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Economic reforms and the evolution of China's total factor productivity

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ABSTRACT

This paper investigates the impact of economic reforms on China's growth in total factor productivity (TFP). I build a model with two sectors in production – the private and the state sectors – that features capital market imperfections on the private sector. Following the removal of prohibitive barriers to private entrepreneurship (reforms), TFP gains follow the expansion of the private sector and the closure of the least productive state enterprises. Although the distribution of production technologies in both sectors is identical, the model generates persistently higher TFP in the private sector via a selection mechanism arising from financial frictions.

1. Introduction

Over the past 20 years, China has experienced one of the most remarkable growth episodes in modern economic history. Total factor productivity (TFP) has been a key engine of China's 7.6 percent annual rise in output per worker in the non-agricultural economy from 1992 to 2007. This rise followed major economic reforms that reduced barriers to entry on private businesses. China has since transitioned from a predominantly state-run to a mixed economy of both private and state sectors. At the time of economic reform in 1992, the private sector accounted for only 12 percent of non-agricultural employment. By 2007, this figure climbed to 52 percent. Additionally, TFP has in the private sector has been 80 percent higher, on average, than the state sector.

The goal of this paper is to quantitatively assess the extent that the economic reforms in the non-agricultural sectors can account for China's aggregate TFP dynamics. I build a quantitative framework suggesting economic reforms that initiated the reallocation of resources given existing production technologies has been a key driver of China's TFP growth since reforms in 1992 to 2007. The model features two sectors in production – the private and the state sector – whose main difference is access to credit markets: the private sector faces financial frictions, modeled as a collateral constraint, while the state sector does not. I analyze the transitional dynamics of the model from the removal of prohibitive barriers to private entrepreneurship (reforms) to a new stationary steady state where financial markets remain undeveloped. Following reforms, entrepreneurs are able to utilize their existing talents, drawing resources to their new, productive businesses. The reallocation of capital and labor to the private sector leads to an overall increase in TFP, mirroring China's 1992 reforms and transition to a two-sector economy.

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The critical factors of the model are the inclusion of financial frictions, endogenous entry and exit, and heterogeneity in talent of operating a business. Individuals belong to either the private or the state sectors. All agents are endowed with an individual production technology (talent) which is identically distributed across both sectors. I refer to an agent's talent in the state sector as "managerial" talent and "entrepreneurial" talent for agents in the private sector. Agents choose the most lucrative option between managing/operating a business and working for a wage. Collateral constraints on private entrepreneurs from poorly developed financial markets distort their occupational choice and size of their business. Are they talented enough to viably operate a business? If so, do they have enough collateral to finance their business?

The removal of barriers to entrepreneurship in this environment leads to TFP dynamics consistent with China's economic transition. First, TFP gradually rises as entrepreneurs accumulate collateral and expand their business. Also, the inclusion of endogenous entry and exit leads to two additional implications. TFP is persistently higher in the private relative to the state sector via a selection mechanism arising from financial frictions, and TFP increases in the state sector from exit of the least productive state businesses.

The model endogenously generates 25 percent of the observed differences in TFP between the state and private sectors. Although the distributions of entrepreneurial talent and managerial talent are identical, the inclusion of financial frictions on the private sector leads to differences in the talent distributions of active entrepreneurs in the private sector and managers in the state sector. Since financial frictions force entrepreneurs to rely on self-financing to expand their operation, only the most talented are able to overcome the constraints and profitably start a business. Financial frictions essentially "prop-up" TFP in the private sector by limiting entry to only the most talented entrepreneurs. Conversely, state enterprises with managerial talents ranging from high to relatively low levels can all produce. This leads to differences in the composition of sector-level productivities: the state sector, although they do have productive managers, has disproportionately more low-productivity businesses than the private sector. I show that TFP gains in the private sector from this selection mechanism (extensive margin) are larger than the TFP losses on the intensive margin (distortion on individual capital use). That is, TFP is magnified in the sector facing incomplete financial markets (the private sector).

The model indicates that nearly one-quarter of TFP growth in the state sector arises from removal of entry barriers (reforms) on the private sector through endogenous exit of state enterprises. Expansion of the private sector after reforms places upward pressure on labor demand, and, hence, wages. The least productive state enterprises are unable to profitably operate at the higher wage level and thus exit, leaving only the most productive state enterprises in business. This mechanism captures China's "grasp the large let go the small" policy of the 1990s. The state privatized or closed its smaller, loss making enterprises while retaining the larger, more profitable ones in effort to increase the overall efficiency and competitiveness of the state sector in the new, market economy.

The theme of this paper is related to Song et al. (2011) who consider a small-open economy, transitional growth model to explain China's growth acceleration and acquisition of foreign assets since China's 1992 reforms. My paper provides additional insights into China's TFP dynamics. First, the private sector influences the equilibrium wage during the transition. Rising wages from private sector expansion induces ongoing exit of the least productive state businesses. Resource reallocation away from these establishments toward more productive ones raises TFP in both sectors. Second, by assuming an identical distribution of talent across both sectors, the model generates TFP differences arising from financial frictions.

The model is similar to Buera and Shin (2013) who also study transitional economies facing imperfect financial markets in an environment with entrepreneurial choice. I extend this framework by including a financially unconstrained sector (state) alongside a financially constrained sector (private). In Buera and Shin, financial frictions faced by all individuals keeps factor prices relatively low allowing entry of "incompetent but wealthy" entrepreneurs that can overcome the constraints, keeping TFP low. I show that the inclusion of the financially unconstrained state sector keeps factor prices high enough such that the "incompetent" entrepreneurs would never be able to enter regardless of wealth. In fact, TFP in the financially constrained sector remains higher than the financially unconstrained sector from selection into entry of only the most talented entrepreneurs. This result relates to Hale and Long (2013) who also explore the link between financial frictions and productivity differences between China's state and private sectors. The authors argue that private firms defy financial constraints by managing working capital more efficiently on the intensive margin. In my model, TFP differences arise primarily on the extensive margin from entry of a larger share of relatively less productive state businesses and more talented entrepreneurs in the private sector.

Recent work that connects growth and micro-level distortions include Restuccia and Rogerson (2008), Buera et al. (2011), Guner et al. (2008), and Midrigan and Xu (2014). My model indicates that distortions from financial frictions have a quantitatively larger effect on total output than TFP. Private sector TFP gains and state sector TFP losses from entry/exit distortions due to financial frictions largely offset each other. However, the majority of lost output comes from the restricted entry of the large number of less talented entrepreneurs due to financial constraints.

Explanations of the sources of China's productivity growth include the reallocation of labor from agricultural to non-agricultural sectors (Dekle and Vandenbroucke, 2010), the fall of micro-level distortions (Hsieh and Klenow, 2009), human capital accumulation (Wang and Yao, 2003), and direct and spillover effects from FDI (Zhao and Zhang, 2010). These mechanisms have all likely influenced China's productivity growth. In this paper, I investigate the effects of the reallocation of resources given existing production technologies on TFP.

The remainder of the paper is as follows. I next present the empirical facts. Section 3 presents the model economy and the characterization of economic reforms. I describe the model parameterization in Section 4 and analyze the simulation results in Section 5. Section 6 concludes.

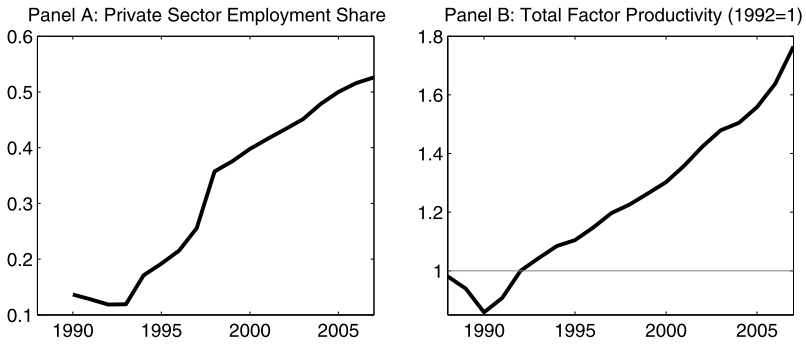

Fig. 1. Private sector employment share and aggregate total factor productivity (TFP). *Notes:* Data is for the non-agricultural economy and the TFP series is normalized by its 1992 level.

2. Data

This section presents the main empirical facts of China's non-agricultural economy from 1992 to 2007. It describes the economic reforms, documents the changes in TFP and rise of the private sector after reforms, and provides evidence of differences in access to credit markets between the state and private sectors. Section 2.3 presents a cross-sectional relationship between access to credit markets and sectoral TFP at the provincial-level: In provinces where the private sector relies less on formal credit markets than the state sector, TFP in the private sector is relatively higher than in the state sector.

2.1. China's economic reforms and TFP growth

Although there were earlier reforms, China's major steps leading to a mixed economy with large state and private sectors in the non-agricultural economy began in 1992. Prior to 1978, China's economy was centrally planned. The government controlled prices, agricultural production decisions, and owned nearly all industrial production. The first wave of economic reforms beginning in 1978 broke up communal agricultural units and gradually relaxed price controls on selected products. Local governments were granted more autonomy leading to the expansion of township and village enterprises (TVEs) – firms owned by local governments – in rural areas.

Across China, a small private sector developed but faced political discrimination. Various movements such as the campaigns against spiritual pollution in 1983 and 1984, the campaign against bourgeois liberation in 1987, and other movements demanding an "attack on speculation" challenged the legitimacy of private enterprises (Li et al., 2008). The central government did create select areas with a market-oriented economic system known as special economic zones (SEZs). The SEZs developed economic practices that fell outside central government economic policy which reigned throughout the rest of China.

In 1989, the Tiananmen Square Incident prompted turnover in Communist Party leadership which put further reforms on hold. In response to the stagnation of reforms, Deng Xiaoping made his famous Southern Economic Tour in early 1992. He traveled to Shenzhen SEZ and, upon witnessing its development under a market-oriented economy, he called on the country to emulate its example. In late 1992 the Communist Party officially endorsed the "socialist market economy." This marked a turning point in reforms and since then China has transitioned from a planned, state dominated economy to a mixed economy with both state and private sectors.

Panel A of Fig. 1 shows the share of private employment in China's non-agricultural economy. The data used in the analysis comes from various issues of the China Statistical Yearbook. Appendix A describes the complete methodology on construction of the aggregate data. The main aggregates of the non-agricultural economy are divided into government and private ownership. Following Dekle and Vandenbroucke (2010, 2012), government ownership is defined as the entirety of state-owned enterprises (SOEs), urban collectively owned units, and township and village enterprises (TVEs), and the private sector consists of private enterprises, self-employed workers, foreign owned firms, and other types of ownership. Throughout the paper, I refer to the government owned sector, as the "state sector." The figure highlights the ignition of private sector following the reforms in 1992. The share of private sector employment accelerated from 11.8 percent in 1992 to over half of the employment in 2007.

