Firm Dynamics and SOE Transformation During China's Economic Reform*

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Abstract

We study China's state-owned enterprises (SOE) reform with a focus on the corporatization of SOEs. We first empirically document that small SOEs are more likely to exit or become privatized, whereas big SOEs are more likely to be corporatized while remaining under state ownership. We then build a three-sector heterogeneous-firms model featuring financial frictions, firm dynamics, and endogenous firm-type choices. Our calibrated model suggests that in the long run, the exit of the inefficient firms in the state sector improves TFP by facilitating resource reallocation to the private sector. In the short run, corporatization increases aggregate output by allowing the most productive SOEs to have a higher borrowing capacity than privatization.

JEL classification: E23, E44, O16, O41, O43, O53

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1 Introduction

A large body of literature (e.g, Hsieh and Klenow (2009) , Song, Storesletten, and Zilibotti (2011)) argues that China's economic growth since the Economic Reform is mainly driven by the reallocation of resources from the less efficient state sector to the more efficient private sector. However, most existing papers ignore the heterogeneous performance of firms in the state sector. Although the output share of the state sector in the aggregate economy declines, individual firms in the state sector become larger and more profitable on average. Our paper fills this gap by studying the transformation in the state sector with a special focus on the corporatization of state-owned enterprises (SOEs) during the transition period after the Economic Reform.

We first empirically document that small SOEs are more likely to exit or become privatized, whereas big SOEs are more likely to become corporatized while remaining state-owned. To quantify the effect of the SOE reform on the aggregate economy, we build a heterogeneous-firms model with endogenous entry and exit, financial frictions, and optimal firm-type choices. In line with the actual policy, we model the SOE reform as allowing incumbent SOEs to make optimal decision between corporatization, privatization, and exiting the market. The parameterized version of our model suggests that in the long run, the SOE reform increases aggregate output mainly by the exit of inefficient firms in the state sector, which facilitates resource reallocation both within the state sector and between the state and the private sector. In the short run, the corporatization of SOEs slows down the resource reallocation to the private sector but increases aggregate output by as much as 5 percent, compared to the counter-factual reform where SOEs are only allowed to become privatized or exit the market.

We start the analysis by empirically documenting the SOE reform using firm-level data from the Annual Survey of Industries. We show the important trend of corporatization of SOEs: since the late 1990s, there are an increasing number of firms that are owned by the state (the state government holds a controlling share of equity in the firm) but are registered as non-SOE corporations. We name this type of firms CSOEs (corporatized state-owned enterprises) to distinguish them from the traditional SOEs.

To study the impact of SOE reform on the state sector (including both SOEs and CSOEs), we first show that at the aggregate level, the output share of the state sector significantly declined. However, the average size of firms in the state sector increased relative to that in the private sector. We further find that this difference at the aggregate and at the individual-firm level is a consistent of the *"grasp the large and let go of the small"* policy, which was implemented in the SOE reform starting from 1999. Namely, small SOEs either exit or become privatized, whereas big SOEs are corporatized and remain in the state sector. The regression analysis illustrates that after an SOE transforms to a POE or a CSOE, it becomes more productive, starts to de-leverage, and its output growth rate increases.

To explain these empirical patterns and quantify the aggregate effects of the SOE reform, we build a heterogeneous-firms model with endogenous entry and exit based on Jovanovic (1982) and Hopenhayn (1992). To capture the firm dynamics that are specific to China's Economic Reform, we augment the model in three dimensions. First, we assume that firms are subject to collateral constraints, similar to Evans and Jovanovic (1989), Buera and Shin (2013), and Gavazza, Mongey, and Violante (2018). Second, we model a three-sector economy (SOE, POE, and CSOE sector) and discipline sector-specific characteristics using micro data. Third, we model SOE reform as allowing incumbent SOEs to optimally choose between corporatization, privatization, and exiting the market. In this way, our model generates endogenous firm measure, firm size, and market shares in different sectors, which allows us to quantify the effect of SOE reform.

In our model, SOEs, CSOEs, and POEs operate under the same decreasing returns to scale technology, but are different in borrowing constraints, borrowing costs, fixed cost of operation, production efficiency, and discount rate. Prior to the SOE reform, all firms make endogenous entry and exit decisions, and the life-cycle decisions of firms are identical across all sectors. Once the SOE reform starts, a fraction of SOEs receive a reform shock in each period. If hit by the shock, an SOE has the opportunity to transform to a CSOE or a POE and continue its operation, in addition to its exit option.

We discipline our model parameters to match the firm-level empirical moments in the pre-reform period. Our calibration suggests that SOEs are 24 percent less efficient in production than POEs, but their borrowing capacity is substantially higher. This explains the coexistence of a small average output and a big share of capital used in the SOE sector in the pre-reform period. In addition, SOEs have a smaller entry cost and a smaller exit value. This is consistent with the empirical fact that SOEs are less efficient but rarely exit the market before the SOE reform.

With these estimated parameters, we quantitatively assess the impact of the SOE reform on the aggregate economy. We first study the long-run effects by comparing the post-reform final steady state to the pre-reform initial steady state. We find that in the long run, replacing SOEs with CSOEs increases aggregate output by 13.1 percent from the initial pre-reform steady state. Next, we perform a decomposition analysis to show how each difference between CSOEs and SOEs contributes to the overall gain of the corporatization in the state sector. We find that the higher exit cutoff contributes the most, which forces the least productive firms to exit the economy. This facilitates resource reallocation both within the state sector and between the state and the private sector. As a result, both TFP and aggregate output increase.

Lastly, we study the short-run effects of the SOE reform on the transition path. Our model predicts that, when given the transformation option, incumbent SOEs with a high technology level choose corporatization, whereas those with a low technology level choose to be privatized or exit the economy. The intuition is that an incumbent SOE weighs the benefit of corporatization - a higher borrowing capacity, and the cost of corporatization - a lower gain in production efficiency. When the incumbent SOE is very productive, the benefit of corporatization outweighs the cost. Under this decision rule, the SOEs that are corporatized are larger than those that are privatized or that exit. Therefore, our model reconciles the empirical finding that the average firm size in the state sector (including both SOEs and CSOEs) increases, while the output share of the state sector decreases.

To quantify the short-run impacts of the SOE reform on the aggregate economy and highlight the importance of the corporatization option, we conduct a counter-factual analysis where SOEs are only given two options: privatization or exiting the market. We find that compared to the actual reform, this privatization-only reform accelerates resource reallocation to the private sector but leads to a smaller gain in aggregate output by as much as 5.0 percent. This difference is mainly due to the fact that without the corporatization option, high productivity SOEs now have to turn to POEs instead of CSOEs and thus face tighter borrowing constraints, which limits their production capacity. The difference in aggregate output between the actual and the counter-factual policies diminishes over time, as POEs gradually accumulate asset to overcome financial frictions.

Related Literature

Our paper builds on the large body of literature studying economic growth in China. Earlier work focuses on identifying the sources of China's economic growth. Evidence has shown that both improvement in TFP and capital deepening contribute to the sustained output growth in China. (See Young (2003), Bosworth and Collins (2008), and Brandt and Zhu (2010), among others.) The recent literature focuses on modeling resource reallocation as the source of TFP improvement, either between the state and the private sector, (Song, Storesletten, and Zilibotti (2011), Brandt, Tombe, and Zhu (2013), Curtis (2016), and Zhu (2012)) or between the heavy-industry and the light-industry sector (Chang et al. (2016))

Different from all the above-mentioned papers, our paper models a three-sector economy and focuses on the corporatization of SOEs. Our paper is most closely related to Hsieh and Song (2015) and Peng (2019), both of which focus on China's SOE reform. Hsieh and

Song (2015) are the first to empirically document that the Economic Reform in China has heterogeneous effects on state-owned enterprises, which can be summarized as *"grasp the large and let go of the Small."* Peng (2019) theoretically models endogenous exit of SOEs by adding non-negative equity constraints to all SOEs after the reform. The main novelty of our paper is that we model the optimal transformation decision of SOEs between corporatization, privatization and exiting the market.

Our model builds on the emerging literature on the role of an imperfect financial market in the dynamics of economic reform or external shocks. A large body of literature uses the dynamic entrepreneurship model developed by Cagetti and De Nardi (2006) and Buera, Kaboski, and Shin (2011) to study the dynamics of TFP (for example, Jeong and Townsend (2007), Caballero, Farhi, and Gourinchas (2008), Buera and Shin (2013), Moll (2014), Midrigan and Xu (2014), Buera and Shin (2017), and Gopinath et al. (2017), among others).

More generally, our paper also contributes to the literature on misallocation pioneered by Restuccia and Rogerson (2008) and Hsieh and Klenow (2009). Specific to the Chinese economy, Bai, Lu, and Tian (2018) find endogenous borrowing constraints can explain one third of TFP loss measured in Hsieh and Klenow (2009). David and Venkateswaran (2019) find that firm-specific factors, especially size-dependent government policies and distortions caused by financial market imperfections, account for around 40 percent of TFP loss.

2 Empirical Evidence

We begin this section by providing an overview of the institutional background of China's Economic Reform. The institutional background helps us to identify corporatized SOEs from the conventional definition of SOEs, which is a key concept in this paper.

We then present a set of empirical findings based on firm-level data from the Annual Survey of Industries (ASI) conducted by China's National Bureau of Statistics.[1] This data set contains all state-owned firms and private firms in the industrial sector whose annual revenue equals or exceeds 5 million RMB.[2] Our sample period is from 1998 to 2007, which covers the pre-reform period and the post-reform transition period.[3] We restrict our sample to firms with positive value-added, positive capital, positive labor, and positive total assets, and in operation. A detailed description on our data cleaning procedure is provided in Appendix A.

[1] The aggregate data on Chinese industrial firms are available at http://www.stats.gov.cn/tjsj/ The firm-level data are not publicly available.

[2] The threshold increased to 20 million RMB in 2011.

[3] Another reason we use the data only through 2007 is that some variables are no longer reported for the full set of firms after 2007.

2.1 Institutional Background

China's Economic Reform started in 1978, setting off China's transition from a planned economy to a market economy. The Economic Reform has gone through several phases. In the first phase leading up to the late 1980s, the reform focused on agriculture in rural areas. For the manufacturing and service sectors, most market-oriented economic policies were only effective in the "special economic zones" such as Shenzhen and Zhuhai. After Deng Xiaoping's 1992 southern tour, the reform was resumed and was extended to the whole country. In this second phase, a set of policies were established to encourage the entry of private firms, including the first Corporation Law, which was enacted in 1993.

