

# INTEREST-RATE LIBERALIZATION AND CAPITAL MISALLOCATION

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**ABSTRACT.** We study the consequences of interest-rate liberalization in a two-sector general equilibrium model of China. The model captures a key feature of China’s distorted financial system: state-owned enterprises (SOEs) have greater incentive to expand production and easier access to credit than private firms. In this second-best environment, liberalizing interest rate controls improves capital allocations within each sector, but exacerbates misallocations across sectors. Under calibrated parameters, interest-rate liberalization may reduce aggregate productivity and welfare, unless other policy reforms are also implemented to alleviate SOEs’ distorted incentives or improve private firms’ credit access.

## I. INTRODUCTION

The Chinese government has maintained tight controls over domestic interest rates. The People’s Bank of China (PBOC), the country’s central bank, sets the benchmark lending and deposit rates for all financial institutions in China. The PBOC has permitted banks to offer a range of deposit and lending rates within a relatively narrow band, and it has adjusted the bands occasionally. Interest rate controls create a wedge between the two types of interest rates (see Figure 1). By 2013, the PBOC has fully liberalized controls over bank lending rates. In 2015, the PBOC further widened the range of deposit rates that banks can offer. According to the standard theory, such interest-rate liberalization should reduce financial frictions and thus improve capital allocation; this should lead to higher aggregate

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productivity and social welfare [e.g., Hsieh and Klenow (2009); Buera et al. (2011); Midrigan and Xu (2014); Moll (2014)].

We argue in this paper that interest-rate liberalization may not improve aggregate productivity and welfare in China, unless other distortions in the Chinese economy can be mitigated or eliminated. In a second-best environment with multiple sources of distortions, the full consequences of interest-rate liberalization can be understood only in a general equilibrium framework that takes into account other existing distortions in China.

We provide such a framework. In particular, we build a two-sector dynamic general equilibrium model to study the macroeconomic implications of interest-rate liberalization in a second-best environment. Our model captures some important features of the existing distortions facing China's financial system. In the model, final goods are produced by firms in two sectors: one sector with state-owned enterprises (SOEs) and the other with private firms (POEs). Consistent with empirical evidence, we assume that SOEs are on average less productive than POEs (Hsieh and Klenow, 2009; Li et al., 2015).

Despite their lower productivity, SOEs can survive in our model because of favorable government policy. Consistent with the institutional features of the Chinese economy, we assume that the government provides production subsidies to SOEs and grants them with favorable credit access. These policies are implemented in China, partly because the country does not have a reliable social safety net, and the government requires SOEs to help provide social insurance and other public goods. Thus, SOE firms face not just the task of profit maximizing, but also the task of maintaining employment and providing social goods. For this reason, the government does not want to shut down loss-making SOEs; instead, it provides various forms of subsidies to SOEs (Bai et al., 2000). Furthermore, SOEs in our model also have easier access to credit than POEs, potentially stemming from government guarantees of SOE debt (Song et al., 2011; Chang et al., 2016).<sup>1</sup>

Within our general equilibrium framework, we study the consequences of interest-rate liberalization for capital allocations and productivity. In the benchmark model with interest rate controls, we assume that government policy creates a wedge between the deposit interest rate and the lending rate. With heterogeneous productivity and credit constraints, the presence of the interest-rate wedge implies that there are three types firms within each sector. Firms with sufficiently high productivity choose to operate, with their production financed by both internal funds and external debt. For these firms, the marginal product of

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<sup>1</sup>Brandt and Zhu (2000) argue that the Chinese government's favorable policy towards the SOE sector in the forms of cheap credits from state-owned banks and money creation by the People's Bank of China helps explain the observation that the SOE output share in the economy has declined steadily since the early 1980s, but the SOE employment and investment shares have remained relatively high.

capital (MPK) exceeds the loan rate and thus external financing is profitable. In the other extreme, firms with sufficiently low productivity choose to save, since their MPKs are below the deposit rate and thus saving gives them a higher return than operating. Those firms with intermediate levels of productivity choose to operate and self finance, because their MPKs lie between the deposit rate and the loan rate.

When liberalization policy removes the interest-rate wedge, the loan and deposit rates converge to a single interest rate, and the distribution of firms collapses to two types (from three). High-productivity firms choose to operate and use both internal funds and external debt to finance their operation. Low-productivity firms choose to save (and do not produce) because their MPKs are below the market interest rate. No firms choose to fully self-finance their production. Compared to the benchmark case with interest rate controls, the marginal firm who is active in production now has higher productivity. Therefore, the liberalization policy improves productivity within each sector. This implication of interest-rate liberalization is similar to that found in the literature with heterogeneous firms and financial frictions in one-sector models (Moll, 2014).

However, the liberalization policy exacerbates capital misallocation across sectors. With a higher deposit rate, aggregate saving rises. The increased saving flows disproportionately to the SOE sector because SOE firms have an incentive to expand production scales and they also have easier access to credit than POEs. The reallocation of capital from POEs to SOEs reduces aggregate productivity because SOE firms have lower average productivity than POE firms.

Overall, interest-rate liberalization has an ambiguous net effect on aggregate productivity and welfare in this second-best environment. To assess the net effect of the liberalization reform, we calibrate the parameters in our model using Chinese data. With calibrated parameters, we compute the transition dynamics from the current steady state with an interest-rate wedge to a new steady state with the wedge removed.

We find that interest-rate liberalization leads to a mild short-run recession (i.e., a decline in aggregate output) and a modest long-run expansion. The short-run recession along the transition path suggests that, under our calibration, the cross-sector misallocation of capital dominates the within-sector improvement in allocation. Indeed, the cross-sector reallocation of capital causes sizable contractions in POE output and expansions in SOE output. In the long run, since aggregate saving rises when the interest-rate wedge is removed permanently, more capital accumulation leads to more output in the new steady state. During the transition periods, however, the cross-sector capital misallocation reduces aggregate TFP and output.

Furthermore, liberalization policy that completely removes the interest-rate wedge reduces consumption and welfare because it exacerbates misallocation of capital across sectors and leads to over-investment in the SOE sector. With our calibration, complete liberalization of interest-rate controls leads to a welfare loss equivalent to 2.9 percent of consumption per year relative to the benchmark economy.

We also show that, in this second-best environment, there is an interior optimum of interest-rate controls. Increasing the interest-rate wedge would alleviate misallocations of capital across sectors, but exacerbate misallocations within each sector. The second-best interest-rate control policy involves a trade off between these two different types of misallocation. Thus, our model implies a hump-shaped relation between the interest-rate wedge and social welfare.

In what follows, we first illustrate in Section II the implications of interest rate controls for capital allocation and productivity in a static, partial-equilibrium model with two sectors, in which firms in each sector face heterogeneous productivity and credit constraints. We then generalize the results to a dynamic model with capital accumulations and study the implications of interest-rate liberalization for transition dynamics under calibrated parameters in Section III. There, we also examine the consequences of interest-rate liberalization in counterfactual environments where other policy reforms are implemented to reduce SOE subsidies or improve POEs' credit access. Finally, we discuss the contributions of our paper relative to the literature in Section IV and provide some concluding remarks in Section V.

## II. A STATIC MODEL

This section presents a simple static two-sector model to highlight the tradeoff for interest-rate liberalization between within-sector and cross-sector capital allocations.

In the economy, a homogeneous good is produced by firms in two sectors –an SOE sector (sector  $s$ ) and a POE sector (sector  $p$ ). There is a continuum of firms within each sector, with a measure  $\mu$  of firms in the SOE sector and  $1 - \mu$  in the POE sector. Firms in each sector have access to a constant-returns technology that transforms capital into a homogeneous final good. Each firm is endowed with  $h$  units of capital. The efficiency of a firm's production in each sector is determined by both a sector-specific productivity and an idiosyncratic productivity. Firms also have access to a financial market where they can borrow or lend.

Under interest rate controls, the government maintains a wedge  $\phi > 0$  between the deposit rate ( $r_d$ ) and the lending rate ( $r_l$ ). Thus, we have

$$r_l = r_d + \phi. \tag{1}$$

Throughout the paper, interest-rate liberalization means the removal of the wedge (i.e., setting  $\phi = 0$ ).<sup>2</sup>

**II.1. Firms in the POE sector.** A firm in the POE sector with idiosyncratic productivity  $\varepsilon$  chooses capital  $k^p(\varepsilon)$ , saving  $s^p(\varepsilon)$  or loans  $l^p(\varepsilon)$  to maximize its profit

$$z^p \varepsilon k^p(\varepsilon) - r_l l^p(\varepsilon) + r_d s^p(\varepsilon), \quad (2)$$

where  $z^p$  denotes the sector-specific productivity in the POE sector and the idiosyncratic productivity  $\varepsilon$  is drawn from the distribution  $\mathbf{F}^p(\varepsilon)$ .

The profit-maximizing decision is subject to the flow of funds constraint

$$k^p(\varepsilon) = h + l^p(\varepsilon) - s^p(\varepsilon), \quad (3)$$

and the borrowing constraint

$$0 \leq l^p(\varepsilon) \leq \theta^p h. \quad (4)$$

where  $\theta^p$  denotes the loan-to-value ratio.

If the firm chooses to save a non-negative amount, the amount of saving cannot exceed the total endowment. Thus, the profit-maximizing choices should also respect the saving constraint

$$0 \leq s^p(\varepsilon) \leq h. \quad (5)$$

**II.2. Firms in the SOE sector.** An SOE firm with the idiosyncratic productivity  $\varepsilon$  chooses capital  $k^s(\varepsilon)$ , saving  $s^s(\varepsilon)$ , and borrowing  $l^s(\varepsilon)$  to maximize the objective function

$$\tau z^s \varepsilon k^s(\varepsilon) - r_l l^s(\varepsilon) + r_d s^s(\varepsilon) \quad (6)$$

where  $\tau > 1$  represents distortions to SOE incentives (e.g., government subsidies to SOEs),  $z^s$  denotes the sector-specific production for SOE firms, and the idiosyncratic productivity  $\varepsilon$  is drawn from the distribution  $\mathbf{F}^s(\varepsilon)$ .

Under our assumption that  $\tau > 1$ , SOEs have an incentive to expand production beyond that motivated by profit-maximizing.<sup>3</sup> The distorted SOE incentive here is consistent with

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<sup>2</sup>The parameter  $\phi$  is a parsimonious way of capturing interest rate controls in China. Under our specification, one of the interest rates (e.g., the deposit rate) is determined endogenously by the loan market clearing condition, and the other rate (e.g., the lending rate) is then pinned down by the policy wedge  $\phi$ . The constant interest-rate wedge here is not crucial for deriving our results. It is easy to show that this setup is equivalent to one in which the government controls the deposit rate  $r_d$ , with the lending rate  $r_l$  and thus the interest-rate wedge endogenously determined (this can be shown using the results stated in Proposition 4 below).

<sup>3</sup>The assumption that  $\tau > 1$  should be broadly interpreted. It captures several sources of distortions, such as SOEs' monopoly rents (Li et al., 2015) or fixed costs (Song and Hsieh, 2015), in addition to explicit or implicit government subsidies.

the multi-task principal-agent theory of SOEs in the literature (Bai et al., 2000). In China, SOEs are owned by the state and their managers are appointed by the government. The performances of SOE managers are evaluated partly based on the firm's contributions to local GDP and employment targets, not just on profits. To prevent loss-making SOEs from exiting business, the government provides subsidies to SOE output. The setup here is also consistent with the "soft budget constraint" theory for SOEs, which argues that the state should be accountable for the poor performance of SOEs since it imposes extra policy burdens on SOEs. In compensation, the state subsidizes the operation of SOEs (Lin et al., 1998; Lin and Tan, 1999).

The SOE firm's optimizing decision is subject to the flow of funds constraint

$$k^s(\varepsilon) = h + l^s(\varepsilon) - s^s(\varepsilon), \quad (7)$$

and the constraints on borrowing and saving

$$0 \leq l^s(\varepsilon) \leq \theta^s h, \quad (8)$$

$$0 \leq s^s(\varepsilon) \leq h, \quad (9)$$

where  $\theta^s$  denotes the loan-to-value ratio for SOEs.<sup>4</sup>

For analytical convenience, we normalize the mean of the idiosyncratic productivity in each sector to one. Consistent with empirical evidence, we assume that SOEs have easier access to credit than POEs, so that  $\theta^p < \theta^s$ . We also assume that SOEs are less productive than POEs on average, so that  $z^s < z^p$ .

**II.3. Equilibrium.** An equilibrium consists of the deposit rate  $r_d$ , the loan rate  $r_l$ , and the allocations  $\{k^s(\varepsilon), l^s(\varepsilon), s^s(\varepsilon)\}$  for each SOE firm indexed by  $\varepsilon \sim \mathbf{F}^s(\varepsilon)$  and  $\{k^p(\varepsilon), l^p(\varepsilon), s^p(\varepsilon)\}$  for each POE firm indexed by  $\varepsilon \sim \mathbf{F}^p(\varepsilon)$ , such that (i) the allocations for each firm in each sector solve the firm's optimizing problem; and (ii) capital market clears

$$\mu \int k^s(\varepsilon) d\mathbf{F}^s(\varepsilon) + (1 - \mu) \int k^p(\varepsilon) d\mathbf{F}^p(\varepsilon) = h. \quad (10)$$

Aggregate output is given by

$$Y = \mu \int z^s \varepsilon k^s(\varepsilon) d\mathbf{F}^s(\varepsilon) + (1 - \mu) \int z^p \varepsilon k^p(\varepsilon) d\mathbf{F}^p(\varepsilon). \quad (11)$$

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<sup>4</sup>Without borrowing constraints, only the most productive firm will operate under the constant returns to scale technology, and thus the model would not be suitable for studying intra-sector capital allocations.

**II.4. Effects of liberalization: The case of homogeneous firms.** We now discuss the effect of interest-rate liberalization on aggregate output.<sup>5</sup> To highlight the potential capital misallocation across sectors associated with interest-rate liberalization, we first consider the special case with homogeneous firms in each sector (i.e.,  $\varepsilon = 1$ ). In this case, changes in aggregate output following a liberalization policy would be driven purely by cross-sector reallocations of capital between SOEs and POEs.

For analytical convenience, we assume that  $\tau z^s > z^p > z^s$ , so that, under government subsidies to SOEs, the representative SOE firm's private marginal product of capital (MPK) exceeds the representative POE firm's MPK. To highlight the effects of interest-rate liberalization on capital reallocation, we focus on a pre-reform benchmark with a sufficiently large interest-rate wedge. In particular, we assume that  $\phi > \tau z^s - z^p$ . Under this assumption, the benchmark economy has an equilibrium with financial autarky, as we show in Proposition 1 below.

*Proposition 1.* Assume that the interest-rate wedge is sufficiently large so that  $\phi > \tau z^s - z^p$ . The only equilibrium is one with financial autarky, with  $r_d \in [\tau z^s - \phi, z^p]$ . Equilibrium capital allocations are given by

$$k^p = k^s = h, \quad (12)$$

Equilibrium aggregate output is given by

$$Y = (1 - \mu)z^p h + \mu z^s h \quad (13)$$

*Proof.* The intuition of the proof is simple. If the deposit and lending rates are too high, then all firms would want to save, which would not be an equilibrium since it violates the loan market clearing condition. On the other hand, if the interest rates are too low, then all firms would want to borrow, which again violates the loan market clearing condition. Only when the interest rate lies in an intermediate range (specifically, in the interval  $[\tau z^s - \phi, z^p]$ ) would there be an equilibrium, which, as we shown formally in the Appendix, is a financial autarky.  $\square$

When interest rate controls are liberalized (i.e.,  $\phi = 0$ ), the equilibrium allocations are in general different from the autarkic allocations. As we show below in Proposition 2, if SOEs have a sufficiently large borrowing capacity relative to the sector's size, then all capital in the economy would flow to the SOE sector after the liberalization. If SOEs face a relatively tight borrowing constraint, then some capital would flow from POEs to SOEs (up to the SOEs' borrowing limit) and firms in both sectors would be active in production. Furthermore,

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<sup>5</sup>In this simple model, aggregate capital stock equals the endowment  $h$ . Thus, changes in output and changes in aggregate productivity are equivalent.

since SOEs are less productive than POEs, reallocating capital from POEs to SOEs reduces aggregate output and productivity relative to the pre-reform benchmark (which is a financial autarky). This last result is summarized in Corollary 1.