The rising importance of the private sector has coincided with an acceleration of China's aggregate TFP growth. Panel B of Fig. 1 plots the evolution of China's TFP in the non-agricultural sector. TFP calculations are estimated as the Solow Residual assuming an aggregate Cobb–Douglas production technology with input factors of capital K, labor L, and TFP A, $Y = AK^{\alpha}L^{1-\alpha}$. I let $\alpha = 0.50$, in line with China's non-agricultural labor share documented in Young (2003) and

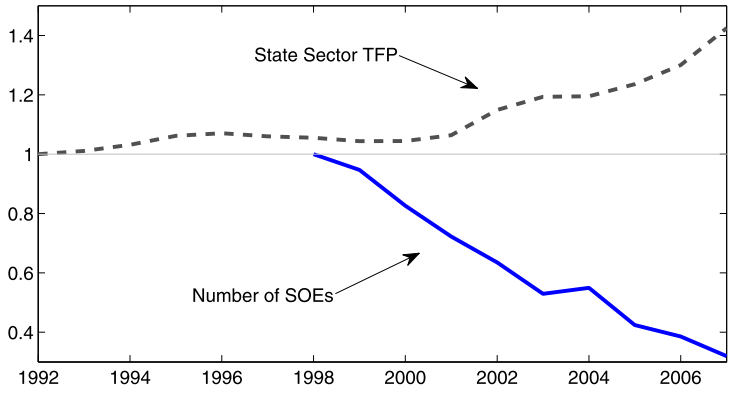

Fig. 2. Number of state owned enterprises (SOEs) and state sector TFP. *Notes:* Each series is normalized by the first observation in the sample. Data for the number of SOEs begins in 1998 and includes the universe of manufacturing and construction enterprises with annual sales over 5 million RMB.

Brandt and Zhu (2010), and I assume identical factor shares in the state and private sectors.[1] Labor L is the number of employed people, and the capital stock K is constructed using the perpetual inventory method with annual depreciation rate 0.075.[2] There are concerns that the implicit GDP deflator reported by China's National Bureau of Statistics understates inflation, thus overstating real GDP. Appendix A reports the alternative price indices used to calculate real GDP and the capital stock estimates based on methodologies in Young (2003) and Brandt and Zhu (2010).

China's TFP has risen nearly 80 percent from 1992–2007. These gains are, in part, a result of resource reallocation towards the more productive private sector as the ratio of private-to-state TFP has averaged 1.82 since 1992.

China's TFP growth has also arisen from productivity gains in the state sector, particularly after 2000. As a response to the overall inefficiency of the state sector, the policy of "grasp the large and letting go the small" was enacted in 1997. This privatized or closed smaller loss-making SOEs while retaining the larger, more efficient state owned firms in an effort to bolster economic competitiveness in the market economy. Fig. 2 illustrates the relationship between state sector TFP and the number of SOEs, both normalized to 1 by their first sample observation. Data for the number of SOEs includes only manufacturing and construction firms with annual sales over 5 million RMB for 1998–2007.[3] I acknowledge that TFP gains may be a result from within-firm productivity gains, but the trends and inflection in state sector TFP show a clear negative relationship with the number of SOEs.

2.2. Differential access to credit in the state and the private sectors

Although private sector TFP has remained higher than in the state sector, the formal financial sector gives preference towards providing finances to the state over the private sector. China's four largest state owned banks still continue to largely control the banking system (Allen et al., 2008).[4] Huang (2004) argues that China's domestic credit markets have a "political pecking order" which gives preferential access to SOEs and collectively owned units. Using firm-level data, Guariglia et al. (2011) find evidence of discrimination in access to credit for private sector firms and Poncet et al. (2010) document that private firms face severe financial constraints while SOEs tend to be unconstrained. Naughton (2007) suggests that the backing of TVE loans by local governments provides them with favorable access to external credit markets. As a result of difficulty obtaining formal credit, private firms have relied more on informal financing, such as from family and friends (Dollar and Wei, 2007). The aim of this paper is to understand the dynamics of China's TFP given the differences in access to credit markets between sectors.

2.3. Access to credit and private-to-state TFP

In China, there are clear differences in TFP and access to credit between the private and state sectors. A key empirical element in this study is the relationship between these two facts. I investigate this cross-sectional relationship using provincial and sector-level data.

[1] Young (2003) reports that the Chinese national accounts calculate employee compensation as all wages, salaries, supplements, employer payments to pensions, and the imputed labor income of the self-employed. He states "Given the methodology of the Chinese national accounts and the small number of self-employed in the economy, this fact provides no basis on which to modify the Chinese estimates."

[2] The initial capital stock is taken from Chow (1993) for 1978. The depreciation rate of 0.075 is between 6 percent in Young (2003) and 9.6 percent in Perkins and Rawski (2008).

[3] In 1998, the NBS reclassified reporting firms to include only those enterprises with annual sales over 5 million RMB creating a discontinuity in the series in 1998. 5 million RMB equal approximately 820,000 US dollars in 2013.

[4] Three of the four banks have been publicly listed with the government as the largest shareholder (Allen et al., 2008).

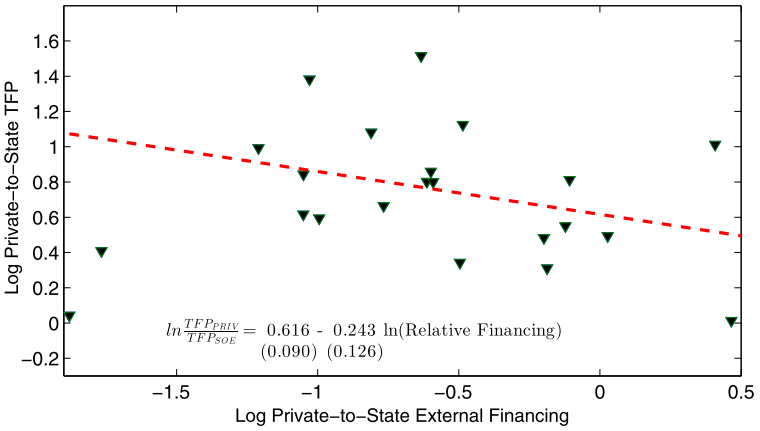

Fig. 3. Log Private-to-State TFP against Log Private-to-State External Financing. *Notes:* Log Private-to-State TFP is the log difference of TFP between sectors. Log Private-to-State External Financing is the log difference of the share of formal loans to investment between sectors. The estimated equation is a GDP-weighted regression with standard errors in parentheses.

Fig. 3 shows the cross-sectional scatter plot between the natural log of private-to-state TFP ($\ln \frac{TFP_{PRIV}}{TFP_{STATE}}$) and a measure of relative access to financial markets, *log private-to-state external financing*, for 23 provinces in 2002.[5] Private-to-state external financing is defined as the log ratio of the share of investment financed by the central government and bank loans in the private sector to the corresponding share in the state sector, $\ln(Loans_{PRIV}/I_{PRIV}) - \ln(Loans_{SOE}/I_{SOE})$. This measure gives a proxy for the differences in access to formal credit markets between the two sectors. The dashed line in the figure is the predicted value of a GDP-weighted regression of *log private-to-state TFP* on *log private-to-state external financing*.[6]

The negative relationship of relative external financing on private-to-state TFP suggests that when private firms have less access to credit markets than state firms, TFP differences between sectors become more pronounced. The regression coefficient on *log private-to-state external financing* is -0.243 with a p-value of 0.067. This does not suggest a causal relationship for there may be other, regional factors behind this correlation.

This relationship may, in part, be due to central government policy that channel investment funds to the relatively poorer western provinces. Brandt et al. (2013) suggest investment in the west was targeted to the state sector which has significantly lower TFP than the non-state sector. At the firm-level, however, Hale and Long (2013) find empirical support that financial constraints on the private sector have forced private firms to become more productive than the state firms by managing working capital more efficiently when access to borrowing is limited in order to remain competitive. In the model I develop, the differences in access to credit markets is the underlying force driving TFP differences between sectors as they limited entry to only the most productive entrepreneurs in the private sector.

3. Model

This section describes an environment that consists of agents that *i*) face imperfect capital rental markets and *ii*) those that do not. Mapping the model to the data, the former corresponds to the private sector and the latter to the state sector. Individuals are exogenously assigned to belonging to one of the two sectors.[7]

All agents in the economy are heterogeneous in their individual talent running a business, e, and wealth. Talent is drawn from a time-invariant distribution $\mu(e)$. The distribution of talent in both sectors is identical. Individual wealth is accumulated via saving.

In each period, all agents face an occupational choice: whether to work for a wage or to operate a business. Their decision weighs the most lucrative option given their talent operating a business (e) and access to capital markets. Each agent is endowed with one unit of labor that can only be supplied to one activity. If a private individual decides to operate a business, I refer to him as an entrepreneur. In the state sector, if an individual decides to operate a business, I refer to him as a manager. However, workers supply their labor to a common labor market and can be employed by businesses in either sector.

Following the description of the model, I introduce output distortions that prohibit entry by private firms (pre-reforms) and then characterize economic reforms as the removal of these barriers.

[5] 2002 is the most recent year that I can estimate TFP by ownership in the provincial data consistent with the method used in the aggregate data. See Appendix A.2 for details on the data.

[6] The two outliers to the bottom left of the graph are Guizhou and Ningxia provinces. Combined, their total GDP is 1.6 percent of total GDP in the sample.

[7] This assumption neglects the role of "Red Capitalists" – former Communist officials or SOE executives that have moved to private enterprise – in China's economic transition.

3.1. The state sector

There is a representative state sector household comprised of S members. Each member is paired with an individual talent of managing a business e.

Preferences The household pools the income of all its members and maximizes lifetime utility over total household consumption C given as

$$\mathbb{E}_t \sum_{t=0}^{\infty} \beta^t S \frac{(C_t/S)^{1-\sigma} - 1}{1-\sigma} \tag{1}$$

where $\beta \in (0,1)$ is the subjective discount factor, σ is the coefficient of relative risk aversion, and each household member consumes an equal share of the household's aggregate consumption.