This paper focuses on the third phase of the reform, which started in 1998 and was led by the then Premier, Zhu Rongji. Before 1998, the manufacturing sector was dominated by SOEs, and many of them were thought to be inefficient. In 1995 and 1996, around 50 percent of the SOEs reported losses (Meng (2003)), but very few SOEs ever went bankrupt. To improve efficiency and to stem the losses of SOEs, the Chinese government announced the SOE reform at the Fifteenth Communist Party Congress in September 1997, with more implementation details laid out in Zhu Rongji's 1999 state council government report. According to the report, the goal of the SOE reform was summarized as "grasp the large and let go of the small."

To achieve this goal, small SOEs were either sold to private owners or liquidized. Big SOEs were incorporated as limited liability corporations. The state government does not directly operate these corporatized SOEs. Instead, the state government established industrial conglomerates to serve as parent companies and hold shares of these corporatized SOEs. In the rest of this section, we provide firm-level evidence of what types of SOEs become corporatized and how these corporatized SOEs perform during the transition period.

2.2 Definition of State Ownership

Since the onset of the SOE reform, the definition of state ownership becomes less clear-cut. Our data provide two types of information on state ownership. The first type of information is the firm's registration type, which has six categories: (1) state-owned, (2) collectively owned (including state jointly owned), (3) privately owned, (4) limited liability corporations, (5) share-holding firms (including publicly traded), and (6) Hong Kong, Macao, Taiwan or foreign owned. The second type of information is the controlling share of a firm, which shows whether the state has (1) an absolute controlling share, (2) a relative controlling share, or

(3) no controlling share of the firm.[4]

The existing literature uses either firm registration type (for example, Bai, Lu, and Tian (2018)), or the controlling share of a firm (for example, Hsieh and Song (2015))[5] to categorize state owned versus privately owned. However, these two definitions of ownership do not always overlap. We use the Sinopec Beijing Yanshan Petrochemical Company as an example. In 2002, this firm's registration type changed from state owned to a limited liability corporation, but the state government continues to have absolute controlling share of this company. The company's registered capital is 100 percent owned by its parent holding company, China Petrochemical Corporation, a state-owned conglomerate administered by SASAC (State-owned Assets Supervision and Administration Commission).[6] The Sinopec Beijing Yanshan Petrochemical Company is a private firm by registration type, but a state-owned company by its controlling share. This is an example illustrating how some state-owned enterprises have changed during the transformation: they have become modern corporations while continuing to be owned by the state government.

Instead of defining state-owned enterprises by either registration type or controlling share, we define three types of firms, making use of both types of information. Specifically, we define traditional state-owned enterprises (SOEs) as firms that are state owned under both definitions. We define state-owned enterprises that have transformed into modern corporations as corporatized SOEs (CSOEs). Firms that are private firms by registration type and are not owned by the state government are privately owned enterprises (POEs). A summary of statistics of SOEs, CSOEs, and POEs under our definition is provided in Appendix A.

Since the onset of the SOE reform, the share of CSOEs in the state sector (including both SOEs and COSEs) has increased from around 10 percent in 1998 to over 60 percent in 2007, as shown in Figure 1. Three factors have contributed to this increase in the share of CSOEs in the state sector: 1) the exit of SOEs, 2) the corporatization of existing SOEs, and 3) the entry of new CSOEs. Figure 1 also shows the importance of the corporatization of existing SOEs, shown by the increasing share of transformed CSOEs among new CSOEs.

Table 1 further illustrates this large-scale reform in the state sector. First, the exit ratio among SOEs surged during the transition period. Among the SOEs that were in operation

[4] The data also provide another type of information indicating ownership type, which is the shares of the registered capital that owned by the state, by a collective, by private persons, by foreigners, and by legal person. However, we do not have additional information on whether the legal person of a firm represents a private person, a private firm, or a state-owned parent holding company. Therefore, we do not use shares of registered capital to define state ownership.

[5] Hsieh and Song (2015) use the combination of the controlling share of the firm and the shares of the registered capital to define state ownership.

[6] Ownership information for the Sinopec Beijing Yanshan Petrochemical Company is available at https://aiqicha.baidu.com

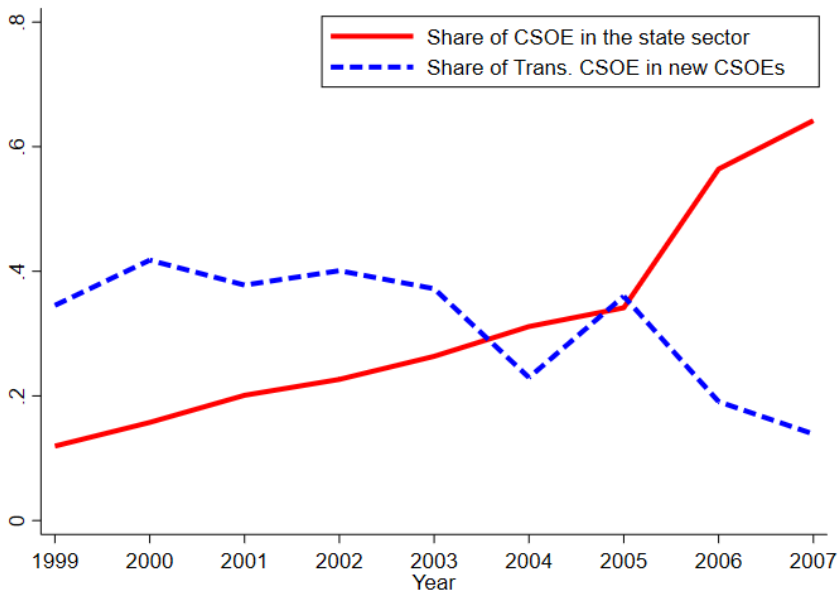

Figure 1: Share of CSOEs and Transformed CSOEs

Source: Authors' calculations based on ASI.

in 1998, around 70 percent of them had exited by 2007. This is in stark contrast to the pre-reform period, when very few SOEs ever went out of business.[7] In addition, the exit ratio of SOEs is significantly higher than the exit ratio of POEs during the same period.[8] Among the SOEs that survived through 2007, around 35 percent were privatized and 24 percent were corporatized. This number does not change much when we include foreign firms (firms whose registration type is Hong Kong/Macao/Taiwan or foreign owned) in the private sector.

2.3 Grasp the Large and Let Go of the Small

We have shown that at the aggregate level, a large fraction of SOEs have either exited or transformed to POEs or CSOEs since 1998. In this section, we investigate the heterogeneous performance of different types of firms during the transition period.

We begin by testing whether the transformation decisions of SOEs are consistent with the slogan of the reform, *grasp the large and let go of the small*. To do so, we first plot the state sector's share of output in the aggregate economy and the median output of the state

[7] The average annual exit rate for SOEs during 1991-1995 is 0.9 percent (Hsieh and Song (2015)).

[8] As the ASI only includes POEs above the scale of the annual revenue, the number of exited POEs in the table 1 is an overestimate of the actual number of exited POEs, because a drop in observation may also be caused by a revenue decline to below the scale.

	No. of firms		Employment	
	D only	F included	D only	F included
SOE in 1998	42.1	42.1	24.6	24.6
→ Exit by 2007	30.5	30.3	12.3	12.1
→ POE by 2007	4.2	4.4	2.0	2.1
→ CSOE by 2007	2.8	2.8	5.0	5.4
POE in 1998	23.9	43.0	5.0	10.0
→ Exit by 2007	15.0	26.0	3.1	5.3
→ SOE by 2007	0.1	0.1	0.05	0.06
→ CSOE by 2007	1.2	2.0	0.4	0.6

Table 1: Firm-Type Changes

Note: Number of firms and employment is in thousands. D stands for domestic firms and F stands for foreign firms. See Appendix A for the exact definition.
Source: Authors' calculations based on ASI.

(a) Output Share (b) Median Output

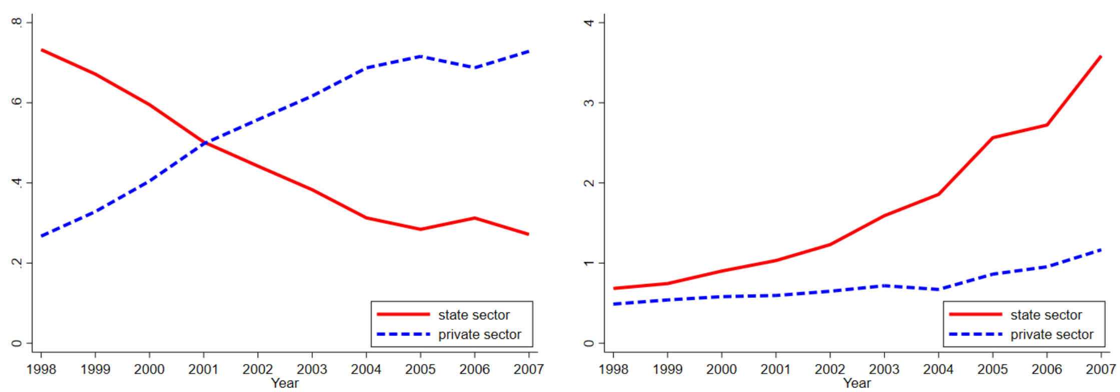

Figure 2: Output Share and Firm Size in the State and the Private Sector

Note: Output is defined by value added. Each firm's output is normalized by the mean within each industry.
Source: Authors' calculations based on ASI.

sector in Figure 2. To control for the industry effect, we normalize each firm's output by the mean within each industry.[9] Although the state sector's share of output in the economy decreases, it increases in firm size on average. This indicates that small SOEs either exited the market or changed to POEs. Larger SOEs, on the other hand, changed to CSOEs and stayed in the state sector.

To further examine the relationship between the transformation decision and output size, in Figure 3 we plot the fraction of exited SOEs among all SOEs and the fraction of corporatized SOEs among all transformed SOEs (either privatized or corporatized) on each

[9]We define industry at the 2-digit level.

