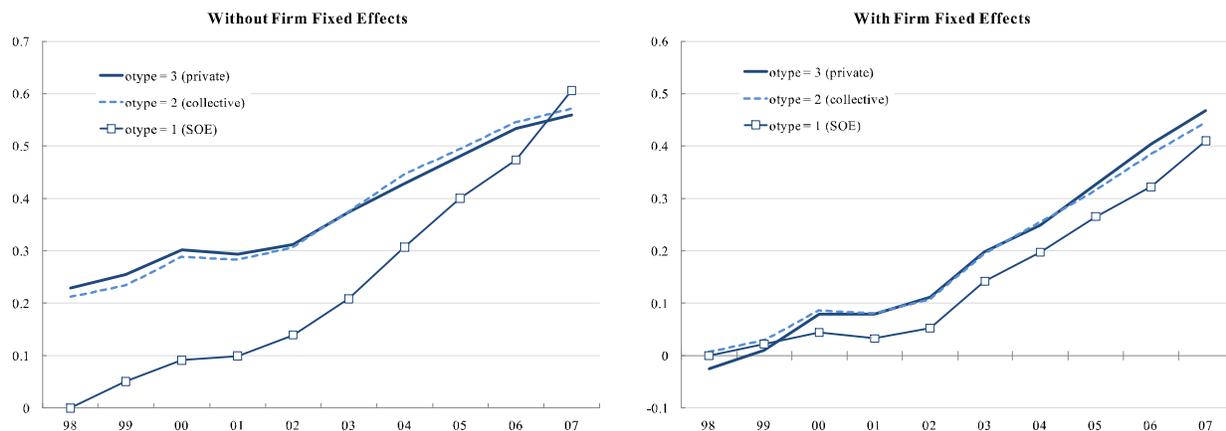
$$y_{it} = \beta_0 + \beta_k k_{it} + \beta_l l_{it} + \beta_m m_{it} + \sum_{\tau=1998}^{2007} (\beta_{soe,\tau} d_{i\tau}^{soe} + \beta_{col,\tau} d_{i\tau}^{col} + \beta_{pri,\tau} d_{i\tau}^{pri}) + \epsilon_{it}, \quad (1)$$

where  $y_{it}$ ,  $k_{it}$ ,  $l_{it}$ , and  $m_{it}$  are the natural logarithms of output, capital, labor, and materials, respectively, at firm  $i$  in year  $t$ . The summation contains ownership-type dummies,  $d_{i\tau}^{soe}$ ,  $d_{i\tau}^{col}$ ,

and  $d_{it}^{pri}$ , which are allowed to differ across years. The  $\beta$ s are their coefficients (with  $\beta_{soe,1998}$  normalized to zero), and  $\epsilon_{it}$  is a firm-year-specific random component (assumed i.i.d. across  $i$  and  $t$ ).

Figure 1 (left) plots the coefficient estimates of these type-year dummies. Private and collective firms' TFP levels are statistically indistinguishable from each other in all years. By contrast, SOEs started with significantly lower TFP in 1998 and followed parallel trends with the other two types. In the last five years, however, SOEs seemed to suddenly catch up. This interesting pattern might have led some researchers to believe SOEs are now more productive than private firms.

Figure 1: OLS Estimates of Productivity by Ownership Type (Full Sample)



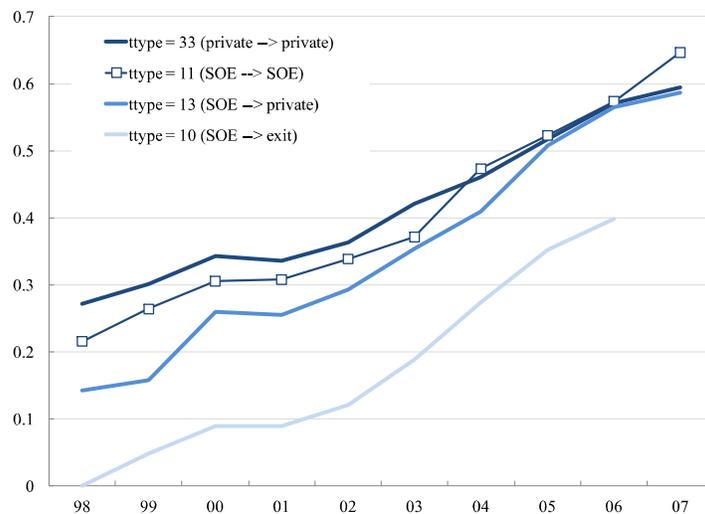
*Note:* These graphs plot the coefficient estimates of type-year interaction dummies, where SOE in 1998 is the reference category, based on the *full* sample (i.e., unbalanced panel data including new entrants during the sample period). See the Appendix for the *1998-cohort-only* version of the same graphs.

Figure 1 (right) paints a qualitatively different picture in which SOEs never closed the gap with the others. For this graph, we added firm fixed effects (FE),  $\delta_i$ , to the RHS of equation (1), thereby “muting” across-firm variation. Whereas the OLS regression (without FE) calculates quasi-permanent differences between types, this FE regression effectively focuses on output changes at “switchers” (i.e., those that experienced changes in ownership type, such as privatization) in each year. Hence, the TFP gap between SOEs and private firms in the right panel reflects *immediate* changes in output/input at those that were SOEs at  $t - 1$  and became private at  $t$ .

How should we reconcile the two different pictures? Figure 2 investigates the underlying heterogeneity that could explain some of these observations. This graph focuses on SOEs

and private firms, and examines their TFP evolution in detail. We codify ownership types as state (“1”), collective (“2”), and private (“3”). We then define “transition types” based on each firm’s ownership types at the beginning (i.e., its first year of appearance) and the end (i.e., the final year of our sample, 2007). For example, some of the SOEs in 1998 were eventually privatized (transition type “1 → 3”, or SOE → private). Others remained state-owned (“1 → 1”); still others exited before 2007 (“1 → 0”, where we codified the firm’s absence by “0”). In this manner, we distinguish between these three transition patterns, rather than pooling firms within each concurrent ownership type.

Figure 2: OLS Estimates of Productivity by Transition Type (Full Sample)



*Note:* The graph plots the coefficient estimates of type-year interaction dummies, where “SOE → exit” in 1998 is the reference category, based on the *full* sample (i.e., unbalanced panel data including new entrants during the sample period). See Appendix A.2 for the *1998-cohort-only* version of the same graphs.

The top line in Figure 2 is the average TFP of always-private firms (transition type “3 → 3”), which is among the highest of all types. Perhaps surprisingly, always-SOEs (“1 → 1”) exhibit similar performances.<sup>17</sup> By contrast, privatized firms (“1 → 3”) started from significantly lower TFP levels but then caught up with always-private firms. Finally, the worst performers are SOEs that eventually disappeared from record by 2007 (“1 → 0”).

These patterns are highly suggestive of *productivity-based selection* among SOEs. The government would shut down and liquidate the worst-performing SOEs, whereas mediocre

<sup>17</sup>The TFP trajectories of all other “transition types” are also similar to “3 → 3” and “1 → 1” types. We omit them from the graph because they are statistically indistinguishable from each other, and showing them would make the graph unreadable.

SOEs would be allowed to continue under private ownership if their managers (or some other entrepreneurs) were willing to buy them out. In the meantime, the government would keep the best SOEs under state ownership. Thus, our OLS estimates by “transition type” echoes the slogan of privatization policy, “Grasp the large, let go of the small,” and gives it an econometric representation in terms of TFP-based selection.

### 4.3 Econometric Issues with the OLS Estimates

Econometrically, however, these OLS regressions are not particularly convincing. If we really want to interpret these  $\hat{\beta}$ s as TFP differences, we would have to embrace the implicit assumptions behind the OLS estimation of equation (1).

Two assumptions are particularly important: (i) functional form and (ii) strict exogeneity. First, equation (1) imposes a linear functional form and the same technology across ownership types, which is a standard assumption, but more flexibility seems desirable. For example, a unit increase in  $k_{it}$  or  $l_{it}$  might affect  $y_{it}$  differently at small, medium, and large scales of operations. Moreover, given our focus on managerial heterogeneity across different types of firms, imposing the same technology *a priori* defeats the purpose.

Second, OLS assumes  $\epsilon_{it}$  is strictly exogenous, which implies the firm does not know anything about  $\epsilon_{it}$ , and rules out unobserved heterogeneity across firms. In reality, however, it is unthinkable that the firm would not know anything beyond what the econometrician observes in the data,  $(y_{it}, k_{it}, l_{it}, m_{it}, d_{it})$ , where ownership type  $d_{it} \in \{1, 2, 3\}$  denotes state, collective, and private ownership, respectively. To the extent that the firm (and the Chinese government) knows more than we do, its actions could depend on such private information. Specifically, its input choices  $(k_{it}, l_{it}, m_{it})$  would reflect its private knowledge about  $\epsilon_{it}$ , which creates a simultaneity problem for estimating  $(\beta_k, \beta_l, \beta_m)$ .<sup>18</sup>

Third, privatization and other changes in ownership types,  $d_{it}$ , are also choices that reflect the government’s policy and its negotiation with the firm’s managers. The institutional context in section 2 and the preliminary data analysis in section 4.2 have shown the privatization/liquidation decisions are likely to be correlated with the firm’s underlying productivity or profitability, thereby creating a selection problem for estimating type-specific factors, such as  $(\beta_{soe}, \beta_{col}, \beta_{pri})$ . Assumption (ii) rules out such possibilities. Consequently, the OLS estimates suffer from selection biases. Incorporating unobserved heterogeneity and allowing for endogenous choices of inputs, ownership type, and exit is critical.

Finally, the OLS estimates based on equation (1) lead to the interpretation of the per-

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<sup>18</sup>See Akerberg, Benkard, Berry, and Pakes (2007, section 2) for detailed accounts.

sistent TFP differences (e.g.,  $\Delta\beta \equiv \beta_{pri} - \beta_{soe}$ ) as the gains from privatization. This interpretation could be valid in the long run, but the formulation is silent about the extent of short-run improvements. By contrast, the FE estimates rely on the immediate changes in TFP within privatized firms, thereby exclusively focusing on the short-run gains. Neither formulation seems to capture the whole story. In reality, privatized SOEs might make quick changes as well as ones that take longer to implement.

We address these issues in the following by modeling the production function more flexibly, incorporating unobserved heterogeneity, and allowing firms to choose inputs *as well as ownership types* (and whether to exit) based on their productivity.

#### 4.4 Augmented ACF/GNR Framework

**Model** Let us relax some of the restrictive assumptions of equation (1) and its OLS estimation. Now we consider the following production function:

$$y_{it} = f(k_{it}, l_{it}, m_{it}, d_{it}) + \omega_{it} + \varepsilon_{it}, \quad (2)$$

where we no longer impose linearity or other functional-form assumptions on  $f(\cdot)$ , such as Cobb-Douglas or Leontief, thereby relaxing Assumption (i). GNR (2017) show the nonparametric production function,  $f(\cdot)$ , is identified under standard assumptions on timing and information in the literature (i.e., ACF and its predecessors), which we explain below. We also allow  $f(\cdot)$  to be heterogeneous across ownership types by including  $d_{it} \in \{1, 2, 3\}$ .

Equation (2) permits persistent unobserved heterogeneity across firms. We add a time-varying firm-specific productivity term,  $\omega_{it}$ , and allow the firm to act on it, thereby relaxing Assumption (ii). Specifically, the firm knows  $\omega_{it}$  before engaging in production (and making other decisions) in year  $t$ , whereas it does not know  $\varepsilon_{it}$  until after production. Note the OLS/FE regressions in the previous subsection restricted  $\omega_{it}$  to be either zero or constant over time (i.e.,  $\omega_{it} = 0$  or  $\omega_{it} = \omega_i \forall t$ ) by construction.