Production Each period, an individual with talent e chooses to work for a wage w_t or manage an establishment. Conditional on becoming a manager, production of the final good y_t requires a combination of capital k_t and labor l_t with a managerial talent e using Lucas (1978) span-of-control production technology

$$y_t = e k_t^{\alpha} (z_t l_t)^{\theta} \tag{2}$$

where $\alpha, \theta \in (0,1)$ and $\alpha + \theta < 1$. Decreasing returns to scale implies that profits are $(1-\alpha-\theta)y_t$. The exogenous productivity process is given by z_t and is identical for all establishments. It evolves according to $z_t = g z_{t-1}$ where g is the growth in the productivity process.

Each manager hires labor at wage w_t and rents capital from a competitive financial intermediary at capital rental rate $R_t = r_t + \delta$, where δ is the capital depreciation rate. Conditional on managing an establishment, a manager with talent e maximizes profit taking the capital rental rate and wage as given. Formally, the profit function is defined as

$$\pi_t^S(e; w_t, R_t) = \max_{k_t, l_t} \left\{ e k_t^{\alpha} (z_t l_t)^{\theta} - w_t l_t - R_t k_t \right\}. \tag{3}$$

The household's problem Individuals within a household pool their collective income. Workers contribute wage w and managers contribute their business level profits. An individual chooses their occupation by whichever one pays the most. Given the wage rate, the decision therefore depends solely on individual managerial talents. Formally, an agent chooses to manage an establishment if his talent is greater than or equal to threshold $\underline{e}$ that solves the indirect profit function $\pi_t^S(\underline{e}; w_t, R_t) = w_t$.

The household chooses sequences of consumption C and saving in a risk free asset a with the financial intermediary which pays interest rate r_t. I restrict asset holding to be non-negative (consumers are not allowed to borrow). Specifically, the household's problem is to maximize the lifetime utility (1) subject to the budget constraints

$$c_t + a_{t+1} \leq \int_{\underline{e}}^{\infty} \pi_t^S(e; w_t, R_t) \mu(de) + \int_0^{\underline{e}} w_t \mu(de) + (1 + r_t) a_t \tag{4}$$

and

$$a_{t+1} \geq 0 \tag{5}$$

where the lower case variables represent per capita notation.[8]

3.2. The private sector

The private sector consists of a measure N of infinitely lived agents that are heterogeneous in entrepreneurial talent e and wealth, the latter is determined by the individual's assets a. This sector is modeled similarly as Buera and Shin (2013).

Each individual's entrepreneurial talent follows a stochastic process where he retains his ability from one period to the next with a probability γ and loses his ability with a probability $1-\gamma$, in which case he redraws a new ability from the distribution. Entrepreneurial talent e_t is thus given with a time subscript. The persistence of ability can be interpreted as the rate of change in the market structure that renders an individual's current talent unprofitable. Although entrepreneurial talent is drawn from the same distribution as in the state sector $\mu(e)$, implicitly the persistence of talent in the state sector

[8] Since members pool profits and wages, each member earns more than the market wage w in total non-saving income. I do not specify the exact definition of a "state sector individual" as it relates to the data other than those who have the option of managing a state establishment. However, SOEs provide higher labor compensation than other types of ownership (see Cai et al., 2008 and references within). Additionally, Appleton et al. (2009) suggest wages are 10–14 percent higher for those in the Communist Party. These empirical observations would be motivation for the model if one considers income of state sector individuals as total labor compensation.

is permanent, i.e., $\gamma = 1$. This reflects that Chinese state firms in major industries such as utilities, energy, financial services, etc., have a stake on the "essential" industries which allows them to survive over time.

Preferences Individuals maximize lifetime utility over consumption c of a single good

$$\mathbb{E}_t \sum_{t=0}^{\infty} \beta^t \frac{c_t^{1-\sigma} - 1}{1-\sigma} \tag{6}$$

where the preference parameters are identical to those in the state sector.

Production Individuals face an occupational choice between working for a wage or operating an establishment. Conditional on operating an establishment, an entrepreneur with talent e_t has access to the same production technology as an establishment in the state sector (2).[9]

Each individual also has access to the financial intermediary that accepts deposits of saved assets a_t, paying interest rate r_t, and rents capital at rate $R_t = r_t + \delta$ to the private entrepreneurs. However, each entrepreneur faces a limitation on his capital rental given by the collateral constraint $k_t \leq \lambda a_t$ where the parameter λ dictates the magnitude of capital market imperfections. This collateral constraint can be motivated from a limited commitment problem and is commonly employed in the literature on financial frictions. It is suitable for China because private businesses do rely heavily on self-financing for investment.

A private entrepreneur maximizes profit taking the rental rate and wage as given. The profit function is defined as

$$\pi_t(a_t, e_t; w_t, R_t) = \max_{k_t, l_t} \left\{ e_t k_t^{\alpha} (z_t l_t)^{\theta} - w_t l_t - R_t k_t \right\} \tag{7}$$

subject to

$$k_t \leq \lambda a_t. \tag{8}$$

The private agent's problem An individual chooses sequences of consumption c and saving in a risk free asset a, along with the decision to become a worker or an entrepreneur. He will decide to become an entrepreneur if his business-level profits exceed the market wage. This decision jointly depends on his entrepreneurial talent and whether his wealth is sufficient to overcome the collateral constraint. An individual with entrepreneurial talent e will operate an establishment if his current assets are greater than or equal to a threshold asset level $\underline{a}(e)$ that solves the indirect profit function $\pi_t(\underline{a_t}(e_t), e_t; w_t, R_t) = w_t$.

The private individual's problem is to maximize (6) subject to the restriction on non-negative asset holdings (5) and

$$c_t + a_{t+1} \leq \max\{\pi_t(a_t(e_t), e_t; w_t, R_t), w_t\} + (1 + r_t)a_t, \tag{9}$$

where the *max* operator captures an individual's optimal choice between operating an establishment or being a worker.

3.3. Equilibrium

A competitive equilibrium is defined as follows where a variable with an asterisk indicates an equilibrium value.
Given a sequence of prices $\{w_t^*, r_t^*, R_t^*\}_{t=0}^{\infty}$, *for all* $t \geq 0$, *the following holds in a competitive equilibrium:*

(i) *for the private sector, the sequences* $\{c_t^*, a_{t+1}^*, l_t^*, k_t^*\}_{t=0}^{\infty}$ *solves the individual's problem*;
(ii) *for the state sector, the sequences* $\{c_t^*, a_{t+1}^*, l_t^*, k_t^*\}_{t=0}^{\infty}$ *solves the household's problem*;
(iii) *the goods market clears;*
(iv) *the markets for capital and labor clear;*
(v) *financial intermediaries make zero profits.*

Since the growth in the productivity process g permanently impacts the level of the productivity process z, output is non-stationary. To solve numerically, I detrend the non-stationary variables. Specifically, for a variable x, I let a tilde denote the detrended variable

$$\widetilde{x_t} = \frac{x_t}{z_t^{\frac{\theta}{1-\alpha}}}. \tag{10}$$

The path of the normalized equilibrium is recovered by multiplying through by $z_t^{\frac{\theta}{1-\alpha}}$. Appendix B describes the model in terms of detrended variables and Appendix C explains the numeric solution method.

[9] The assumption of decreasing returns to scale in production for both sectors implies that no single establishment will obtain the entire market share. This modeling assumption is attractive for China because the central government has remained committed to keeping the coexistence of state and non-state enterprises.

Table 1
Parameter values.

Moments	Data	Model	Parameter
Labor income share	0.50	0.50	$\theta = 0.50$
Profit share of output	0.195	0.195	$\alpha + \theta = 0.805$
Ave. aggregate TFP growth 1980–1992	0.016	0.016	$g = 1.045$
Establishment exit rate	0.116–0.12	0.115	$\gamma = 0.88$
External finance to GDP 2007	1.46	1.46	$\lambda = 1.435$
Private employment share 2007	0.52	0.52	$\frac{S}{N} = 0.061$
Top 10 percent employment share 2004	0.71	0.71	$\eta = 4.65$

3.4. Distortions and economic reforms

This section describes the characterization of economic reforms on the model economy. Initially (pre-reform) individuals in the private sector face prohibitive barriers to entrepreneurship. Reforms are the removal of this barrier. The main results analyze the transition path between stationary steady states from the pre-reform to the post-reform model economy.

In the initial, pre-reform economy, I model restrictions to entry by private entrepreneurs as an output distortion τ, representing all obstacles to production. Business level production for a private entrepreneur is thereby

$$(1-\tau)e_t k_t^{\alpha}(z_t l_t)^{\theta} \tag{11}$$

where $\tau = 1$. This initial value ensures that no private entrepreneurs operate a business.

Reforms are introduced by the permanent and unexpected change from $\tau = 1$ to $\tau = 0$. Once the reform takes place, everyone realizes the change is permanent and individuals in the private sector have the option of operating their own business. The entirety of China's actual reforms may not have been as abrupt as this characterization, but the data suggest that the reforms were drastic through reallocation of labor and production following the 1992 reforms.

4. Parameterization

There are 11 parameters specified for the quantitative analysis. I set the coefficient of relative risk aversion to set to $\sigma = 1.5$ and $\delta = 0.075$ for the one year depreciation rate of capital.

Table 1 reports the parameters that are disciplined by moments in the data. Of these parameters, the relative size of the state to the private sector N/S, the magnitude of the collateral constraint λ, and the distribution of talent are determined by matching the model to the Chinese data along the transition.

First, the labor share of output θ is 0.50, matching the labor share in the Chinese data. To find the capital share of output, I use income accounts from Hsueh and Li (1999) and various issues of the China's Statistical Yearbook that reports aggregate depreciation of fixed assets, net taxes on production, and operating surplus. I assume that the depreciation of fixed assets is assigned to capital and split the net taxes and operating surplus equally between capital and profits. This choice implies $\alpha = 0.305$. The returns to scale, $\theta + \alpha = 0.805$, is in the range used in recent studies informed by the US data. Restuccia and Rogerson (2008) use a value of 0.85, Guner et al. (2008) use 0.802, and Buera and Shin (2013) calibrate a value of 0.79 to match earning shares.

Next, consider the growth of the exogenous productivity process g. I simulate the pre-reform economy ($\tau = 1$), find total capital and labor in the model, and then use the aggregate Cobb–Douglas production function to back out TFP. To be consistent with the TFP calculations in the data, I assign equal shares to capital and labor in the aggregate production function. I let $g = 1.045$, matching the average growth rate of aggregate TFP in the pre-reform model with that in the data from 1980 to 1992, 1.6 percent.

The initial interest rate is set to match the aggregate capital–output ratio from 1980 to 1991, 2.42. In the detrended problem, normalizing initial exogenous productivity z_0 to 1, the corresponding discount factor can be written as $\widetilde{\beta} = \beta g^{\frac{\theta(1-\sigma)}{1-\alpha}}$. The initial steady state requires $\widetilde{\beta}(1+r^*) = g^{\frac{\theta}{1-\alpha}}$ which implies $\widetilde{\beta} = 0.982$.