(a) Share of Exited SOEs (b) Share of Corporatized SOEs

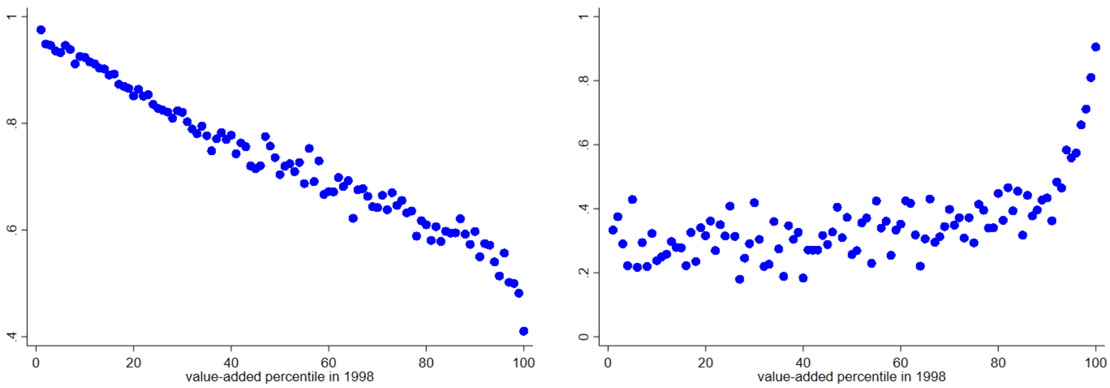

Figure 3: Exit and Corporatization Ratio by Output Size

Panel (a) calculates the percentage of SOEs that exited the market by 2007 for each size bin defined by percentiles of the firms' value added in 1998. Panel (b) calculates the ratio of corporatized SOEs over transformed SOEs (including both privatized and corporatized) for each size bin under the same definition for the balanced panel between 1998 to 2007. Each firm's output is normalized by the mean within each industry.

size bin defined by their value added in 1998. It shows that the exit ratio significantly reduces with the size of value added of the SOEs. For the transformed SOEs, larger SOEs are more likely to become corporatized rather than become privatized. These patterns are consistent with the official slogan of the SOE reform, *grasp the large and let go of the small*. The implementation is imperfect, however, as there are also small SOEs become CSOEs rather than POEs.

How have firms changed after transformation? To study this question systematically, we regress variables of interest on firms' type (SOE, CSOE, POE) with interaction terms that indicate the time of the transformation. Table 2 reports the regression results.

Table 2 shows that compared to SOEs, POEs and CSOEs have higher productivity in terms of both capital and labor. The gap in labor productivity between POEs and CSOEs is smaller than the gap in capital productivity. The coefficients on transformation terms show that when an SOE transforms to a POE or a CSOE, its productivity increases gradually, but does not catch up to the productivity level of a corresponding POE or CSOE within two years.

For leverage, both POEs and CSOEs borrow less than SOEs. After an SOE transforms to a POE or CSOE, it starts to gradually de-leverage. The results also show that a privatized SOE no longer enjoys a low borrowing rate. The output growth of POEs is the fastest, followed by CSOEs and SOEs. When an SOE transforms to a POE or CSOE, its growth rate increases immediately. In addition, a transformed CSOE grows faster in the year of

Variables	$log(Y/K)$	$log(Y/L)$	leverage	output growth
POE	0.8645***	0.7950***	-0.1616***	0.1886***
	(0.0052)	(0.0041)	(0.0013)	(0.0053)
CSOE	0.5474***	0.6124***	-0.1166***	0.0467***
	(0.0065)	(0.0052)	(0.0017)	(0.0076)
POE Trans.	-0.4621***	-0.4486***	0.1105***	-0.0211
at t	(0.0119)	(0.0098)	(0.0031)	(0.0158)
POE Trans.	-0.3358***	-0.3156***	0.0886***	-0.0487*
at $t-1$	(0.0133)	(0.0110)	(0.0035)	(0.0179)
CSOE Trans	-0.2820***	-0.2844***	0.0627***	0.0619***
at t	(0.0129)	(0.0107)	(0.0034)	(0.0175)
CSOE Trans	-0.2552***	-0.2454***	0.0563***	-0.0229
at $t-1$	0.0153	(0.0128)	(0.0041)	(0.0210)
Observations	1,382,668	1,382,668	1,382,668	951,647
R-Squared	0.1887	0.2648	0.0400	0.0147
Year FE	Yes	Yes	Yes	Yes
Industry FE	Yes	Yes	Yes	Yes

Table 2: The Effects of SOE Transformation

Note: Leverage is defined as total debt over total assets. Output is defined by value added in nominal value. Trans. at t means the firm is an SOE in year $t-1$ and a POE or CSOE in year t. For the regression of output growth reported in column (5), we dropped observations whose output growth rate is greater than 1000 percent, as such output changes are more likely due to mergers and acquisitions instead of business operations. All regressions control for the industry effect and year fixed effect.

transformation than the average growth rate of all CSOEs.

In conclusion, we find empirical evidence suggesting that small SOEs either exit or become privatized, whereas big SOEs become corporatized. After an SOE transforms to a POE or a CSOE, it becomes more productive, starts to de-leverage, and its output growth rate increases.

3 Model

We build on a firm dynamics model in which firms are heterogeneous in productivity and asset levels and make endogenous entry or exit decisions. To capture the specific features in the Chinese economy, we augment this model in three dimensions. First, firms face borrowing constraints and can overcome the constraints by accumulating assets. Second, the economy has three sectors (SOE, CSOE, and POE sectors), and firms in different sectors differ in production efficiency, and borrowing capacity, among others. Third, SOE reform is modeled as allowing an SOE to choose between continuing production as a CSOE or as a POE, or exiting the market.

In this section, we first describe the model environment in Section 3.1. Then, we present the firm optimization problems in the pre-reform period in Section 3.2 and post-reform period in Section 3.3.

3.1 Environment

The economy has three sectors in the economy, i.e., SOE sector (s), POE sector (p), and CSOE sector (c). Each sector is populated by a continuum of firms. In what follows, we use $i \in \{s,c,p\}$ to index firms in different sectors. The distinct features of each sector are specified below.

Production function. Firms are heterogeneous in their assets a, which are endogenously accumulated, and productivity z, which follows an AR(1) process, which is given by

$$\log(z') = \rho \log(z) + \epsilon \tag{1}$$

where $\epsilon \sim \mathrm{N}(0,\sigma)$ and is *i.i.d.* across all firms.

Firms have access to a decreasing-returns-to-scale production technology that combines two factors of inputs: labor l and capital k. The production function takes a standard Cobb-Douglas form given by

$$f(z,k,l) = z(k^{\alpha} l^{1-\alpha})^{\gamma}, \tag{2}$$

where $\gamma < 1$ is the span-of-control parameter. A share γ of output goes to factors of inputs. Out of this, a fraction of α goes to capital and $1-\alpha$ goes to labor. The output of production is a homogeneous final good, whose competitive price is the numéraire of the economy. We assume that the production technology and the process of productivity shocks do not vary across sectors.

Profit maximization problem. Incumbent firms solve a static profit maximization problem in every period. Their profit depends on productivity level z and assets a that are chosen in the previous period.

Given the wage rate w and the borrowing interest rate r^i, firms maximize their operating profit by choosing the optimal capital and labor. There exists a collateral constraint that limits the maximum amount of capital a firm can rent:

$$k \leq \lambda^i a, \tag{3}$$

This upper bound of capital depends on a firm's asset level and the tightness of credit conditions, captured by the parameter λ^i.

Each firm has to pay a fixed operation cost $\chi^i z$ in every period. This cost is proportional to the firms' productivity, meaning that firms with a higher productivity level have to pay more fixed costs to continue their business.

The profit optimization problem is given by:

$$\pi^i(a,z) = \max_{k,l \geq 0} \left\{ (1-\eta^i) z (k^\alpha l^{1-\alpha})^\gamma - wl - (r^i + \delta)k - \chi^i z \right\} \tag{4}$$

subject to the collateral constraint in equation (3). δ is the capital depreciation rate, r^i is the sector-specific borrowing interest rate, and η^i is the sector-specific parameter augmenting firms' productivity. Note that we normalize $\eta^p = 0$, so $1 - \eta^i \leq 1$ captures the productivity inefficiency of SOEs and CSOEs relative to POEs.

In summary, the efficiency level, borrowing cost, borrowing capacity, and fixed cost of operation vary across sectors, all of which affect a firm's profitability.

Firm dynamics. Prior to the SOE reform, the life-cycle of firms is identical across sectors. Specifically, an exogenous measure M^i of potential entrants in sector i, ($i \in \{s, c, p\}$) decides whether to enter the market in every period. After entering the market, the firm becomes an incumbent firm. In each period, the incumbent firm choose whether to exit the market conditional on its new draw of productivity. Due to the endogenous entry and exit decisions, the firm measure in all sectors is endogenous.

All incumbent firms in this economy solve a two-stage optimization problem. In the first stage, conditional on their ownership type, i, asset a, and productivity draw z, they choose optimal capital and labor inputs to maximize their profits. In the second stage, conditional on their available resources, including after-tax profit and interest on corporate savings, incumbent firms choose their dividend payout d, and savings for the next period a'.

3.2 Firm Dynamics in the Pre-Reform Period

In this section, we describe the firm dynamics in the pre-reform period. We start by defining firms' entry and exit conditions and then characterize the dynamic optimization problem for incumbent firms.

Entry. A potential entrant in sector $i \in \{s, c, p\}$ with initial net worth a_0^i draws its initial productivity z from an initial distribution $\mu^*(z)$. Conditional on this draw, the firm decides whether to enter and become an incumbent through paying an entry cost κ_e^i. The discrete entry decision is characterized by the following condition:

$$max\left\{v^i(a_0^i,z)-\kappa_e^i,\bar{v}_e^i\right\} \tag{5}$$

where v^i is the value of an incumbent firm, a function of initial conditions (a_0^i,z). An entrant's value of being an incumbent firm $v^i(a_0^i,z)$, net of the entry cost κ_e^i, must be greater than the fixed parameter $\bar{v}_e^i$, which is the exit value of an incumbent firm in sector i.