The firm makes two kinds of decisions based on its knowledge of  $\omega_{it}$ : input choices  $(m_{it}, k_{i,t+1}, l_{i,t+1})$  and ownership-type choices  $(d_{i,t+1})$ . The firm can choose  $m_{it}$  after observing its own productivity state,  $\omega_{it}$ , because intermediate inputs are usually the most flexibly adjustable component of production. By contrast, the plans for capital investment, as well as hiring and firing, take some time for implementation. This lag structure on  $(k_{it}, l_{it})$  follows one of ACF's (2015) identifying assumptions, as well as GNR's (2017) main specification.<sup>19</sup>

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<sup>19</sup>ACF permits another specification in which the firm can flexibly choose  $l_{it}$  (like  $m_{it}$ ) after observing  $\omega_{it}$ ,

Negotiations with the government regarding whether to privatize, liquidate, or remain unchanged are similarly time consuming. Our investigation suggests the decision-making process of privatization usually takes 12 ~ 16 months from the time of proposal until the actual implementation (see the paragraphs on “The Timeline and Procedures” in section 2.2). Accordingly, we extend ACF/GNR’s model by incorporating  $d_{it}$  as another time-consuming choice variable, thereby endogenizing privatization and other ownership changes.

We follow OP’s (1996) specification of persistent heterogeneity, in which  $\omega_{it}$  follows a first-order Markov process,

$$\begin{aligned}\omega_{it} &= E[\omega_{it}|\omega_{i,t-1}, \textit{collectivized}_{it}, \textit{privatized}_{it}] + \xi_{it} \\ &\equiv h(\omega_{i,t-1}, \textit{collectivized}_{it}, \textit{privatized}_{it}) + \xi_{it} + \delta_t,\end{aligned}\tag{3}$$

where the first term on the RHS represents part of  $\omega_{it}$  that is predictable by the firm (based on  $\omega_{i,t-1}$ ), and the second term,  $\xi_{it}$ , is exogenous and unpredictable by the firm, and  $\delta_t$  controls for the secular time trend (e.g., the overall growth trend in Figure 1).

The two additional conditioning variables,  $\textit{collectivized}_{it}$  and  $\textit{privatized}_{it}$ , represent specific changes in ownership types. We define

$$\textit{collectivized}_{it} = \begin{cases} 1 & \text{if } d_{i,t-1} = 1 \text{ and } d_{it} = 2, \text{ and} \\ 0 & \text{otherwise,} \end{cases}\tag{4}$$

and

$$\textit{privatized}_{it} = \begin{cases} 1 & \text{if } d_{i,t-1} \neq 3 \text{ and } d_{it} = 3, \text{ and} \\ 0 & \text{otherwise.} \end{cases}\tag{5}$$

This formulation means  $\omega_{it}$  depends on its past level,  $\omega_{i,t-1}$ , as well as whether the firm has just been privatized or collectivized,<sup>20</sup> thereby allowing us to distinguish between the immediate and eventual gains from privatization.

**Parameters of Interest** The effects of privatization on productivity are our main parameters of interest. We allow two different types of privatization effects, long run and short run. The long-run (or “eventual”) effect reflects the lasting difference in production levels between ownership types. For example, better management of products and processes, or reduced instances of political interventions, would make private firms more productive than SOEs. The OLS regression of equation (1) tried to capture this effect within a lin-

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but this alternative timing assumption seems less natural in the context of Chinese SOEs.

<sup>20</sup>Kasahara and Rodrigue (2008) and de Loecker (2013) specified similar laws of motion in other contexts.

ear functional form, by including the ownership-type dummies as differential intercepts,  $(\beta_{soe}, \beta_{col}, \beta_{pri})$ . We generalize this notion to our nonparametric production function by defining the “persistent difference” between private (or collective) firms and SOEs as

$$\beta_{pri}(k, l, m) \equiv f(k, l, m, d = 3) - f(k, l, m, d = 1), \text{ and} \quad (6)$$

$$\beta_{col}(k, l, m) \equiv f(k, l, m, d = 2) - f(k, l, m, d = 1), \quad (7)$$

respectively, where subscripts are suppressed for ease of exposition and  $f(k, l, m, d)$  is the deterministic part of the production function.<sup>21</sup>

However, these “long-run” effects may not materialize overnight (e.g., between periods  $t$  and  $t + 1$ ). We would imagine organizational changes, discovery of new clients, and introduction of new products/processes are time-consuming activities, especially at former SOEs. Therefore, we allow for the possibility that some initial productivity gap may exist between “already-private” firms and “just-privatized” firms. Over the years, such a gap would narrow and eventually become negligible, the speed of which would depend on the persistence of  $\omega_{it}$ .

Formally, the “initial gap” between already-private firms and just-privatized firms (or between already-collective firms and just-collectivized firms) is

$$\gamma_{pri} \equiv h(\omega, 0, 0) - h(\omega, 0, 1), \text{ and} \quad (8)$$

$$\gamma_{col} \equiv h(\omega, 0, 0) - h(\omega, 1, 0), \quad (9)$$

where  $h(\omega, \text{collectivized}, \text{privatized})$  is the deterministic, state-dependent component of next  $\omega$  in its law of motion (3). Thus, the “immediate effect” of privatization (or collectivization) is

$$\beta_{pri}(k, l, m) - \gamma_{pri}(\omega), \text{ and} \quad (10)$$

$$\beta_{col}(k, l, m) - \gamma_{col}(\omega). \quad (11)$$

That is, the immediate productivity gains are anchored to the eventual gains but discounted by the initial gaps. This formulation permits many qualitatively different time paths of productivity dynamics after privatization. See Figure 6 in Appendix B.1 for illustration.

**Identification and Estimation** We extend GNR’s nonparametric two-stage approach, in which the partial derivative of  $f(\cdot)$  with respect to  $m_{it}$  is identified and estimated in the first stage, with the rest of the production function recovered in the second stage, as follows.

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<sup>21</sup>Note this formulation includes the separable case, such as equation (1), as a special case:  $f(k, l, m, d) = \tilde{f}(k, l, m) + \tilde{g}(d)$ .

**Proposition 1** *Suppose, for a fixed  $(k', l', m')$  in the support of  $(k_t, l_t, m_t)$ ,*

$$\int_{\underline{m}}^{m'} \frac{\partial}{\partial m} f(k', l', \tilde{m}, \tilde{d}_t) d\tilde{m}$$

*is identified up to a constant for every  $d_t \in \{1, 2, 3\}$ , and let*

$$\mathcal{Y}_t \equiv y_t - \varepsilon_t - \int_{\underline{m}}^{m_t} \frac{\partial}{\partial m} f(k_t, l_t, \tilde{m}, d_t) d\tilde{m}.$$

*Also suppose some  $(k, l, \mathcal{Y})$  exist in the support of  $(k_{t-1}, l_{t-1}, \mathcal{Y}_{t-1})$  such that the conditional support of  $\mathcal{Y}_t$  conditional on  $(k', l', k, l, \mathcal{Y}, d_t = d', d_{t-1} = d)$  is non-empty for seven of the nine possible combinations of  $(d', d)$  except for  $(1, 3)$  (private firms becoming SOEs), and except for either one of  $(3, 2)$  (collective firms becoming private) or  $(3, 1)$  (SOEs becoming private). Then  $\beta_{pri}(k', l', m')$ ,  $\beta_{col}(k', l', m')$ ,  $\gamma_{pri}(\omega)$ , and  $\gamma_{col}(\omega')$  are identified for the fixed  $(k', l', m')$  and for some  $\omega$  and  $\omega'$  determined by  $(k, l, \mathcal{Y})$ .*

**Proof.** See Appendix B.3. ■

The first assumption requires that GNR's identification holds for each of the three ownership types,  $d_{it} \in \{1, 2, 3\}$ . The second assumption requires that sufficient variation exists in input levels, for seven of the nine transition patterns of ownership types. The rest of the procedures follows GNR in a straightforward manner. Hence, we limit our exposition to the minimum here (and present a longer version with more details in Appendix B.4).

GNR's first stage focuses on the role of the “flexible” input,  $m_{it}$ . By “flexible,” GNR mean the factor that can be flexibly adjusted within the same period, after the firm observes  $\omega_{it}$ . The firm's first-order condition with respect to  $m_{it}$  allows us to identify and estimate the slope of the production function,  $\frac{\partial}{\partial m_t} f(k_t, l_t, m_t, d_t)$ .

The second stage of GNR recovers the part of  $f(\cdot)$  that relates to “predetermined” inputs  $(k_t, l_t, d_t)$  from the slope estimate, as well as the law of motion for  $\omega_t$ ,  $h(\cdot)$ . We employ GMM to find  $(\theta_c, \theta_h)$ , the parameters of polynomial sieves, that satisfy moments of the form

$$\begin{aligned} E \left[ \hat{\xi}_{it} k_{it}^{a_k} l_{it}^{a_l} \right] &= 0, \text{ and} \\ E \left[ \hat{\xi}_{it} k_{it}^{a_k} l_{it}^{a_l} d_{it}^\tau \right] &= 0, \end{aligned}$$

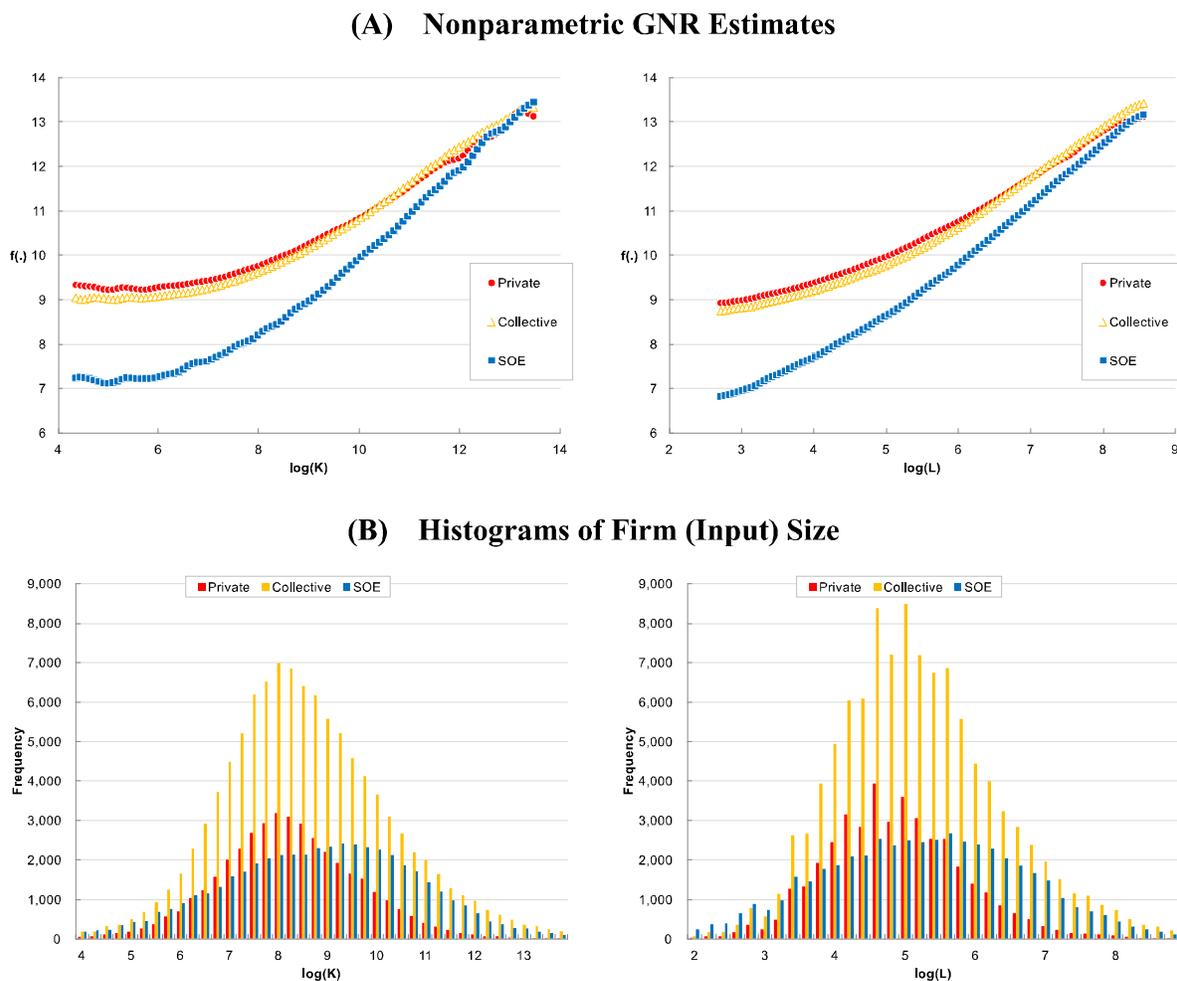
where  $\hat{\xi}_{it}$  is calculated as the residual in the second stage,  $0 \leq a_k + a_l \leq 2$ , and  $\tau \in \{col, pri\}$ . Thus, the second stage of GNR amounts to a nonparametric version of the familiar, nonlinear GMM procedure as in OP, LP, and ACF.