The persistence of talent γ governs the exit rate of entrepreneurs in the stationary state. Hsieh and Song (2013) report that the annual exit rates for industrial firms in the private sector has been steady at 11.6 percent from 1991 to 2005 and 12 percent from 1998 to 2007.[10] I let $\gamma = 0.88$, leading to an exit rate of private firms of 11.5 percent in the stationary model economy.

Given the above parameter values, the remaining parameters are jointly calibrated to match model moments with the data along the transition. I simulate the model from the pre-reform ($\tau = 1$) to the post-reform economy ($\tau = 0$) to identify the parameter values. First, the magnitude of the collateral constraint λ targets China's external finance to GDP ratio in

[10] Hsieh and Song (2013) also report that the exit rate for SOE industrial firms was 0.9 percent from 1991 to 1995, supporting the assumption that $\gamma = 1$ for the state sector.

2007 of 146 percent. External finance is the sum of domestic and foreign bank credit, private bond market capitalization, and stock market capitalization.[11] I let $\lambda = 1.435$ which matches the external finance to GDP ratio in the data.

Second, I assume the distribution of talent e follows a truncated and discretized Pareto distribution with probability density function $\eta e^{-(\eta+1)}$ where η determines the dispersion of talent across individuals.[12] In absence of financial frictions, there is a mapping between talent e and employment. Since the presence of financial frictions distorts establishment size, given λ, I target the distribution of the talent parameter η to the Chinese firm size by employment. I set η to 4.65 which matches the model employment share of the largest 20 percent of firms in 2004 to the 2004 data reported in the 2005 Chinese Industrial Census, 0.71.[13] The distribution of talent is the same across both sectors in the model economy.

Third, I match the private sector's employment share of 52 percent in 2007 with the relative size of the state to the private sector S/N. The number of simulated private agents is fixed to $N = 150{,}000$ and S/N is adjusted to 0.061.

The final step is to assign the initial asset holdings. The initial distribution of assets impacts the speed of the transition. For example, if individuals in the private sector have enough assets to overcome the collateral constraints, they can immediately produce at their optimal scale. Since data on the wealth distribution in 1992 is scarce, I assume the initial distribution of assets follows the income share of the top 10 percent reported in the World Bank's *World Development Indicators* from 1992 to 2005, 0.30. Specifically, agents within the same sector have an equal amount of assets, however the level is higher in the state sector than in the private sector.

5. Quantitative results

Section 5.1 begins by presenting the main quantitative simulations. The model economy generates several results consistent with the evolution of China's TFP. First, the rise in aggregate TFP follows reforms that removed prohibitive barriers to entrepreneurship. The rise in aggregate TFP comes from the expansion of the private sector and TFP gains in the state sector from the closure of less productive state enterprises. The model also generates differences in TFP between the state and private sectors. I then detail the mechanisms underlying these results. Section 5.2 assesses the contribution of financial frictions on the model dynamics. Section 5.3 presents a sensitivity analysis and Section 5.4 considers a small open economy version of the model.

5.1. Baseline model results

This section presents the main results which analyzes the transition from an initial stationary equilibrium where all active businesses belong to the state sector ($\tau = 1$) to a mixed economy with both private and state entrepreneurs ($\tau = 0$). Recall that the reforms do not include financial market development, i.e. the magnitude of the collateral constraint λ remains fixed throughout.

Fig. 4 presents the transition dynamics of TFP, private employment share, private-to-state TFP, and factor input prices. To be consistent with the TFP calculations in the data, I aggregate capital and labor and use the Cobb–Douglas production function to back out TFP, assigning equal shares to both inputs. Panel A shows the Baseline simulations in the dashed lines against the data in the solid black line. To compare the model dynamics to the trend growth in technology, the series titled 'No Reform' plots the pre-reform path of TFP which is also the implied TFP if there were no reforms in the model economy. All changes in TFP in the model above the 'No Reform' simulation are the result of resource reallocation given existing production technologies. Following the 1992 reforms, model TFP jumps and continues to evolve, growing 21.5 percentage points above the pre-reform trend by 2007. The model matches TFP growth in the data up through 2002 and by 2007 it accounts for 63 percent of observed TFP growth since reforms. Clearly, additional institutional and societal factors beyond the modeled reforms have impacted the Chinese economy, but the model indicates that the 1992 reforms alone may have sparked substantial changes in TFP over this time-frame.

Three mechanisms contribute to the TFP growth above the exogenous technology gains. First, reforms introduce a wave talented private entrepreneurs with enough assets to overcome the collateral constraints and operate at a profitable level to enter into production. Financial frictions, however, impede entry of the less talented. Highly talented individuals profitably operate a business using fewer capital inputs than less talented individuals. In contrast, individuals in the state sector do not face this barrier to entry, so there are relatively more low-talent managers operating establishments in this sector. This selection mechanism results in a relatively larger share of talented entrepreneurs in the private sector than in the state sector, generating a difference in the composition of talent between these sectors. This ultimately leads to persistent differences in TFP (Panel C) with the private sector displaying higher TFP.

[11] I follow Buera et al. (2011) to calculate external finance using data from Beck et al. (2010). The market value of the stock market capitalization overstates the book value so I multiply the stock market capitalization by 0.33. This calculation does not account for private consumer credit, so the actual value of borrowing for investment is likely smaller.

[12] I truncate the Pareto distribution by finding $\bar{e}$ that solves $G(\bar{e}) = 1–0.0005$ where $G(\cdot)$ is the c.d.f. of the Pareto distribution. This cutoff ensures that the mass above $\bar{e}$ is probabilistically very small.

[13] The 1995 Chinese Industrial Census (reported in Brandt et al., 2012) shows that employment share of the largest 33 percent of firms is 80 percent. The corresponding employment share in the model is 78 percent.

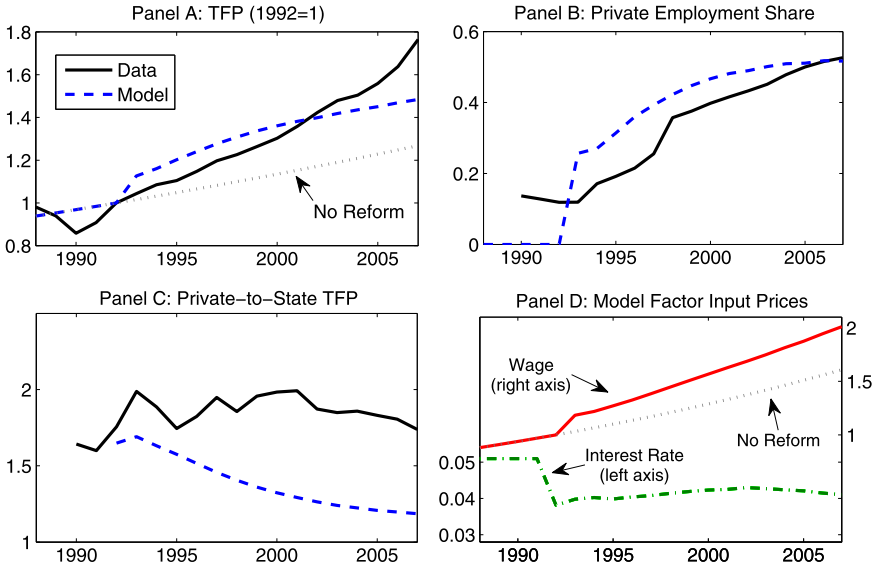

Fig. 4. Transition in the Baseline economy. *Notes:* Panels A, B, and C compare the Baseline model with the data. Panel D reports the evolution of factor input prices from model simulations. The 'No Reform' series shows the pre-reform trends of TFP (Panel A) and wages (Panel D).

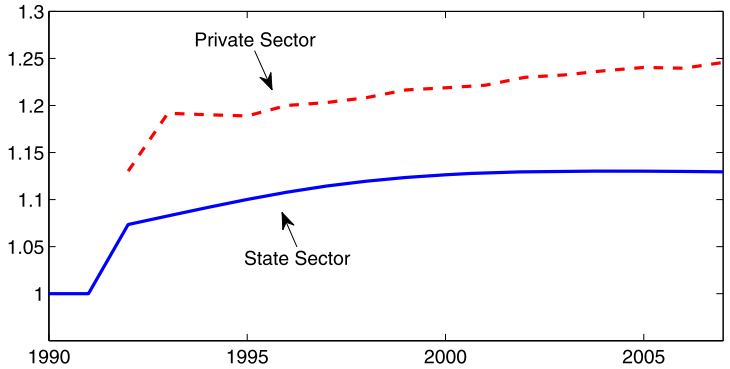

Fig. 5. Average talent e of active entrepreneurs/managers by sector normalized by the pre-reform average talent level of the state sector.

Second, TFP growth comes from the exit of marginally talented state managers. Ongoing productivity growth causes a rise in the equilibrium wage (Panel D), which induces the exit of less productive state enterprises on two fronts. First, business level profits decline. Second, the outside option of being a worker becomes more attractive.

Third, the entry and expansion of the private sector results in a reallocation of productive resources to more efficient use. Panel B shows the evolution of the private sector employment share which was calibrated to match the data in 2007. Following reforms, financial frictions cause private entrepreneurs to operate at an inefficiently small scale. As private entrepreneurs accumulate wealth to increase collateral and approach the profit-maximizing scale, this sector expands and gradually attracts more labor.

Now, I explore these mechanisms in more detail.

5.1.1. TFP differences between the private and state sectors

In this section, I explore the mechanisms that lead to the differences in TFP between the state and private sectors. Fig. 5 shows the average individual productivity e of active managers/entrepreneurs normalized by the pre-reform average talent level of the state sector. Although the distribution of individual talent e is identical in both sectors, the talent pool of active entrepreneurs is higher than what is found in the state sector. These differences arise from financial frictions that alter an individual's decision to become a worker or entrepreneur.

Consider the occupational decision rules for both sectors. Fig. 6 shows these rules by plotting assets a against individual talent e. For an agent in the private sector, the decision to become an entrepreneur depends jointly on his talent and wealth.[14] The threshold asset level a at a given entrepreneurial talent e is given by $\underline{a}(e)$. To the right of the cutoff, the agent

[14] This figure plots the occupational decision rules in the final stationary steady state.