*Proposition 2.* In the liberalized economy with  $\phi = 0$ , the equilibrium deposit rate and lending rate are identical, and lies in the interval  $[z^p, \tau z^s]$ . Equilibrium capital allocations are given by

$$k^p = \frac{1 - \mu(1 + \theta^s)}{1 - \mu} h < h \quad (14)$$

$$k^s = (1 + \theta^s) h > h \quad (15)$$

and aggregate output  $Y$  is given by

$$Y = \begin{cases} z^p h - (z^p - z^s) \mu (1 + \theta^s) h & \text{if } \theta^s < 1/\mu - 1, \\ z^s h & \text{if } \theta^s \geq 1/\mu - 1. \end{cases} \quad (16)$$

*Proof.* See the Appendix. □

Compared to the pre-reform benchmark (which is a financial autarky), interest-rate liberalization reduces capital used by the POEs and increases capital used by the SOEs. Since the SOEs are less productive, this reallocation of capital reduces aggregate output and productivity. Formally, one can use Equations (13) and (16) to verify that aggregate output in the economy with liberalized interest rates is lower than that under interest rate controls. Therefore, in this economy with homogeneous firms within each sector, removing interest rate controls unambiguously reduces aggregate output. Since aggregate capital stock is fixed at  $h$ , the liberalization policy also reduces aggregate total factor productivity (TFP). This result is stated in Corollary 1.

*Corollary 1.* With homogeneous firms within each sector, aggregate output and TFP are lower in the economy with liberalized interest rates ( $\phi = 0$ ) than those under interest rate controls ( $\phi > 0$ ).

The finding that liberalizing interest-rate controls reduces aggregate output and TFP is surprising, but economically intuitive in this second-best environment. When interest rate controls are lifted, the deposit interest rate rises and the loan rate falls. In our simple model, the deposit rate rises to levels above the MPK for the POEs, inducing POEs to save. The decline in the loan rate along with government subsidies would provide incentive for SOEs to borrow. Since POEs are more productive than SOEs, capital flows from POEs to SOEs represent a misallocation of resources that reduces aggregate output and TFP.

If firms within each sector have heterogeneous productivity, then interest-rate liberalization can improve within-sector capital allocation and offset (at least partially) the adverse



impact of the cross-sector misallocation on aggregate productivity. We now discuss the case with heterogeneous firms in the next section.

**II.5. Effects of liberalization: The case of heterogeneous firms.** Consider the case where firms in each sector face idiosyncratic productivity shocks drawn from the distribution  $\mathbf{F}^j(\varepsilon)$ , with the support  $[\varepsilon_{\min}, \infty)$ . The following proposition characterizes the equilibrium allocations of credit and capital.

*Proposition 3.* In the economy with heterogeneous firms, there exist two threshold levels of idiosyncratic productivity, denoted by  $\underline{\varepsilon}^j$  and  $\bar{\varepsilon}^j$  for each sector  $j \in \{s, p\}$ , such that

$$s^j(\varepsilon) = \begin{cases} h & \text{if } \varepsilon_{\min} \leq \varepsilon < \underline{\varepsilon}^j \\ 0 & \text{if } \underline{\varepsilon}^j \leq \varepsilon \end{cases}, \quad (17)$$

$$l^j(\varepsilon) = \begin{cases} 0 & \text{if } \varepsilon_{\min} \leq \varepsilon < \bar{\varepsilon}^j \\ \theta^j h & \text{if } \bar{\varepsilon}^j \leq \varepsilon \end{cases}, \quad (18)$$

$$k^j(\varepsilon) = \begin{cases} 0 & \text{if } \varepsilon_{\min} \leq \varepsilon < \underline{\varepsilon}^j \\ h & \text{if } \underline{\varepsilon}^j \leq \varepsilon < \bar{\varepsilon}^j \\ (1 + \theta^j) h & \text{if } \bar{\varepsilon}^j \leq \varepsilon \end{cases}. \quad (19)$$

where the thresholds  $\underline{\varepsilon}^j$  and  $\bar{\varepsilon}^j$  are defined as

$$\underline{\varepsilon}^j = \frac{r_d}{z^j \tau^j}, \quad (20)$$

$$\bar{\varepsilon}^j = \frac{r_d + \phi}{z^j \tau^j}, \quad (21)$$

where  $\tau^j$  denotes the output subsidy rates for sector  $j$  (and we normalize sector  $p$  subsidies to  $\tau^p = 1$ ).

We provide a proof in the Appendix. The proposition shows that, under interest-rate controls, the wedge between the lending and deposit rates imply that there are 3 different groups of firms. Firms with sufficiently high productivity choose to produce using both internal funds and external debt. Firms with sufficiently low productivity choose to save instead of producing. Firms with intermediate levels of productivity choose to produce, but financing their production with internal funds only.

The equilibrium deposit rate (or the lending rate) is determined by the capital market clearing condition

$$K = (1 - \mu) K^p + \mu K^s = h, \quad (22)$$

where  $K^j$  denotes aggregate demand for capital in section  $j \in \{s, p\}$  given by

$$K^j = \left[ \int_{\underline{\varepsilon}^j}^{\bar{\varepsilon}^j} d\mathbf{F}(\varepsilon) + (1 + \theta^j) \int_{\bar{\varepsilon}^j}^{\infty} d\mathbf{F}(\varepsilon) \right] h. \quad (23)$$

It is easy to show that aggregate output in section  $j \in \{s, p\}$  is related to the sector's aggregate capital input through

$$Y^j = A^j K^j, \quad (24)$$

where the term  $A^j$  denotes sector  $j$ 's TFP given by

$$A^j = z^j \frac{\int_{\underline{\varepsilon}^j}^{\bar{\varepsilon}^j} \varepsilon d\mathbf{F}(\varepsilon) + (1 + \theta^j) \int_{\bar{\varepsilon}^j}^{\infty} \varepsilon d\mathbf{F}(\varepsilon)}{\int_{\underline{\varepsilon}^j}^{\bar{\varepsilon}^j} d\mathbf{F}(\varepsilon) + (1 + \theta^j) \int_{\bar{\varepsilon}^j}^{\infty} d\mathbf{F}(\varepsilon)}. \quad (25)$$

Thus, sector  $j$ 's TFP contains both an exogenous component  $z^j$  and an endogenous component. The endogenous component of the sectoral TFP stems from within-sector reallocations of capital across firms with different idiosyncratic productivity, and its level depends on the two threshold values  $\underline{\varepsilon}^j$  and  $\bar{\varepsilon}^j$ . Proposition 3 shows that those threshold values are functions of the equilibrium deposit rate  $r_d$ , which itself is a function of the policy wedge  $\phi$ , along with other parameters in the model.

When interest-rate liberalization removes the wedge  $\phi$  between the lending and deposit rates, Proposition 3 shows that the two threshold levels of productivity  $\underline{\varepsilon}^j$  and  $\bar{\varepsilon}^j$  would coincide, and the distribution of firms would collapse to two types (from three). The following Proposition shows that the liberalization policy raises the deposit rate and reduces the lending rate, which makes two interest rates converge to each other.

*Proposition 4.* The deposit rate  $r_d$  decreases with the interest-rate wedge  $\phi$  and the lending rate  $r_l$  increases with  $\phi$ . Thus, interest-rate liberalization (that lowers  $\phi$ ) would raise the deposit rate  $r_d$  and reduce the lending rate  $r_l$ .

*Proof.* See the Appendix. □

To the extent that interest-rate liberalization changes equilibrium deposit and lending rates, it also affects sectoral TFP through reallocating capital across firms within each sector. In addition, interest-rate liberalization also affects aggregate TFP through reallocating capital across the two sectors. Since aggregate capital supply is fixed (at  $h$ ) in this simple model, aggregate TFP moves one-for-one with aggregate output.

Specifically, aggregate output is given by

$$Y = A^s K + (A^p - A^s) (1 - \mu) K^p. \quad (26)$$

Aggregate TFP is given by

$$\text{TFP} = \frac{Y}{K} = A^s + (A^p - A^s) (1 - \mu) \frac{K^p}{h}. \quad (27)$$

Thus, given the sectoral TFPs  $A^s$  and  $A^p$  and that  $A^p > A^s$ , a policy reform that leads to capital flows from POEs to SOEs would reduce aggregate TFP. The next proposition

provides the conditions under which such cross-sector misallocation can occur following an interest-rate liberalization reform.

*Proposition 5.* Assume that the idiosyncratic shocks in the two sectors are drawn from the same distribution, with the probability density function  $f(\varepsilon)$ . Assume further that the density function satisfies the condition that  $g(\varepsilon) \equiv \frac{f'(\varepsilon)\varepsilon}{f(\varepsilon)}$  decreases with  $\varepsilon$ . Under these conditions, we obtain

$$\frac{\partial K^s}{\partial \phi} < 0, \quad \frac{\partial K^p}{\partial \phi} > 0. \quad (28)$$

We also obtain  $\frac{\partial A^p}{\partial \phi} < 0$  whereas  $\frac{\partial A^s}{\partial \phi}$  has an ambiguous sign. Furthermore, the relation between aggregate output and the interest-rate wedge is also ambiguous (i.e.,  $\frac{\partial Y}{\partial \phi}$  has an ambiguous sign). The same is true for aggregate TFP.

*Proof.* See the Appendix. □

Proposition 5 shows that a liberalization policy that reduces  $\phi$  would lead to capital flows from POEs to SOEs. Although such liberalization improves the level of TFP in the POE sector, it has ambiguous effects on the TFP of the SOE sector. This ambiguity arises because, although the liberalization policy turns some low-productivity SOE firms into savers (by raising the deposit rate), it also attracts capital inflows to the SOE sector, with the increased capital distributed across all active firms, including unproductive ones. The liberalization policy also leads to ambiguous effects on aggregate output and aggregate TFP, because of the offsetting roles played by the within-sector improvement in capital allocations and the cross-section deterioration.

Thus, the overall impact of interest-rate liberalization on the macro economy depends on the parameter values. To illustrate the non-monotonic relations between the interest-rate wedge and aggregate output, we provide a numerical example. In that example, we set  $\frac{z^p}{z^s} = 2$ ,  $\frac{\theta^s}{\theta^p} = 3$ ,  $\tau = 3$ ,  $\mu = 0.5$ ,  $\phi = 0.02$ . We assume that the idiosyncratic shocks are drawn from the log-normal distribution with a mean value of one and a standard deviation of 0.4.<sup>6</sup>

Figure 2 shows that the relation between aggregate output (or equivalently, aggregate TFP, since aggregate capital supply is fixed) and the interest-rate wedge  $\phi$ . In this numerical example, there exists an interior optimum of  $\phi$  that maximizes aggregate output. For example, if  $\theta^p = 0.25$ , then aggregate output reaches its peak at  $\phi = 0.015$ . With a higher value of  $\theta^p$  (but keeping  $\frac{\theta^s}{\theta^p} = 3$ ), we obtain similar hump-shaped relations between output and  $\phi$ , indicating the tradeoff between within-sector improvement in capital allocations and cross-section deterioration when lifting interest-rate controls.

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<sup>6</sup>These parameter values are broadly in line with our calibration in the fully-fledged dynamic model presented in Section III.

### III. INTEREST-RATE LIBERALIZATION AND TRANSITION DYNAMICS

We have studied the steady-state effects of interest-rate liberalization. We now examine the implications of such liberalization policy for transition dynamics. We first describe the economic environment in the dynamic model, then study the transition dynamics under calibrated parameters, and finally, we examine the consequences of interest-rate liberalization under counterfactual policy regimes with reduced distortions to SOE incentives or improved credit access for POE firms.

**III.1. The dynamic model.** The economy has two types of private agents: firms and households. There are two sectors of production: SOE and POE. We normalize the measure of firms in each sector to one. Firms in each sector produce a final consumption goods to be sold to the households. Firms also accumulate capital stocks over time. Households consume the final goods and supply labor to firms. The government controls the wedge between the lending rate and the deposit rate, also provides subsidies to SOE firms. Government subsidies are financed by lump-sum taxes imposed on the households. The households own all firms and financial intermediaries and receive dividend payments in each period.

**III.1.1. The firms.** In the beginning of period  $t$ , a firm in sector  $j \in \{s, p\}$  has capital stock  $k_t^j$ , loans  $l_t^j$ , and savings  $s_t^j$ . After observing the sector-specific productivity  $z^j$ , the firm produces a final good using labor  $n_t^j$  and effective capital  $\varepsilon_{t-1}^j k_t^j$  as inputs, where  $\varepsilon_{t-1}^j$  is an idiosyncratic productivity shock observed at the end of period  $t - 1$ .<sup>7</sup> The production function is given by

$$y_t^j = (z^j \varepsilon_{t-1}^j k_t^j)^\alpha (n_t^j)^{1-\alpha}. \quad (29)$$

The firm takes the real wage rate  $W_t$  as given and chooses labor input  $n_t^j$  to solve the static problem

$$\pi_t^j (\varepsilon_{t-1}^j, k_t^j) = \max_{n_t^j} \tilde{\tau}^j (z^j \varepsilon_{t-1}^j k_t^j)^\alpha (n_t^j)^{1-\alpha} - W_t n_t^j. \quad (30)$$

The optimal labor demand function is given by

$$n_t^j = \left[ \frac{\tilde{\tau}^j (1 - \alpha)}{W_t} \right]^{\frac{1}{\alpha}} z^j \varepsilon_{t-1}^j k_t^j. \quad (31)$$

The maximum profit is given by

$$\pi_t^j (\varepsilon_{t-1}^j, k_t^j) = \tau^j R_t z^j \varepsilon_{t-1}^j k_t^j, \quad (32)$$

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<sup>7</sup>Our timing assumption here follows that in Buera and Moll (2015) and helps to avoid the well-understood issue of “uninsured idiosyncratic investment risks” (Angeletos, 2007).

where  $\tau^j \equiv (\tilde{\tau}^j)^{\frac{1}{\alpha}}$  is the effective capital subsidy rate and  $R_t \equiv \alpha \left( \frac{1-\alpha}{W_t} \right)^{\frac{1-\alpha}{\alpha}}$  is the pre-subsidy rate of return to capital. We normalize the subsidy rate for POEs to  $\tau^p = 1$  and we assume that SOEs receive positive subsidies so that  $\tau^s > 1$ .

After finishing production but before making investment and saving or borrowing decisions, the firm faces a probability  $\delta_e$  of exiting the market. Upon exiting, the firm transfers all net worth to the households who own the firm. An equal measure of new firms enters the market, and each new entrant receives  $h_{0t}^j$  units of start-up funds from the households.