We denote by $\xi_e^i(a_0^i,z)\in\{0,1\}$ the entry decision, which takes the value 1 if the firm chooses to enter the market and 0 otherwise. Moreover, because $v^i(a,z)$ is increasing in z, there exists an endogenous cutoff $\underline{z}^i$ such that for all $z\geq\underline{z}^i$, potential entrants choose to enter. The measure of entrants in sector i is given by

$$n_e^i=M^i\int\mathbb{I}\left\{\xi_e^i(a_0^i,z)=1\right\}d\mu^*=M^i\left[1-\mu^*(\underline{z}^i)\right], \tag{6}$$

where M^i is the mass of potential entrants in sector i.

Exit. Once it becomes an incumbent, the firm is allowed to endogenously exit the market. After observing its new productivity at the beginning of each period, the incumbent firm decides whether to exit by solving the following discrete-choice problem:

$$max\left\{v^i(a,z),\bar{v}_e^i\right\}, \tag{7}$$

where $\bar{v}_e^i$ is an exogenous parameter that reflects the exit value of incumbent firms in sector i.

We denote the exit decision by $\xi_x^i(a,z)\in\{0,1\}$, which takes the value 1 if the firm chooses to exit and 0 otherwise. The measure of incumbent firms in sector i is given by

$$n^i=n_e^i+n_-^i\int\mathbb{I}\left\{\xi_x^i(a,z)=0\right\}d\mu^i, \tag{8}$$

where μ^i is the distribution of incumbent firms in sector i at the beginning of a period and n_-^i is the measure of firms in the previous period.

Incumbent. For incumbent firms, their corporate income is derived from operating profits $\pi^i(a,z)$ and interest from assets ra. Firms that make positive profits are subject to a corporate income tax at the rate of τ_c. Incumbent firms in sector i solve the following recursive problem

$$v^i(a,z)=max\left\{log(d)+\beta^i\mathbb{E}_{z'}\left[max\left\{v^i(a',z'),\bar{v}_e^i\right\}\right]\right\} \tag{9}$$

subject to

$$d + a' = (1 + r)a + \pi^i(a,z) - \tau_c max\{\pi^i(a,z), 0\}, \tag{10}$$

$$d, a' \geq 0. \tag{11}$$

Equation (11) imposes the restriction that incumbent firms cannot borrow assets or issue dividends. Note that the continuation value $v^i(a', z')$ in equation (9) reflects incumbents' exit option in the following period.

3.3 Firm Dynamics in the Post-Reform Period

In this subsection, we present the firm dynamics problem after the start of the SOE reform. In the post-reform period, the firm dynamics of CSOEs and POEs are the same as in the pre-reform period. The change applies only to the SOEs.

Since the start of the SOE reform, a fixed fraction, θ, of incumbent SOEs receive a transformation shock. If hit by this shock, an SOE has the opportunity to transform to a CSOE or a POE (conditional on paying a transformation cost κ_{tr}^i, with $i \in \{c, p\}$.). All incumbent SOEs, whether hit by the transformation shock or not, continue to make exit decisions. The SOE chooses to exit if the values derived from both options are lower than the exit value of firms in both the CSOE and the POE sectors. Note that the transformation choice is permanent, which means that firms are not allowed to switch from POE/ CSOE to SOE again in the future.

If an SOE receives the transformation shock in this period, the SOE's transformation or exit decision is described by the following discrete-choice problem

$$v_{tr}^s(a,z) = max \left\{ \underbrace{min\{\bar{v}_e^c, \bar{v}_e^p\}}_{\text{Exit}}, \underbrace{v^c(a,z) - \kappa_{tr}^c}_{\text{SOE to CSOE}}, \underbrace{v^p(a,z) - \kappa_{tr}^p}_{\text{SOE to POE}} \right\}, \tag{12}$$

where the first term in the curly bracket is the value of exit, the second term is the value of transformation to a CSOE, and the third term is the value of transformation to a POE. Here, we assume that a transformed SOE can perfectly inherit its own assets and productivity.

We denote by $\xi_{tr}^s(a,z) \in \{0, 1, 2\}$ the transformation (or exit) decision of SOEs, which depends on a firm's level of assets and productivity. It takes the value 0 if the SOE chooses to exit, the value 1 if the SOE chooses to become a CSOE, and the value 2 if the SOE chooses to become a POE. The measure of transformed SOEs to sector i in period $t \geq 1$ is given by

$$n_{tr,t}^c = \theta n_{t-1}^s \int \mathbb{I}\left\{\xi_{tr,t}^s(a,z) = 1\right\} d\mu_t^s, \tag{13}$$

$$n^p_{tr,t} = \theta n^s_{t-1} \int \mathbb{I}\left\{\xi^s_{tr,t}(a,z) = 2\right\} d\mu^s_t, \tag{14}$$

where n^s_{t-1} is the measure of SOEs in period $t-1$, which will be specified next. Note that the reform shock hits the economy in $t = 1$ so that n^s_0 is the steady-state measure of SOEs (before the reform). In addition, μ^s_t is the distribution of incumbent SOEs over assets and productivity in period t. Notice that the measure of remaining SOEs geometrically decreases after the the reform begins.

In the post-reform period, the measure of incumbent firms in sector $i \in \{c, p\}$ is given by

$$n^i_t = n^i_{e,t} + n^i_{t-1} \int \mathbb{I}\left\{\xi^i_{x,t}(a,z) = 0\right\} d\mu^i_t + n^i_{tr,t}, \tag{15}$$

where $n^i_{e,t}$ is the measure of entrants, μ^i_t is the distribution of incumbent firms, and $\xi^i_{x,t}(a,z)$ is the exit decision of firms in sector i and period t. The difference between the measure of incumbent firms in the pre-reform period (equation (8)) and in the post-reform period (equation (15)) highlights the transformation decision of SOEs.

In addition to giving the transformation opportunity to incumbent SOEs, we also shut down SOE entry as another element of the SOE reform. Accordingly, the measure of incumbent firms in the SOE sector is given by

$$n^s_t = (1-\theta) n^s_{t-1} \int \mathbb{I}\left\{\xi^s_{x,t}(a,z) = 0\right\} d\mu^s_t, \tag{16}$$

where $t \geq 1$ and $t = 1$ is the first period of reform.

With the transformation option, the firm dynamics of SOEs in the post-reform period are summarized to be

$$v^s(a,z) = max\left\{log(d) + \beta^s \mathbb{E}_{z'}\left[\theta v^s_{tr}(a',z') + (1-\theta) max\left\{v^s(a',z'), \bar{v}^s_e\right\}\right]\right\} \tag{17}$$

subject to

$$d + a' = (1+r)a + \pi^s(a,z) - \tau max\{\pi^s(a,z), 0\}, \tag{18}$$

$$d, a' \geq 0. \tag{19}$$

Note that the new SOE problem becomes the same as equation (9) when $\theta = 0$.

Parameter		Value		
Capital share	α		0.40	
Depreciation rate	δ		0.10	
Span of control	γ		0.83	
Corporate income tax	τ_c		0.33	
Interest rate (saving) (%)	r		4.05	
		SOE	CSOE	POE
Interest rate (borrowing) (%)	r^i	4.05	4.17	8.36

Table 3: Externally Assigned Parameters

4 Calibration

In this section, we discuss our calibration strategy. First, Section 4.1 shows the subset of parameters that are calibrated externally. The values we assign to these parameters are either standard ones in the literature or can be directly measured from the data. The rest of the parameters, which represent the unique features in the Chinese economy, are calibrated internally in Section 4.2. The internally calibrated parameters are chosen such that the pre-reform firm dynamics modeled in Section 3.2 match the Chinese economy in 1998, the year before the SOE reform begins. Section 4.3 evaluates the performance of our calibration by comparing the non-targeted moments by model predictions with their empirical counterparts.

4.1 Externally Parameters

We calibrate the model at an annual frequency. Table 3 summarizes all the externally calibrated parameters. Specifically, we set the capital share parameter $\alpha = 0.40$. Following Bai, Hsieh, and Qian (2006), we set the depreciation rate of capital $\delta = 0.10$. The span of control parameter is set to be $\gamma = 0.83$, consistent with Peng (2019). In line with China's tax policy on domestic firms in 1998, we set the corporate income tax rate $\tau_c = 0.33$.

The interest rate on capital borrowing is estimated from the 1998 ASI. We calculate the sector-specific interest rate in the data as the ratio of interest rate expense over total debt (including both short-term and long-term debt) averaged across all firms in each sector. As shown in Table 3, the borrowing costs in the private sector are significantly higher than in the state sector (including both SOEs and CSOEs). The interest rate on savings is set to

Parameter		Value		
Persistence of z	ρ		0.88	
Standard deviation of z	σ		0.15	
Wage rate	w		0.88	
		SOE	CSOE	POE
Discount rate	β^i	0.94	0.94	0.88
Efficiency loss	η^i	0.24	0.02	0.00
Borrowing constraint	λ^i	12.0	2.97	1.19
Fixed operation cost	χ^i	0.05	0.18	0.08
Mass of potential entrants	M^i	0.10	0.01	0.08
Entry cost	κ^i	2.50	3.68	2.50
Initial asset	a_0^i	1.22	6.19	0.88
Exit value	v_e^i	-30.8	-8.58	-17.5

Table 4: Internally Calibrated Parameters

equal the capital borrowing rate of SOEs.

4.2 Internally Calibrated Parameters

Table 4 lists the remaining 26 parameters that are internally estimated within the model. We choose the set of parameters by minimizing the distance between the moments generated from the model and their empirical counterparts. Table 5 lists the targeted moments and their empirical and model-predicted values. Even though every targeted moment is determined simultaneously by all parameters, in what follows, we discuss each of the moments in relation to the parameter for which, intuitively, the moment yields the most identification power.

We first discuss the parameters that are chosen across all sectors. We follow the strategy in Bai, Lu, and Tian (2018) in calibrating the parameters that govern the process of productivity shocks. Specifically, we choose $\rho = 0.88$ and $\sigma = 0.15$ to match the serial correlation of firms' output and the standard deviation of output growth. The wage rate is chosen to ensure that total labor demand in all sectors equals labor supply, which we normalize to 1.

We then describe how we choose the sector-specific parameters that govern firms' saving and production decisions. The sector-specific discount factor, β^i, is chosen to match the respective assets to output ratio in each sector. As shown in Table 4, the discount rate in the state sector is larger than in the private sector, reflecting the fact that POEs are more patient and thus accumulate more internal assets relative to their output.