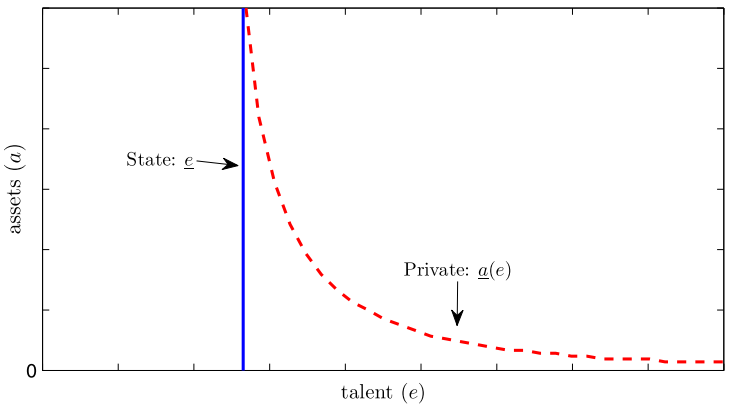

Fig. 6. Occupational decision rules. *Notes:* The x-axis is talent e and the y-axis is individual asset holdings a. For the state sector, agents with talent to the left of the cutoff value will become workers and the to the right will manage a state enterprise. For the private sector, agents with combinations of talent e and assets a to the left of the private sector cutoff will become workers and to the right will become entrepreneurs.

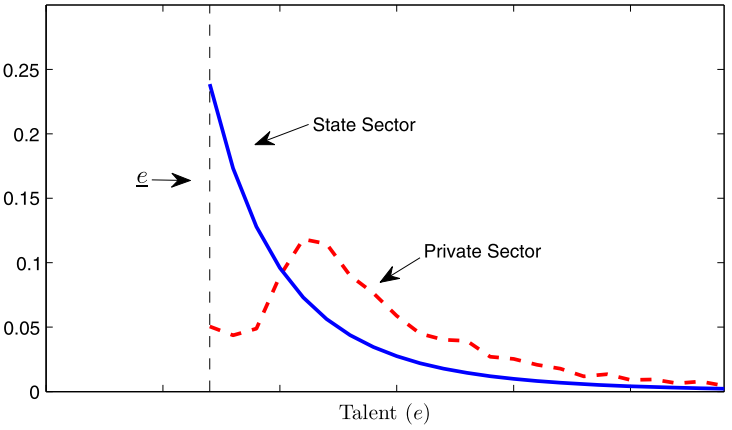

Fig. 7. The probability density function (p.d.f.) of active entrepreneurial/managerial talent e by sector. *Notes:* The vertical dashed line corresponds to the occupational cutoff value for the state sector $\underline{e}$ from Fig. 6.

operates an establishment as an entrepreneur and to the left he becomes a worker. The downward slope of the decision rule indicates that more talented individuals require fewer assets to enter entrepreneurship.

For agents in the state sector, the occupational choice cutoff only depends on individual talent since they face complete access to capital rental markets: The level of asset holdings for these individuals is irrelevant for their occupational choice. The vertical line at $\underline{e}$ shows the cutoff for the state sector. It is worthwhile to point out that an individual in the private sector would never choose to be an entrepreneur if his talent was below $\underline{e}$ no matter how wealthy he may be.

The difference in the occupational decision rules illustrates a barrier to entrepreneurship due to financial constraints that particularly affects the less talented. For example, a private agent with talent and assets that place them in the area between $\underline{e}$ and $\underline{a}(e)$ would not become an entrepreneur but an agent in the state sector would manage a business in this region. As a result, the share of active, low-talent managers is higher than the share of active, low-talent entrepreneurs. This mechanism generates the variation in the composition of talent between sectors.

Fig. 7 shows the corresponding probability density functions (p.d.f.) of active individual entrepreneurial/managerial talent in each sector. The point where the distribution starts corresponds to $\underline{e}$ from Fig. 6. Observe that close to $\underline{e}$ on the right, the state sector has a large mass of active entrepreneurs while the private sector does not. Individuals in the private sector in this range of talent cannot save the necessary collateral to operate at a profitable scale. In the absence of collateral constraints, these distributions would be identical.

The overall difference in private-to-state TFP is a result of two opposing factors. On the one hand, collateral constraints cause private entrepreneurs to operate at an inefficiently small scale, suppressing TFP. On the other hand, the composition effect – selection of the most talented entrepreneurs – raises TFP. I measure these individual effects on aggregate TFP and GDP in Section 5.2.

The differences in average productivity between sectors is influenced by the persistence of ability γ. If γ equals 1, all private agents' talents remain indefinitely relevant. In this scenario, all potential private entrepreneurs with talent $e > \underline{e}$

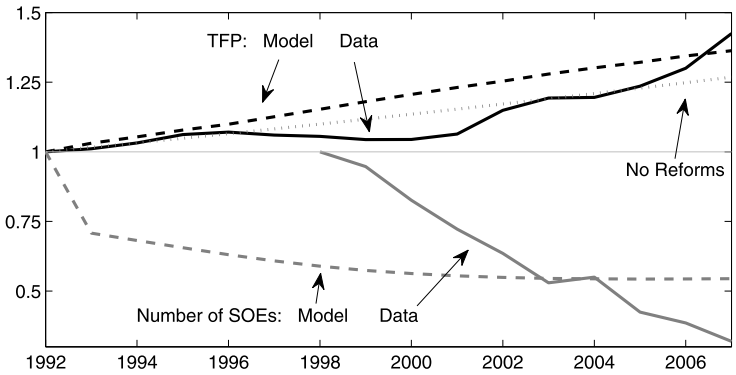

Fig. 8. The number of state enterprises and state sector TFP in the data and the model. *Notes:* All series are normalized by the first observation in the sample. The 'No Reforms' series plots the pre-reform path of state sector TFP. Data for the number of SOEs begins in 1998 and includes the universe of manufacturing and construction firms with annual sales over 5 million RMB.

eventually overcome the collateral constraints and the steady state composition of talent will be the same in both sectors.[15] At a low persistence of talent, since asset accumulation takes time, saving to overcome the collateral constraints may be futile because an agent's current ability may become obsolete before he can profitably become an entrepreneur.[16]

Interest rates also impact an individual's ability to overcome the financial constraints. Following reforms, the interest rate falls a full percentage point (see Fig. 4 Panel D). With lower interest rates, private agents become more impatient, rendering them less willing to save in order to overcome collateral constraints.

Interest rates initially fall from the decline of capital demand in the state sector. State entrepreneurs exit and production shifts towards the less capital intensive private sector. Over time, interest rates continue to remain low as private entrepreneurs increase savings to self-finance investment. Additionally, when the persistence of talent $\gamma < 1$ private entrepreneurs save to smooth consumption for future periods when they will most likely be workers. These forces work in tandem to depress interest rates.

5.1.2. TFP growth in the state sector

TFP also arises from the exit of the least talented manager in the state sector. As the private sector expands, the increased labor demand raises the equilibrium wage, inducing exit of the least productive managers (i.e., $\underline{e}$ shifts to the right). As a result, the average managerial talent in the state sector increases (as previously shown in Fig. 5).

Fig. 8 compares the number of state establishments and the state sector TFP.[17] The model simulations and the data are shown in the dashed and solid lines, respectively, and the series titled 'No Reforms' shows the pre-reform path of state sector TFP.[18] Each series is normalized by the first observation. It is clear that in both the data and model that TFP growth is inversely related to the number of state businesses. In the model, exit is the only mechanism that changes TPF in this sector. Only the least talented managers close their establishment leaving the most talented ones managing a business. This channel alone accounts for an additional 9 percentage point growth in the state sector in state sector TFP above the 'No Reform' economy. This mechanism mirrors the central government's policy of "grasping the large and letting go the small." In reality entry and exit decisions of state enterprises may not be entirely made at the establishment level, but these results support the inclusion of endogenous entry and exit of the state sector into the model.

5.1.3. Resource reallocation

Panel A of Fig. 9 graphs the evolution of the capital–output ratio. The fall in the capital–output ratio at reforms is a result of production being shifted towards the less capital intensive private sector. The financial frictions cause private entrepreneurs to operate at an inefficiently small scale, but as time progresses they save collateral to expand their scale of production which results in the increase in the capital–output ratio after 2000.

Resource reallocation has additionally occurred among individuals following the 1992 reforms. Entrepreneurs acquire interest bearing assets and business-level profits, skewing the income distribution. Panel B of Fig. 9 shows the income Gini coefficients in the model and the urban Chinese data as reported in Chen et al. (2010). The rising income Gini coefficients captures inequality growth from higher returns to skilled labor following reforms (entrepreneurial talent in the model). Although the predicted level is slightly lower, the model captures over two thirds of the observed increase in the Gini coefficient.

[15] Section 5.3 presents the model with $\gamma = 1$.

[16] In the model, approximately 4 percent of private agents meet the talent requirement ($e > \underline{e}$) to become an entrepreneur. Thus, even though it is possible for a potential private entrepreneur to draw a higher talent if he loses his current talent, it is more likely that such an agent would become less talented.

[17] The data in this figure is described in Section 2.1.

[18] The model series for number of SOEs is smoothed using the Hodrick–Prescott filter with smoothing parameter $\lambda = 100$ to capture the trend.

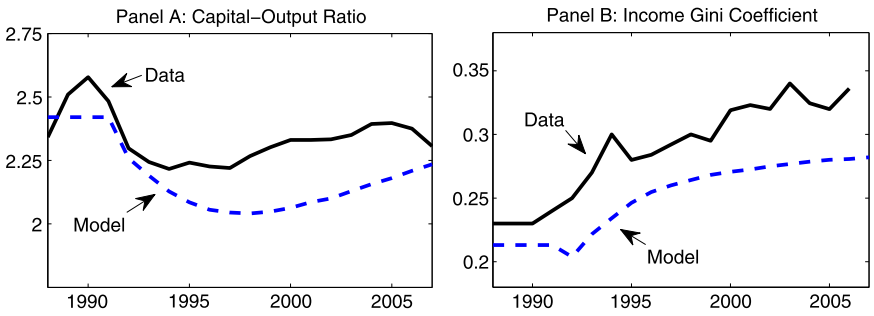

Fig. 9. The aggregate capital–output ratio and the income Gini coefficient in the data and Baseline model. *Notes:* Data on the income Gini coefficient is for urban areas only reported by Chen et al. (2010).