## 4.5 Main Results

We focus on the 1998 cohort of firms (i.e., those that already existed on record in 1998) to avoid mixing different generations of firms. Section 5.1 studies a new cohort of firms as well.

Figure 3 (Panel A) shows private firms are more productive than SOEs at almost all scales of operations. These graphs report our nonparametric GNR estimates of production functions, which are allowed to be flexible and heterogeneous across ownership types.

Figure 3: Nonparametric Estimates of Production Functions (1998 Cohort)



*Note:* Panel A plots our nonparametric GNR estimates of production functions with respect to  $k_{it}$  (left) and  $l_{it}$  (right), respectively. Panel B shows the firm-size distribution in terms of  $k_{it}$  and  $l_{it}$ . The top 1 percentile and the bottom 1 percentile are excluded, because nonparametric estimates become noisy at the end of support.

Such flexibility turns out to be important. The productivity gaps are wider at small-scale

operations but narrower at large-scale operations. In other words, smaller SOEs are a lot less productive than similarly sized private firms, whereas the largest SOEs and private firms exhibit little difference in productivity. Thus, our parameters of interest,  $\beta_{pri}(k, l, m)$  and  $\beta_{col}(k, l, m)$ , are heterogeneous across sizes.

These heterogeneous effects of ownership types could explain why opposing views regarding the benefits of privatization coexist. On the one hand, our estimates show SOEs are substantially less productive than private firms in the majority of cases (see Panel B for the size distributions), thereby supporting the usual critique of “inefficient” SOEs. On the other hand, the largest SOEs in the top 5 ~ 10 percentile are comparable to the largest private firms, which seems to agree with the anecdotal evidence about “superstar” SOEs. These findings highlight the usefulness of nonparametric estimation.

How do these results compare with the OLS estimates? Our GNR estimates are non-parametric, but we may approximate them using a (more familiar) linear functional form for the sake of comparison. Specifically, we approximate  $f(\cdot)$  and  $h(\cdot)$  by linear functions,

$$\hat{E}[f|k_{it}, l_{it}, m_{it}, d_{it}] \approx \beta_0 + \beta_k k_{it} + \beta_l l_{it} + \beta_m m_{it} + \beta_{soe} d_{it}^{soe} + \beta_{col} d_{it}^{col} + \beta_{pri} d_{it}^{pri}$$

and

$$\hat{E}[h|\omega_{i,t-1}, collectivized_{it}, privatized_{it}] \approx \gamma_0 + \rho\omega_{i,t-1} + \gamma_{col} collectivized_{it} + \gamma_{pri} privatized_{it}.$$

By designating SOE as a reference category (i.e.,  $\beta_{soe} \equiv 0$ ), we may interpret  $\beta_{col}$  and  $\beta_{pri}$  as the differential TFP levels of collective and private firms:

$$\begin{aligned} TFP_{it} &\equiv \beta_{col} d_{it}^{col} + \beta_{pri} d_{it}^{pri} + \omega_{it} \\ &= \beta_{col} d_{it}^{col} + \beta_{pri} d_{it}^{pri} + \gamma_0 + \rho\omega_{i,t-1} + \gamma_{col} collectivized_{it} + \gamma_{pri} privatized_{it} + \xi_{it}. \end{aligned} \tag{12}$$

Table 3 contrasts the OLS (column 1) and GNR results (columns 2, 3, and 4). According to the preliminary OLS estimates, neither capital nor labor plays a major role in production (i.e.,  $\hat{\beta}_k = 0.027$  and  $\hat{\beta}_l = 0.092$ ), whereas materials and other intermediate inputs account for almost all of outputs ( $\hat{\beta}_m = 0.876$ ). Collective and private firms respectively produce 15% and 16% more than SOEs given the same inputs (i.e.,  $e^{0.140} = 1.150$  and  $e^{0.147} = 1.158$ ). Relatively small “initial gaps” suggest most of these long-run gains materialize in the first year after collectivization and privatization (i.e., the immediate gains will be  $e^{0.140-0.053} = 1.091$  and  $e^{0.147-0.005} = 1.153$ ). These productivity improvements are respectable, but far from what Table 2 (descriptive statistics of labor productivity) and Figure 3 (nonparametric

production-function estimates) suggest.

Table 3: Production-Function Estimates (1998 Cohort)

Method:	OLS (1)	GNR (2)	GNR (3)	GNR (4)
Capital ( $\beta_k$ )	0.027 (0.002)	0.244 (0.032)	0.220 (0.028)	0.193 (0.029)
Labor ( $\beta_l$ )	0.092 (0.003)	0.443 (0.065)	0.447 (0.062)	0.460 (0.067)
Materials ( $\beta_m$ )	0.876 (0.003)	0.288 (0.096)	0.247 (0.093)	0.281 (0.099)
Collective ( $\beta_{col}$ )	0.140 (0.006)	0.868 (0.129)	0.801 (0.105)	0.747 (0.109)
Collectivization initial gap ( $-\gamma_{col}$ )	-0.053 (0.008)	-0.818 (0.124)	-0.769 (0.105)	-0.709 (0.102)
Private ( $\beta_{pri}$ )	0.147 (0.006)	1.168 (0.188)	0.887 (0.135)	0.850 (0.147)
Privatization initial gap ( $-\gamma_{pri}$ )	-0.005 (0.004)	-0.375 (0.094)	-0.185 (0.063)	-0.170 (0.074)
Autocorrelation ( $\rho$ )	- -	0.738 (0.030)	0.765 (0.026)	0.744 (0.030)
Year dummy	Yes	No	Yes	Yes
2-digit CIC dummy	Yes	No	No	Yes
Number of observations	195,980	195,980	195,980	195,980
Number of privatization/collectivization	10,910	10,910	10,910	10,910

*Note:* Each of columns 2, 3, and 4 reports a *linearly approximated version* of the nonparametric GNR estimates. Standard errors (in parentheses) are clustered by firm and computed from 200 bootstrap draws. SOE is the omitted ownership-type category. CIC is Chinese industry classification code. This table focuses on year-1998 cohort (i.e., 10-year unbalanced panel of firms that were active in 1998).

By contrast, the GNR estimates of input elasticities seem more reasonable. Our preferred specification in column 4 includes a full set of year and industry dummies. Its input coefficients,  $(\hat{\beta}_k, \hat{\beta}_l, \hat{\beta}_m) = (0.193, 0.460, 0.281)$ , suggest both capital and labor substantially contribute to production. What is the source of downward bias in the OLS estimates of  $\beta_k$  and  $\beta_l$ ? Sections 2.2 and 4.2 suggest less productive SOEs are more likely to be “restructured,” that is, either liquidated or privatized. When liquidated, they drop out of the sample. However, larger SOEs tend to remain state owned and survive throughout the sample period. These selection mechanisms in the unbalanced panel create data patterns in which larger  $k_{it}$  and  $l_{it}$  do not necessarily lead to larger  $y_{it}$ .

In a similar vein, the productivity gaps between ownership types are more conspicuous in the GNR estimates than in the OLS ones. If endowed with the same amount of inputs, collective and private firms would produce more than double the output of SOEs (i.e.,  $e^{0.747} = 2.111$  and  $e^{0.850} = 2.340$ ). This magnitude of TFP differences might appear surprising at first glance, but these results are not an artifact of the functional form. Our nonparametric

plots in Figure 3 indicate clear gaps in output levels (approximately  $1 \sim 2$  log points), which translate into 3-  $\sim$  7-fold differences in raw numbers (i.e.,  $e^1 = 2.718$  and  $e^2 = 7.389$ ). Likewise, the descriptive statistics in Table 2 show the average output per worker at collective and private firms is  $2 \sim 3$  times higher than SOEs’.

Not all of the long-run gains materialize at the time of ownership change. In fact, the “immediate” gain from collectivization is small and statistically insignificant (i.e.,  $e^{0.747-0.709} = 1.039$ ). Collectivization does not seem to bring radical changes.

By contrast, a lot of the “eventual” gains from privatization seem to materialize in the short run (i.e.,  $e^{0.850-0.170} = 1.974$ ). This speed of improvement after privatization is surprising because one would expect organizational changes to be time consuming. Nevertheless, such a quick turnaround would be natural if the main problem for SOEs were “artificial.” If some arbitrary regulations and political interventions were playing the role of negative TFP shocks, the changes in legal and political status might as well remove such constraints and unleash the capabilities of former SOE managers.<sup>22</sup>

## 4.6 Shareholding-based Definition of Ownership Type

The main estimates in the above used the definition of SOEs based on the registration type of firms, as in Yu (2014). This subsection investigates the consequence of using an alternative, shareholding-based definition of SOEs.

Table 4: Shareholding-based Definitions of Ownership Types (1998 Cohort)

	Baseline: Registration-based			Total
	SOE	Collective	Private	
Shareholding-based (50% threshold)				
SOE	21,324	4,481	79	25,884
Collective	8,983	3,720	77	12,780
Private	18,672	97,592	40,254	156,518
Total	48,979	105,793	40,410	195,182
Shareholding-based (20% threshold)				
SOE	30,307	8,201	156	38,664
Collective	3,436	4,124	178	7,738
Private	15,236	93,468	40,076	148,780
Total	48,979	105,793	40,410	195,182

*Note:* Shareholding-based definitions classify as SOEs the firm-year observations for which the government’s share exceeds either 50% or 20%. See text for details.

<sup>22</sup>Another possibility is that privatization allowed former SOEs to shed unnecessary assets and fire redundant workers, which would immediately boost TFP as well. We revisit these results and discuss potential mechanisms in section 6.

Table 4 cross tabulates the baseline and the two alternative (shareholding-based) definitions in terms of firm-year counts. The baseline definition classifies the total of 195,182 firm-years into 48,979 SOEs, 105,793 collectives, and 40,410 private firms.<sup>23</sup> The first alternative definition uses two thresholds of government ownership (50% and 20%) to determine SOEs and collectives, whereas the second one uses 20% and 0%.<sup>24</sup> Both of them lead to significantly *fewer* observations in the SOE and collective categories and more in the private category, relative to the baseline definition, because most firm-year observations feature zero government shares. According to the alternative definitions, only 25,884 and 38,664 observations classify as SOEs, respectively. Conversely, as many as 156,518 and 148,780 (of the total 195,182) observations classify as “private” by share ownership, which are almost four times larger than 40,410 private firm-years by registration type.

A potential reason for this discrepancy is cross-shareholding. That is, some firms are not directly owned by the governments but are still indirectly controlled as SOEs via a complicated, hierarchical network of ownerships. Therefore, although most firms belong to non-SOE categories according to the shareholding criteria, such definitions could miss an important part of *de facto* SOEs. Small and medium-sized SOEs (i.e., the main target of privatization and restructuring) would be more susceptible to this kind of misclassification, because the central government tends to directly own and control only the largest SOEs.

Table 5: Estimates by Shareholding-based Definition of Ownership Types (1998 Cohort)

Definition: Method:	50% shareholding threshold		20% shareholding threshold	
	OLS	GNR	OLS	GNR
	(1)	(2)	(3)	(4)
Collective ( $\beta_{col}$ )	0.076 (0.009)	0.184 (0.034)	0.072 (0.010)	0.230 (0.058)
Collectivization initial gap ( $-\gamma_{col}$ )	0.011 (0.013)	-0.471 (0.028)	0.014 (0.016)	-0.444 (0.032)
Private ( $\beta_{pri}$ )	0.090 (0.009)	0.378 (0.026)	0.063 (0.006)	0.362 (0.026)
Privatization initial gap ( $-\gamma_{pri}$ )	-0.071 (0.007)	-0.123 (0.032)	-0.074 (0.007)	-0.215 (0.101)
Number of observations	195,182	195,182	195,182	195,182
Number of privatization/collectivization	10,230	10,230	10,014	10,014

*Note:* The table reports a *linearly approximated version* of the nonparametric GNR estimates. Standard errors (in parentheses) are clustered by firm and computed from 200 bootstrap draws. The full set of year and CIC dummies are included.