At the end of period  $t$ , the firm observes an idiosyncratic productivity shock  $\varepsilon_t^j$  and then chooses new capital  $k_{t+1}^j$ , savings  $s_{t+1}^j$ , and loans  $l_{t+1}^j$  for the next period. The firm faces the flow-of-funds constraint

$$h_t^j = k_{t+1}^j + s_{t+1}^j - l_{t+1}^j, \quad (33)$$

where  $h_t^j$  denotes the firm's net worth given by

$$h_t^j = (\tau^j z^j \varepsilon_{t-1}^j R_t + 1 - \delta) k_t^j - (1 + r_{l,t-1}) l_t^j + (1 + r_{d,t-1}) s_t^j. \quad (34)$$

The firm also faces the borrowing constraint

$$l_{t+1}^j \leq \theta^j h_t^j, \quad (35)$$

where the parameter  $\theta^j$  measures the loan-to-value ratio for firms in sector  $j$ . In addition, the firm's savings  $s_{t+1}^j$  must satisfy

$$0 \leq s_{t+1}^j \leq h_t^j. \quad (36)$$

The objective of the firm at the end of period  $t$  is the expected present value of the future terminal dividend

$$V_t^j = \mathbf{E}_t \left[ \sum_{s=1}^{\infty} (1 - \delta_e)^s \beta^s \frac{\Lambda_{t+s}}{\Lambda_t} h_{t+s}^j \right], \quad (37)$$

where  $\beta^s \frac{\Lambda_{t+s}}{\Lambda_t}$  is the stochastic discount factor derived from the household side. The firm then chooses  $\{s_{t+1}^j, l_{t+1}^j, k_{t+1}^j\}$  to maximize  $V_t^j$  subject to (33), (34), (35), and (36). The following proposition summarizes the optimizing decisions.

*Proposition 6.* Given the net worth  $h_t^j$ , the optimal decisions of  $\{s_{t+1}^j, l_{t+1}^j, k_{t+1}^j\}$  follow the trigger strategies

$$s_{t+1}^j = \begin{cases} h_t^j & \text{if } \varepsilon_{\min}^j \leq \varepsilon_t^j < \underline{\varepsilon}_t^j \\ 0 & \text{if } \underline{\varepsilon}_t^j \leq \varepsilon_t^j < \varepsilon_{\max}^j \end{cases}, \quad (38)$$

$$l_{t+1}^j = \begin{cases} 0 & \text{if } \varepsilon_{\min}^j \leq \varepsilon_t^j < \bar{\varepsilon}_t^j \\ \theta^j h_t^j & \text{if } \bar{\varepsilon}_t^j \leq \varepsilon_t^j < \varepsilon_{\max}^j \end{cases}, \quad (39)$$

$$k_{t+1}^j = \begin{cases} 0 & \text{if } \varepsilon_{\min}^j \leq \varepsilon_t^j < \underline{\varepsilon}_t^j \\ h_t^j & \text{if } \underline{\varepsilon}_t^j \leq \varepsilon_t^j < \bar{\varepsilon}_t^j \\ (1 + \theta^j) h_t^j & \text{if } \bar{\varepsilon}_t^j \leq \varepsilon_t^j < \varepsilon_{\max}^j \end{cases}, \quad (40)$$

where the cutoffs  $\{\underline{\varepsilon}_t^j, \bar{\varepsilon}_t^j\}$  are defined as

$$\underline{\varepsilon}_t^j = \frac{r_{dt} + \delta}{\tau^j z^j R_{t+1}}, \quad (41)$$

$$\bar{\varepsilon}_t^j = \frac{r_{lt} + \delta}{\tau^j z^j R_{t+1}}. \quad (42)$$

*Proof.* These decision rules are corner solutions that directly follow from the linearity of optimizing problem.  $\square$

The interpretations of the investment and saving or lending decisions in this dynamic model are analogous to those in the static model. In particular, under interest-rate controls, firms with sufficiently high productivity ( $\varepsilon_t^j > \bar{\varepsilon}_t^j$ ) choose to invest using both internal net worth and external debt. Firms with sufficiently low productivity ( $\varepsilon_t^j < \underline{\varepsilon}_t^j$ ) choose to save. Firms with intermediate levels of productivity invest, but rely solely on their internal net worth. The cutoff levels of productivity  $\underline{\varepsilon}_t^j$  and  $\bar{\varepsilon}_t^j$  are endogenously determined by the deposit rate or the lending rate relative to the effective returns to capital, as shown in equations (41) and (42).

**III.2. Households.** There is a continuum of identical and infinitely lived households with measure one. The representative household is a hand-to-mouth consumer. She supplies inelastically one unit of labor to firms and chooses consumption  $C_t$  to maximize the present value of utility

$$\max \sum_{t=0}^{\infty} \beta^t \log C_t, \quad (43)$$

subject to

$$C_t \leq W_t N_t + D_t - T_t. \quad (44)$$

where  $D_t$  denotes the dividend income received from the financial intermediaries and firms net of the start-up funds for new firms, and  $T_t$  denotes the lump sum taxes imposed by the government to finance subsidies to SOEs.

**III.3. Aggregation and Competitive Equilibrium.** In a competitive equilibrium, the markets for labor, capital, loanable funds, and final goods all clear.

Define the aggregate effective units of capital as

$$\tilde{K}_t^j = z^j \int \varepsilon_{t-1}^j k_t^j (H_{t-1}^j, \varepsilon_{t-1}^j) d\mathbf{F}^j(\varepsilon_{t-1}^j). \quad (45)$$

Aggregating the net worth in Eq. (34) across all firms in sector  $j \in \{s, p\}$  implies that the total net worth in sector  $j$  is given by

$$H_t^j = (1 - \delta_e) \left[ \tau^j R_t \tilde{K}_t^j + (1 - \delta) K_t^j - (1 + r_{l,t-1}) L_t^j + (1 + r_{d,t-1}) S_t^j \right] + \delta_e h_{0t}^j. \quad (46)$$

Loanable funds market clearing implies that aggregate savings equal to aggregate loans. In particular, we have

$$\sum_{j=\{s,p\}} L_{t+1}^j = \sum_{j=\{s,p\}} S_{t+1}^j. \quad (47)$$

where

$$L_{t+1}^j = \int l_{t+1}^j (H_t^j, \varepsilon_t^j) d\mathbf{F}^j (\varepsilon_t^j), \quad (48)$$

$$S_{t+1}^j = \int s_{t+1}^j (H_t^j, \varepsilon_t^j) d\mathbf{F}^j (\varepsilon_t^j). \quad (49)$$

Capital market clearing then implies that

$$K_{t+1} = \sum_{j=\{s,p\}} H_t^j, \quad (50)$$

where  $K_{t+1}$  is the new capital stocks accumulated by firms in both sectors, and is given by

$$K_{t+1} \equiv \sum_{j=\{s,p\}} K_{t+1}^j = \sum_{j=\{s,p\}} \int k_{t+1}^j (H_t^j, \varepsilon_t^j) d\mathbf{F}^j (\varepsilon_t^j). \quad (51)$$

Goods market clearing implies that

$$C_t = Y_t - K_{t+1} + (1 - \delta) K_t, \quad (52)$$

where  $Y_t$  denotes aggregate output given by

$$Y_t = \sum_{j=\{s,p\}} Y_t^j = \sum_{j=\{s,p\}} \left( \tilde{K}_t^j \right)^\alpha (N_t^j)^{1-\alpha}. \quad (53)$$

**III.4. Calibration.** The time period is one year. We partition the model parameters into two sets. The first set  $\Theta_1 = \{\beta, \alpha, \delta, \delta_e, \phi\}$  contains four standard parameters and one policy parameter  $\phi$ . The second set  $\Theta_2$  contains sector-specific parameters.

For the parameters in  $\Theta_1$ , we follow the real business cycle literature and set the discounting factor  $\beta$  to 0.96. We set the capital income share  $\alpha$  to 0.5, in line with empirical evidence (Brandt et al., 2008; Zhu, 2012). We assume that the capital stock depreciates at an annual rate of 10%, so that  $\delta = 0.1$ . We set the exit rate  $\delta_e$  to 0.06 in light of the firm-level evidence provided by Brandt et al. (2012).<sup>8</sup> We set  $\phi = 0.04$ , implying that the annual loan rate is 4%

<sup>8</sup>Brandt et al. (2012) construct a comprehensive annual firm-level dataset to study the firm dynamics for Chinese economy. According to their report (Figure 1), private firms account for half of the total exit which is around 4% of the total mass of firms. Meanwhile, the number of private firms is around 63% of the full sample, therefore the implied annual exit rate of private firms is 6%.

higher than the deposit rate, in line with the average difference between these two interest rates in China for the period from 1996 to 2013.

The second set of parameters in  $\Theta_2$  contains sector specific parameters. We calibrate their values by matching the model-implied moments in the stationary equilibrium under the interest-rate control regime to the counterparts in the Chinese data. We assume that the idiosyncratic productivity in the two sectors follows the same log-normal distribution, with a mean normalized to one and a standard deviation of  $\sigma^j = \sigma$  to be calibrated. We also normalize the subsidy rate to POEs to  $\tau^p = 1$ . We restrict the sector-specific loan to value ratios  $\theta^j$  to be consistent with Chinese data. In particular, Song et al. (2011) document that the share of SOE investment financed by bank loans is about three times as large as that for POEs. Thus, we set  $\theta^s = 3\theta^p$ . We calibrate the start-up funds for new firms  $h_0^j$  to be 25% of the average size of capital stock owned by existing firms in sector  $j$ .

There are five parameters in  $\Theta_2$  remaining to be calibrated, including  $z^s$ ,  $z^p$ ,  $\sigma$ ,  $\tau^s$ , and  $\theta^p$ . We calibrate these five parameters to match five empirical moments in Chinese data. These empirical moments (denoted by  $\mathbf{M}^{\text{data}}$ ) include

- (1) the share of SOE output in aggregate output (0.40),
- (2) the real deposit interest rate with one-year maturity (0.9%),
- (3) the aggregate saving rate (0.41),
- (4) the ratio of short-term loans to real GDP (0.5), and
- (5) the TFP gap between SOEs and POEs (1.6).

We describe the details of these moments in the Appendix.<sup>9</sup> We choose the values of the five parameters to solve the problem

$$\min_{\Theta_2} (\mathbf{M}^{\text{model}}(\Theta_2) - \mathbf{M}^{\text{data}})' \hat{\mathbf{W}} (\mathbf{M}^{\text{model}}(\Theta_2) - \mathbf{M}^{\text{data}}), \quad (54)$$

where  $\mathbf{M}^{\text{model}}(\Theta_2)$  denotes the corresponding moments in the model, which are functions of the model parameters to be calibrated. For simplicity, we use an identity weighting matrix (i.e.,  $\hat{\mathbf{W}} = \mathbf{1}$ ) for this minimizing problem.

Table 1 below compares the model-implied moments and those in the data. Table 2 summarizes the calibrated parameter values.<sup>10</sup>

<sup>9</sup>We interpret the SOE sector in our model broadly as corresponding to the government-favored sector, such as the heavy industry. Chen et al. (2017a) shows that, although the industrial share of SOE output (with SOEs officially classified by China's National Bureau of Statistics) declined to about 20% by 2016, the heavy industry output share remained relatively high at above 50%. Our calibration of the SOE output share of 0.4 is conservative relative to the heavy industry share in the data. Calibrating the SOE output share to 0.5 does not change the qualitative implications of our model.

<sup>10</sup>The calibrated value of  $\tau^s$  is 2.56, which implies the SOE firms put a weight  $\tilde{\tau}^s$  of 1.6 ( $\tau^s = (\tilde{\tau}^s)^{\frac{1}{\alpha}}$ ) on output. As we have argued, this apparently high value of  $\tilde{\tau}^s$  captures not just government subsidies to



**III.5. Transition Dynamics.** We now discuss the dynamic effects of interest-rate liberalization. The economy starts with the initial steady state with interest-rate controls (i.e.,  $\phi = 0.04$ ). Suppose that, in period 2, the interest-rate wedge is permanently removed (i.e.,  $\phi = 0$ ). Over time, the economy will eventually converge to a new steady state with no interest-rate controls. We focus on the transition dynamics following the the interest-rate liberalization.

Figure 3 shows the transition dynamics of the loan and deposit interest rates, the capital stocks in the two sectors, aggregate output, and aggregate consumption. Consistent with the analytical results stated in Proposition 4, the loan rate declines and the deposit rate rises and the two rates collapse into one immediately after the interest-rate wedge is removed. Under government subsidies, SOEs have an incentive to expand their scale and they also have easier access to credit than POEs. Thus, capital flows from POEs to SOEs, leading an increase in SOE capital and a decline in POE capital along the transition paths. Under our calibration, this reallocation of capital also leave SOEs with permanently higher capital and POEs with permanently lower capital in the new steady state. Since SOEs have lower social marginal product of capital, the reallocation following the interest-rate liberalization leads to a lower aggregate TFP and thus a short-run decline in aggregate output. Over time, however, output rises above the initial steady state and reaches a permanently higher new steady-state level. This is because the aggregate capital stock rises over time. Capital accumulation increases because the interest-rate liberalization raises the deposit rate, inducing firms with intermediate levels of productivity to save instead of producing. The increase in savings contributes to the increase in capital stock over time. However, the distorted SOE incentive also leads to over investment in the aggregate economy, resulting in a decline in aggregate consumption.

Figure 4 shows the transition dynamics of the sectoral and aggregate TFP as well as the share of capital held by SOEs. Within each sector, the interest-rate liberalization reallocates capital from low-productivity firms to high-productivity firms. Thus, TFP rises in both sectors. However, the liberalization also shifts capital away from the more productive POEs to the less productive SOEs. Thus, the overall effect on aggregate TFP can be ambiguous, as we show in the static model with analytical solutions (see Proposition 5). Under our calibration, the liberalization policy reduces aggregate TFP, both during the transition process and in the new steady state.

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SOEs, but also some other forms of distorted incentives such as monopoly rents (Li et al., 2015) and fixed costs of operation (Song and Hsieh, 2015).

In our model, interest-rate liberalization policy also has important welfare implications that are different from the standard model. In the standard model, interest-rate liberalization raises aggregate TFP and improves welfare unambiguously (Moll, 2014). In our two-sector model, however, the distorted SOE incentives create a tradeoff between within-sector allocation efficiency and cross-section allocation efficiency following an interest-rate liberalization.

Figure 5 shows the welfare losses following a removal of the interest rate wedge of a given size (indicated on the horizontal axis) during the transition process. For example, if the wedge is initially at  $\phi = 0.04$ , as in our calibration, then removing the wedge would incur a welfare loss equivalent to 2.9 percent of steady-state consumption per year. The figure also reveals that the welfare loss is not a monotone function of the initial interest-rate wedge. In this second-best environment, the tradeoff for interest-rate liberalization implies that there exists an “optimum” interest rate wedge that maximizes social welfare.

**III.6. Counterfactual experiments.** The non-standard results about aggregate TFP and social welfare in our model stem from two key sources of distortions: SOE subsidies and restricted POE credit access. To highlight the role played by these two particular forms of distortions, we now examine two counterfactual experiments, one with reduced SOE subsidies, and the other with improved POE credit access.

**III.6.1. Reducing SOE subsidies.** In our calibrated model, SOEs receive favorable government subsidies for production ( $\tau^s > \tau^p = 1$ ). We now consider the transition dynamics following an interest-rate liberalization in a counterfactual economy with a lower SOE subsidy. In particular, we consider the case with  $\tau^s$  20% lower than that in the benchmark model.

Figure 6 shows the transition dynamics. With a smaller  $\tau^s$ , SOEs have a relatively smaller incentive to expand production and care more about the cost of capital. Thus, the interest-rate liberalization policy would lead to a smaller capital flow from POEs to SOEs, resulting in less misallocation of capital across the two sectors. Under our calibrated parameters (and with a lower value of  $\tau^s$ ), aggregate output rises along the transition path before reaching a permanently higher steady-state level. Reducing the SOE subsidy also mitigates the expansion of SOE output, and leads to an expansion (instead of a contraction observed in the benchmark economy) of POE output during the transition.

Furthermore, with a lower subsidy to SOEs, the interest-rate liberalization leads to a smaller expansion of SOE capital stock and an increase in POE capital stock as well. Aggregate capital stock also increases less than in the benchmark model, suggesting that, with lower SOE subsidies, the economy has less of an over-investment problem.

The interest-rate liberalization in this counterfactual case not just raises sectoral TFP, but also aggregate TFP in the short run. With a smaller incentive to expand its capital stock, the SOE sector also experiences a greater increase in TFP than in the benchmark economy.