We jointly calibrate the parameter of production inefficiency, η^i, and the parameter of borrowing capacity, λ^i, to match the average output and the aggregate share of capital used in each sector. For the production efficiency parameter, we set $\eta^p = 1$, so the production inefficiency of SOEs and CSOEs is calibrated relative to that of POEs. Our calibration strategy captures the coexistence of a small average output and a big share of capital used in the SOE sector, which can be explained by SOEs' low production efficiency and loose borrowing constraint relative to POEs.

Based on our calibration, the SOE sector is 24 percent less efficient, and the CSOE sector is 2 percent less efficient than the POE sector. POEs can borrow up to 19 percent of their internal assets, and the other two sectors are substantially less financially constrained. The fixed cost parameters, χ^i, is informed by the share of profit-making firms in each sector, which is computed using the 1998 ASI.

Next, we explain how we choose the sector-specific parameters that mainly affect firms' entry and exit decisions. We normalize the total measure of incumbent firms to 1 and choose the sector-specific mass of potential entrants, M^i, to match their respective number of incumbents in 1998 ASI. We choose the initial asset for potential entrants and entry cost jointly in each sector by targeting the assets and output size of entrants relative to incumbents. Under our calibration, the entry cost of CSOEs and POEs are significantly larger than those of SOEs. A large entry cost screens out small potential entrants, which makes the relative size of entrants in the CSOE and POE sector bigger than in SOE sector.

Finally, the exit value, v_e^i, is informed by the exit rate of incumbent firms in sector i. The exit value reflects the opportunity cost for an incumbent to continue its business. So a higher exit value leads to a higher exit rate. Our estimation yields a very low exit value for SOEs, which reconciles the empirical fact that SOEs, even the least profitable ones, rarely exit in the pre-reform period. Three remaining parameters, θ, κ_{tr}^c, and κ_{tr}^p, need to be calibrated in the transition dynamics, which we explain in Section 6.1.1.

Table 5 shows that our calibrated model matches well the targeted empirical moments. For the aggregate economy, our calibration matches well the output process, including the serial correlation and the standard deviation. For each sector, our model matches well the asset to output ratio, the average output, the share of capital, and the share of profit-making firms. Our model also reproduces reasonably well the other moments related to firm entry and exit, although it slightly understates the entrants to incumbents average asset ratio of CSOEs and understates the exit rate of CSOEs.

Target	Data	Model
Serial correlation of output ρ	0.81	0.82
Standard deviation of output σ	0.66	0.64
Labor supply (normalization) w	1.00	1.00

	SOE		CSOE		POE	
	Data	Model	Data	Model	Data	Model
Asset to output β^i	1.40	1.34	1.79	1.81	0.96	0.96
Average output (POE = 1) η^i	1.15	1.15	3.60	3.60	-	-
Share of total capital λ^i	0.65	0.65	0.21	0.20	0.14	0.15
Share of profit-making firms χ^i	0.58	0.57	0.71	0.70	0.84	0.86
Firm measure (Total = 1) M^i	0.59	0.59	0.07	0.07	0.34	0.34
Entrant/incumbent avg. output κ^i	0.49	0.50	0.72	0.71	0.71	0.72
Entrant/incumbent avg. asset a_0^i	0.57	0.56	0.73	0.68	0.64	0.66
Firm exit rate v_e^i	0.16	0.16	0.13	0.11	0.14	0.13

Table 5: Targeted Moments

Moments in the data are calculated from the 1998 Annual Survey of Industries. Asset is defined as total asset net total liability. Output is defined as value added. All moments are normalized by their industrial mean.

4.3 Model Performance

To evaluate our calibration, we show that our model predictions match well with the empirical counterparts regarding the moments that we do not directly target in the estimation.

Table 6 compares the model-predicted and the empirical non-targeted moments. Specifically, our model reproduces well the concentration of employment at the top of the distribution. For example, the largest 10 percent of firms hire 56 percent of labor in the data and 55 percent in the model. Similarly, the largest 20 percent of firms hire 71 percent of labor in both the data and the model. Although our model understates the concentration of capital at the top compared to the data, it predicts that the distribution of capital is more concentrated than that of labor, which is consistent with the data.

In our calibration we only targeted the average output of each sector (relative to the POE sector) and the share of capital used by each sector. Table 6 shows that our model-predicted median output and capital (relative to the POE sector) matches the data very well in the CSOE sector, though not very well in the SOE sector. The model also reproduces well the

Moment	Data	Model
Employment, share top 10%	0.56	0.55
Employment, share top 20%	0.71	0.71
Capital, share top 10%	0.72	0.59
Capital, share top 20%	0.84	0.75

	SOE		CSOE		POE	
	Data	Model	Data	Model	Data	Model
Median output (POE = 1)	0.62	0.44	2.16	2.63	-	-
Median capital (POE = 1)	1.36	0.88	4.76	5.19	-	-
Median capital to output	2.61	2.36	2.49	2.34	1.16	1.12
Std. dev. of log output	1.93	1.84	1.69	1.41	1.11	0.93
Std. dev. of log capital	2.09	1.82	1.88	1.34	1.42	0.81

Table 6: Non-targeted Moments

Moments in the data are calculated from the 1998 Annual Survey of Industries. All moments are normalized by their industrial mean (or median).

median capital to output ratio in each sector.

Finally, Table 6 also shows that the model reproduces reasonably well the standard deviation of log output and capital in each sector. In particular, the distribution of firms in the state sector is more dispersed than that in the private sector in our model, which is in line with the data.

5 The Long-Run Effects of the SOE Reform

We model two main aspects of the SOE reform. First, the entry of new SOEs is shut down. Second, incumbent SOEs are given the opportunity to choose between exiting the market, corporatization, or privatization. In the final steady state, only the first aspect matters. This is because all incumbent SOEs will either exit or transform during the transition period. In other words, none of the firms in the final steady state are born in the pre-reform period.

In this section, we focus on the final steady-state comparison and analyze how the closure of the SOE sector improves aggregate output. In Section 5.1, we compare the model-predicted post-reform steady state with the initial steady state to which our model is calibrated. The final steady state consists only of CSOEs and POEs. To illustrate the advantage of CSOEs over SOEs, we run a counter-factual experiment where it is the CSOE sector rather than the SOE sector that is closed. This counter-factual analysis helps us to further identify how each feature of CSOEs leads to the overall improvement, which we illustrate in Section 5.2.

5.1 Post-Reform Steady State

We study the general equilibrium effect of the closure of the SOE sector in the long run. To do so, we need to keep aggregate labor and capital at their pre-reform levels by adjusting the equilibrium wage and borrowing limits. As a result, output growth is entirely driven by TFP growth led by the improvement in the allocative efficiency resulting from the closure of the least efficient sector. Section 5.1.1 explains our implementation strategy and Section 5.1.2 shows the result.

5.1.1 Implementation

Since our model does not feature labor market distortions, we model the same equilibrium wage in both the CSOE and the POE sectors. The challenge is how to adjust the borrowing limit, λ^i, to clear the capital market while capturing the fact that CSOEs still have a higher credit limit than POEs. To do so, we first assume that $1 \leq \lambda^i \leq 12$, meaning that the upper bound of borrowing limit in each sector equals the borrowing limit of SOEs in the pre-reform period. Then, we make sure that CSOEs get capital from the closure of SOEs before POEs do. Specifically, if the aggregate capital demand in the computed final steady state is less than the pre-reform baseline level, we will first raise λ^c until $\lambda^c = 12$ and then increase λ^p if necessary.

The implementation strategy described above creates a natural interaction between the size of the state sector and the tightness of the borrowing constraint imposed on the private sector. A decline in the size of the state sector can relax the financial constraint for private firms and thus boost both aggregate productivity and allocative efficiency.

In addition to the closure of the SOE sector, we also feed in three other exogenous shocks to the final steady state, which capture the macro trends in the Chinese economy. Specifically, we reduce the corporate income tax rate from 33 to 25 percent, which is in line with China's 2008 tax reform. We re-calibrate fixed operation costs for each sector so that the shares of profit-making firms in the benchmark reform match the data in the 2007 ASI. We also completely remove the entry costs for all potential entrants, which is motivated by

	Policy	Output (aggregate)	Output (median)	POE Share (%)			λ^i		
				Firm #	Output	Capital	SOE	CSOE	POE
(a)	Pre-reform	1.77	0.73	33.8	26.7	14.4	12.0	3.0	1.2
		%Δ from the pre-reform steady state							
(b)	Close SOE	13.1	13.7	55.7	51.8	56.9	-	12.0	3.6
(c)	Close CSOE	10.1	-22.7	22.1	35.0	34.2	12.0	-	2.2

Table 7: The Long-Run Effects of the SOE Reform

the fact that the average entrant to incumbent output ratio continued to decline from 1998 to 2007 in the ASI.

5.1.2 Results

Table 7 presents the equilibrium outcomes for (a) the initial steady state in the pre-reform period, (b) the final steady state after the actual reform, and (c) the final steady state in the counter-factual experiment where the CSOE sector is closed rather than the SOE sector.

Comparing row (b) with row (a), we find that closing the SOE sector improves aggregate output by 13.1 percent and increases median output in the economy. Two main reasons drive the result. First, CSOEs are more efficient in production than SOEs, so replacing SOEs with CSOEs increases aggregate output and increases the median firm size. Second, the capital that is released from the exited SOEs is reallocated to CSOEs and POEs, leading to a relaxation of borrowing constraints in both the CSOE and the POE sectors, indicated by the change in λ^i from 2.97 (see Table 4) to 3.6 in the final steady state..

Comparing the actual policy in row (b) and the counter-factual experiment in row (c), we find that both policies increase aggregate output from the pre-reform level, but the magnitude of the increase is larger in the actual policy, which closes the SOE sector. The biggest difference is that the counter-factual experiment, which replaces CSOEs with SOEs, reduces rather than increases median output.

What drives these differences? First, as the SOEs have a smaller exit value, the counter-factual economy leaves a large fraction of small and inefficient SOEs still running, which results in a 22.7 percent drop in median output. In addition, this fraction of SOEs limits resource reallocation to the more efficient POE sector. This can be shown by the difference

		Output (aggregate)	Output (median)	POE Share (%)			λ^i	
				Firm #	Output	Capital	CSOE	POE
		% **below** the benchmark reform						
(1)	$\eta^c = 0.24$	-1.9	11.2	-4.9	-19.3	-25.6	12.0	6.4
(2)	$v_e^c =$ -30.8	4.4	26.2	46.0	53.9	56.4	1.3	1.0
(3)	$M^c = 0.1$	1.0	24.3	46.5	57.7	58.3	1.5	1.0
(4)	$a_0^c = 1.22$	-1.5	-16.6	-6.5	-11.9	-15.9	12.0	5.3

Table 8: Comparison between the SOE and the CSOE Sector

of the change in POE share, as well as the difference in λ^i in the POE sector.