<sup>23</sup>The difference between 195,980 (the original sample size) and 195,182 in this subsection reflects the fact that some observations are missing shareholding information.

<sup>24</sup>Ownership share exceeding 50% establishes clear majority, whereas 20% is another threshold in modern accounting for delineating parent-subsidiary relationships.

Table 5 shows the shareholding-based versions of the OLS and GNR estimates. Both the eventual and immediate gains from privatization are much less pronounced than in the baseline estimates. For example, column 2 features  $\hat{\beta}_{pri} = 0.378$ , which means private firms are more productive than SOEs by a factor of  $e^{0.378} = 1.459$ . This difference is impressive but far from the baseline estimates of  $e^{0.850} = 2.340$  in Table 3.

The attenuation of the private-SOE gap could be the result of two factors. One is the suspected tendency of the shareholding-based definition to over-sample larger SOEs. The other is that larger SOEs are often as productive as larger private firms, according to our nonparametric estimates in Figure 3.

## 5 Heterogeneity across Time, Regions, and Industries

### 5.1 New Era, New Cohort

The main results in section 4.5 focused on the 1998 cohort of firms and used their entire 10 years of observations through 2007. One may wonder, however, whether this particular sampling masks richer patterns that might vary across time. For example, China’s accession to the WTO in 2002/2003 was a major macroeconomic event in the middle of our sample period, which might create some inter-temporal heterogeneity.

Let us investigate this issue in two ways. First, we split the sample period into two sub-periods, 1998–2002 and 2003–2007, which conveniently straddle the WTO accession. To ensure “apples-to-apples” comparison, we maintain our exclusive focus on the 1998 cohort. Columns 1 and 2 of Table 6 report our GNR estimates by sub-period, before and after the WTO accession. The number of firm-year observations decreases with time because of exit (i.e., liquidation). Nevertheless, both sub-periods contain sufficiently many privatization/collectivization events for the nonparametric estimation, the results of which we linearly approximate and summarize in this table.

Both the eventual and immediate gains from privatization are broadly similar to the full-sample results in Table 3 (column 4). An interesting difference between columns 1 and 2 is the magnitude of  $\hat{\beta}_{pri}$ , which seems to grow from 0.804 to 1.008 between two sub-periods. This difference is economically significant, with  $e^{0.804} = 2.234$  and  $e^{1.008} = 2.740$  (i.e., private firms are 123% and 174% more productive than SOEs, respectively), although we should also note relatively large standard errors due to smaller sample sizes. This pattern suggests the overall economic environment became more friendly to private firms, which seems consistent with various market-oriented reforms, including the WTO

Table 6: Estimates by Sub-period and Cohort

Cohort: Period: Method:	1998 cohort		2003 cohort
	1998–2002	2003–2007	2003–2007
	GNR (1)	GNR (2)	GNR (3)
Collective ( $\beta_{col}$ )	0.644 (0.180)	0.791 (0.153)	0.494 (0.061)
Collectivization ( $-\gamma_{col}$ )	-0.597 (0.157)	-0.604 (0.145)	-0.524 (0.066)
Private ( $\beta_{pri}$ )	0.804 (0.224)	1.008 (0.210)	0.478 (0.067)
Privatization ( $-\gamma_{pri}$ )	-0.184 (0.068)	-0.325 (0.119)	-0.021 (0.025)
Number of observations	123,707	72,273	426,642
Number of privatization/collectivization	6,113	4,797	16,470

*Note:* The table reports a *linearly approximated version* of the nonparametric GNR estimates. Standard errors (in parentheses) are clustered by firm and computed from 200 bootstrap draws. The full set of year and CIC dummies are included.

accession, whereas no major improvement took place within SOEs of the 1998 cohort.

The second way to investigate changes over time is to study a new generation of firms that appeared after 2002. Column 3 applies the same, augmented-GNR method to the 2003 cohort (i.e., firms that appeared for the first time in 2003). Their sample size is much larger than the 1998 cohort because many new firms sprang up and entered various industries. Most of them were private firms, but new firms appeared in SOE and collective categories as well, with sufficiently many counts of privatization/collectivization.

This new cohort shows patterns that are qualitatively different from the 1998 cohort. The private-firm premium ( $\hat{\beta}_{pri}$ ) among the 2003 cohort is smaller than that of the 1998 cohort, although it is still sizeable at 61% (i.e.,  $e^{0.478} = 1.613$ ). The initial gap ( $\hat{\gamma}_{pri}$ ) is negligible at  $-0.021$ , and hence privatized SOEs of the 2003 cohort seem to achieve the full gains from privatization within a short period of time. By contrast, although the TFP premium of collectively owned firms,  $\hat{\beta}_{col}$ , is as large as  $\hat{\beta}_{pri}$ , none of the eventual gain seems to materialize in the short run (i.e.,  $0.494 - 0.524 = -0.03$ ). In summary, some economically important gaps remain between SOEs and non-SOEs of the 2003 cohort, but the new generation of SOEs appear to be better managed than older SOEs.

How should we interpret these two pieces of evidence concerning 2003–2007? On the one hand,  $\hat{\beta}_{pri}$  among the 1998 cohort is larger in this sub-period than in early years, suggesting private firms widened their lead over SOEs. On the other hand,  $\hat{\beta}_{pri}$  among the 2003 cohort is smaller than either of the two results for the 1998 cohort. Did the TFP gap widen or

narrow? One possibility is that new SOEs faced less stringent constraints than old SOEs. If arbitrary regulations and historical “legacy costs” are the main source of low TFP at SOEs, SOEs that are born in the new era (under more relaxed rules) would be operating with greater managerial freedom from the beginning. We discuss these underlying mechanisms in section 6.

## 5.2 Regional Differences

Geography is another dimension in which the results could vary, and Table 7 shows the estimates are indeed different across regions. Columns 1 and 2 split Chinese provinces into North and South, where South includes Jiangsu, Shanghai, Zhejiang, Fujian, Guangdong, Hainan, Guangxi, Jiangxi, Hunan, Anhui, Hubei, Sichuan, Yunnan, and Guizhou.<sup>25</sup> The rest of the provinces and territories (excluding Tibet, which belongs to neither group) is classified under North, which is traditionally closer to the power center of the country and therefore more “political.” By contrast, South is considered more economically liberal and prosperous.

Conceptually, we could imagine “economically more liberal” environments to either expand or narrow the private-SOE gap in TFP. One possibility is that private firms face fewer constraints and could widen their lead over SOEs. Another possibility is that SOEs are also allowed to operate more flexibly and could catch up with their private peers. The net effect of “economic liberty” is an open empirical question.

The estimates show a clear contrast. Both the short-run and long-run gains from privatization are larger in North than South. In other words, SOEs in North are much less productive than their private peers, whereas SOEs in South are “closer” to private firms in the same region.<sup>26</sup> This North-South contrast suggests important regional differences and somewhat resembles the inter-temporal heterogeneity in the previous subsection.

Columns 3 and 4 split the country in another way: Inland versus Coastal regions. The East Coast includes Liaoning, Shandong, Jiangsu, Shanghai, Zhejiang, Fujian, Guangdong, and Hainan; the rest of the provinces and territories belong to the Inland category. Of course, the Northeastern industrial landscape of Liaoning (which is famous for large SOEs in heavy industries) could be different from the more liberal atmosphere of Shanghai and

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<sup>25</sup>We also tried a slightly different, narrower definition of South, which excludes the last five provinces, but the results hardly changed.

<sup>26</sup>Relatively large standard errors suggest this geographical split is probably too coarse to uncover the underlying heterogeneity at the provincial or municipal level, although finer geographical splits would also increase standard errors due to smaller sample sizes.

Table 7: Estimates by Region (1998 Cohort)

Geographical split: Region: Method:	North vs. South		Inland vs. Coast	
	North	South	Inland	East Coast
	GNR	GNR	GNR	GNR
	(1)	(2)	(3)	(4)
Collective ( $\beta_{col}$ )	0.845 (0.389)	0.484 (0.331)	0.819 (0.171)	0.517 (0.385)
Collectivization ( $-\gamma_{col}$ )	-0.788 (0.329)	-0.419 (0.360)	-0.758 (0.188)	-0.517 (0.290)
Private ( $\beta_{pri}$ )	1.140 (0.500)	0.499 (0.379)	1.116 (0.219)	0.526 (0.485)
Privatization ( $-\gamma_{pri}$ )	-0.344 (0.158)	-0.080 (0.140)	-0.408 (0.113)	-0.054 (0.156)
Number of observations	81,339	114,464	90,674	105,129
Number of privatization/collectivization	3,927	6,976	4,458	6,445

*Note:* The table reports a *linearly approximated version* of the nonparametric GNR estimates. Standard errors (in parentheses) are clustered by firm and computed from 200 bootstrap draws. The full set of year and CIC dummies are included. See text for the definition of regions.

Guangdong, for example. Such sub-regional heterogeneity seems to manifest itself in large standard errors on column 4, whereas column 3 features much lower standard errors for the Inland region. These subtleties notwithstanding, the overall patterns from the Inland-Coast comparison are similar to those arising from the North-South split in columns 1 and 2, as well as the “generation gap” comparison between the 1998 and 2003 cohorts in the previous subsection.

In this and the previous subsection, we split the sample into subsamples in terms of time and space, respectively. In most of these inter-temporal and cross-sectional comparisons, the TFP gap between SOEs and private firms is larger in the “less economically liberal” subsamples (i.e., the 1998 cohort, North, and Inland) and smaller in “more economically liberal” subsamples (i.e., the 2003 cohort, South, and East Coast). Thus, the performances of SOEs and private firms would seem to converge as economic liberalization progresses.

### 5.3 Estimates by Industry Type

So far we have not distinguished between industries, but both technologies and regulatory contexts differ across industries. Ideally, we would like to estimate production function by CIC. However, only a limited number of privatization/collectivization events occurred within each CIC, and nonparametric methods require a relatively large sample size. Consequently, we group industries into four sectors, so that each subsample focuses on a broadly similar

type of industry and contains at least 1,000 privatization/collectivization events.

The first category (“final goods”) includes the following CICs: 13 (agricultural products), 14 (foods), 15 (beverages), 17 (textile), 18 (apparel and footwear), 19 (leather and fur), 20 (wood products), 21 (furniture), 23 (printing), 24 (cultural), 31 (mineral products), and 34 (metal products).<sup>27</sup> These CICs tend to be consumer-facing, “light” manufacturing industries.

By contrast, the second category (“materials”) contains more industrial, “heavy” manufacturing: 22 (paper), 25 (petroleum), 26 (chemical), 28 (chemical fibers), 29 (rubber), 30 (plastics), 32 (ferrous metals), and 33 (non-ferrous metals). Although certain subcategories of these 2-digit CICs could include final goods, most of them are homogeneous, intermediate goods that are transacted between businesses rather than sold directly to consumers.

The third category (“high-tech”) broadly encompasses industries with relatively more complicated processes and products: 27 (pharmaceutical), 35 (general-purpose machinery), 36 (special-purpose machinery), 37 (transport equipment), 39 (electrical machinery), 40 (electronics), 41 (precision instruments), and 42 (artwork).

These three sectors are designed to be mutually exclusive, whereas the fourth category (“strategic”) includes 24, 25, 27, and 37 and therefore overlaps with the other groups. The purpose of this last category is to focus on tightly regulated industries that the Chinese government designated as “strategic” or somewhat special in its industrial policy.

Table 8 shows the “final-goods” and “high-tech” sectors exhibit larger gains from privatization than the “materials” sector. We interpret this contrast as follows. Privatization increases the degree of managerial freedom, and the commercial return on this additional flexibility would be particularly high in industries that face diverse tastes of consumers and/or fast-changing technologies (i.e., the final-goods and high-tech sectors). In both cases, the management of demand and technology would require agility and dexterity. By contrast, heavy industries with homogeneous goods seem more amenable to the “central planning” style of management. Hence, although private firms outperform SOEs in the materials sector as well, the TFP gaps are relatively small. Finally, the “strategic” sector features mostly opposite signs, but standard errors are large, presumably due to its small sample size.

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<sup>27</sup>CIC 31 (mineral products) might not appear to be a “consumer-facing” industry at first glance, but this industry includes many final goods such as glassware and kitchenware.