Figure 7 shows that the welfare outcome associated with interest-rate liberalization in this counterfactual economy is also substantively different from the benchmark model. In particular, the liberalization policy leads to smaller welfare losses for all sizes of the initial interest-rate wedge. For a large range of the values of  $\phi$ , liberalization policy leads to welfare gains.

III.6.2. *Improving POE access to credit.* In our benchmark model, the loan-to-value ratio for SOEs is three times as large as that for POEs ( $\theta^s = 3\theta^p$ ). The easier credit access for SOEs also contributed to the misallocation of capital across sectors. We now consider a counterfactual case with equal credit access for the two types of firms (i.e., with  $\theta^s = \theta^p$ ), holding all the other parameters unchanged at their calibrated values.

Figure 8 compares the transition dynamics following an interest-rate liberalization in this counterfactual case with those in the benchmark model. The figure shows that easing credit access for POEs improves allocative efficiency within both sectors, and it also contributes to an improvement in aggregate TFP.

Allowing POEs to have equal credit access as SOEs also improves welfare following interest-rate liberalization. Figure 9 shows that removing the interest-rate wedge unambiguously improves welfare, in contrast to the welfare losses obtained in the benchmark economy.

#### IV. RELATED LITERATURE

Our paper contributes to several strands of the literature. First, our paper is closely related to the literature that studies the impact of capital market distortion on the aggregate economy. Examples include Restuccia and Rogerson (2008), Hsieh and Klenow (2009), Greenwood et al. (2010), Buera et al. (2011), Bartelsman et al. (2013), Midrigan and Xu (2014), and Moll (2014), among many others.<sup>11</sup> We build on this literature and add to it by highlighting a potential tradeoff facing financial liberalization in a second-best environment such as China. Such a tradeoff arises because the liberalization policy improves within-sector capital allocation, at the cost of exacerbated across-sector misallocation.

Our paper is also related to the literature that evaluates the impact of financial liberalization. The early studies such as McKinnon (2010) and Shaw (1974) argue that higher interest rates that follow the removal of interest rate ceilings will generate higher savings, and in turn,

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<sup>11</sup>Other studies on this topic include Banerjee and Moll (2010), Brandt et al. (2013), Gilchrist et al. (2013), Caggese and Cuñat (2013), Buera et al. (2013). See Restuccia and Rogerson (2013) for a comprehensive survey of this literature.

higher investment. Devereux and Smith (1994) argue that financial liberalization could have ambiguous effects on aggregate saving and investment because, in an improved risk-sharing environment, households would have incentive to reduce saving.<sup>12</sup> There is some empirical evidence that financial liberalization helps improve allocation efficiency. For example, Galindo et al. (2007) use firm-level data from 12 developing countries and find a positive and significant effect of financial liberalization on the efficiency of capital allocation. Abiad et al. (2008) document evidence of a positive “quality effect” of financial liberalization on allocative efficiency, as measured by dispersion in Tobin’s Q across firms.<sup>13</sup>

Several recent studies examine the macroeconomic implications of China’s interest rate liberalization. Based on case studies and a simple static model, Porter et al. (2009) find that removing the ceiling on the deposit rate will likely result in higher interest rates, discourage marginal investment, improve the effectiveness of intermediation and monetary transmission, and enhance the financial access of underserved sectors. Porter and Xu (2009) construct a stylized model of China’s interbank market and argue that the regulation of lending and deposit rates diminishes the ability of the market determined rates to act as independent price signals, or as benchmarks for use in asset pricing and monetary policy. Chen et al. (2013) extend the theoretical work of Porter and Xu (2009) and show that regulation of deposit and lending rates prevents the interbank lending rate from signaling monetary policy stance and transmitting the effect of policy to the growth of bank loans. Liao and Tapsoba (2014) empirically documents the effect of interest rate liberalization on stability of China’s money demand function (MDF), and find that the financial reform leads to a structural break of China’s MDF. Li et al. (2015) constructs a static general equilibrium model for China’s financial system, where a state-owned monopolistic banking sector coexists, endogenously, with markets for corporate bonds and private loans. The model predicts that removing the controls on bank lending rates or tightening the supply of external finance would reduce bank loans but increases bond finance.<sup>14</sup> Our paper contributes to this growing literature on China’s financial frictions and liberalization policy by constructing a fully-fledged two-sector dynamic general equilibrium model that captures China’s key existing institutional features

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<sup>12</sup>Bandiera et al. (2000) argue that the ambiguous effect of financial liberalization on private saving is also due to the fact that the financial liberalization is a multi-dimensional and phased process, sometimes involving reversals.

<sup>13</sup>There is also a large literature documenting the empirical relationship between financial development and growth. Examples include King and Levine (1993b), King and Levine (1993a), Rajan and Zingales (1998), Levine (1997), Levine and Zervos (1998), Levine et al. (2000), and many others. Levine (2005) provides a comprehensive survey on this topic.

<sup>14</sup>For some other recent studies of China’s financial system, and in particular, on China’s shadow banking system, see Hachem and Song (2015), Wang et al. (2016), Acharya et al. (2017), Chen et al. (2017b).

and distortions. Within this general equilibrium framework, we are able to examine the potential tradeoffs facing interest-rate liberalization in a second-best environment.

Our paper is also related to the literature that studies China's monetary policy in a DSGE framework. For example, Chang et al. (2015b) build a DSGE model of China to examine the implications of China's capital controls for its domestic monetary policy when external shocks raise the cost of sterilization. Chang et al. (2016) study the role of reserve requirements for China's macroeconomic stabilization in a two-sector DSGE model with SOEs and POEs having access to segmented credit markets. Unlike these studies that focus on business cycle stabilization, our focus is on the implications of interest-rate liberalization on the economy's steady state equilibrium and transition dynamics.

Finally, our paper contributes to the literature that quantitatively documents the structural transformation of Chinese economy. Brandt et al. (2008) based on multi-sector growth accounting model to examine the impact of within-sector productivity growth and cross-sector allocations on the overall growth. They find that reducing credit market distortions provides substantial potential gains for China's economic growth. Brandt and Zhu (2010) develop a three-sector dynamic model to quantify the sources of China's growth. They find that the less efficient state sector continues to absorb more than half of all fixed investment, which causes the significant misallocation in the capital market. Song et al. (2011) construct a two-sector growth model with less productive SOEs and more productive but financially constrained POEs. They quantitatively show that the credit market imperfection provides a key mechanism to understand China's economic transition. Chang et al. (2015a) build a two-sector model with a special emphasis on resource and credit reallocations between the heavy and light sectors and by introducing a collateral constraint on producers in the heavy sector and a lending friction in the banking sector. Their calibrated model is able to replicate both the empirically observed trend and cyclical patterns of China's aggregate economy. Our structural model adds to this literature by considering the heterogeneous sectors and capital market imperfections. Instead of understanding China's spectacular growth trend in the past two decades, we aim to evaluate the effect of financial reform on China's economic transition.

## V. CONCLUSION

We have studied implications of interest-rate liberalization for capital allocation, aggregate productivity, and social welfare in a two-sector general equilibrium model with Chinese characteristics. In the model, SOE firms have easier access to credit than private firms despite their lower average productivity. In addition, government subsidies to SOEs create an incentive for SOE firms to expand production scales. Our model also features heterogeneous

productivity across firms within each sector, so that credit and capital allocations under interest rate controls depend on the distribution of idiosyncratic productivity across firms. We show that reforms that lift interest-rate controls can improve capital allocation efficiency within each sector, but exacerbate misallocations across sectors. Since SOEs have easier access to credit and an incentive to expand scales, the extra savings induced by the reform disproportionately flow to the SOE sector. The overall effects of interest-rate liberalization on aggregate TFP and welfare depend on parameters. With calibrated parameters, the model implies that interest-rate liberalization by itself can modestly reduce aggregate TFP and welfare. This surprising welfare implication of interest-rate reforms is obtained because our model has a second-best environment with multiple sources of distortions. We further show that, if other structural reforms that mitigate SOEs' incentive to expand scales or improve POEs' access to credit are simultaneously pursued, interest-rate liberalization can be welfare improving.

## Appendix

### APPENDIX A. PROOFS OF PROPOSITIONS

*Proposition 1.* Assume that the interest-rate wedge is sufficiently large so that  $\phi > \tau z^s - z^p$ . Then the only equilibrium is one with financial autarky, under which  $k^s = k^p = h$  and  $r_d \in [\tau z^s - \phi, z^p]$ . Aggregate output is given by

$$Y = (1 - \mu)z^p h + \mu z^s h \quad (\text{A.1})$$

*Proof.* There are 3 possible cases for the deposit rate: (i)  $r_d < \tau z^s - \phi$ , (ii)  $r_d > z^p$ , and (iii)  $r_d \in [\tau z^s - \phi, z^p]$ . We show that the first 2 cases are not consistent with any equilibrium. We also show that, in the third case, there is an autarkic equilibrium, with no borrowing or lending between the two sectors.

If  $r_d < \tau z^s - \phi$ , then the SOEs' private MPK  $\tau z^s$  exceeds the loan interest rate  $r_d + \phi = r_l$ . The borrowing constraint for SOEs will be binding, so that  $l^s = \theta^s h$ . However, under the assumption that  $\phi > \tau z^s - z^p$ , we have  $r_d < \tau z^s - \phi < z^p$ . That is, POEs' MPK exceeds the deposit rate, so that they choose not to save (i.e.,  $s^p = 0$ ). But this contradicts the loan market clearing condition since  $s^p = 0$  implies  $l^s = 0$ .

If  $r_d > z^p$ , then POEs would choose to save instead of producing since their MPK is lower than the deposit rate. This implies that  $s^p = h$ . However, in this case,  $\tau z^s < z^p + \phi < r_d + \phi = r_l$ . Thus, SOEs would choose not to borrow (so that  $l^s = 0$ ) since the loan rate exceeds their private MPK. The positive saving by POEs and zero borrowing by SOEs again violates the loan market clearing condition and cannot be an equilibrium.

In the case with  $r_d \in [\tau z^s - \phi, z^p]$ , however, there is an equilibrium. In particular, since  $r_d < z^p < \tau z^s$ , firms in both sectors choose not to save. They do not borrow either because the loan rate exceeds their MPKs (i.e.,  $r_d + \phi > \tau z^s > z^p$ ). Thus, the only equilibrium is the financial autarky with no cross-sector capital flows. In this equilibrium, we have  $k^s = k^p = h$  and aggregate output is given by  $Y = (1 - \mu)z^p h + \mu z^s h$ .  $\square$

*Proposition 2.* Assume that  $\tau z^s > z^p > z^s$ . In the liberalized economy with  $\phi = 0$ , the equilibrium deposit rate satisfies  $r_d \in [z^p, \tau z^s]$  and aggregate output  $Y$  is given by

$$Y = \begin{cases} z^p h - (z^p - z^s) \mu (1 + \theta^s) h & \text{if } \theta^s < 1/\mu - 1, \\ z^s h & \text{if } \theta^s \geq 1/\mu - 1. \end{cases} \quad (\text{A.2})$$

*Proof.* Since  $\phi = 0$ , the loan rate and the deposit rate are identical (i.e.,  $r_l = r_d$ ). Following the same logics as in the proof of Proposition 1, we can show that  $r_d < z^p$  and  $r_d > \tau z^s$  are both inconsistent with an equilibrium. The equilibrium interest rate thus lies in the closed interval  $[z^p, \tau z^s]$ , which is non-empty under our assumption.

If  $r_d = z^p$ , then POEs are indifferent between saving or not. Since  $\tau z^s > z^p = r_d$ , SOEs will choose not to save but to borrow up to the limit (i.e.,  $s^s = 0$  and  $l^s = \theta^s h$ ). The capital stock held by each SOE firm would be  $k^s = (1 + \theta^s)h$ . The capital market clearing condition (10) implies that  $(1 - \mu)k^p + \mu(1 + \theta^s)h = h$ . Thus, POEs would stay operating (i.e.,  $k^p > 0$ ) if and only if  $\theta^s < \frac{1}{\mu} - 1$ . In this case, aggregate output is given by  $Y = (1 - \mu)z^p k^p + \mu z^s k^s = z^p h - (z^p - z^s)\mu(1 + \theta^s)h$ .

If  $r_d \in (z^p, \tau z^s]$ , then POEs would choose to save all their endowment (i.e.,  $s^p = h$ ). The capital market clearing condition (10) implies that SOEs will own all capital stock in the economy provided that  $\theta^s \geq \frac{1}{\mu} - 1$ . In this case, aggregate output is given by  $Y = z^s h$ .  $\square$

*Proposition 3.* In the economy with heterogeneous firms, there exist two threshold levels of idiosyncratic productivity, denoted by  $\underline{\varepsilon}^j$  and  $\bar{\varepsilon}^j$  for each sector  $j \in \{s, p\}$ , such that

$$s^j(\varepsilon) = \begin{cases} h & \text{if } \varepsilon_{\min} \leq \varepsilon < \underline{\varepsilon}^j \\ 0 & \text{if } \underline{\varepsilon}^j \leq \varepsilon \end{cases}, \quad (\text{A.3})$$

$$l^j(\varepsilon) = \begin{cases} 0 & \text{if } \varepsilon_{\min} \leq \varepsilon < \bar{\varepsilon}^j \\ \theta^j h & \text{if } \bar{\varepsilon}^j \leq \varepsilon \end{cases}, \quad (\text{A.4})$$

$$k^j(\varepsilon) = \begin{cases} 0 & \text{if } \varepsilon_{\min} \leq \varepsilon < \underline{\varepsilon}^j \\ h & \text{if } \underline{\varepsilon}^j \leq \varepsilon < \bar{\varepsilon}^j \\ (1 + \theta^j)h & \text{if } \bar{\varepsilon}^j \leq \varepsilon \end{cases}. \quad (\text{A.5})$$

where the thresholds  $\underline{\varepsilon}^j$  and  $\bar{\varepsilon}^j$  are defined as

$$\underline{\varepsilon}^j = \frac{r_d}{z^j \tau^j}, \quad (\text{A.6})$$

$$\bar{\varepsilon}^j = \frac{r_d + \phi}{z^j \tau^j}. \quad (\text{A.7})$$

*Proof.* The optimization problem of the firm in  $j$  sector can be written as

$$\max_{\{l^j(\varepsilon), s^j(\varepsilon)\}} \tau^j z^j \varepsilon [h + l^j(\varepsilon) - s^j(\varepsilon)] - r_l l^j(\varepsilon) + r_d s^j(\varepsilon), \quad (\text{A.8})$$

subject to

$$0 \leq l^j(\varepsilon) \leq \theta^j h, \quad (\text{A.9})$$

$$0 \leq s^j(\varepsilon) \leq h. \quad (\text{A.10})$$

Because of the linearity, we can define two cutoffs as  $\underline{\varepsilon}^j = \frac{r_d}{z^j \tau^j}$  and  $\bar{\varepsilon}^j = \frac{r_l}{z^j \tau^j}$ , where  $r_l = r_d + \phi$ . For the productivity  $\varepsilon$  below the cutoff  $\underline{\varepsilon}^j$ , producing is not profitable since  $\tau^j z^j \varepsilon < r_d$ , so the firm chooses to save, i.e.,  $s^j(\varepsilon) = h$ ,  $l^j(\varepsilon) = 0$  and  $k^j(\varepsilon) = 0$ . If the productivity  $\varepsilon$  lies in  $[\underline{\varepsilon}^j, \bar{\varepsilon}^j)$ , producing earns positive return while the return cannot cover the external financing cost (i.e.,  $r_d \leq \tau^j z^j \varepsilon < r_l$ ), so the firm's optimal decision is producing



and self-finance, that is  $s^j(\varepsilon) = l^j(\varepsilon) = 0$  and  $k^j(\varepsilon) = h$ . For the case where the productivity  $\varepsilon$  is sufficiently large (i.e.,  $\tau^j z^j \varepsilon \geq r_l$  or  $\varepsilon \geq \bar{\varepsilon}^j$ ), it is optimal for the firm to expand the production through the external finance. Therefore, in this case the borrowing constraint is binding, and we have  $s^j(\varepsilon) = 0$ ,  $l^j(\varepsilon) = \theta^j h$  and  $k^j(\varepsilon) = (1 + \theta^j) h$ .  $\square$

*Proposition 4.* The deposit rate  $r_d$  decreases with the interest-rate wedge  $\phi$  and the lending rate  $r_l$  increases with  $\phi$ . Thus, interest-rate liberalization (that lowers  $\phi$ ) would raise the deposit rate  $r_d$  and reduce the lending rate  $r_l$ .