5.2 Traditional vs. Corporatized SOEs

How does the corporatization of SOEs increase aggregate output and facilitate resource reallocation? In Section 3.1, we showed that the four main differences between SOEs and CSOEs are the sectoral efficiency, the exit value, the number potential entrants, and the initial asset level. In this section, we study how each of these differences contributes to the gain of the SOE corporatization. In other words, we decompose the differences between row (b) and row (c).

5.2.1 Implementation

To isolate the effect of each feature, we do the following decomposition analysis. First, we remove the CSOE sector's efficiency advantage over the SOE sector, meaning that we increase the production inefficiency of CSOEs, η^c from its actual value, 0.02 (see Table 4) to $\eta^c = \eta^s = 0.24$. Then, we compute the final steady state of this counter-factual experiment and compare it with the steady state in the actual reform, which we use as a benchmark. We repeat the same procedure by removing all of these features one at a time to see the effects of these features separately. When conducting these experiments we still keep aggregate labor and capital at their pre-reform levels by adjusting wage and borrowing limits.

5.2.2 Results

Table 8 summarizes the results. Row (1) shows that when we reduce the production efficiency of CSOEs equal to that of SOEs, aggregate output *increases* by 1.9 percent, relative to the benchmark actual reform. Although this result seems counter-intuitive at first sight, the reason can be understood by comparing λ^p for this experiment to the actual reform. As the efficiency of the CSOE sector becomes substantially lower than it actually is, more capital and labor are reallocated to the more productive POE sector, which results in a dramatic increase of λ^p from 3.6 to 6.4.

Row (2) of Table 8 shows that when we reduce the exit value for CSOEs to equal that of SOEs, aggregate output *decreases* from the actual reform benchmark. The decrease in the CSOEs' exit value leaves a large fraction of small and less productive CSOEs still running in the economy, which is associated with a 26.2 percent *decline* in median output. Additionally, the presence of these CSOEs slows down the resource reallocation to the POE sector. This tightens the borrowing constraint for the entire economy and therefore leads to a sharp loss of output.

Row (3) of Table 8 shows that, when we increase the mass of potential CSOE entrants from its actual value, 0.01 percent to 0.1 percent, aggregate output *decreases*. The decrease is due to a larger fraction of CSOEs in the steady state, which crowds out POEs and tightens borrowing constraints for both CSOEs and POEs. This also shows up in a decrease in median output and a decrease in the POE's share of the economy.

Row (4) of Table 8 shows that, when we decrease the initial asset level of CSOEs to 1.22, it *increases* aggregate output as well as median output and the POE's share of the economy from those in the actual reform economy, respectively. The reason is that with a lower level of initial assets, the entry productivity cutoff of CSOEs becomes higher in this counter-factual economy. As a result, only the most efficient CSOEs enter, which generates a larger firm size on average and a smaller share of the CSOE sector. In addition, the increase in the CSOE entry cutoff also leads to more recourse being reallocated to the surviving CSOEs and POEs, both of which are more productive.

In summary, among the four key features of the CSOE sector, a higher exit value plays the most important role in promoting output growth and resource reallocation. The smaller number of potential entrants also helps. On the other hand, higher production efficiency and larger initial asset levels both have negative impacts on aggregate output.

The main policy implication is that in the long run, the corporatization of SOEs increases aggregate output by facilitating resource reallocation to the private sector. Even if the production efficiency of the state sector does not improve, as long as the state sector has a high exit cutoff, aggregate output can still increase.

6 Short-Run Effects of the SOE Reform

In this section, we evaluate the short-run outcomes of the SOE reform by studying the perfect foresight transition dynamics of the model after the SOE reform. In Section 6.1, we analyze how incumbent SOEs optimally choose firm-type following the reform and the implications on the state sector's average firm size and its aggregate output share in the economy. Next, in Section 6.2, we illustrate the importance of the corporatization of SOEs in the aggregate economy by comparing the actual reform to a counter-factual reform in which incumbent SOEs are only allowed to exit or become POEs.

6.1 Transition Dynamics of the SOE Reform

In our model, the SOE reform is completely unexpected, but once it happens, every firm understands that it is a permanent change. In this section, we first discuss how we calibrate the additional parameters along the transition path and then analyze the optimal firm-type choice for incumbent SOEs and its implications on the performance of the state sector.

6.1.1 Implementation

The economy starts in the steady state ($t = 0$). The government gradually closes the SOE sector, starting at the beginning of $t = 1$. We set $\theta_t = 0.261$ for $t \geq 1$, which means that 26.1 percent of the remaining SOEs receive the reform shock in each period. θ_t is chosen to match the 77.2 percent decline in the number of SOEs from 1998 to 2007 in the data. Panel C(i) in Figure 4 shows that the simulated number of SOEs along the transition path is consistent the data.

We also feed in four other shocks together with the SOE reform, including the reduction in the corporate income tax rate (τ_c), fixed operation cost (χ^i), entry cost (κ_e^i), and borrowing constraints (λ^i), all of which are consistent with the parameter changes in the final steady state studied in Section 5.1. The corporate income tax remains 33 percent for $t \leq 9$ and then permanently declines to 25 percent. This is in line with the actual tax reform in China. The other three shocks gradually decline to their final steady-state values by $t = 9$. Panel A and B in Figure 4 shows that, with these exogenous shocks, the model-predicted entrants to incumbents average size and the share of profit-making firms in all sectors are reasonably close to their data counterparts from 1998 to 2007. In addition, Panel C(ii) shows that our model can replicate the hump-shaped average output ratio between the CSOE and the POE sector during transitional periods.

The remaining parameters to calibrate are the ones that govern the transformation de-

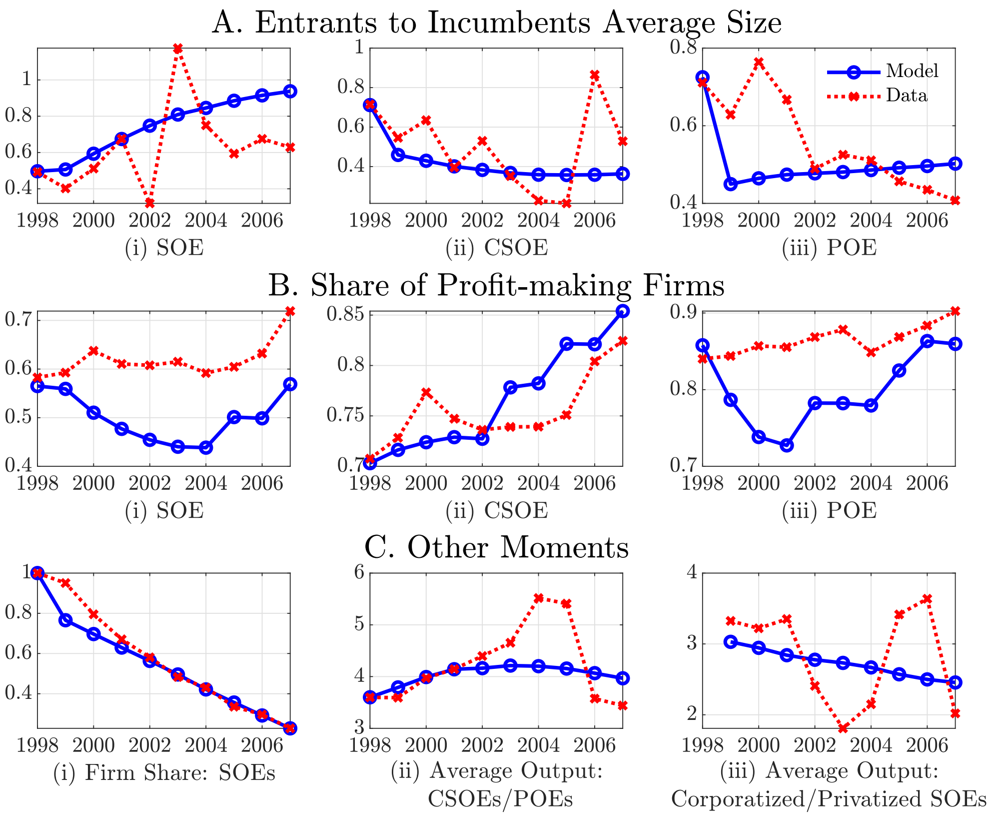

Figure 4: Model-Predicted and Empirical Moments Along the Transition Path

Empirical moments are calculated based on the Annual Survey of Industries from 1998 to 2007. Firms' output is normalized by the mean of each industry.

cision for the incumbent SOEs. We set the cost of corportization, $\kappa_{tr}^{c} = 10.0$ and the cost of privatization, $\kappa_{tr}^{p} = 6.5$. These two parameters are calibrated to match the empirical moments that among all the SOEs hit by the reform shock during $1 \leq t \leq 9$ (including new entrant SOEs), 15 percent transform to POEs, 13 percent transform to CSOEs, and the rest exit the market in the data.[10] Although we only target these two fractions by calibrating the transformation costs, Panel C(iii) shows that our model can reproduce the average output ratio between corporatized SOEs and privatized SOEs from 1999 to 2007. Specifically, on average, corporatized SOEs are 2.5-3.0 times larger than privatized SOEs. In Subsection 6.1.2 we analyze what leads to this outcome by presenting SOEs' optimal transformation decision.

[10]This number is different from Table 1, because Table 1 does not include entrants of new SOEs after 1998.