Table 8: Estimates by Industry Type

Industry type: Method:	Final goods GNR (1)	Materials GNR (2)	High-tech GNR (3)	“Strategic” GNR (4)
Collective ( $\beta_{col}$ )	0.895 (0.222)	0.436 (0.276)	0.914 (0.387)	-0.058 (0.380)
Collectivization initial gap ( $-\gamma_{col}$ )	-0.749 (0.191)	-0.510 (0.295)	-0.908 (0.400)	-0.179 (0.387)
Private ( $\beta_{pri}$ )	1.003 (0.295)	0.445 (0.304)	1.057 (0.477)	-0.236 (0.451)
Privatization initial gap ( $-\gamma_{pri}$ )	-0.206 (0.135)	-0.017 (0.104)	-0.199 (0.323)	0.192 (0.182)
Number of observations	79,044	59,481	56,161	18,694
Number of privatization/collectivization	4,269	3,445	3,171	1,071

*Note:* The table reports a *linearly approximated version* of the nonparametric GNR estimates. Standard errors (in parentheses) are clustered by firm and computed from 200 bootstrap draws. Final-goods industries include the following CICs: 13, 14, 15, 17, 18, 19, 20, 21, 23, 24, 31, and 34. Materials industries include 22, 25, 26, 28, 29, 30, 32, and 33. High-tech industries includes 27, 35, 36, 37, 39, 40, 41, and 42. These three categories are mutually exclusive. Finally, strategic (or highly regulated) industries include 24, 25, 27, and 37. SOE is the omitted ownership-type category.

## 6 Discussions

Four findings emerged from the empirical analysis in the previous sections. First, SOEs are less productive than private firms. The only exception is the largest firms in the top 5 ~ 10 percentile of size distribution, the production functions of which are indistinguishable across ownership types. Second, privatization confers both short-run and long-run gains, whereas collectivization does not seem to effectuate any immediate change in productivity. Third, the private-SOE gap is less pronounced within new cohorts of firms and in provinces that are known to be more economically liberal. Fourth, the private-SOE gaps are larger in consumer-facing and/or high-tech markets than in the ones for homogeneous, industrial goods.

A natural question is: Why? We investigate potential mechanisms behind our findings in this section. Like most datasets that are used for production-function estimation, our main dataset, the ASIE, is not particularly helpful for answering questions about the underlying economic mechanisms, but we may consult the institutional background as well as qualitative case studies for hints. We also analyze auxiliary data on “new products” and patents.

### 6.1 Why Were SOEs Less Productive?

Our first question is: Why were SOEs less productive than privately owned firms? This question sounds almost silly given the historical context in which SOEs as a whole recorded a

loss in 1995 and were blamed for poor management. Nevertheless, obtaining a clearer picture of the causes of inefficiency is desirable for understanding the benefits of privatization.<sup>28</sup>

### 6.1.1 Sources of Negative TFP Shocks at SOEs

Section 2 summarized the historical background of SOEs, private enterprises, and privatization. What went wrong with state ownership? During the central planning period (1953–1977), SOEs were not independent firms but mere plants to implement the Five-Year Plans. The (plant) managers were not entrepreneurs but bureaucratic superintendents in charge of the efficient execution of the plans. The separation of planning from implementation led to inconsistencies due to lack of information. Moreover, dual chains of command existed within each SOE, in which the government’s and the party’s reporting lines caused confusion and inefficiency. For example, the Party’s organization department appointed managers from among the government officials, but the government’s central planning committee determined production plans, and the department of finance was in charge of funds for operations and investments.

During the reform period since 1978 and especially after 1993, SOEs’ ownership and management were separate, SOEs became financially more “independent” than before (i.e., they could now go bankrupt and be liquidated), and the managers of SOEs were given more autonomy and became responsible for the performances. Nevertheless, two main critiques of SOEs seem to persist among researchers: that SOEs pursue profits at the expense of private rivals instead of serving public purposes, and that SOEs are still relatively unproductive.<sup>29</sup>

In 2003, the State-owned Assets Supervision and Administration Commission of the State Council (SASAC) was established to pool the ownership of the 196 largest SOEs, but the corporate governance structure remains convoluted because the Party appoints the SOEs’ top executives and the Finance Department controls their budgets. The SASAC introduced a modern evaluation system based on financial metrics such as return on equity, but more subjective items such as “political aptitude” are also part of the criteria and could add noise to managers’ incentives and decision-making.<sup>30</sup>

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<sup>28</sup>This and the next subsection draw primarily on Bei (2014) and Yuan (2009).

<sup>29</sup>Kato, Watanabe, and Ohashi (2013, ch. 3–4).

<sup>30</sup>Jin (2013).

### 6.1.2 Case Studies

**Lenovo: A Privately Managed SOE** Not all SOEs are doomed to fail, of course. Lenovo, a computer maker, has become a global brand, but its majority owner is the Chinese Academy of Sciences, a government institute. Lenovo epitomizes a new type of SOE in high-tech industries, at which managers are basically given free reign: “state-owned privately managed” enterprises. Nevertheless, Lenovo could be an exception that proves the norm.

**Start: The Perils of State Ownership** Fujian Start Computer (henceforth Start) is another famous “state-owned privately managed” firm, founded in 1988 by 16 former employees of the Fujian Province Electronic Computer Research Institute and the Fujian Province Fumin Economic Development Corporation (henceforth Corporation), an SOE that belonged to the Chinese Air Force. These public-sector entities had agreed to finance 70% of Start’s equity and also promised to give complete autonomy to its managers. After its initial success and a setback, Start was going through organizational reforms in 1999 when the Corporation, its largest shareholder, had to transfer all of its stake to a different former SOE in Beijing for extraneous reasons (i.e., the prime minister’s order to stop the armed forces’ involvement in commercial activities).

This new lead shareholder did not understand Start’s business and reacted to its losses by ousting the president, Ye Long, who recounted the problems with the state ownership as follows. First, the government was just like any other shareholders in that all they demanded was profits and dividends, and would happily stay silent as long as profits were increasing. Second, however, once the firm’s performance weakened, these shareholders started interventions that reflected peculiar internal politics of each government institution. Third, their decision-making was too slow and was influenced by the turnover of officials in charge (who became board members). Thus, state ownership seems to confer advantages in terms of resources and is not inconsistent with profit maximization per se, but adds a major source of random noise and delay to the firm’s decision-making process.

**Geely Auto: An “Always-Private” Firm** By contrast, the private enterprises that have emerged since 1978 seem truly entrepreneurial. They have overcome all sorts of discrimination and regulatory barriers to entry, as illustrated by Geely Auto’s trajectory of entry and growth. The central government’s 1994 industrial policy prioritized the automobile industry and effectively barred new entry, because the plan was to consolidate car manufacturing among the top eight SOEs: the three largest makers (First Automobile Works, Dongfeng Motor, and Shanghai Automotive Industry Corporation), three smaller makers (Beijing, Tianjin, and Guangzhou), and two “light automobile” makers (Chang’an and Guizhou).

The founder of Geely, Li Shufu, was a farmer in rural Zhejiang, who opened a refrigerator parts workshop in 1984, set up a joint venture with a failing local firm to obtain the license to manufacture motorcycles in 1994, acquired 70% ownership of an SOE in Sichuan to obtain the license for light vehicles (i.e., under 900cc) in 1997, and finally entered the regular sedan market in 2001 through a joint venture with another SOE in Jiangnan that had the sedan license. To overcome the institutional handicaps as a private enterprise, Li recruited his management team from among the former officers of the top three SOEs and the provincial government. Another typical challenge for private firms is to grow beyond the mold of family business, which Li accomplished by transforming the firm into a professionally managed organization in 2003 by delegating the authority to those managers from outside his family.

In summary, being an SOE seems a mixed blessing at best. Being part of officialdom used to be the only way to run a “legitimate” business, and “superstar” SOEs such as Lenovo do exist, but the burden of bureaucratic control and other constraints seemed to outweigh the benefits in many cases.

## 6.2 What Changed after Privatization?

Our second question is: How could privatization improve the productivity of former SOEs almost immediately? In other words, what happened to those privatized firms? The institutional background and several examples in section 6.1 already suggest the removal of bureaucracy and political interventions could be highly effective, but a few detailed accounts of privatized firms would help illustrate both the form and function of privatization in China.

**Cases from North East** Many industrial SOEs were concentrated in China’s North East, especially Liaoning province, which became a target of the pilot program for SOE reforms. By 2004, 73.2% of 3,640 small and medium-sized SOEs had been privatized. Bei (2014) conducted in-depth surveys of privatized firms in Shenyang, the capital city.

Privatization does not change everything overnight, and Bei (2014) shows privatized firms are organizationally different from always-private enterprises. In fact, all seven successful cases in Bei (2014) feature former small SOEs that retained their core technologies, management teams, physical assets, and the majority of the labor force from the SOE era.

What changed was the increased degree of freedom for management, including product choice, technology choice, marketing, investment, and the design of incentive schemes. In other words, the managers of SOEs had to deal with the unwritten rules and governments’ interventions, which seemed to work as persistent negative shocks to their performances and built-in inflexibility to their decision-making in various ways. After privatization, those firms

broke free from such constraints, making better decisions and implementing better schemes. Thus, privatization removed the main sources of negative TFP shocks.

**Huajing’s Semiconductor Plant** Another case study of privatization and performance improvement, due to Yuan (2009), comes from the coastal South. Huajing Electronics is an example of how privatization and better management could drastically improve the performance of a former SOE. Huajing has its origin in the mid-1960s when the 4th Machine Industry Department (which controlled the semiconductor industry at the time) established the 742nd plant in Wuxi, as part of Mao’s efforts to develop electronic devices for military use at the height of China’s international isolation. In 1978, the plant became a vehicle for the technology transfer from Toshiba of Japan, and in 1989, it became an integrated device manufacturer (IDM), Huajing Electronics.

The eighth Five-Year Plan (1991–95) contained a major government project to develop electronics and semiconductor industries. In 1991, the Electronics Industry Department proposed a plan to build an advanced semiconductor plant with  $0.9\mu m$ -technology production lines. However, the construction took eight years and the technology had become obsolete by 1998. The delays stemmed from a coordination problem among multiple government agencies, including the Electronics Industry Department, the Planning Committee, the Finance Department, and the Commerce Department.

Huajing could not find a productive use of this brand new (but obsolete) plant by itself, but Central Semiconductor Manufacturing Company, a private firm, agreed to manage it as a foundry. In 1999, the government authorized the privatization of the plant as a joint venture in which the private firm has the majority ownership. The new firm, Wuxi Huajing CSMC Semiconductor, became the first Chinese foundry and turned profitable within a few years. Thus, finding a profitable use of existing assets seems to be the key managerial input from the private entrepreneurs in this case as well.

This pattern resembles the finding of Braguinsky et al. (2015) in the context of M&As that the new management (i.e., managers coming from the acquiring firms) improved the profitability of the target firms primarily by better managing the demand for the existing products, rather than by changing products or improving physical productivity.

### 6.3 Downsizing Was Not the Main Channel

Another possible channel through which former SOEs could rapidly improve their TFP is by shedding unnecessary inputs, that is, useless assets and redundant workers. Episodes of layoffs as part of SOE reforms and privatization are abundant. Hence, one would suspect

the reduction of inputs (rather than the growth of outputs and revenues) might be the main source of TFP improvement.

To assess the extent to which such input reductions actually matter, we run regressions of the following form:

$$\begin{aligned}
 x_{it} = & \alpha_0 + \alpha_1 x_{i,t-1} + \alpha_2 \text{privatized}_{it} + \alpha_3 \text{collectivized}_{it} \\
 & + \alpha_4 x_{i,t-1} \times \text{privatized}_{it} + \alpha_5 x_{i,t-1} \times \text{collectivized}_{it} + \eta_{it},
 \end{aligned}
 \tag{13}$$

where  $x_{it}$  is an input variable (either  $k_{it}$  or  $l_{it}$ ) and  $\alpha$ s are the coefficients on  $x_{i,t-1}$ , privatization/collectivization indicators, and their interaction terms. We also incorporate the full sets of year and CIC dummies and run separate OLS regressions for SOEs and collectively owned firms. For example, if the immediate gain from privatization stems from fire sale of assets and layoffs,

$$\alpha_2 \text{privatized}_{it} + \alpha_4 x_{i,t-1} \times \text{privatized}_{it} < 0
 \tag{14}$$

should hold.