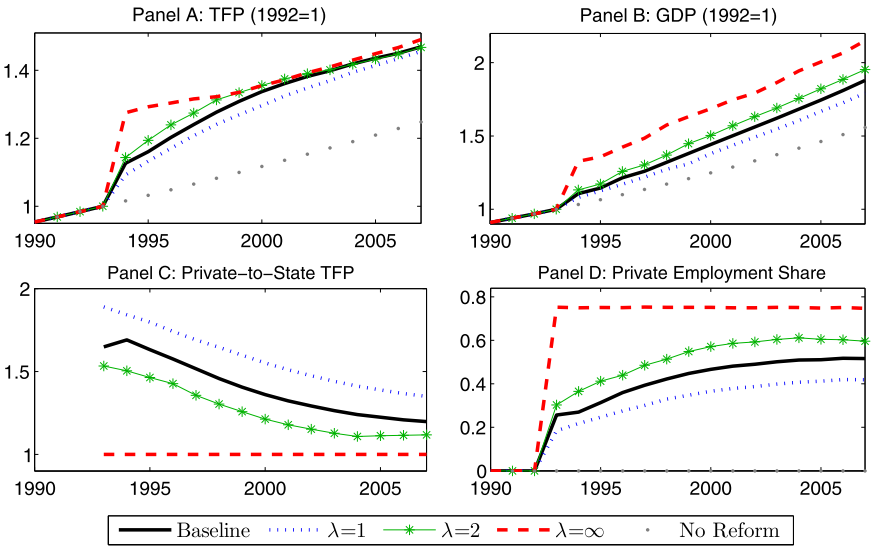

Fig. 10. Variations in financial development. *Notes:* Each series considers a different magnitude of the collateral constraint λ. In the Baseline economy $\lambda = 1.435$, when $\lambda = \infty$ all agents have complete access to capital rental markets, and when $\lambda = 1$ private agents have no access to credit. The 'No Reform' series shows the pre-reform path of each variable.

During China's centrally planned period, the government chose equity over efficiency through compressed wages and a large social safety net. Economic reforms were enacted knowing inequality would rise with increased returns to private enterprise under the premise that economic growth would improve incomes of everyone. In the model, incomes increased for all groups, particularly at the highest end of the income group, mirroring the China's broad trends over this period.[19] The simulations show that incomes for the 10th percentile of income grew 89 percent and the 90th percent of income grew 180 percent from 1992 to 2007.

5.2. Measured impacts of financial frictions

This section analyzes the measured impacts of financial frictions. I first vary the magnitude of the collateral constraint and show how this impacts key variables. I then quantify the distortions from financial frictions on capital intensity and entry and exit decisions. Fig. 10 shows the model at four different stages of financial market development: (1) The Baseline economy, $\lambda = 1.435$; (2) entrepreneurs are excluded from financial markets and must self-finance all capital, $\lambda = 1$; (3) all entrepreneurs can rent capital up to two times their asset holdings, $\lambda = 2$; and (4) all agents have complete access to capital rental markets, $\lambda = \infty$. I refer to this last case as the 'Frictionless' economy.

The size and speed of private sector expansion is increasing in access to capital rental markets. Panels A and B show that TFP and GDP jump at reforms in the absence of financial frictions. In the Frictionless economy, all firms can immediately borrow the necessary collateral which causes the dynamics to evolve more starkly. Overall, financial frictions inhibit entry of talented individuals with low amounts of collateral and distort the scale of credit constrained businesses. Compared to

[19] Meng (2004) found that urban incomes fell briefly in the mid-1990s following layoffs from SOE restructuring. Since all agents in the model are employed, the rise in income for all groups represents positive wage growth for all working agents.

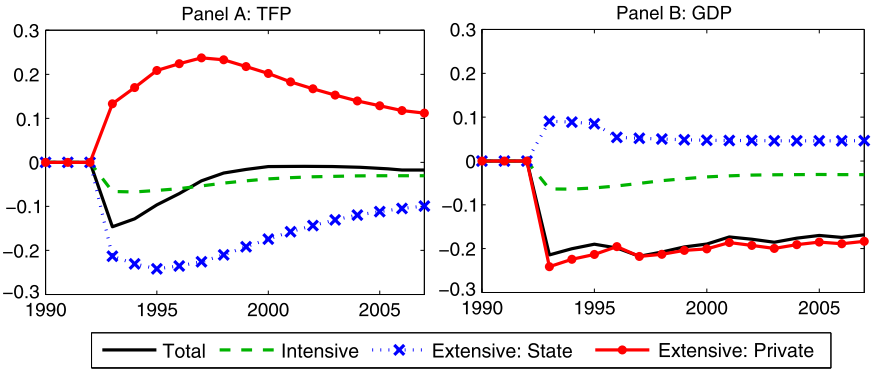

Fig. 11. Measured distortions from financial frictions. *Notes:* The solid line is the percentage difference between the Baseline and Frictionless ($\lambda = \infty$) economies. The remaining series decomposes this difference into contributions from intensive and extensive margin distortions.

the Frictionless economy, GDP in the Baseline economy grows 18 percentage points less (Panel B) and private employment is 30 percent smaller (Panel D).

Panel C shows private-to-state TFP for different magnitudes of the collateral constraint. As financial frictions are lessened, TFP for both sectors becomes more similar and are identical in the absence of financial frictions. This happens for two reasons. First, since financial frictions restrict entry to only the most talented entrepreneurs, the overall composition of private entrepreneurial talent (e) is higher the more severe the financial frictions. As financial frictions are removed, less talented entrepreneurs can profitably enter, lowering the talent composition and, hence, private sector TFP. Second, with the removal of financial frictions, firms can operate at a larger scale which increases wage growth and causes marginally talented state enterprises to close. This raises the talent composition of state managers and state sector TFP. In 2007, for example, the average talent in the state sector is 11 percent higher but there are 40 percent less state enterprises in the Frictionless compared to the Baseline economy.

I next measure the impact of financial frictions in the Baseline economy from distortions of entry and exit decisions and the allocation of capital. Fig. 11 quantifies these distortions. The solid line shows the percentage difference of TFP and GDP in the Baseline economy from the Frictionless economy for each year. These deviations are further decomposed into distortions on the intensive margin on the private sector (distortions on capital use) and the extensive margin (distortions on entry and exit decisions).

Intensive margin distortions on the private sector are shown by the dashed lines. The intensity of capital use by state enterprises is not distorted since they have complete access to capital rental markets; the intensive margin distortions occur exclusively on the private sector. These distortions are measured by first holding the total capital, labor, and pool of active entrepreneurs in the private sector constant for each year. Capital is then redistributed among the set of entrepreneurs to equalize the marginal product of capital among them. The intensive margin distortions keep TFP and GDP between 7 and 3 percentage points lower than the perfect credit economy. These distortions lessen over time as entrepreneurs save collateral to expand their capital use closer to their profit maximizing scale.

I next measure extensive margin distortions from financial frictions separately for the state and private sectors. For the state sector, I impose the number and distribution of state businesses in the Baseline economy to be at the levels of the Frictionless economy for each corresponding year. This results in a lowering of aggregate TFP as high as 24 percent in 1996. Intuitively, financial frictions both restrict entry and capital intensity on private entrepreneurs, thereby keeping wages lower than the frictionless economy. Businesses in the state sector with relatively low productivity e remain active that would otherwise be inactive if financial constraints were removed.[20] However, this distortion leads to higher output in the state sector. The larger the number of state businesses, albeit with lower managerial talent e, results in more output for that sector.

I attribute the remaining contribution of TFP and GDP differences to extensive margin distortions on the private sector. Throughout the transition, extensive margin distortions on the private sector on aggregate TFP are positive. Financial frictions act to restrict entry on entrepreneurs with relatively low talent e. As a result, the talent composition of active entrepreneurs is higher than the Frictionless economy. Visually, we see that the TFP gains on the private sector through this extensive margin distortion outweigh TFP losses from intensive margin distortions. However, the restricted entry of these entrepreneurs with lower talents results in a much smaller number of total active entrepreneurs and thus a loss of potential output. Almost all of the loss of GDP from financial frictions is accounted for by the distorted entry decisions on the private sector.

The results indicate that financial frictions in the model amplifies TFP in the sector facing financial frictions (private) and dampens TFP in the sector with complete access to capital rental markets (state). However, the effects of financial frictions

[20] That is, higher wages would move $\underline{e}$ right enticing the marginally talented managers to close their business.

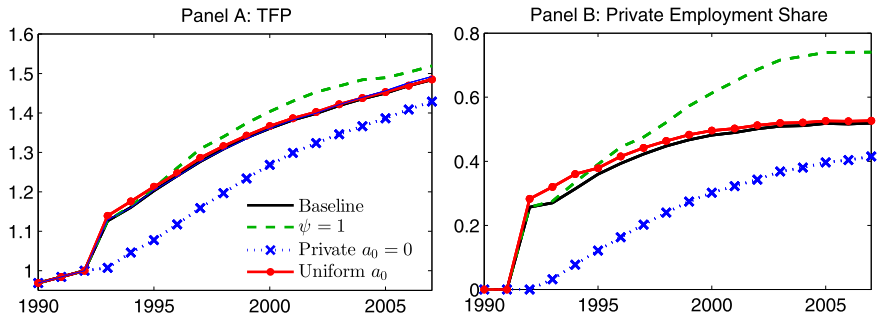

Fig. 12. Sensitivity analysis. *Notes:* The solid line is the Baseline economy and the remaining series describe three alternative characterizations: ($\psi = 1$) permanent persistence in entrepreneurial talent; (Private $a_0 = 0$) initial assets for private sector individuals is zeros; and (Uniform a_0) all agents initially have the same asset holdings.

have opposite effects on sector size, measured by the number of businesses and output. This analysis suggests that financial frictions on the private sector may be an important component in understanding TFP and size differences between sectors, and that there is a potential for large output gains with the removal of barriers to credit markets.

5.3. Sensitivity analysis

This section describes four alternative cases to the Baseline economy: (1) permanent persistence of entrepreneurial talent, (2) setting initial assets held by individuals in the private sector at zero, (3) uniformly distributing initial assets among all individuals in the economy, and (4) gradually reducing the output distortion τ over time. Each experiment retains the Baseline model parameterization except for the component in question. The first three scenarios are plotted in Fig. 12 against the Baseline model.

First, suppose the persistence of talent on individuals in the private sector is permanent (i.e. $\gamma = 1$). Initially, financial frictions on private entrepreneurs distort selection into entry and capital intensity. Eventually, all entrepreneurs all acquire the necessary collateral to operate at their profit maximizing scale. By 2007, the private sector employment share, 0.74, is nearly the same as in the prefect credit economy (see Fig. 10). Additionally, both the compositions and sectoral TFPs between the private and state sectors are eventually identical (figure not shown).