*Proof.* Denote the probability density function of  $\varepsilon$  as  $f^j(\varepsilon)$ ,  $j \in \{s, p\}$ . The capital market clearing condition (22) implies that

$$1 = \mu \left[ \int_{\underline{\varepsilon}^s}^{\varepsilon^{\max}} d\mathbf{F}^s(\varepsilon) + \theta^s \int_{\bar{\varepsilon}^s}^{\varepsilon^{\max}} d\mathbf{F}^s(\varepsilon) \right] + (1 - \mu) \left[ \int_{\underline{\varepsilon}^p}^{\varepsilon^{\max}} d\mathbf{F}^p(\varepsilon) + \theta^p \int_{\bar{\varepsilon}^p}^{\varepsilon^{\max}} d\mathbf{F}^p(\varepsilon) \right]. \quad (\text{A.11})$$

where

$$\underline{\varepsilon}^s = \frac{r_d}{z^s \tau}, \quad \bar{\varepsilon}^s = \frac{r_d + \phi}{z^s \tau}, \quad (\text{A.12})$$

$$\underline{\varepsilon}^p = \frac{r_d}{z^p}, \quad \bar{\varepsilon}^p = \frac{r_d + \phi}{z^p}. \quad (\text{A.13})$$

Taking derivative on both sides w.r.t.  $\phi$  yields

$$0 = \frac{\mu}{z^s \tau} \left\{ [f^s(\underline{\varepsilon}^s) + \theta^s f^s(\bar{\varepsilon}^s)] \frac{\partial r_d}{\partial \phi} + \theta^s f^s(\bar{\varepsilon}^s) \right\} + \frac{1 - \mu}{z^p} \left\{ [f^p(\underline{\varepsilon}^p) + \theta^p f^p(\bar{\varepsilon}^p)] \frac{\partial r_d}{\partial \phi} + \theta^p f^p(\bar{\varepsilon}^p) \right\}. \quad (\text{A.14})$$

With some algebra, we obtain

$$\frac{\partial r_d}{\partial \phi} = -\frac{1}{1 + \psi}, \quad (\text{A.15})$$

where

$$\psi = \frac{\mu f^s(\underline{\varepsilon}^s) + (1 - \mu) f^p(\underline{\varepsilon}^p) \frac{\tau z^s}{z^p}}{\mu f^s(\bar{\varepsilon}^s) \theta^s + (1 - \mu) f^p(\bar{\varepsilon}^p) \frac{\tau z^s}{z^p} \theta^p}. \quad (\text{A.16})$$

Since  $\psi > 0$ , we have  $\frac{\partial r_d}{\partial \phi} < 0$  and  $\frac{\partial(r_d + \phi)}{\partial \phi} > 0$ . That is, the interest-rate liberalization reduces the deposit rate  $r_d$  but raises the lending rate  $r_d + \phi$ .  $\square$

*Proposition 5.* Assume that the idiosyncratic shocks in the two sectors are drawn from the same distribution, with the probability density function  $f(\varepsilon)$ . Assume further that the density function satisfies the condition that  $g(\varepsilon) \equiv \frac{f'(\varepsilon)\varepsilon}{f(\varepsilon)}$  decreases with  $\varepsilon$ . Under these conditions, we obtain

$$\frac{\partial K^s}{\partial \phi} < 0, \quad \frac{\partial K^p}{\partial \phi} > 0. \quad (\text{A.17})$$

We also obtain  $\frac{\partial A^p}{\partial \phi} < 0$  whereas  $\frac{\partial A^s}{\partial \phi}$  has an ambiguous sign. Furthermore, the relation between aggregate output and the interest-rate wedge is also ambiguous (i.e.,  $\frac{\partial Y}{\partial \phi}$  has an ambiguous sign). The same is true for aggregate TFP.

*Proof.* We first discuss how liberalization affects the capital flows across sectors. For any  $\phi > 0$ , the capitals in two sectors are given by

$$K^s = \mu h \left[ \int_{\underline{\varepsilon}^s}^{\infty} f(\varepsilon) d\varepsilon + \theta^s \int_{\bar{\varepsilon}^s}^{\infty} f(\varepsilon) d\varepsilon \right], \quad (\text{A.18})$$

$$K^p = (1 - \mu) h \left[ \int_{\underline{\varepsilon}^p}^{\infty} f(\varepsilon) d\varepsilon + \theta^p \int_{\bar{\varepsilon}^p}^{\infty} f(\varepsilon) d\varepsilon \right]. \quad (\text{A.19})$$

where cutoffs are defined in (A.12) and (A.13). The partial derivative  $\frac{\partial K^s}{\partial \phi}$  is

$$\frac{\partial K^s}{\partial \phi} = -\mu h \left[ f(\underline{\varepsilon}^s) \frac{\partial \underline{\varepsilon}^s}{\partial \phi} + \theta^s f(\bar{\varepsilon}^s) \frac{\partial \bar{\varepsilon}^s}{\partial \phi} \right]. \quad (\text{A.20})$$

According to the definition of cutoffs, we have  $\frac{\partial \underline{\varepsilon}^s}{\partial \phi} = \frac{1}{z^s \tau} \frac{\partial r_d}{\partial \phi}$  and  $\frac{\partial \bar{\varepsilon}^s}{\partial \phi} = \frac{1}{z^s \tau} \left( 1 + \frac{\partial r_d}{\partial \phi} \right)$ , where  $\frac{\partial r_d}{\partial \phi} = -\frac{1}{1+\psi}$  (see A.15). Then we have

$$\begin{aligned} \frac{\partial K^s}{\partial \phi} &= -\frac{\mu h}{z^s \tau} \left\{ [f(\underline{\varepsilon}^s) + \theta^s f(\bar{\varepsilon}^s)] \frac{\partial r_d}{\partial \phi} + \theta^s f(\bar{\varepsilon}^s) \right\}, \\ &= \frac{\mu h}{z^s \tau} \frac{f(\underline{\varepsilon}^s) + \theta^s f(\bar{\varepsilon}^s) - \theta^s f(\bar{\varepsilon}^s) (1 + \psi)}{1 + \psi}. \end{aligned} \quad (\text{A.21})$$

We now rewrite  $\frac{\partial K^s}{\partial \phi}$  more compactly. Replacing  $\psi$  in the numerator of last equation by (A.16) yields

$$\begin{aligned} \frac{\partial K^s}{\partial \phi} &= \frac{\mu h}{z^s \tau (1 + \psi)} \left\{ f(\underline{\varepsilon}^s) + \theta^s f(\bar{\varepsilon}^s) - \theta^s f(\bar{\varepsilon}^s) \left[ 1 + \frac{\mu f(\underline{\varepsilon}^s) + (1 - \mu) f(\underline{\varepsilon}^p) \frac{\tau z^s}{z^p}}{\mu f(\bar{\varepsilon}^s) \theta^s + (1 - \mu) f(\bar{\varepsilon}^p) \frac{\tau z^s}{z^p} \theta^p} \right] \right\} \\ &= \frac{\mu h (1 - \mu) f(\underline{\varepsilon}^s) f(\bar{\varepsilon}^p) \theta^p - \theta^s f(\bar{\varepsilon}^s) f(\underline{\varepsilon}^p)}{z^p (1 + \psi) \mu f(\bar{\varepsilon}^s) \theta^s + (1 - \mu) f(\bar{\varepsilon}^p) \frac{\tau z^s}{z^p} \theta^p} \\ &= \frac{h (1 - \mu) f(\underline{\varepsilon}^s)}{z^p (1 + \psi)} \frac{\frac{f(\bar{\varepsilon}^p) \theta^p}{f(\bar{\varepsilon}^s) \theta^s} - \frac{f(\underline{\varepsilon}^p)}{f(\underline{\varepsilon}^s)}}{1 + \frac{1 - \mu}{\mu} \frac{f(\bar{\varepsilon}^p)}{f(\bar{\varepsilon}^s)} \frac{\tau z^s}{z^p} \frac{\theta^p}{\theta^s}} \\ &= \chi_1 \left[ \frac{f(\bar{\varepsilon}^p) \theta^p}{f(\bar{\varepsilon}^s) \theta^s} - \frac{f(\underline{\varepsilon}^p)}{f(\underline{\varepsilon}^s)} \right], \end{aligned} \quad (\text{A.22})$$

where  $\chi_1 = \frac{h(1-\mu)f(\underline{\varepsilon}^s)}{z^p(1+\psi)\left[1+\frac{1-\mu}{\mu}\frac{f(\bar{\varepsilon}^p)}{f(\bar{\varepsilon}^s)}\frac{\tau z^s}{z^p}\frac{\theta^p}{\theta^s}\right]}$ . The third line is obtained by dividing the numerator and the denominator simultaneously by  $\mu \theta^s f(\bar{\varepsilon}^s) f(\underline{\varepsilon}^s)$ .

The assumption that  $\frac{f'(\varepsilon)\varepsilon}{f(\varepsilon)}$  is decreasing in  $\varepsilon$  implies  $\frac{f(\varkappa\varepsilon)}{f(\varepsilon)}$ , for any  $\varkappa > 1$ , is decreasing in  $\varepsilon$ . As a result, the condition  $\tau z^s > z^p$  ensures  $\frac{f\left(\frac{r_d+\phi}{r_d}\underline{\varepsilon}^s\right)}{f(\underline{\varepsilon}^s)} \geq \frac{f\left(\frac{r_d+\phi}{r_d}\underline{\varepsilon}^p\right)}{f(\underline{\varepsilon}^p)}$ , or equivalently  $\frac{f(\bar{\varepsilon}^s)}{f(\underline{\varepsilon}^s)} \frac{f(\underline{\varepsilon}^p)}{f(\bar{\varepsilon}^p)} \geq 1$ . Notice that the monotonicity assumption of  $\frac{f'(\varepsilon)\varepsilon}{f(\varepsilon)}$  is fairly weak, it can be satisfied by many commonly used distributions, for instance, log-normal or Pareto distributions. Moreover,  $\theta^p < \theta^s$  further implies  $\frac{f(\bar{\varepsilon}^s)f(\underline{\varepsilon}^p)}{f(\bar{\varepsilon}^p)f(\underline{\varepsilon}^s)} \geq 1 > \frac{\theta^p}{\theta^s}$  or the second term in (A.22) less than zero, i.e.,  $\frac{f(\bar{\varepsilon}^p)\theta^p}{f(\bar{\varepsilon}^s)\theta^s} - \frac{f(\underline{\varepsilon}^p)}{f(\underline{\varepsilon}^s)} < 0$ . Therefore,  $\frac{\partial K^s}{\partial \phi} < 0$ . The capital market clearing condition  $K^s + K^p = h$  immediately gives  $\frac{\partial K^p}{\partial \phi} > 0$ .

We now discuss the effects on output. According to the definition of sectoral output, we have

$$Y^j = \mu^j z^j h \left[ \int_{\underline{\varepsilon}^j}^{\infty} \varepsilon f(\varepsilon) d\varepsilon + \theta^j \int_{\bar{\varepsilon}^j}^{\infty} \varepsilon f(\varepsilon) d\varepsilon \right], \quad j \in \{s, p\}, \quad (\text{A.23})$$

where  $\mu^s = \mu$ ,  $\mu^p = 1 - \mu$ .

We first look at the SOE sector. The impact of interest-rate liberalization on the output is

$$\begin{aligned} \frac{\partial Y^s}{\partial \phi} &= \mu h z^s \left[ -\underline{\varepsilon}^s f(\underline{\varepsilon}^s) \frac{\partial \underline{\varepsilon}^s}{\partial \phi} - \theta^s \bar{\varepsilon}^s f(\bar{\varepsilon}^s) \frac{\partial \bar{\varepsilon}^s}{\partial \phi} \right] \\ &= \frac{\mu h}{\tau} \left\{ -[\underline{\varepsilon}^s f(\underline{\varepsilon}^s) + \theta^s \bar{\varepsilon}^s f(\bar{\varepsilon}^s)] \frac{\partial r_d}{\partial \phi} - \theta^s \bar{\varepsilon}^s f(\bar{\varepsilon}^s) \right\} \\ &= \frac{\mu h}{\tau} \left\{ [\underline{\varepsilon}^s f(\underline{\varepsilon}^s) + \theta^s \bar{\varepsilon}^s f(\bar{\varepsilon}^s)] \frac{1}{1 + \psi} - \theta^s \bar{\varepsilon}^s f(\bar{\varepsilon}^s) \right\} \\ &= \frac{\mu h \underline{\varepsilon}^s f(\underline{\varepsilon}^s) + \theta^s \bar{\varepsilon}^s f(\bar{\varepsilon}^s) - \theta^s \bar{\varepsilon}^s f(\bar{\varepsilon}^s) (1 + \psi)}{\tau (1 + \psi)}. \end{aligned} \quad (\text{A.24})$$

The second and third lines are due to the definition of cutoffs and (A.15). Replacing  $\psi$  in the numerator of last equation by (A.16) and rearranging terms yield

$$\begin{aligned} \frac{\partial Y^s}{\partial \phi} &= \frac{1}{\tau} \left\{ r_d \chi_1 \left[ \frac{f(\bar{\varepsilon}^p) \theta^p}{f(\bar{\varepsilon}^s) \theta^s} - \frac{f(\underline{\varepsilon}^p)}{f(\underline{\varepsilon}^s)} \right] + \chi_1 \frac{\mu (\underline{\varepsilon}^s - \bar{\varepsilon}^s) z^p}{1 - \mu} \left[ 1 + \frac{f(\underline{\varepsilon}^p)}{f(\underline{\varepsilon}^s)} \frac{1 - \mu \tau z^s}{\mu z^p} \right] \right\} \\ &= \frac{1}{\tau} \left( r_d \frac{\partial K^s}{\partial \phi} - \frac{\mu}{1 - \mu} \frac{z^p}{z^s \tau} \chi_1 \chi_2 \phi \right), \end{aligned} \quad (\text{A.25})$$

where  $\chi_1 = \frac{h(1-\mu)f(\underline{\varepsilon}^s)}{z^p(1+\psi)\left[1+\frac{1-\mu}{\mu}\frac{f(\bar{\varepsilon}^p)}{f(\bar{\varepsilon}^s)}\frac{\tau z^s}{z^p}\frac{\theta^p}{\theta^s}\right]}$  and  $\chi_2 = 1 + \frac{1-\mu}{\mu} \frac{z^s \tau}{z^p} \frac{f(\underline{\varepsilon}^p)}{f(\underline{\varepsilon}^s)}$ . The second line is obtained by replacing  $\chi_1 \left[ \frac{f(\bar{\varepsilon}^p) \theta^p}{f(\bar{\varepsilon}^s) \theta^s} - \frac{f(\underline{\varepsilon}^p)}{f(\underline{\varepsilon}^s)} \right]$  with  $\frac{\partial K^s}{\partial \phi}$ .

Since  $\frac{\partial K^s}{\partial \phi} < 0$ ,  $\chi_1, \chi_2 > 0$ , we have  $\frac{\partial Y^s}{\partial \phi} < 0$ , i.e., the interest rate liberalization (reducing  $\phi$ ) will unambiguously increase the output in SOE sector.