Table 9: Immediate Changes in Input Volumes after Privatization/Collectivization

Ownership type at $t-1$ : Input variable ( $x_{it}$ ):	SOE		Collective	
	Capital (1)	Labor (2)	Capital (3)	Labor (4)
$x_{i,t-1}$ ( $\alpha_1$ )	0.970 (0.002)	0.952 (0.001)	0.921 (0.001)	0.931 (0.001)
$\text{privatized}_{it}$ ( $\alpha_2$ )	1.202 (0.205)	0.397 (0.095)	0.586 (0.044)	0.209 (0.017)
$\text{collectivized}_{it}$ ( $\alpha_3$ )	0.522 (0.099)	0.023 (0.030)	— (—)	— (—)
$x_{i,t-1} \times \text{privatized}_{it}$ ( $\alpha_4$ )	-0.146 (0.024)	-0.090 (0.018)	-0.071 (0.005)	-0.046 (0.003)
$x_{i,t-1} \times \text{collectivized}_{it}$ ( $\alpha_5$ )	-0.051 (0.010)	0.002 (0.005)	— (—)	— (—)
Number of observations	72,296	72,296	292,445	292,445
Adjusted $R^2$	0.917	0.909	0.834	0.872

*Note:* This table reports OLS regressions using data on all cohorts. Standard errors (in parentheses) are clustered by firm. The full sets of year and CIC dummies are included

Table 9 shows the opposite is the case, with curious heterogeneity. Columns 1 and 2 suggest privatized SOEs basically *increase* their input use (i.e.,  $\hat{\alpha}_2 > 0$ ), but larger SOEs tend to reduce it (i.e.,  $\hat{\alpha}_4 < 0$ ). These LHS terms in (14) sum to zero at  $k_{i,t-1} = 8.233$  and  $l_{i,t-1} = 4.411$ , which are approximately the modal size of both private and collective firms

(see Figure 3). Thus, small and medium-sized SOEs tend to increase their inputs ( $k_{it}$  and  $l_{it}$ ), as well as output and TFP, immediately after privatization.

By contrast, larger SOEs seem to experience downsizing after privatization. Collectivization entails qualitatively similar results regarding  $k_{it}$ , whereas the coefficient estimates are statistically insignificant for  $l_{it}$ . Finally, columns 3 and 4 show similar patterns for the privatization of collectively owned firms, for which the “break-even” input volumes are  $k_{i,t-1} = 8.254$  and  $l_{i,t-1} = 4.543$ .

## 6.4 “New Products” and Patents

Our analysis in section 6.3 rejects downsizing as the main driver of productivity gains from privatization, at least for small and medium-sized (former) SOEs, which were the main targets of privatization policy. In fact, these firms’ inputs and outputs seem to increase after privatization. The case studies in section 6.2 suggest the introduction of new products and other forms of “innovation” as possible channels. In Appendices C.1 and C.2, we explore these possibilities with additional data, and find three curious patterns. First, SOEs are more likely to report the introduction of “new products” than collectively/privately owned firms. Second, however, conditional on reporting new products, private firms earn greater fractions of revenues from new products than SOEs and collectives. Third, collectives exhibit higher propensities to patent than SOEs, whereas few private firms obtain patents. We suspect the political economy of innovation-related statistics could complicate the relationship between the underlying innovative activities and the official statistics.

## 7 Conclusion

This paper measures the effects of privatization on firm-level productivity. We address the inherent endogeneity problems due to selection on unobserved heterogeneity by augmenting the ACF/GNR framework to incorporate ownership types and their changes, and by leveraging the institutional context that creates a lag structure in data.

We find the dynamics of TFP after privatization exhibit both short-term and long-term gains, primarily by increasing the degree of managerial freedom and reducing negative shocks (i.e., bureaucratic delays and interventions). Downsizing does not appear to be the main channel for improved productivity/profitability among small and medium-sized privatized firms, which were the focus of the privatization programs.

The private-SOE gaps in TFP tend to be smaller among younger firms and in economically more open regions, which seems to suggest their differences might diminish with the progress of economic liberalization. Our estimates by industry type show the gains from privatization are larger in the final-goods and high-tech sectors than in the materials sector. This result seems to suggest the return on managerial flexibility increases with the complexity of the environment. The analysis of “new products” and Chinese patents produces curious but inconclusive findings. Careful, micro-level studies of these innovation-related measures might be a fruitful direction for future research.

We focused on the impact of privatization in this paper, because one of the most important episodes of privatization and productivity has just unfolded in China, the largest socialist economy to date. But our econometric approach is not confined to the context of privatization, and can be adapted to studies of other (endogenous) determinants of firm-level productivity, such as exporting and innovation.

# Appendix (For Online Publication)

## A.1 Data Construction and Summary Statistics

As we briefly explained in section 3.3, our data-cleaning procedures for the ASIE data follow BVZ (2012). We added the Chinese patent data as follows. First, we matched each firm in the ASIE with patents whose assignees' names are the same. When the exact matches could not be found, we removed various designators of corporate forms such as “company,” “inc.,” and “corporation” from both the ASIE firm names and the patent-assignee names, and matched them based on these pre-processed names. Likewise, we removed address information such as “Hunan Province” and “Shanghai” from the names, and performed a rematch based on these pre-processed names as well as the first four digits of the zip code (which identify the cities in which the firms are located). Finally, we removed both the designators of corporate forms and the address information from the names, and matched them based on these pre-processed names and the first four digits of the zip code.

Table 10: Summary Statistics (1998 Cohort)

Variable	Number of observations	Mean	Standard deviation	Minimum	Maximum
Log output	195,980	9.9291	1.6662	-0.6082	18.4706
Log capital	195,980	8.6846	1.8173	-4.8423	17.7498
Log labor	195,980	5.2592	1.2285	2.0794	12.0249
Log materials	195,980	9.6917	1.6611	-0.2748	17.7955
Ownership type $\in \{1, 2, 3\}$	195,980	1.9557	0.6754	1	3
Collectivization (type 1 $\rightarrow$ 2)	195,980	0.0167	0.1282	0	1
Privatization (types 1, 2 $\rightarrow$ 3)	195,980	0.0390	0.1935	0	1
New products (frac. of revenue)	180,825	0.0365	0.1391	0	1
Invention patent application	195,980	0.1150	17.4005	0	4,940
Invention patent granted	195,980	0.0807	12.6753	0	3,474
Design patent application	195,980	0.0614	1.1774	0	210
Utility patent application	195,980	0.0644	2.4739	0	485
Indicator {invention patents $> 0$ }	195,980	0.0062	0.0788	0	1
Indicator {invention granted $> 0$ }	195,980	0.0046	0.0675	0	1
Indicator {design patents $> 0$ }	195,980	0.0088	0.0088	0	1
Indicator {utility patents $> 0$ }	195,980	0.0043	0.0043	0	1

Note: Ownership types are coded as follows: SOE (1), collective (2), and private (3).

Table 11: Count of Transition between Ownership Types (1998 Cohort)

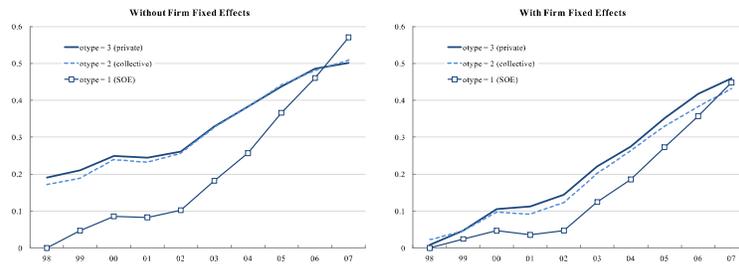
Ownership type: Current year ( $t$ )	Next year ( $t + 1$ )			Total
	SOE	Collective	Private	
SOE	48,151	3,276	500	51,927
Collective	1,031	100,226	7,134	108,391
Private	46	2,701	32,915	35,662
Total	49,228	106,203	40,549	195,980

Table 10 reports summary statistics of the 1998 cohort of firms, which is the main focus of our empirical analysis in sections 4 and 5. Table 11 reports the transition patterns of ownership types between current ( $t$ ) and next ( $t + 1$ ) years. The majority of firms in each type continue to be the same types, but small fractions of SOEs turn into collective or private firms, and some collective firms become private. Sometimes changes in the reverse direction occur, which is rare (and hence not our main focus) but helps identification of the type- and transition-specific parameters.

## A.2 Preliminary OLS Estimates for the 1998 Cohort

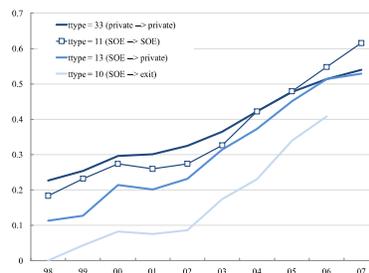
Section 4.2 showed the preliminary analysis of TFP by ownership type and “transition type” for the full sample including new entrants. For the sake of completeness, Figures 4 and 5 report the corresponding OLS estimates for the 1998 cohort (only), which is the focus of our main analysis. The trajectories of TFP are broadly similar to the full-sample version in section 4.2.

Figure 4: OLS Estimates of Productivity by Ownership Type (1998 Cohort)



*Note:* These graphs plot the coefficient estimates of type-year interaction dummies, where SOE in 1998 is the reference category.

Figure 5: OLS Estimates of Productivity by Transition Type (1998 Cohort)



*Note:* The graph plots the coefficient estimates of type-year interaction dummies, where “SOE  $\rightarrow$  exit” in 1998 is the reference category.

## B.1 Illustration of Possible TFP Dynamics

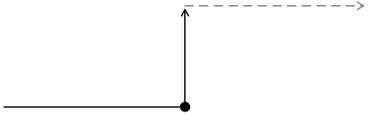
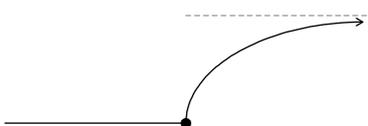
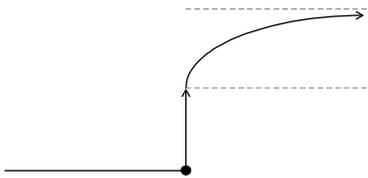
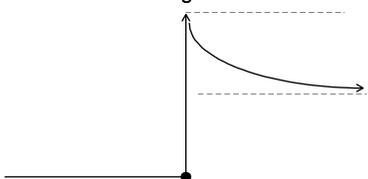
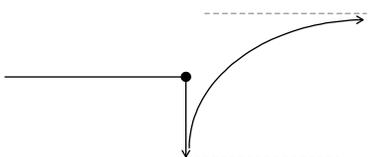
As section 4.4 explained, we distinguish between the immediate and eventual changes in productivity after privatization/collectivization. Our results in section 4.5 suggest the gains from privatization are positive both in the short run and the long run.

Our formulation does *not* impose positive gains, and permits radically different patterns. Figure 6 illustrates five examples of qualitatively different trajectories when  $\beta_{pri} > 0$  (i.e., private firms are more productive than SOEs, and hence the eventual gains from privatization is positive).

- In Case 1, all eventual gains are realized immediately, because the “initial gap” is zero (i.e.,  $\gamma_{pri} = 0$ ).
- In Case 2, all gains are realized eventually and not immediately, because the initial gap cancels out the eventual gain at the moment of privatization (i.e.,  $\beta_{pri} - \gamma_{pri} = 0$ ).
- In Case 3, both immediate and eventual gains are positive because the initial gap exists but is not dominant (i.e.,  $\beta_{pri} - \gamma_{pri} > 0$ ).
- In Case 4, the initial gap is negative (i.e.,  $\gamma_{pri} < 0$ ), which means the privatized firm’s performance overshoots its long-run potential.
- Finally, Case 5 describes a situation in which the short-run performance is rather disappointing (i.e.,  $\beta_{pri} - \gamma_{pri} < 0$ ) due to some transitional glitches.

These five cases are not meant to be exhaustive. In principle, private firms could be less productive than SOEs (i.e.,  $\beta_{pri} < 0$ ), in which case five additional time paths would become possible. We do not illustrate such patterns, because almost all of our results entail  $\beta_{pri} > 0$ , but our model permits such possibilities.