I next show how the allocation of initial assets impacts the speed of the transition. I allocate initial assets such that the sum of all assets is equal to the aggregate capital stock, but consider alternative distributions of assets among agents. The dotted 'x' line shows the economy when private agents initially have zero assets. At reforms, private agents are unable to select into entrepreneurship because they have no collateral. This is evident in Panel B as there is a one period delay after reforms before agents save and the private employment share is positive. The transitional dynamics are more gradual than the Baseline economy as entrepreneurs slowly overcome their initial deficiency of assets. When assets are uniformly distributed among *all* agents, shown in the 'Uniform a_0' series, the transition is much faster and the dynamics are quantitatively similar to the Baseline simulation.

Additionally, I consider variations of the coefficient of relative risk aversion, $\sigma = 3$ and logarithmic utility ($\sigma \to 1$). These cases are omitted from the figure because the dynamics are close to the Baseline economy. As σ increases, agents save more aggressively, but quantitatively, the effects are small. TFP and GDP growth are all within a total of 1.5 percentage points of each other across all simulations throughout the transition.

Finally, Fig. 13 shows the case of gradual a gradual reduction in the output distortion τ. Prior to reforms the production technology for a private entrepreneur is $(1-\tau)e_t k_t^{\alpha}(z_t l_t)^{\theta}$. At reforms, τ decreases from $\tau = 1$ to $\tau = 0$ over a span of 10 years in increments of 0.1. Panel A compares this experiment, labeled 'Gradual τ,' with the data and baseline model. The transition is more gradual than the baseline model and fits the dynamics of the data more closely. Panel B shows the average talent in the private sector normalized by the average talent of the state sector prior to reforms. In the first two periods, there is no entry by private entrepreneurs (τ values of 0.9 and 0.8). In the following periods, the average talent starts out high and gradually decreases. When the output distortion is high, only the most talented entrepreneurs are able to operate under these circumstances.

5.4. Small open economy

This section presents a small open economy model to explore the implications of China's economic reforms on foreign asset holdings. Since 1992, China has consistently run a current account surplus and has acquired a large stock of foreign assets. From 1992 to 2007, China's net foreign asset as a share of GDP rose from −2.7 to 24.4 percent and foreign reserves reached $1.5 trillion by 2007 (Lane and Milesi-Ferretti, 2007).

In the small open economy model, interest rates are fixed at their initial value and wages adjust to clear the domestic labor market. The domestic financial intermediary receives deposits and rents capital but clears the difference between

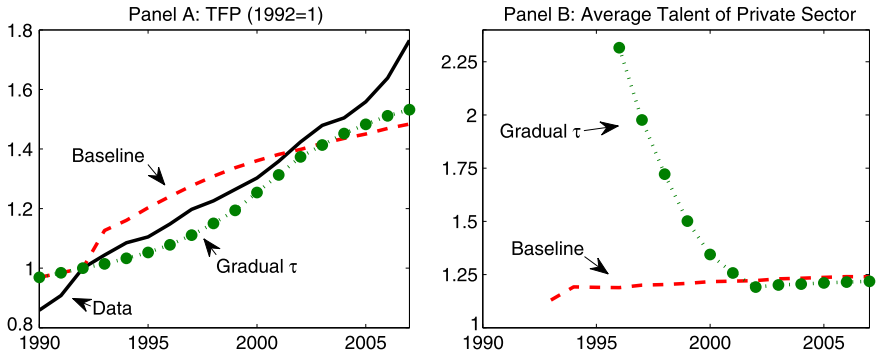

Fig. 13. Gradual reduction of output distortion τ. *Notes:* The solid line is the data, the dashed line is the Baseline model, and the '•' series shows when the output distortion τ is gradually reduced from 1 at reform to 0 over a span of 10 years in increments of 0.1.

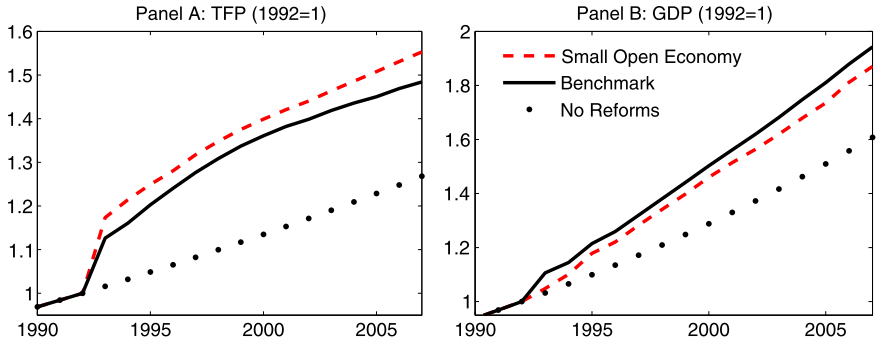

Fig. 14. TFP and GDP in the small open economy. *Notes:* The small open economy model fixes interest rates at their initial, pre-reform value. The 'No Reforms' series plots the path of the pre-reform variables.

total capital and deposits in international markets. This model retains the Baseline parameterization of the closed economy model except the initial net foreign asset position is set to match that in the data in 1992, −2.7 percent of GDP. For numeric tractability, each agent faces a portfolio adjustment cost of holding assets different from their initial level. The adjustment cost is $\psi(a_t - a_0)^2$ where a_0 are the initial assets and parameter $\psi = 0.00075$.[21]

The dashed lines of Fig. 14 present the levels TFP and GDP for the small open economy model. For comparison, the Baseline closed economy model and the economy in absence of reforms are given by the solid black and the dotted lines, respectively. TFP in the closed economy rises faster and remains above TFP in the closed economy. Since the domestic capital rental rate is equated to the world rate, interest rates after reforms are higher than in the closed economy (see Fig. 4). It is thus easier for constrained entrepreneurs to save for self-financing which results in less distortion due to financial frictions. These higher interest rates also reduce capital intensity. Throughout the transition, the capital stock is 12.5 percent smaller, on average, than the closed economy model. Although there are fewer distortions from financial frictions, the smaller capital stock reduces output below that in the closed economy.

Fig. 15 shows net foreign assets as a share of GDP in the small open economy model and the data. In the model, net foreign assets rise sharply at reforms and continue to rise thereafter. Collateral constraints play a pivotal role in the accumulation of foreign assets. Investment initially shifts away from financially unconstrained state enterprises. Since the new entrants in the private sector are credit constrained, total borrowing falls and is exceed by aggregate savings. These entrepreneurs gradually accumulate assets for collateral and the higher interest rates than the closed economy speed the rate of asset accumulation. Overall, this generates a foreign surplus. Quantitatively, the model over predicts the size of the foreign surplus; the net foreign asset position is 88 percent of GDP in 2007 compared to 25 percent in the data.

Illustrating the role of financial frictions on net capital outflows, the dashed line in Fig. 15 presents the small open economy model with complete access to capital rental markets ($\lambda = \infty$). On impact of reforms, private entrepreneurs borrow all of the necessary capital to immediately operate at their profit maximizing scale. This leads to a sharp reduction in the foreign asset position to −76 percent of GDP. The foreign asset position becomes less negative over time and reaches −20 percent in the long run. Recall that the persistence of entrepreneurial talent $\gamma < 1$, so entrepreneurs accumulate assets to consume in periods when their entrepreneurial ability will become irrelevant. This explains why the net foreign deficit in the model becomes smaller after 1993.

[21] The transition in the small open economy is longer than the closed economy model. The portfolio adjustment cost ensures that the model converges to its final growth path within 300 periods. The results are not sensitive for reasonable ψ values.

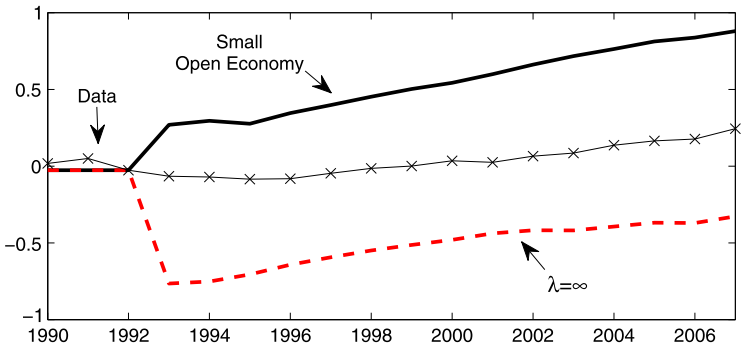

Fig. 15. Net foreign assets as a share of GDP in the data and in the model. *Notes:* The small open economy model fixes interest rates at their initial, pre-reform value. The solid line retains the Baseline parameter values. The series '$\lambda = \infty$' shows the model when all entrepreneurs have complete access to capital rental markets. The data comes from the updated and extended version of the *External Wealth of Nations Mark II* database constructed by Lane and Milesi-Ferretti (2007).

The role of financial frictions in generating the net foreign surplus is similar to Song et al. (2011). They also consider a small open economy of China's economic transition that consists of financially unconstrained and constrained firms (conceptually the state and private sectors, respectively). Financial frictions play a similar role in generating capital outflows as the exercise above. As the financially constrained sector expands, investment in the unconstrained sector falls. Total domestic borrowing falls and savings are diverted into international markets. The implied foreign asset position in their model is quantitatively close to the data. Although my model can only qualitatively mirror the data, these exercises show that financial frictions are essential in generating capital outflows in these model economies.

6. Conclusion

China has experienced large gains to TFP following major economic reforms in 1992 that sparked the emergence of the private sector. This paper investigates the quantitative effects of these reforms on China's TFP dynamics. The model suggests that the reallocation of resources given the existing production technology can account for 21.5 percentage points of TFP growth from 1992 to 2007 from the removal of prohibitive barriers to entrepreneurship. Entrepreneurs are able to utilize their talents after reforms, and the upward pressure on wages forces unprofitable state enterprises to close.

The key components of the analysis include endogenous entry and exit and differences in financial frictions faced by the private and state sectors. Financial frictions on the private sector impede entry of the less talented entrepreneurs leaving only the most talented in business. In the financially unconstrained state sector, managers with a range of very high to relatively low ability are unhampered by financial constraints. Together, this mechanism captures the difference in TFP between sectors in the model economy. Hence, the model presents a scenario where financial frictions amplify TFP in the sector facing financial frictions. Future research could further investigate the impacts of heterogeneity in financial frictions at the aggregate and disaggregated levels.

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Appendix A. Data

The data reported is for the non-agricultural economy. Due to data revisions, lack of some disaggregated series, and questions on China's reported price indices, the following sections describe the steps used to construct the data.