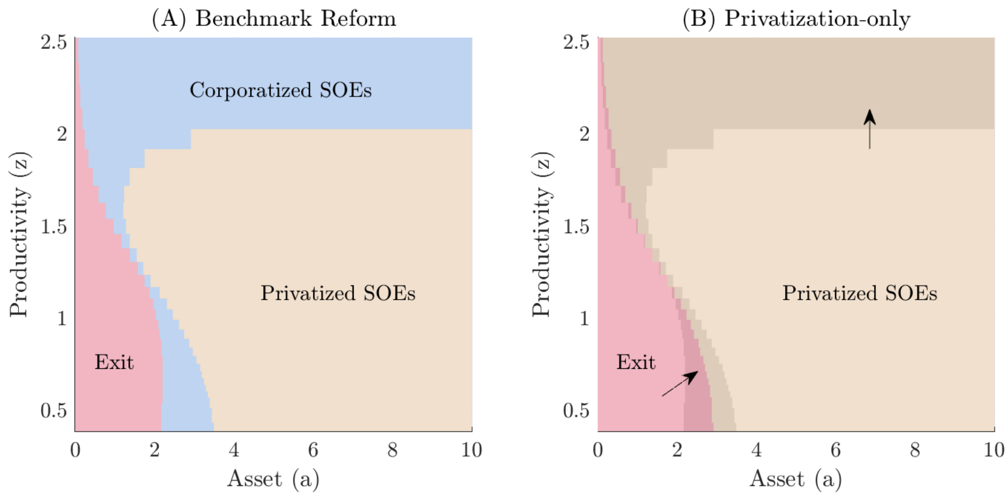

Figure 5: Optimal Transformation Decision in the Actual and Privatization-Only Reform

6.1.2 Decision Rule: Exit, Corporatization, or Privatization?

Figure 5 panel (a) shows the optimal transformation decision in the actual reform. Upon receiving the reform shock, if the SOE has a very high productivity level, it chooses to become corporatized for all asset levels. The intuition is that when the SOE chooses to become a CSOE rather than a POE, the benefit is a higher borrowing limit and the cost is a smaller increase in production efficiency. With high productivity, the firm demands more capital, which makes maintaining the high borrowing limit more important than the improvement in production efficiency.

SOEs with low productivity and low asset levels choose to exit, as the firms' continuation value is lower than their exit value. On the other hand, if an SOE has low productivity but a high asset level, it chooses to become a POE, as this type of firm is able to self-finance its capital demand. In this case, it chooses to become a POE to benefit from the larger efficiency gain and the lower transformation cost.

6.1.3 Effects of the Optimal Transformation Choice

Figure 6 illustrates the effects of the optimal transformation decision on the average firm size and aggregate output. It shows that our model prediction reconciles the key empirical result in Section 2.3 that the state sector's share of output in the economy declines but the average size increases at the same time. The reason for the increasing average output size is due to the change the composition effect. First, small SOEs that have low technology and low asset levels exit the market. Second, big SOEs that have high technology levels become CSOEs and remain in the state sector. The reason for the state sector's declining share of output

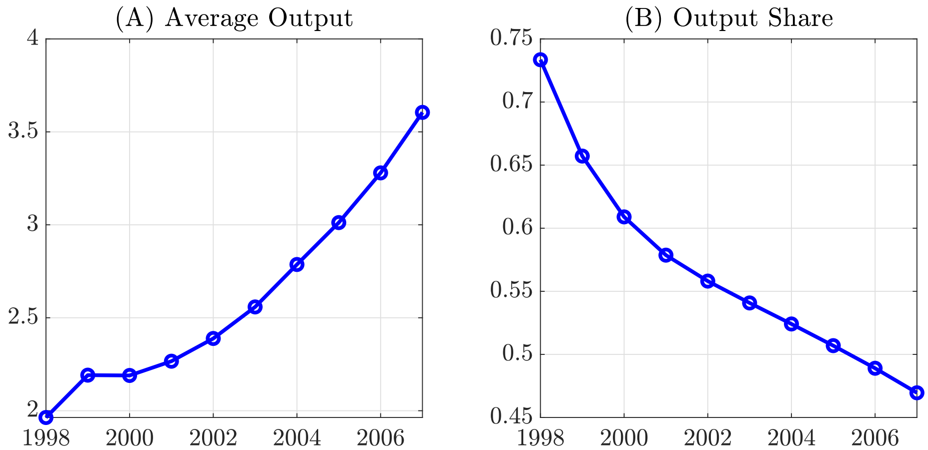

Figure 6: The Effects on the State Sector in the Transition

is that in addition to the exit of small SOEs, the entry rate of SOEs gradually decreases following the reform.

6.2 Corporatization vs. Privatization

To analyze the gain of the SOE corporatization along the transition path, we perform a counter-factual experiment where we allow only exit or privatization for incumbent SOEs.

6.2.1 Implementation

To model that SOEs do not have the corporatization option, we set the corporatization cost $\kappa_{tr}^{c} = \infty$ and keep everything else unchanged. As in the analysis of the actual reform, we allow the wage rate to adjust so that labor demand equals its initial steady-state level over the entire transition path.

6.2.2 The Contribution of SOE Corporatization

Figure 7 compares aggregate output and the private sector's share of output along the transition path under the actual benchmark reform and the counter-factual reform. Panel (A.1) shows that the biggest difference in annual aggregate output is 5.0 percent, which occurs in 2003. Panel (B.1) shows that the counter-factual privatization-only reform accelerates the resource reallocation to the private sector compared to the actual benchmark reform. However, this faster resource reallocation to the private sector results in a slower aggregate output growth, compared to the actual reform.

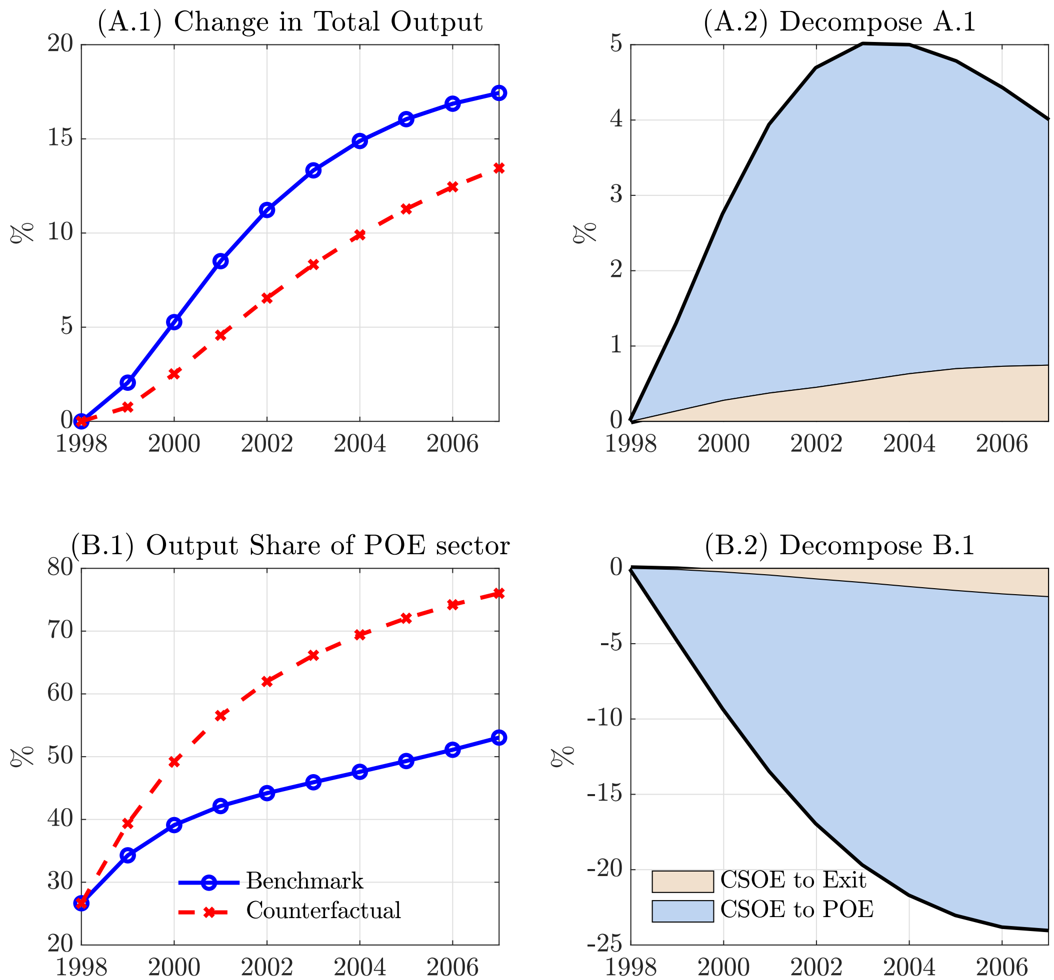

Figure 7: The Actual vs. the Counter-factual Economy in the Transition

The reason for the differences between the actual and the counter-factual reform can be explained by the optimal decision rule in the privatization-only reform, which is shown in panel (B) of Figure 5. Comparing it with the decision rule under the actual reform, we find that the output loss in the privatization-only reform is due to two reasons. First, without the corporatization option, SOEs with higher productivity now have to turn to POEs instead of becoming CSOEs. Although transforming to a POE results in a larger efficiency gain, it also leads to a lower borrowing limit, which restricts the firm's production capacity right after the transformation. Second, a fraction of low productivity SOEs that could be corporatized under the actual reform have to exit in the privatization-only reform. This additional fraction of exiting SOEs also contributes to the loss in aggregate output along the transition path.

Meanwhile, since privatization becomes the only option for surviving SOEs, the resource reallocation to the private sector is more rapid than the actual benchmark reform.

To quantitatively assess the importance of the two factors, we conduct a decomposition exercise to disentangle the effects of each channel. Panel (A.2) of Figure 7 shows that nearly 90 percent of output difference is caused by the share of high technology SOEs that are forced to be privatized. Similarly, Panel (B.2) shows that the increase in the speed of resource reallocation to the private sector is almost entirely driven by the same reason.

Panel (A.1) also shows that output gap between the actual and the counter-factual reform declines over time. This is mainly driven by two factors. First, although privatized SOEs are smaller right after the transformation due to the tighter financial constraint, they gradually accumulate assets to overcome financial constraints. Therefore, privatized SOEs have a more persistent output growth compared to CSOEs after the transformation. Second, the impact of transformed SOEs on aggregate output will vanish in the long run, since they will eventually exit the market, meaning that the two economies converge to the same final steady state.

7 Conclusion

This paper studies the firm dynamics during China's Economic Reform, with special attention to the transformation in the state sector. We first show the empirical patterns of the transformation in the state sector, which can be described as *"grasp the large and let go of the small."* Specifically, big SOEs become corporatized, whereas small SOEs either exit or become privatized.