Figure 6: Possible Time Paths of Productivity after Privatization

Transition dynamics	Initial gap between private and privatized	Description
<p><b>Case 1: Immediate gain only</b></p> 	$\gamma = 0$	<p>All eventual gain materializes immediately after privatization. No initial gap exists between private and privatized firms.</p>
<p><b>Case 2: Eventual gain only</b></p> 	$\beta - \gamma = 0$	<p>No immediate gain. In the short run, initial gap completely offsets eventual gain.</p>
<p><b>Case 3: Immediate &amp; eventual gains</b></p> 	$\beta - \gamma > 0$	<p>Both immediate and eventual gains. Initial gap exists but does not offset eventual gain completely.</p>
<p><b>Case 4: Over-shooting</b></p> 	$\gamma < 0$	<p>Short-run gain is larger than long-run gain. Initial gap is negative.</p>
<p><b>Case 5: Switch-over disruption</b></p> 	$\beta - \gamma < 0$	<p>Negative change in short run. Initial gap more than offsets (long-run) private TFP premium.</p>

*Note:* This figure illustrates five qualitatively different time paths of productivity dynamics after privatization. In the middle column,  $\beta$  represents private firms' long-term TFP premium relative to SOEs (assumed to be positive in these diagrams for expositional purposes), whereas  $\gamma$  is the initial gap between already-private firms and just-privatized firms. See text and section 4.4 for the details.

## B.2 Identification when Prices/Markups Are Heterogeneous

We show GNR's identification is robust to measurement error (e.g., the presence of firm-level output prices and hence markups). Suppose firm  $i$ 's true output is

$$Y_{it}^* = F(x_{it})e^{\omega_{it} + \varepsilon_{it}},$$

where  $x_{it}$  is the vector of inputs, but our output data,

$$\begin{aligned} Y_{it} &= \frac{P_{it}}{P_t} Y_{it}^* \\ &= \frac{P_{it}}{P_t} F(x_{it}) e^{\omega_{it} + \varepsilon_{it}}, \end{aligned}$$

contain measurement errors because of idiosyncratic factors affecting firm-level prices.

Let  $p_{it}^* \equiv \frac{P_{it}}{P_t} - 1$ . That is, we express firm-level heterogeneity as a fractional deviation from the industry-average price,  $P_t$ . We consider classical measurement error in (the log of) the industry-average price and assume  $P(p_{it}^* | \mathcal{I}_{it}) = P(p_{it}^*)$  and  $P(\varepsilon_{it} | \mathcal{I}_{it}) = P(\varepsilon_{it})$ . Taking logarithm of the production function, we have

$$y_{it} = f(x_{it}) + \omega_{it} + \varepsilon_{it} + \log(1 + p_{it}^*).$$

We may reparametrise this model as

$$y_{it} = \tilde{f}(x_{it}) + \omega_{it} + \tilde{\varepsilon}_{it},$$

where  $\tilde{f}(x_{it}) = f(x_{it}) + E[\log(1 + p_{it}^*)]$  and  $\tilde{\varepsilon}_{it} = \varepsilon_{it} + \log(1 + p_{it}^*) - E[\log(1 + p_{it}^*)]$ , so that  $E[\tilde{\varepsilon}_{it}]$  is normalized to 0. The models  $(\tilde{f}, \tilde{\varepsilon})$  and  $(f, \varepsilon)$  are equivalent up to an additive constant.

We show this reparameterization does not affect the numerical relation in the firm's FOC. After this reparameterization, the optimization problem becomes

$$\max_{M_{it}} P_t E[\tilde{F}(x_{it}) e^{\omega_{it} + \tilde{\varepsilon}_{it}} | \mathcal{I}_{it}] - \rho_t M_{it},$$

where  $\tilde{F}(x_{it}) = F(x_{it}) \exp(E[\log(1 + p_{it}^*)])$ . The FOC is

$$P_t \frac{\partial}{\partial M_{it}} \tilde{F}(x_{it}) e^{\omega_{it} + \tilde{\varepsilon}_{it}} = \rho_t,$$

where  $\tilde{\mathcal{E}} = E[e^{\varepsilon_{it} + \log(1 + p_{it}^*) - E[\log(1 + p_{it}^*)]}]$ , and hence

$$\log \frac{P_t}{\rho_t} + \log \frac{\tilde{F}(x_{it})}{M_{it}} + \log \frac{\partial \tilde{f}}{\partial m} + \omega_{it} + \log \tilde{\mathcal{E}} = 0.$$

Note

$$\log Y_{it} = \log(1 + p_{it}^*) + \log F(x_{it}) + \omega_{it} + \varepsilon_{it} = \log \tilde{F}(x_{it}) + \omega_{it} + \tilde{\varepsilon}_{it}.$$

Differencing  $\log Y_{it}$ , we have

$$\log \frac{P_t}{\rho_t} + \log \frac{\partial \tilde{f}}{\partial m} - \tilde{\varepsilon}_{it} + \log \tilde{\mathcal{E}} = -\log Y_{it} + \log M_{it},$$

and hence

$$s_{it} \equiv \log \left( \frac{\rho_{it} M_{it}}{P_t Y_{it}} \right) + \log \frac{\partial \tilde{f}}{\partial m} - \tilde{\varepsilon}_{it} + \log \tilde{\mathcal{E}},$$

which is the same as equation (11) of GNR (2017). Because the slope of  $\tilde{f}$  is equivalent to the slope of  $f$ , the two models,  $(f, \varepsilon)$  and  $(\tilde{f}, \tilde{\varepsilon})$ , are numerically equivalent in the identification property of  $f$  (i.e., the identification up to an additive constant).

### B.3 Proof of Proposition 1

**Proof.** From the assumption, we identify

$$\int_m^{m'} \frac{\partial}{\partial m} f(k', l', \tilde{m}, d_t) d\tilde{m} = f(k', l', m', d_t) + C(k', l', d_t)$$

where  $C(k', l', d_t)$  is an integration constant, for each of the three ownership types,  $d_t \in \{1, 2, 3\}$ . Also from the assumption, there exist  $(k, l, \mathcal{Y})$  in the support of  $(k_{t-1}, l_{t-1}, \mathcal{Y}_{t-1})$  such that

$$E[\mathcal{Y}_t | k', l', d_t, \mathcal{Y}, k, l, d_{t-1}]$$

is identified all combinations of  $(d_t, d_{t-1})$  except for  $\{1, 3\}$  and either one of  $\{3, 2\}$  or  $\{3, 1\}$ .

The existence of such  $(k, l, \mathcal{Y})$  for  $\{d_t, d_{t-1}\} \in \{\{3, 3\}, \{2, 3\}, \{2, 2\}, \{1, 2\}\}$  is sufficient for the identification of  $\beta$ s. In fact,

$$f(k', l', m', 2) + C(k', l', 2) - (f(k', l', m', 1) + C(k', l', 1))$$

is known, and  $C(k', l', 2) - C(k', l', 1)$  is identified from

$$\begin{aligned} & E[\mathcal{Y}_t | k', l', \mathcal{Y}, 1, k, l, 2] - E[\mathcal{Y}_t | k', l', \mathcal{Y}, 2, k, l, 2] \\ &= -C(k', l', 1) + h(\mathcal{Y} - C(k, l, 2), 0, 0) - (-C(k', l', 2) + h(\mathcal{Y} - C(k, l, 2), 0, 0)) \\ &= C(k', l', 2) - C(k', l', 1). \end{aligned}$$

Hence,  $\beta_{col}(k', l', m')$  is identified.

Similarly,  $C(k', l', 3) - C(k', l', 2)$  is identified from

$$\begin{aligned} & E[\mathcal{Y}_t | k', l', \mathcal{Y}, 2, k, l, 3] - E[\mathcal{Y}_t | k', l', \mathcal{Y}, 3, k, l, 3] \\ &= -C(k', l', 2) + h(\mathcal{Y} - C(k, l, 3), 0, 0) - (-C(k', l', 3) + h(\mathcal{Y} - C(k, l, 3), 0, 0)) \\ &= C(k', l', 3) - C(k', l', 2). \end{aligned}$$

Thus, we may use  $\beta_{col}(k', l', m')$  to identify

$$f(k', l', m', 3) - f(k', l', m', 2)$$

which identifies  $\beta_{pri}(k', l', m')$  as well.

In addition,  $\gamma$ s are identified, given the identification of  $C(k', l', 3) - C(k', l', 1)$ , and  $C(k', l', 2) - C(k', l', 1)$  and the support conditions for the two remaining transition patterns. If the transition  $(d', d) = \{3, 1\}$  satisfies the support condition, then we have

$$\begin{aligned} E[\mathcal{Y}_t | k', l', 1, \mathcal{Y}, k, l, 1] - E[\mathcal{Y}_t | k', l', 3, \mathcal{Y}, k, l, 1] \\ = C(k', l', 3) - C(k', l', 1) + h(\omega, 0, 0) - h(\omega, 1, 0), \end{aligned}$$

where  $\omega \equiv \mathcal{Y} - C(k, l, 1)$ , so that  $\gamma_{pri}(\omega)$  is identified. If instead the transition  $(d', d) = \{2, 1\}$  satisfies the support condition, then  $\gamma_{pri}(\omega')$  is identified by the same kind of equation with  $\omega' \equiv \mathcal{Y} - C(k, l, 2)$ .

Finally,  $\gamma_{col}(\omega)$  is identified as follows:

$$\begin{aligned} E[\mathcal{Y}_t | k', l', 1, \mathcal{Y}, k, l, 1] - E[\mathcal{Y}_t | k', l', 2, \mathcal{Y}, k, l, 1] \\ = C(k', l', 2) - C(k', l', 1) + h(\omega, 0, 0) - h(\omega, 0, 1). \end{aligned}$$

■

## B.4 The GNR Estimation Procedures

Section 4.4 sketched the GNR's estimation method; this Appendix section provides a longer version with more details.

GNR's first stage focuses on the role of the "flexible" input,  $m_{it}$ . By "flexible," GNR mean the factor that can be flexibly adjusted within the same period, after the firm observes  $\omega_{it}$ . The firm's first-order condition with respect to  $m_{it}$  is

$$P_t \frac{d}{dM_t} F(k_t, l_t, m_t, d_t) e^{\omega_t} E[e^{\varepsilon_t}] - p_t = 0, \quad (15)$$

where we suppressed subscript  $i$  for simplicity.  $P_t$  and  $p_t$  are the prices of output and materials, respectively;  $M_t$  is the non-log version of  $m_t$ ; and  $F(\cdot)$  is the non-log counterpart of  $f(\cdot)$ . Transform (15) into a log additively separable form as follows:

$$s_t \equiv \log \frac{p_t M_t}{P_t Y_t} = \underbrace{\log E[e^{\varepsilon_t}] + \log \frac{\partial}{\partial m_t} f(k_t, l_t, m_t, d_t)}_{\equiv \log D^\varepsilon(k_t, l_t, m_t, d_t)} - \varepsilon_t, \quad (16)$$

where  $s_t$  denotes the logged revenue share of the expenditure on materials,  $Y_t$  is the non-log counterpart of  $y_t$ , and  $D^\varepsilon(\cdot)$  is a nonparametric function that subsumes the first two terms on the RHS. We estimate the partial derivative  $\frac{\partial}{\partial m_t} f(k_t, l_t, m_t, d_t)$  by the following nonlinear

least squares calculation:

$$\min_{\theta_d} \sum_t \{s_t - \log D^\varepsilon(k_t, l_t, m_t, d_t; \theta_d)\}, \quad (17)$$

where  $D^\varepsilon(k_t, l_t, m_t, d_t; \theta_d)$  is a polynomial sieve approximation (parameterized by  $\theta_d$ ) of  $D^\varepsilon(\cdot)$ . In this manner, we may identify and estimate the slope of the production function with respect to the flexible input (i.e.,  $m_t$ ).