For the POE sector, similarly we have

$$\begin{aligned} \frac{\partial Y^p}{\partial \phi} &= (1 - \mu) z^p h \left[ -\underline{\varepsilon}^p f(\underline{\varepsilon}^p) \frac{\partial \underline{\varepsilon}^p}{\partial \phi} - \theta^p \bar{\varepsilon}^p f(\bar{\varepsilon}^p) \frac{\partial \bar{\varepsilon}^p}{\partial \phi} \right] \\ &= (1 - \mu) h \frac{\underline{\varepsilon}^p f(\underline{\varepsilon}^p) + \theta^p \bar{\varepsilon}^p f(\bar{\varepsilon}^p) - \theta^p \bar{\varepsilon}^p f(\bar{\varepsilon}^p) (1 + \psi)}{1 + \psi}. \end{aligned} \quad (\text{A.26})$$

Replacing  $\psi$  in the numerator of last equation by (A.16) and rearranging terms yield

$$\begin{aligned} \frac{\partial Y^p}{\partial \phi} &= \chi_1 \left[ r_d \frac{f(\underline{\varepsilon}^p)}{f(\underline{\varepsilon}^s)} - (r_d + \phi) \frac{\theta^p f(\bar{\varepsilon}^p)}{\theta^s f(\bar{\varepsilon}^s)} - \frac{1 - \mu}{\mu} \frac{f(\underline{\varepsilon}^p) f(\bar{\varepsilon}^p)}{f(\underline{\varepsilon}^s) f(\bar{\varepsilon}^s)} \frac{\tau z^s \theta^p}{z^p \theta^s} \phi \right] \\ &= r_d \frac{\partial K^p}{\partial \phi} - \frac{\theta^p f(\bar{\varepsilon}^p)}{\theta^s f(\bar{\varepsilon}^s)} \chi_1 \chi_2 \phi. \end{aligned} \quad (\text{A.27})$$

The second line is obtained by replacing  $\chi_1 \left[ \frac{f(\underline{\varepsilon}^p)}{f(\underline{\varepsilon}^s)} - \frac{f(\bar{\varepsilon}^p) \theta^p}{f(\bar{\varepsilon}^s) \theta^s} \right]$  with  $\frac{\partial K^p}{\partial \phi}$ .

Since the liberalization causes capital outflow ( $\frac{\partial K^p}{\partial \phi} > 0$ ) and efficiency improvement (see the proof below), the total effect on  $Y^p$  is ambiguous. We now discuss the effects on sectoral TFPs. The TFPs are defined as  $A^j = \frac{Y^j}{K^j}$ , therefore

$$\frac{\partial A^j}{\partial \phi} = \frac{1}{K^j} \left[ \frac{\partial Y^j}{\partial \phi} - A^j \frac{\partial K^j}{\partial \phi} \right]. \quad (\text{A.28})$$

Equations (A.18), (A.19), (A.25) and (A.27), imply

$$\frac{\partial A^s}{\partial \phi} = \frac{1}{K^s} \left[ (z^s \underline{\varepsilon}^s - A^s) \frac{\partial K^s}{\partial \phi} - \frac{\mu}{1 - \mu} \frac{z^p}{z^s \tau^2} \chi_1 \chi_2 \phi \right], \quad (\text{A.29})$$

$$\frac{\partial A^p}{\partial \phi} = \frac{1}{K^p} \left[ (z^p \underline{\varepsilon}^p - A^p) \frac{\partial K^p}{\partial \phi} - \frac{f(\bar{\varepsilon}^p) \theta^p}{f(\bar{\varepsilon}^s) \theta^s} \chi_1 \chi_2 \phi \right]. \quad (\text{A.30})$$

The impact of interest-rate liberalization on the TFP consists of two components. The first term in the blanket ( $z^j \underline{\varepsilon}^j - A^j$ )  $\frac{\partial K^j}{\partial \phi}$  reflects the effect of the between-sector capital flows on the efficiency. Since  $z^j \underline{\varepsilon}^j < A^j$ , the capital inflows to SOE sector caused by the interest-rate liberalization ( $\frac{\partial K^s}{\partial \phi} < 0$ ) may provide more capitals for those relatively low efficient firms to produce, therefore may reduce the sectoral productivity. This is the case for the SOE sector. While, for the POE sector, the interest-rate liberalization leads to capital outflows ( $\frac{\partial K^p}{\partial \phi} > 0$ ), resulting a positive impact on the productivity.

The second term in the blanket reflects the direct impact of interest rate liberalization on the sectoral productivity. The negative value (or minus a positive value) of the second term implies the liberalization (reducing  $\phi$ ) would improve the sectoral efficiency.

Combining the above two effects, the interest-rate liberalization unambiguously improves the TFP in POE sector. While, for the SOE sector, the effect of interest-rate liberalization on the within-sector TFP is not clear, since the capital inflow causes negative effect on the efficiency, i.e.,  $(z^s \underline{\varepsilon}^s - A^s) \frac{\partial K^s}{\partial \phi} > 0$ . Notice that if interest rate control is sufficiently large,  $\frac{\partial A^s}{\partial \phi}$  could be negative.

The effect of liberalization on the aggregate output is given by

$$\frac{\partial Y}{\partial \phi} = \frac{\partial Y^s}{\partial \phi} + \frac{\partial Y^p}{\partial \phi} = \frac{r_d}{z^p} \left( \frac{1}{\tau} - 1 \right) \frac{\partial K^s}{\partial \phi} - \chi_1 \chi_2 \phi \left[ \frac{\mu}{1 - \mu} \frac{1}{z^s \tau^2} + \frac{f(\bar{\varepsilon}^p) \theta^p}{f^s(\bar{\varepsilon}^s) \theta^s} \frac{1}{z^p} \right]. \quad (\text{A.31})$$

Under the condition  $\tau > 1$  (due to  $z^s < z^p$  and  $\tau z^s > z^p$ ), the interest-rate liberalization have two opposite effects on aggregate output (the first term is positive and the second term is negative), which reflects that complete liberalization may not be desirable.  $\square$

## APPENDIX B. DATA

- (1) The SOE share of aggregate output is calculated as  $\frac{\text{Industrial value added of SOEs}}{\text{Total value added}}$ . The series are monthly from 1998M8 to 2014M9 downloaded from CEIC database. The SOEs include state-owned enterprises and state-holding enterprises. The SOE share

of output presents a downward trend starting from 1998M8 at around 60% and stays at a stable level around 38% after 2004. The average value for the whole sample is about 44%. In our calibration, we set the target SOE share to 40%. This number is also close to the one calculated in Szamosszegi and Kyle (2011). In the model, this moment is the steady-state  $\frac{Y^s}{Y}$  in the interest rate control regime.

- (2) The real deposit rate with one-year maturity. This series is annual nominal deposit rate adjusted by the CPI. The series is from 1996 to 2013 and downloaded from WDI database. The average value is about 0.9%.
- (3) The aggregate savings rate. We use the gross domestic savings (% GDP) in WDI database. We calculate the average rate for the sample from 1998 to 2013, which is 0.45.<sup>15</sup> The counterpart in the model is defined as the steady-state  $1 - \frac{C}{Y}$  in the interest rate control regime.
- (4) The short-term loan to GDP ratio. This series is annual from 2002 to 2013 downloaded from CEIC database. The average value is about 0.5. The model implied ratio is defined as the steady-state  $[\theta^s (1 - \mathbf{F}^s(\bar{\varepsilon}^s)) H^s + \theta^p (1 - \mathbf{F}^p(\bar{\varepsilon}^p)) H^p] / Y$  in the interest rate control regime.
- (5) The TFP gap between SOE sector and POE sector. Brandt et al (2008) estimates an average gap of 1.8 during 1998-2004, while Hsieh and Kelnow (2009) estimate a average gap of 1.42. In our calibration, we set the target to 1.6 which is the middle. The model-implied TFP gap is defined as  $\frac{Y^p / (K^p)^\alpha / (N^p)^{1-\alpha}}{Y^s / (K^s)^\alpha / (N^s)^{1-\alpha}}$ .

### APPENDIX C. FULL DYNAMIC SYSTEM

This appendix summarizes the full dynamic system.

1. Aggregate output  $Y_t$  :

$$Y_t = \sum_{j=\{s,p\}} Y_t^j, \quad (\text{C.1})$$

where the sectoral output  $Y_t^j$  satisfies

$$Y_t^j = \left( \tilde{K}_t^j \right)^\alpha \left( N_t^j \right)^{1-\alpha}. \quad (\text{C.2})$$

and  $\tilde{K}_t^j$  is the effective capital

$$\tilde{K}_t^j = \int z^j \varepsilon_{t-1}^j k_t^j (H_t^j, \varepsilon_{t-1}^j) d\mathbf{F}^j(\varepsilon_{t-1}^j) = \left[ \int_{\varepsilon_{t-1}^j}^{\infty} \varepsilon_{t-1}^j d\mathbf{F}^j(\varepsilon_{t-1}^j) + \theta^j \int_{\tilde{\varepsilon}_{t-1}^j}^{\infty} \varepsilon_{t-1}^j d\mathbf{F}^j(\varepsilon_{t-1}^j) \right] z^j H_{t-1}^j, \quad (\text{C.3})$$

<sup>15</sup>As China's access to WTO is at 2002, we choose the sample periods starting from 2003. The average value does not change too much if the periods prior to 2003 is included.

and aggregate labor is fixed,

$$N_t = \sum_{j=\{s,p\}} N_t^j = 1, \quad (\text{C.4})$$

The sectoral labor demand is

$$N_t^j = \tau^j \left( \frac{1-\alpha}{W_t} \right)^{\frac{1}{\alpha}} \tilde{K}_t^j. \quad (\text{C.5})$$

2. Aggregate capital  $K_t$  :

$$K_t \equiv \sum_{j=\{s,p\}} K_t^j. \quad (\text{C.6})$$

3. Sectoral capitals  $K_t^j$  :

$$K_t^j = \left[ \int_{\underline{\varepsilon}_{t-1}^j}^{\infty} d\mathbf{F}^j(\varepsilon_{t-1}^j) + \theta^j \int_{\bar{\varepsilon}_{t-1}^j}^{\infty} d\mathbf{F}^j(\varepsilon_{t-1}^j) \right] H_{t-1}^j, \quad j \in \{s,p\}. \quad (\text{C.7})$$

4. Resource constraint:

$$C_t + K_{t+1} - (1-\delta)K_t = Y_t. \quad (\text{C.8})$$

5. Credit market equilibrium:

$$K_t = \sum_{j=\{s,p\}} H_{t-1}^j. \quad (\text{C.9})$$

6. Rate of return to effective capital

$$R_t = \alpha \left( \frac{1-\alpha}{W_t} \right)^{\frac{1-\alpha}{\alpha}}. \quad (\text{C.10})$$

7. Cut-offs  $\{\underline{\varepsilon}_t^j, \bar{\varepsilon}_t^j\}$ ,  $j \in \{s,p\}$ ,

$$\underline{\varepsilon}_t^j = \frac{r_{dt} + \delta}{\tau^j z^j R_{t+1}}, \quad (\text{C.11})$$

$$\bar{\varepsilon}_t^j = \frac{r_{lt} + \delta}{\tau^j z^j R_{t+1}}, \quad (\text{C.12})$$

8. Interest rate gap:

$$r_{lt} = r_{dt} + \phi. \quad (\text{C.13})$$

9. Aggregate TFP  $A_t$

$$A_t = \frac{Y_t}{K_t^\alpha N_t^{1-\alpha}}. \quad (\text{C.14})$$

10. Sectoral TFP  $A_t^j$ ,  $j \in \{s,p\}$ ,

$$A_t^j = \frac{Y_t^j}{(K_t^j)^\alpha (N_t^j)^{1-\alpha}} = \left[ \frac{z^j \int_{\underline{\varepsilon}_{t-1}^j}^{\infty} \varepsilon_{t-1}^j d\mathbf{F}^j(\varepsilon_{t-1}^j) + \theta^j \int_{\bar{\varepsilon}_{t-1}^j}^{\infty} \varepsilon_{t-1}^j d\mathbf{F}^j(\varepsilon_{t-1}^j)}{\int_{\underline{\varepsilon}_{t-1}^j}^{\infty} d\mathbf{F}^j(\varepsilon_{t-1}^j) + \theta^j \int_{\bar{\varepsilon}_{t-1}^j}^{\infty} d\mathbf{F}^j(\varepsilon_{t-1}^j)} \right]^\alpha. \quad (\text{C.15})$$

11. Aggregate consumption  $C_t$  :

$$C_t + K_{t+1} - (1-\delta)K_t = Y_t. \quad (\text{C.16})$$

12. Sectoral aggregate net worth  $H_t^j$  :

$$H_t^j = (1 - \delta_e) \left[ \tau^j R_t \tilde{K}_t^j + (1 - \delta) K_t^j - (1 + r_{d,t-1} + \phi) L_t^j + (1 + r_{d,t-1}) S_t^j \right] + \delta_e h_{0t}^j. \quad (\text{C.17})$$

13. Sectoral aggregate loans  $L_t^j$  :

$$L_t^j = \theta^j \int_{\underline{\varepsilon}_{t-1}^j}^{\infty} d\mathbf{F}^j(\varepsilon_{t-1}^j) H_{t-1}^j. \quad (\text{C.18})$$

14. Sectoral aggregate saving

$$S_t = \int_{\varepsilon_{\min}}^{\underline{\varepsilon}_{t-1}^j} d\mathbf{F}^j(\varepsilon_{t-1}^j) H_{t-1}^j. \quad (\text{C.19})$$

#### APPENDIX D. STEPS FOR SOLVING THE STEADY STATE

This appendix presents the procedure for solving the steady state. From definitions of cutoffs  $\{\underline{\varepsilon}^j, \bar{\varepsilon}^j\}$ , we can solve  $\underline{\varepsilon}^j$  and  $\bar{\varepsilon}^j$  as functions of  $r_d$  and  $R$ . Assume that  $\mathbf{F}^j(\varepsilon^j)$  follows Pareto CDF. From (C.3), (C.7) and (C.18), we can solve ratios  $\frac{\tilde{K}^j}{H^j}$ ,  $\frac{K^j}{H^j}$  and  $\frac{L^j}{H^j}$  as

$$\frac{\tilde{K}^j}{H^j} = z^j \left[ \int_{\underline{\varepsilon}^j}^{\infty} \varepsilon^j d\mathbf{F}^j(\varepsilon^j) + \theta^j \int_{\underline{\varepsilon}^j}^{\infty} \varepsilon^j d\mathbf{F}^j(\varepsilon^j) \right], \quad (\text{D.1})$$

$$\frac{K^j}{H^j} = \int_{\underline{\varepsilon}^j}^{\infty} d\mathbf{F}^j(\varepsilon^j) + \theta^j \int_{\underline{\varepsilon}^j}^{\infty} d\mathbf{F}^j(\varepsilon^j), \quad (\text{D.2})$$

$$\frac{L^j}{H^j} = \theta^j \int_{\underline{\varepsilon}^j}^{\infty} d\mathbf{F}^j(\varepsilon^j), \quad (\text{D.3})$$

$$\frac{S^j}{H^j} = \int_{\varepsilon_{\min}}^{\underline{\varepsilon}^j} d\mathbf{F}^j(\varepsilon^j), \text{ for } j \in \{s, p\}. \quad (\text{D.4})$$

(C.17) provides an equation to solve  $H^j$  as a function of  $r_d$  and  $R$

$$1 = (1 - \delta_e) \left[ \tau^j R \frac{\tilde{K}^j}{H^j} + (1 - \delta) \frac{K^j}{H^j} - (1 + r_d + \phi) \frac{L^j}{H^j} + (1 + r_d) \frac{S^j}{H^j} \right] + \delta_e \frac{h_0^j}{H^j}. \quad (\text{D.5})$$

Then  $\{\tilde{K}^j, K^j, L^j\}$  can be easily expressed as functions of  $r_d$  and  $R$ . Aggregate variables  $\{K, \tilde{K}\}$  are easy to obtain. Given the fixed labor supply  $N = 1$ , we can compute the equilibrium wage from labor demand function

$$N = \left( \frac{1 - \alpha}{W} \right)^{\frac{1}{\alpha}} \sum_{j \in \{s, p\}} \tau^j \tilde{K}^j = 1. \quad (\text{D.6})$$

And the sectoral labors are given by

$$N^j = \frac{\tau^j \tilde{K}^j}{\tau^s \tilde{K}^s + \tau^p \tilde{K}^p}. \quad (\text{D.7})$$

Then it is easy to compute the sectoral output  $Y^j = \left(\tilde{K}^j\right)^\alpha (N^j)^{1-\alpha}$  and aggregate output  $Y = \sum_{j \in \{s,p\}} Y^j$ . Aggregate consumption can be solved from the resource constraint (C.16). Recall that we still need two equations to pin down  $r_s$  and  $R$ , which are capital market equilibrium (C.9) and the definition of  $R$ , (C.10).