The key contribution of our paper is to quantify the effect of the SOE reform on the aggregate economy. To do so, we build a heterogeneous-firms model in a three-sector economy, in which firms are subject to financial frictions and make endogenous entry and exit decisions. We model SOE reform as allowing the incumbent SOEs to optimally choose between exiting the market, corporatization, and privatization.

We find that in the long run, the SOE reform increases aggregate output by facilitating resource reallocation to the private sector, and the biggest contribution comes from the higher exit cutoff for firms in the state sector. In the short run, the corporatization option for incumbent SOEs explains the empirical fact that the state sector's output share in the aggregate economy decreases, but average firm size increases. In addition, although the corporatization of SOEs slows down the speed of resource reallocation to the private sector, it increases aggregate output along the transition path, relative to the counter-factual policy which only allows SOEs to exit or become privatized. This is because most productive incumbent SOEs can choose corporatization, which gives them a higher borrowing capacity than privatization.

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Appendices

A Data Cleaning and the Definition of Ownership Types

In this appendix we describe our data cleaning steps and our definition of the three ownership types, SOEs, POEs, and CSOEs.

A.1 Data Cleaning

We implement the following standard steps to drop observations with reporting errors.

1. We drop firm-year observations that are not in operation.

2. The data does not report value added in year 2001 and 2004. We compute value added as

   $$value\ added = total\ output - intermediate\ input + tax\ on\ value\ added$$

   We also checked that this definition yields the same results for value added that is reported in other years.

3. We drop firm-year observations that report missing information or report negative values of value added, employment, fixed asset, or total asset.

A.2 Definition of Ownership Types

Since our paper focuses on the comparison between firms of different ownership types, we take the following steps to further restrict our sample for analysis.

- We drop firm-year observations that have missing information on registration type or controlling share.

- We define that a firm is *state-owned* by *registration type* if its registration type is one of the following type: 1) state-owned, 2) state jointly owned, and state and collective jointly owned.

- We define that a firm is *privately-owned* by *registration type* if its registration type is one of the following type: 1) private enterprises, 2) private partnership enterprises, 3) limited liability companies, and share-holding corporations.

- We define that a firm is an **SOE** if 1) the state has absolute or relative controlling share of the firm, and 2) the firm is state-owned by registration type.

Year	SOE	POE		CSOE		Total	
		D Only	F Included	D Only	F Included	D Only	F Included
1998	42.1	23.9	43.0	4.8	8.1	70.8	93.1
1999	40.0	30.6	52.4	5.4	8.4	76.2	100.8
2000	33.5	41.8	65.8	6.3	9.0	81.6	108.2
2001	28.2	60.7	87.9	7.1	9.8	96.0	125.9
2002	24.5	75.7	105.6	7.2	9.6	107.3	139.6
2003	20.3	98.7	134.1	7.3	9.4	126.3	163.9
2004	18.1	160.0	211.6	8.2	10.5	186.2	240.2
2005	14.1	160.6	213.9	7.3	9.2	182.0	237.2
2006	12.5	179.7	236.4	16.2	18.8	208.5	267.7
2007	9.6	221.2	284.8	17.2	20.1	248.0	314.5

Table 9: Number of Firms by Ownership Types, 1998 - 2007

Source: Authors' calculation, based on China's Annual Industrial Survey
Number of firms is in thousands.
D means domestic firms only. F means including firms which are registered as Hong Kong/ Macao/ Taiwan owned or Foreign owned.

- We define that a firm is a **POE** if 1) the state does not have absolute or relative controlling share of the firm, and 2) the firm is privately-owned by registration type.
- We define that a firm is a **CSOE** if 1) the state has absolute or relative controlling share of the firm, and 2) the firm is privately-owned by registration type.
- We drop the firms which are 1) the state does not have absolute or relative controlling share of the firm, and 2) the firm is state-owned by registration type.
- Notice that under our definition, we do not count firms that are collective owned (except state and collective jointly owned).
- In addition, as we focus on financing patterns in mainland China, we do not count firms that have access to foreign capital markets, i.e., firms which are Hong Kong/ Macao/ Taiwan owned or Foreign owned. These type of firms are mostly POEs, as shown in Table 9. The exclusion of this type of firms does not affect our main analysis of the SOE reform, as shown in Table 1.

Table 9 shows the number of firms of each type by year after we take the above procedures to restrict our data for analysis.

B Computational Algorithm

In this computational appendix we first lay out the solution method for solving the heterogeneous firms problems. We then discuss the computation algorithm for simulating the transitional dynamics.

B.1 Steady State

In this subsection we first discuss how to solve firms' optimization problem using collocation methods. We next describe how to construct the stationary distribution using a non-stochastic simulation method.

Value and policy functions We use the algorithm described by Mongey (2015) to compute the recursive equilibria. This approach accelerates computation speed by adapting Judd et al. (2017) method on pre-computation of expectation functions for approximating value functions. Moreover, Miranda and Fackler (2004) toolbox allows us to efficiently find optimal policies using vectorized golden-section search and solve fixed point problems using Broyden's algorithm.

Let $s = [a, z]$ be the firm's idiosyncratic state. We solve for an approximant of the expected value function $v^{i,e}(a', z)$ of sector i, which gives the firm's expected value condition on current decisions for asset:

$$v^{i,e}(a', z) = \sum_{z'} \pi(z'|z) v^i(a', z')$$

where the integrand is the value given in Equation (9) and (17).

To compute decision rules for incumbent firms, we set the number of asset grid point $N_a = 250$, the number of firm productivity grid point $N_z = 35$. In total, there are $N = N_a \times N_z = 8,750$ collocation nodes. We choose asset nodes to have a higher density at lower values. We choose the upper bound for asset, $\bar{a}$, so that $a'(\bar{a}, z_{max}) < \bar{a}$. We use Tauchen method to approximate z and the associated transition matrix, $\pi(z'|z)$.

We approximate $v^{i,e}(s)$ using a linear spline with N coefficients. We replace the functions we want to approximate with interpolants so that

$$v^{i,e}(s_l) = \sum_{j=1}^{N} \phi(s_l) c_j^{i,e}$$

where l is l_{th} collocation nodes, ϕ is a basis function, and $c^i = (c_1^i, ..., c_N^i)'$ is a vector of coefficients.

Given a guess for the spline's coefficients, we iterate towards a vector of coefficients that solve the system of N Bellman equations. In each iteration, we use vectorized golden-section search method to compute the optimal policies of all states and the associated value functions.

We also speed up convergence by using the Broyden's (Quasi-Newton) algorithm. In practice, we start with initial guess for coefficients and iterate on Bellman equation for two times. Then we use the updated coefficients.

Next, to implement the Broyden's (Quasi-Newton) algorithm, we rewrite the system of Bellman equations as a zero-system, $g(c_k^i)$, which means we can solve the problem using the root-finding algorithm. We next compute the Jacobian of the zero-system $D(c_k^i)$ and the updating scheme for collocation coefficients is as follows

$$c_{l,k+1}^i = c_{l,k}^i - D(c_{l,k}^i)^{-1} g(c_{l,k}^i)$$

where k is the number of iterations and $D(c_{l,k}^i)^{-1}$ is the inverse of the corresponding Jacobian.

After we find the fixed points of value functions, we can also solve the entry decision for the potential entrants.

Stationary equilibrium To construct the stationary distribution, we use the method of non-stochastic simulation from Young (2010). We create a new, finer grid of points for asset on which we approximate the stationary distribution using a histogram. We set $N_a = 1000$.

We first guess the distribution of firms μ_0^i over asset a and productivity z for each sector. Second, to ensure that the number of firms in each sector matches the data, we also guess the mass of potential entrants M_0^i for initial steady state. The iteration is then as follows:

1. Solve for the asset, entry, and exit decision rules on finer grid points. Create "big" transition matrices that characterize the law-of-motion of the distribution using asset policy functions and exogenous transitions matrix $\pi(z'|z)$ for each sector.

2. For iteration k, use the mass of potential entrants M_k^i to compute the distribution of successful entrants
$$\mu_k^{entry,i} = \mathbb{I}\left\{\xi_e^i(a_0, z) = 1\right\} M_k^i \mu^*(a_0, z).$$

   (a) For iteration j, compute the distribution of exit firms
$$\mu_{k,j}^{exit,i} = \mathbb{I}\left\{\xi^i(a, z) = 0\right\} \mu_{k,j}^i(a, z),$$

   (b) Combining the surviving firms and successful entrants, we obtain the distribution incumbent firms

$$\mu_{k,j}^{inc,i} = \mu_{k,j}^{i} - \mu_{k,j}^{exit,i} + \mu_{k}^{entry,i}.$$

(c) Apply the corresponding big transition matrix on each $\mu_{k,j}^{inc,i}$ to obtain $\mu_{k,j+1}^{i}$.

(d) Iteration stops if the convergence criterion $max\{\parallel \mu_{k,j+1}^{s} - \mu_{j}^{s} \parallel, \parallel \mu_{k,j+1}^{c} - \mu_{k,j}^{c} \parallel, \parallel \mu_{k,j+1}^{p} - \mu_{k,j}^{p} \parallel\} < 10^{-10}$ is satisfied. Otherwise, repeat step $2(a)$.

3. Check if the number of firms in each sector matches the data. If yes, the iteration stops. Otherwise, replace the previous guess on the number of entrants with M_{k+1}^{i} and go back to step 2.

B.2 Transition Dynamics

In this subsection, we describe the algorithm for computing the perfect-foresight transitional dynamics.

1. Set $\theta = 0$ and solve for initial stationary equilibrium. Save stationary distributions μ_0^s, μ_0^c, and μ_0^p.

2. Set $\theta > 0$ and solve for final stationary equilibrium. Save value functions $c_T^{s,e}$, $c_T^{c,e}$, and $c_T^{p,e}$. We set total transition periods $T = 300$.

3. Construct paths of exogenous aggregate shocks.

4. Given the sequences of shocks, we start from the final continuation values and iterate backward from $t = T$ to $t = 1$.

5. For each period t, solve for asset, entry, exit, and transformation decision rules on finer points of grid and construct the big transition matrices using asset policy functions, exogenous transitions matrices, and entry, exit, and transformation decisions.

6. Given initial distribution μ_0^s, μ_0^c, and μ_0^p, iterate forward on firm distributions using the big transition matrices.

7. For each t, aggregate across all individual firms and compute aggregate variables.