A.1. Aggregate data

GDP deflators The CSY separates GDP by the primary, secondary, and tertiary sectors. The primary sector consists of agriculture, fisheries, forestry, and mining. I refer to this as the agricultural sector and I classify the non-agricultural sector as the sum of the secondary (industry and construction) and tertiary (service and transportation) sectors. Young (2003) claims real GDP is overstated because the implicit GDP deflators reported by China's National Bureau of Statistics (NBS) understates inflation. He instead proposes an alternative set of deflators based on final goods prices.

For the secondary sector, I follow Young and use the ex-factory price index. This deflator grows 6.1 percent annually from 1985 to 2009 compared to 4.8 percent from the implicit deflator. For the tertiary sector, I use the implicit deflator which was revised after the 2005 economic census.

Investment I use gross fixed capital formation (GFCF) from the CSY. To net out primary sector investment, I use data from Hsueh and Li (1999) who report primary sector GFCF for 26 provinces. I next use fixed asset investment as my investment series, a slightly different series than GFCF, based on enterprise surveys which separates fixed investment by ownership. I assume that the ratio of primary sector GFCF to total GFCF is the same for the fixed asset investment series, and I subtract primary sector investment from the series. For 1996–2007, I use primary sector investment from the CSY and various issues of the *China Statistical Yearbook of Fixed Asset Investment*. Three years are absent from these reports, so I assume that the share of primary sector investment in these missing years is the average of the previous and next year.

Next, I calculate the investment deflator following Young (2003) and Brandt and Zhu (2010) based on separate deflators for equipment and structures. I construct the real capital stock using the perpetual inventory method with 7.5 percent annual depreciation. I begin the series from the capital stock in 1978 reported in Chow (1993).

Employment Employment by ownership and broad economic sector is reported in the CSY. I use data from the *China Labour Statistical Yearbook 2009* and subtract primary sector employment for each ownership classification. The NBS made an upward adjustment in the employment series in 1990 following new information from the population census in 2000. Data prior to 1990 is unrevised, so I report the employment series from 1990 onward.

GDP by ownership The CSY does not report output by ownership in the non-agricultural economy for urban areas, however it does in rural areas. I divide output by ownership in urban areas using average wage data by ownership and the total number of employees by sector. Following Brandt and Zhu (2010), I assume that wages are proportional to their average value products and the labor shares are identical across ownership. I then infer the division of output based on this measure in urban areas. In rural areas, the NBS reports output by TVEs and other ownership types until 2005. For 2006 and 2007, such data is not available. Instead I construct an out-of-sample forecast of real TVE output based on TVE output growth regressed on GDP growth, TVE employment growth, and a time trend. I then add the rural and urban data to obtain the division of output for the whole economy.

A.2. Provincial data

The provincial data is used in Fig. 3. I focus only on 2002, the most recent year where the data allows me to separate output by ownership at the provincial level. TFP calculations only require GDP and employment in 2002, but a long investment series is needed to estimate the capital stocks. I calculate employment, investment, and GDP by ownership and province in the same way as the aggregate data. For the GDP deflators in the secondary and tertiary sectors, I use the province-specific implicit deflators reported in the CSY. Investment data are deflated using province level price indexes on investment goods from 1993 to 2007. Data prior to 1993 is unavailable as well as data for Tibet and Chongqing (which was part of Sichuan until 1997). I follow Brandt et al. (2013) and estimate an out-of-sample forecast of the provincial deflators based on regressing GDP deflators and year and province fixed effects on provincial investment deflators. I then assume that an individual province's share of investment from 1978 to 1985 is proportional to that province's share of the aggregate capital stock in 1978.

Total loans by ownership and province are from the individual provincial statistical yearbooks and the *China Yearbook of Fixed Asset Investment 2003*. These sources do not include loans for TVEs, so I assume that they use the same proportion of loans for investment as urban collectively owned units. Data for this series is only available for 23 of the 31 provinces.

Appendix B. The detrended model

The following shows how the model can be written down in terms of detrended variables. Given decreasing returns to scale production, variables at the individual level are detrended by $z_t^{\theta/(1-\alpha)}$ with normalization for a variable x as $\widetilde{x}_t = x_t/z_t^{\theta/(1-\alpha)}$.

State sector Preferences can be written as

$$\mathbb{E}_t \sum_{t=0}^{\infty} \widetilde{\beta}^t S \frac{\left(\widetilde{C}_t/S\right)^{1-\sigma}}{1-\sigma} \tag{B.1}$$

with $\widetilde{\beta} = \beta g^{\frac{\theta(1-\sigma)}{(1-\alpha)}}$ assuming $z_0 = 1$. Establishment-level production is given as

$$\widetilde{y}_t = e\widetilde{k}_t^{\alpha} l_t^{\theta} \tag{B.2}$$

and the firm's problem is to maximize profits

$$\widetilde{\pi}_t(e; \widetilde{w}_t, R_t) = \max_{\widetilde{k}_t, l_t} \left\{ e\widetilde{k}_t^{\alpha} l_t^{\theta} - \widetilde{w}_t l_t - R_t \widetilde{k}_t \right\}. \tag{B.3}$$

The budget constraints are

$$\widetilde{c}_t + \widetilde{a}_{t+1} g^{\frac{\theta}{(1-\alpha)}} \leq \int_{\underline{e}}^{\infty} \widetilde{\pi}_t(e; \widetilde{w}_t, R_t)\mu(de) + \int_{0}^{\underline{e}} \widetilde{w}_t \mu(de) + (1 + r_t)\widetilde{a}_t \tag{B.4}$$

and

$$\widetilde{a}_t \geq 0. \tag{B.5}$$

Private sector Preferences can be written as

$$\mathbb{E}_t \sum_{t=0}^{\infty} \widetilde{\beta}^t \frac{\widetilde{c}_t^{1-\sigma}}{1-\sigma} \tag{B.6}$$

with the same discount factor as the state sector. Conditional on becoming an entrepreneur, production follows that of the state sector, (B.2) and profits are given as

$$\widetilde{\pi}_t(e_t, \widetilde{a}_t; \widetilde{w}_t, R_t) = \max_{\widetilde{k}_t, l_t} \left\{ e_t \widetilde{k}_t^{\alpha} l_t^{\theta} - \widetilde{w}_t l_t - R_t \widetilde{k}_t \right\} \tag{B.7}$$

subject to

$$\widetilde{k}_t \leq \lambda \widetilde{a}_t. \tag{B.8}$$

The household budget constraints are

$$\widetilde{c}_t + \widetilde{a}_{t+1} g^{\frac{\theta}{(1-\alpha)}} \leq \max\{\widetilde{\pi}_t(\widetilde{a}_t(e), e_t; \widetilde{w}_t, R_t), \widetilde{w}_t\} + (1 + r_t)\widetilde{a}_t \tag{B.9}$$

and (B.5).

Appendix C. Numerical solution method

In this appendix, I describe the numerical solution method. I first detrend the model equations as given in Appendix B. I then solve the initial steady state in the pre-reform economy to find the wage and interest rate that clears the labor and capital markets, respectively. In the pre-reform economy, output distortion $\tau = 1$ on the individual production technology (11). At reforms, time $t = 0$, τ unexpectedly and permanently changes to $\tau = 0$.

Next, I solve for the transitional dynamics and the final stationary steady state. The aggregate problem is solved by finding wage and interest rate sequences such that labor and capital markets clear in all periods.

Detrended capital and labor market clearing conditions For private entrepreneurs with talent e_t and assets $\widetilde{a}_t$, let the demand for capital and labor for a given $\widetilde{w}_t$ and R_t be $\widetilde{k}_t(\widetilde{a}_t, e_t; \widetilde{w}_t, R_t)$ and $l_t(\widetilde{a}_t, e_t; \widetilde{w}_t, R_t)$. Also, let $F_t(\widetilde{a}_t, e_t)$ be the joint cumulative density function of assets and talent. For a state manager with talent e, let $\widetilde{k}_t(e; \widetilde{w}_t, R_t)$ and $l_t(e; \widetilde{w}_t, R_t)$ be the capital and labor demands. Market clearing in the capital market requires

$$N \int \left[\int_{\underline{\widetilde{a}}_t(e_t)}^{\infty} \widetilde{k}_t(\widetilde{a}_t, e_t; \widetilde{w}_t, R_t) F_t(d\widetilde{a}_t, e_t) - \int_{0}^{\infty} \widetilde{a}_t F_t(d\widetilde{a}_t, e_t) \right] \mu(de)$$
$$+ S \left[\int_{\underline{e}_t}^{\infty} \widetilde{k}_t(e; \widetilde{w}_t, R_t)\mu(de) - \widetilde{a}_t(\cdot) \right] = 0 \tag{C.1}$$

where the first term in each bracket is total capital demand by the private and the state sector, respectively, and the second term is total assets.

Market clearing in the labor market each period requires

$$N\int\left[\int_{\underline{\widetilde{a}}_t(e_t)}^{\infty} l_t(\widetilde{a}_t,e_t;\widetilde{w}_t,R_t)F_t(d\widetilde{a}_t,e_t)-F_t(\underline{\widetilde{a}}_t(e_t),e_t)\right]\mu(de)$$
$$+S\left[\int_{\underline{e}_t}^{\infty} l_t(\widetilde{a}_t,e;\widetilde{w}_t,R_t)\mu(de)-\int_0^{\underline{e}_t}\mu(de)\right]=0 \tag{C.2}$$

where the left term in each bracket is total labor demand by the private and the state sector, respectively, and the right term is labor supply (total workers).

The equilibrium solution for each period after reforms follows these steps:

1. Choose the number of transition periods T. I choose $T=110$. This is long enough for the model to reach a new stationary steady state.
2. Guess wage and interest rate sequence spanning time $t=0$ to $t=T$, $\{\widetilde{w}_t\}_{t=0}^{T}$ and $\{r_t\}_{t=0}^{T}$, where $t=0$ is the period at reforms.
3. Compute the value functions for the state and the private sectors at time T. Iterate the value functions backwards from time $t=T$ to $t=0$. Simulate $N+S$ individuals for T periods using the optimal policy functions and the initial distribution of assets and talent as given. I choose $N+S=159076$. Aggregate up total labor demanded by the establishments and labor supply each period. Update the wage transition sequence and repeat this step until the labor market clears in each period (C.2).
4. After the labor market clears, again compute the value functions for each sector at time T. Iterate backwards the value functions from time T to 0 and simulate $N+S$ individuals. Aggregate up total capital demanded by establishments and total assets saved. Update the interest rate sequence and repeat this step until the capital market clears in each period (C.1).
5. Repeat steps 3 and 4 until labor and capital markets both clear in each period.
6. Retrend the model by multiplying through by $z_t^{\theta/(1-\alpha)}$. In the final stationary steady state the retrended aggregate variables grow at their pre-reform growth rates.

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