TABLE 1. Aggregate Moments: Model v.s. Data

	Model	Data
Output share of SOEs	0.4	0.4
Real deposit rate	0.009	0.009
Saving rate	0.41	0.43
Ratio of short-term loans to GDP	0.5	0.5
TFP gap between POEs and SOEs	1.60	1.60

TABLE 2. Calibrated Parameter Values

		SOEs	POEs
$\beta$	discounting factor	0.96	
$\alpha$	capital share	0.5	
$\delta$	capital depreciation rate	0.1	
$\delta_e$	firm exit rate	0.06	
$\phi$	interest rate gap	0.04	
$\theta^j$	borrowing constraint	0.490	0.163
$\sigma^j$	standard deviation of $\varepsilon^j$	0.217	0.217
$\mu^j$	mean of $\varepsilon^j$	1	1
$z^j$	sector-specific TFP	0.021	0.055
$\tau^j$	subsidies	2.56	1
$h_0^j$	endowment of new firms	0.10	0.06

## China deposit and lending rates

1995-present

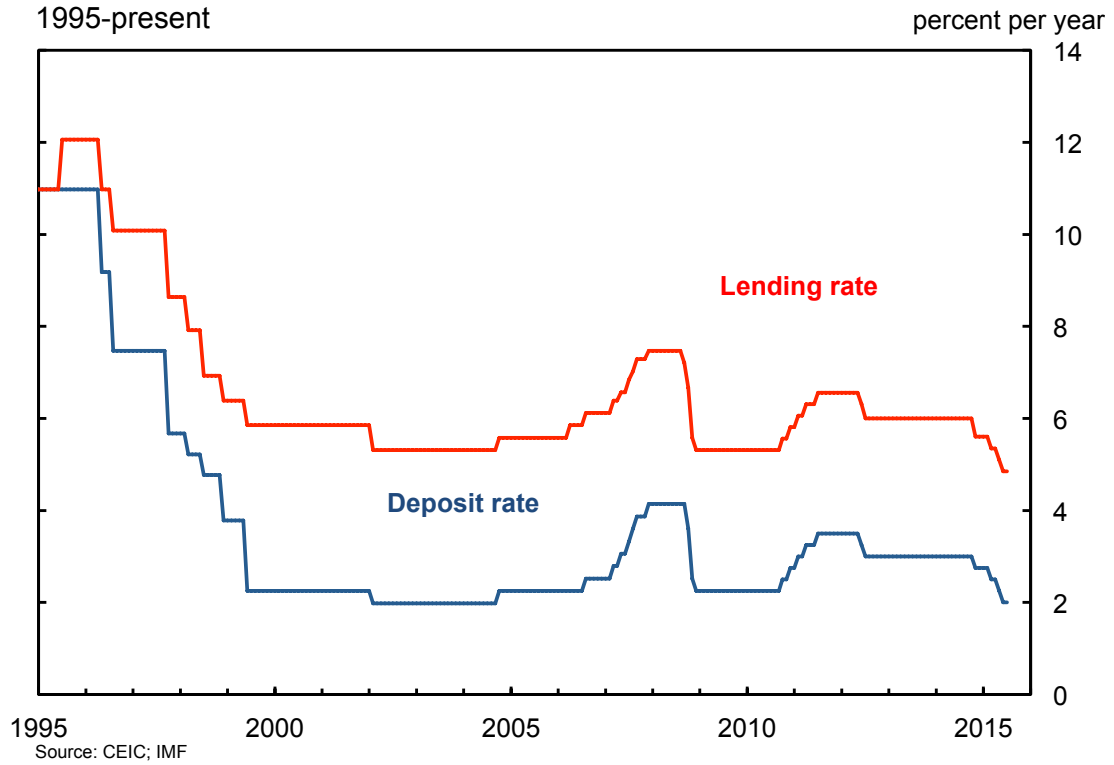


FIGURE 1. Time series of China's deposit and loan interest rates.

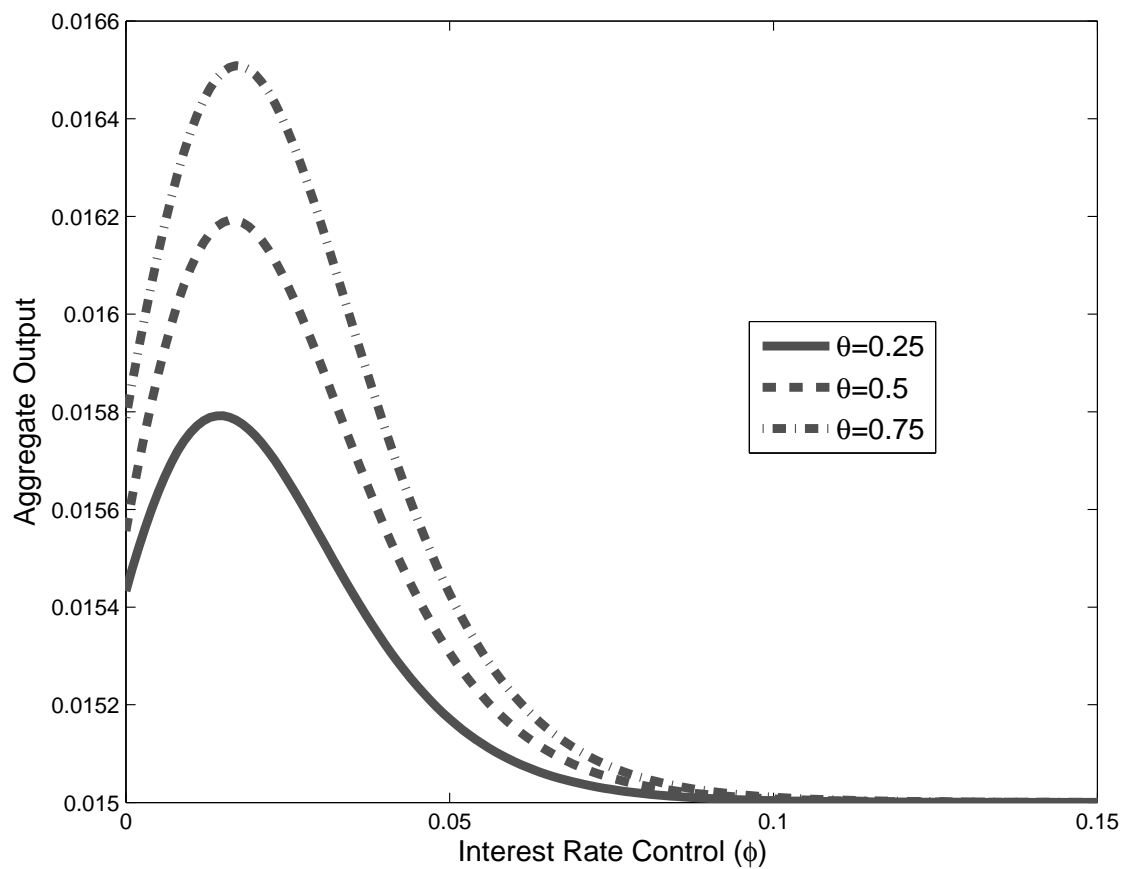


FIGURE 2. Financial frictions and aggregate output in the static model. The horizontal axis is the interest rate wedge ( $\phi$ ). Each line in the figure represents the relation of aggregate output with  $\phi$  for a particular value of  $\theta$  that determines the borrowing capacity of private firms.

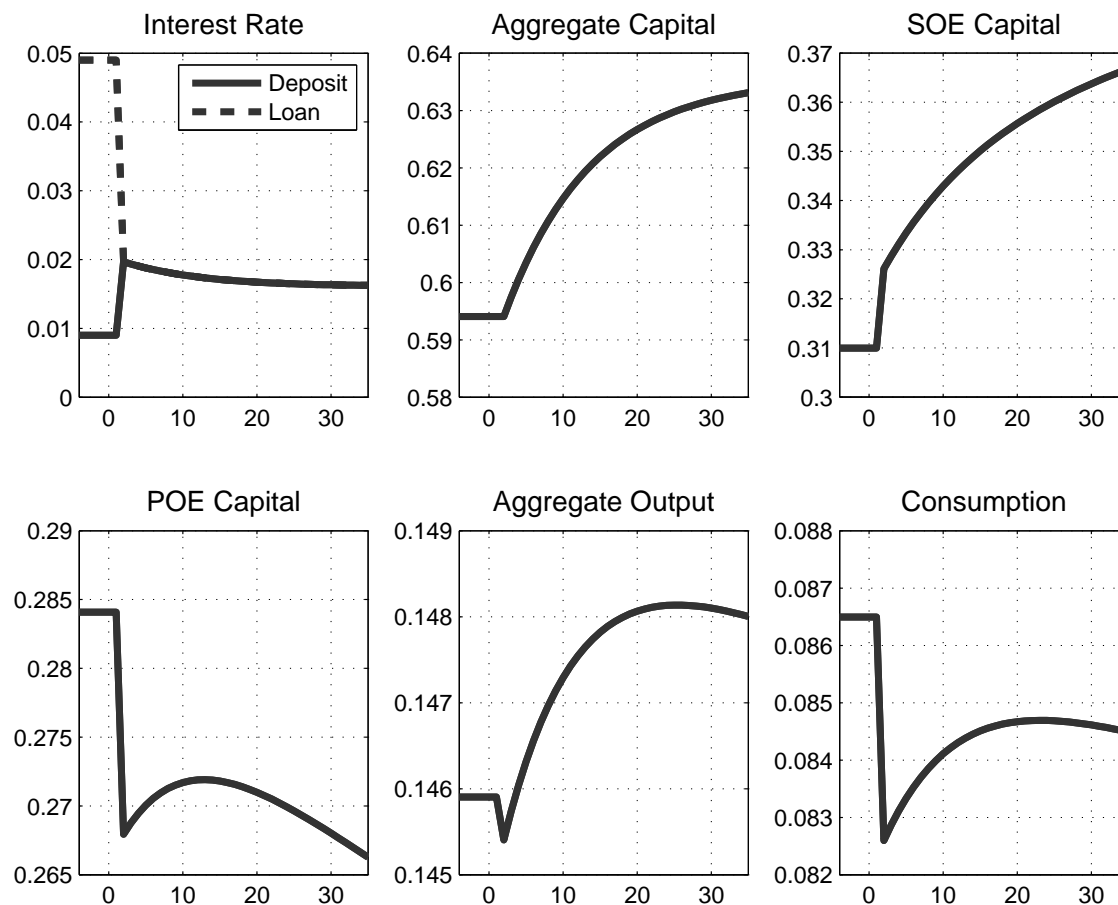


FIGURE 3. Transition dynamics of some key aggregate variables following an interest-rate liberalization in the benchmark model.

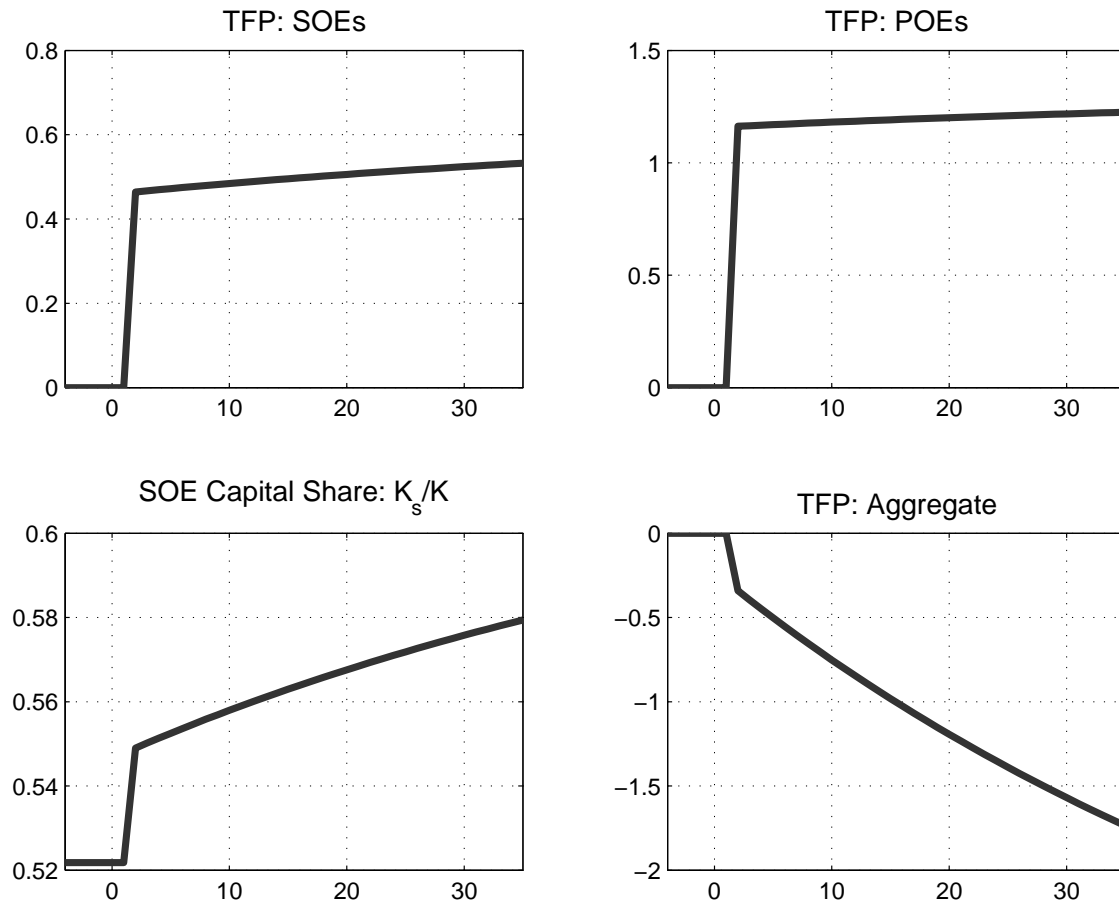


FIGURE 4. Transition dynamics of TFP (percentage change) and the share of capital held by SOEs following an interest-rate liberalization in the benchmark model.