The second stage of GNR recovers the part of  $f(\cdot)$  that relates to “predetermined” inputs ( $k_t, l_t, d_t$ ) from the slope estimate, as well as the law of motion for  $\omega_t$ ,  $h(\cdot)$ . Given the identification of  $D^\varepsilon(\cdot)$ , the production function  $f(\cdot)$  is identified up to an integration constant,  $C$ , as a function of  $(k_t, l_t, d_t)$ :

$$f(k_t, l_t, m_t, d_t) + C(k_t, l_t, d_t) = \int \frac{D^\varepsilon(k_t, l_t, m_t, d_t)}{E[e^{D^\varepsilon(k_t, l_t, m_t, d_t; \theta_d)} - s_t]} dm_t \equiv \mathcal{D}^\varepsilon(k_t, l_t, m_t, d_t), \quad (18)$$

where  $\mathcal{D}^\varepsilon(\cdot)$  is a nonparametric function. Let

$$\begin{aligned} \mathcal{Y}_t &\equiv \log \frac{Y_t}{e^{\varepsilon_t} e^{\mathcal{D}^\varepsilon(k_t, l_t, m_t, d_t)}} \\ &= y_t - \varepsilon_t - f(k_t, l_t, m_t, d_t) - C(k_t, l_t, d_t) \\ &= -C(k_t, l_t, d_t) + \omega_t, \end{aligned} \quad (19)$$

where we used the definition of the production function in (2) in the second equation. We may replace  $\omega_t$  in equation (19) with the Markov process in (3), and rewrite

$$\begin{aligned} \mathcal{Y}_t &= -C(k_t, l_t, d_t) + h(\omega_{t-1}, \text{collectivized}_t, \text{privatized}_t) + \xi_t \\ &= -C(k_t, l_t, d_t) + h(\mathcal{Y}_{t-1} + C(k_{t-1}, l_{t-1}, d_{t-1}), \text{collectivized}_t, \text{privatized}_t) + \xi_t. \end{aligned} \quad (20)$$

To approximate  $C(\cdot)$  and  $h(\cdot)$  in the above, we use polynomial sieves,  $C(k_t, l_t, d_t; \theta_c)$  and  $h(\omega_{t-1}, \text{collectivized}_t, \text{privatized}_t; \theta_h)$ , respectively. Regress  $\mathcal{Y}_t$  on these sieves to estimate the law of motion by OLS, and calculate  $\hat{\xi}_t$  as its residual. We employ GMM to find  $(\theta_c, \theta_h)$ , the parameters of the polynomial sieves, that satisfy moments of the form

$$E \left[ \hat{\xi}_{it} k_{it}^{a_k} l_{it}^{a_l} \right] = 0 \text{ and} \quad (21)$$

$$E \left[ \hat{\xi}_{it} k_{it}^{a_k} l_{it}^{a_l} d_{it}^\tau \right] = 0, \quad (22)$$

where  $0 \leq a_k + a_l \leq 2$  and  $\tau \in \{\text{col}, \text{pri}\}$ . Thus, the second stage of GNR amounts to a nonparametric version of the familiar, nonlinear GMM procedure as in OP, LP, and ACF.

## C.1 “New Products”

The ASIE records the revenue from “new products” as a separate item. The definition of “new” is relative and firm-year specific. A product is “new” during the current year if the firm has not developed and marketed it until then. In this respect, the definition of “new product” does not necessarily reflect the objective novelty of the products, and is similar to

that of the “product innovation” record in the European community surveys. We do not take a stand on what the “right” definition of innovation is, or whether such self-reported measures are meaningful. Instead, we run regressions with similar specifications to those we used in our main analysis, and try to understand the characteristics of such data.

Table 12: “New Products” and Ownership Type

Sample: LHS: New products (fraction of revenues)	Full sample			Subsample ( $> 0$ )		
	(1)	(2)	(3)	(4)	(5)	(6)
Constant	0.0400 (0.0012)	0.0331 (0.0011)	-0.0016 (0.0015)	0.2758 (0.0054)	0.2815 (0.0057)	0.1355 (0.0287)
Collective ( $\beta_{col}$ )	-0.0029 (0.0014)	-0.0052 (0.0014)	-0.0033 (0.0015)	0.0393 (0.0069)	0.0435 (0.0072)	0.0481 (0.0071)
Collectivization ( $-\gamma_{col}$ )	0.0270 (0.0033)	0.0297 (0.0033)	0.0250 (0.0032)	-0.0290 (0.0109)	-0.0335 (0.0110)	-0.0330 (0.0108)
Private ( $\beta_{pri}$ )	-0.0118 (0.0017)	-0.0210 (0.0018)	-0.0178 (0.0019)	0.0680 (0.0109)	0.0793 (0.0118)	0.0785 (0.0118)
Privatization ( $-\gamma_{pri}$ )	-0.0029 (0.0018)	0.0026 (0.0018)	0.0027 (0.0018)	-0.0110 (0.0158)	-0.0157 (0.0158)	-0.0073 (0.0158)
Year dummy	No	Yes	Yes	No	Yes	Yes
2-digit CIC dummy	No	No	Yes	No	No	Yes
Number of observations	180,825	180,825	180,825	21,569	21,569	21,569
Adjusted $R^2$	0.0016	0.0077	0.0446	0.0065	0.0094	0.0443

Note: SOE, 1998-99, and CIC13 are the omitted categories. Standard errors (in parentheses) are clustered by firm.

In Table 12, the first three columns regress the fraction of revenue from new products on ownership types (and the indicators of their changes) using OLS. Surprisingly, SOEs (the omitted category) seem more active in “product innovation” than the other two types. Column 1 shows SOEs earn 4% of revenues from new products on average, whereas the corresponding numbers for collectives and private firms are 3.71% and 2.82%, respectively. The inclusion of year and CIC dummies in columns 2 and 3 does not change their ranking. This result is a stark contrast to the superior TFP performance of private firms in section 4.

Another important feature of the “new products” variable is that only 21,569, or 11%, of firm-year observations record positive numbers. Once we focus on this subsample (with non-zero revenue from new products), the signs on the collective- and private-ownership dummies become positive in columns 4, 5, and 6. Within this subsample, new products account for 13.55% of revenues at SOEs, 18.36% at collectives, and 21.4% at private firms (column 6). Thus, conditional on reporting new products, private firms earn greater fractions of revenues from new products than SOEs and collectives.

The initial gap between always-private firms and just-privatized firms ( $\gamma_{pri}$ ) exists but is small relative to  $\beta_{pri}$ , which means the immediate gain is substantial. By contrast, the immediate gains from collectivization is smaller (i.e., the magnitude of  $\gamma_{col}$  is close to that of  $\beta_{col}$ ). These patterns are similar to our findings on TFP in section 4.

The discrepancy between the full sample (columns 1, 2, and 3) and the subsample (columns 4, 5, and 6) suggests important heterogeneity among private firms. However, the subjective nature of “new product” record precludes any definitive conclusions based on

this analysis alone.<sup>31</sup>

## C.2 Chinese Patents

Besides TFP and new products, patents are an obvious measure of innovative activities. However, the Chinese patent statistics portray a puzzling picture. Table 13 reports probit and Poisson regressions of patents on ownership types, in a manner that is comparable to the estimation of TFP.

The summary statistics in the Appendix (Table 10) show the average number of patent applications per firm-year is  $0.1150 + 0.0614 + 0.0644 = 0.2408$  across three types of patents, which are type 1 (invention), type 3 (design), and type 4 (utility). Type-1 patent applications undergo nontrivial examinations and about half of them are rejected. Thus, columns 2 and 6 of Table 13 focus on type-1 patent applications that are subsequently approved (“granted”). The average number of patents is very low because less than 1% of all observations contain a non-zero number of patents. Hence, we use binary probit in columns 1 through 4, with an indicator of non-zero patent as the dependent variable (i.e.,  $y_{it} = 1$  if  $\#patents_{it} > 0$  and  $y_{it} = 0$  otherwise). Collectives exhibit higher propensities to obtain patents than SOEs, whereas private firms look worse than SOEs except for type-4 patents.

Table 13: Chinese Patents and Ownership Type

Sample: Method: LHS variable:	Full sample				Subsample ( $\#patents_{it} > 0$ )			
	Probit $\{y_{it} = 1 \text{ if } \#patents_{it} > 0\}$				Poisson			
	Type 1 (1)	Granted (2)	Type 3 (3)	Type 4 (4)	Type 1 (5)	Granted (6)	Type 3 (7)	Type 4 (8)
Collective ( $\beta_{col}$ )	0.0894 (0.0339)	0.1001 (0.0393)	0.0621 (0.0289)	0.1667 (0.0320)	1.1677 (0.5940)	1.5081 (0.6917)	0.0760 (0.1730)	0.6027 (0.1490)
Collectivization ( $-\gamma_{col}$ )	0.0736 (0.0607)	0.0702 (0.0724)	0.2704 (0.0476)	0.2168 (0.0532)	-1.8611 (0.9725)	-1.9648 (1.0930)	-0.1442 (0.1486)	-0.3781 (0.2118)
Private ( $\beta_{pri}$ )	-0.2674 (0.0452)	-0.2854 (0.0393)	-0.2273 (0.0403)	0.0213 (0.0445)	-0.7789 (0.4728)	-0.2778 (0.4368)	-0.2285 (0.2334)	1.4649 (0.5123)
Privatization ( $-\gamma_{pri}$ )	0.0170 (0.0512)	0.0321 (0.0734)	0.0207 (0.0505)	0.0161 (0.0560)	-0.4619 (0.6272)	-1.0947 (0.6539)	-0.3447 (0.2024)	-0.6590 (0.5863)
Year dummy	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
2-digit CIC dummy	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Number of observations	195,980	195,980	195,980	195,980	2,209	1,441	3,511	2,067
(Pseudo) $R^2$	0.1330	0.1392	0.1374	0.1030	N/A	N/A	N/A	N/A
Log likelihood	-10,494	-7,330	-15,182	-10,284	-48,715	-30,705	-12,795	-15,133

Note: SOE is the omitted ownership-type category. Standard errors (in parentheses) are clustered by firm.

Unlike the analysis of “new products” in the previous subsection, conditioning on non-zero observations does not completely alter the pattern. Columns 5 through 8 use count-data (Poisson) regression for the very small subsample with positive patents. The patterns are qualitatively similar to the probit results on the full sample, with collectives’ out-performance

<sup>31</sup>For example, we could imagine many private firms simply did not bother reporting true numbers for such an ambiguous survey item.

and private firms' under-performance relative to SOEs (with the exception of type-4 patents again). Large standard errors and the small subsample size suggest firms are heterogeneous and only a few of them patent. Thus, patents are interesting but do not seem to reveal much about the mechanism that links privatization and productivity.

We suggest two directions of interpretation. One is to assume patents reflect genuine technical progress, in which case SOEs might be innovative in terms of science and engineering but struggle to commercialize and monetize these efforts relative to private firms. This interpretation broadly agrees with the assessment of SOEs by *The Economist's* special report, in which a senior foreign executive is quoted as saying, "SOEs have the smartest people in science and technology but cannot get a branded product out the door."<sup>32</sup> Engineers at SOEs could also be working on more "basic" sciences than "applied" ones that are readily commercialized, in which case the public and private R&D efforts play qualitatively different roles.

Another interpretation is to temporarily forget about the intrinsic contents of Chinese patents, and consider firms' incentives for patent applications. Patents have increasingly become a direct target of the governments' economic policy and evaluation criteria for the allocation of subsidies. Under the banner of "indigenous innovation," central planners have set the national targets for the number of patents (14 per 10,000 people by 2020) and R&D spending (2.8% of GDP, which is America's current rate). The number of patent applications has soared, but many are deemed worthless, according to *The Economist* and WIPO.

As Griliches (1990) cautioned, statistics become useless as a truthful measure of the underlying economic activities when they are tied to rewards or punishments, because firms will respond to such incentives. This microeconomic view would suggest that, ceteris paribus, the results reflect greater political incentives to file patent applications among SOEs relative to private firms, because the managers of SOEs are evaluated based on not only purely economic standards, but also politically relevant performance criteria (e.g., "political aptitude;" see section 5.1). Igami and Subrahmanyam's (2015) study of U.S. patents in the hard disk drive industry found that even among American high-tech firms of equal innovativeness (measured by the quality of new products), systematic heterogeneity in patenting propensity exists between different types of firms, such as established conglomerates and specialized startups. Thus, we would expect different incentives to patent between SOEs and private firms in China.

The truth should lie somewhere in the middle, but both of these two logical possibilities suggest we need to use caution when we interpret patent statistics as an indicator of innovative activities. The first view would highlight the discrepancy between invention and commercialization, pointing to the contrast between SOEs' under-performance in TFP and superior patenting records; the second view would emphasize the political economy of heterogeneous incentives across different types of firms and caution against the pitfall of using economic statistics as a monitoring device when they are tied to rewards such as subsidy and promotion.

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<sup>32</sup> "Back to business: Special Report on Business in China," September 12, 2015.

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