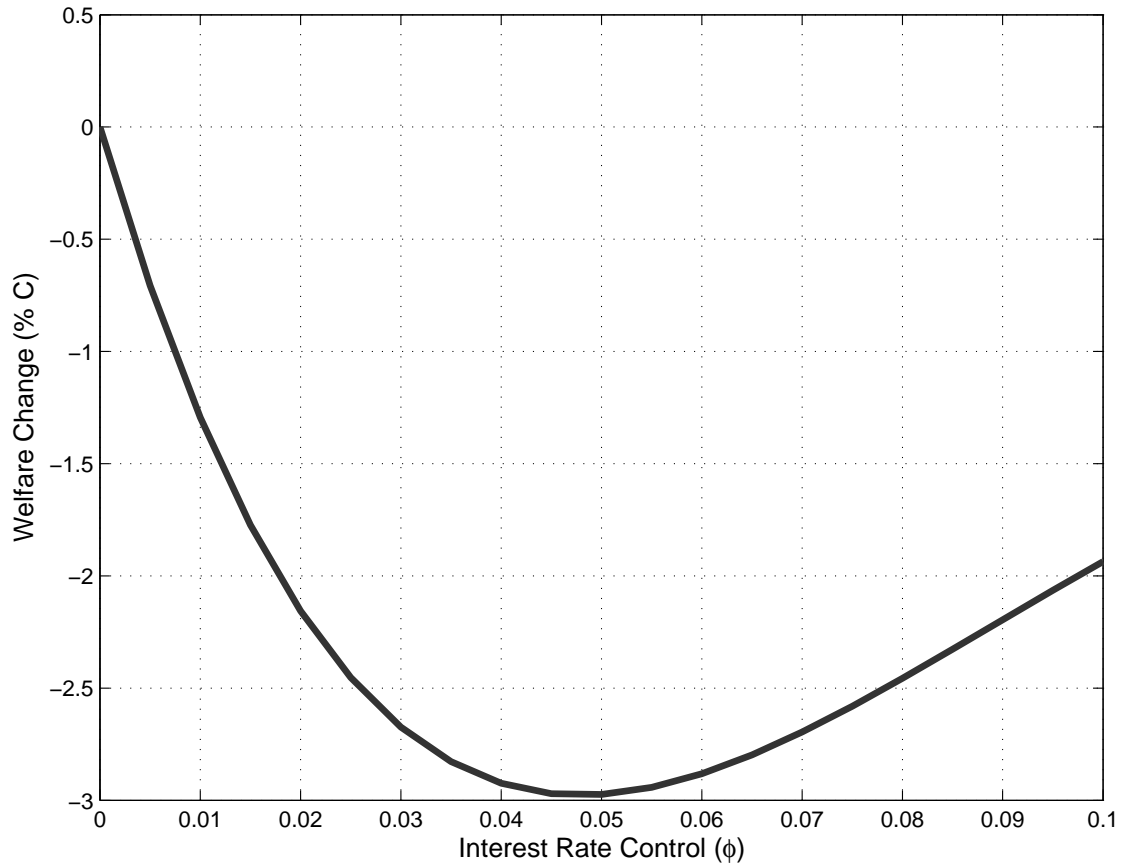


FIGURE 5. Welfare effects of interest-rate liberalization during the transition process. Welfare is measured by consumption equivalence. A point on the line represents the welfare loss when the initial interest-rate wedge ( $\phi$ ) is removed.

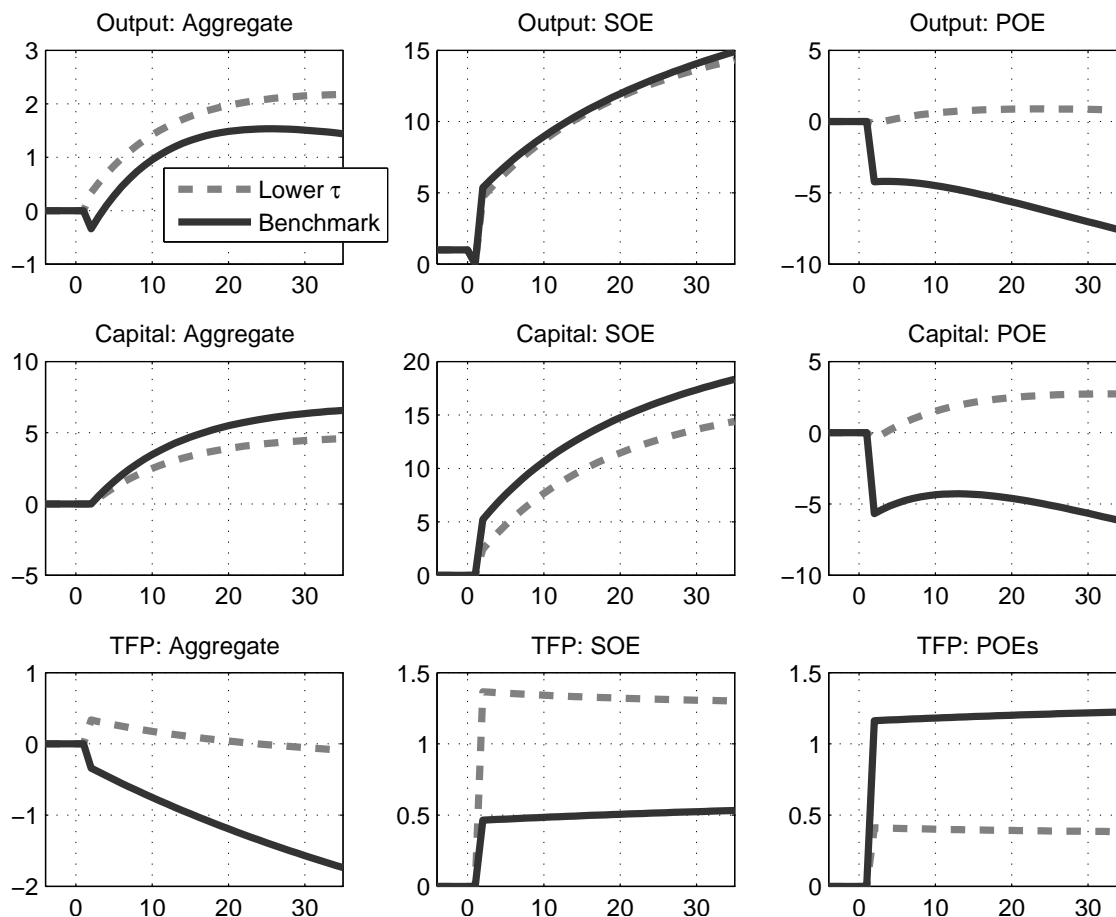


FIGURE 6. Transition dynamics following interest-rate liberalization in the counterfactual model with lower SOE distortions (i.e., lower  $\tau$ ).

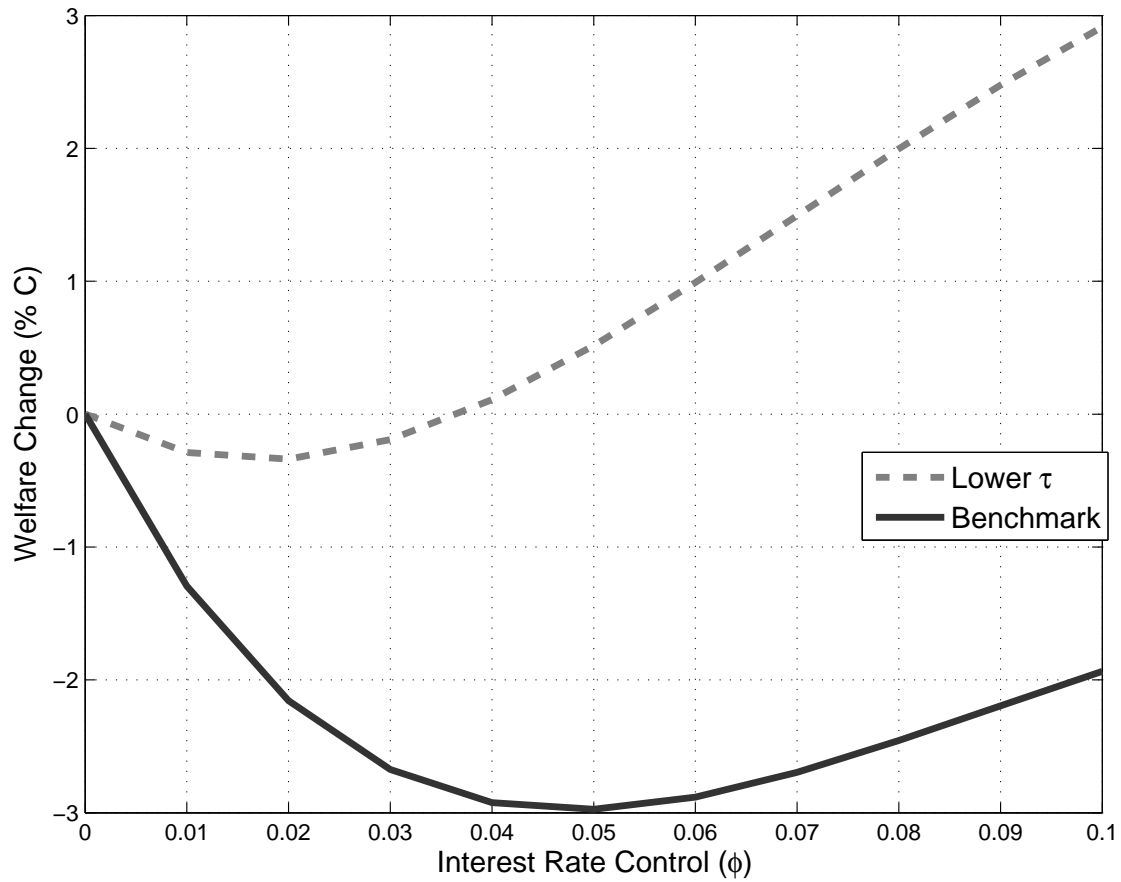


FIGURE 7. Welfare along the transition path of interest-rate liberalization in a counterfactual with low SOE distortions ( $\tau$ ). A point on the line represents the welfare loss when the initial interest-rate wedge ( $\phi$ ) is removed.



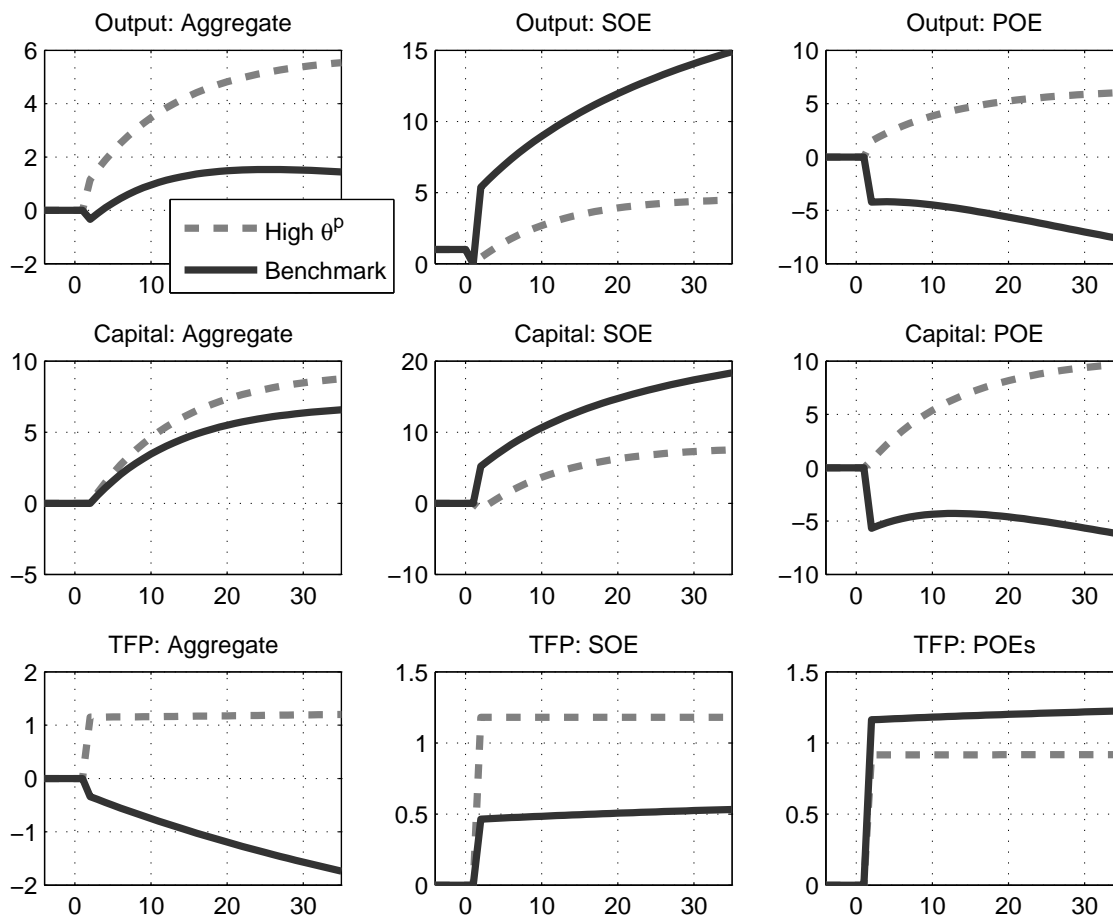


FIGURE 8. Transition dynamics following interest-rate liberalization in the counterfactual model with POEs having equal access to credit as SOEs (i.e.,  $\theta^p = \theta^s$ ).

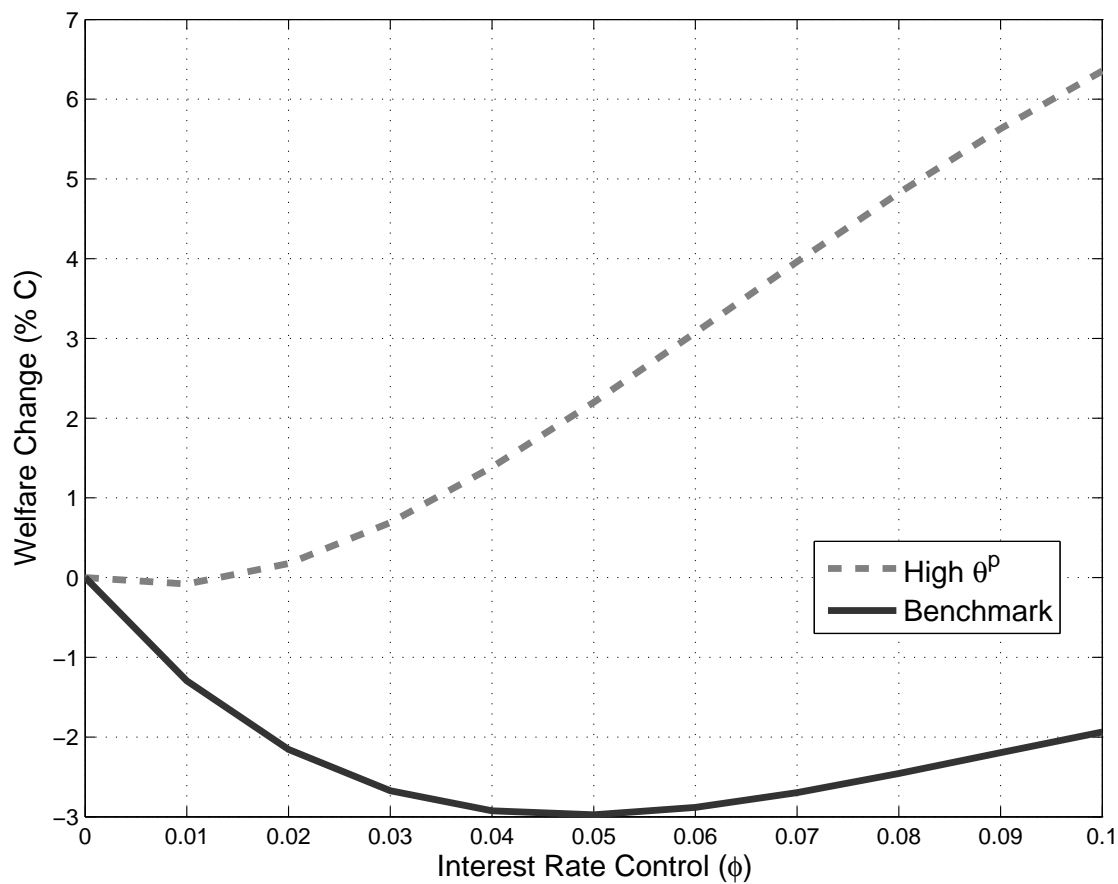


FIGURE 9. Welfare along the transition path of interest-rate liberalization in a counterfactual with POEs gaining equal access to credit as SOEs. A point on the line represents the welfare loss when the initial interest-rate wedge ( $\phi$ ) is removed.

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