ONLINE APPENDIX: OPTIMAL CAPITAL ACCOUNT LIBERALIZATION IN CHINA

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Abstract. In this appendix (not for publication), we examine the robustness of the benchmark model in Liu et al. (2020) to alternative parameter calibrations and an alternative approach to modeling financial repression (with bailout guarantees on directed loans to SOEs).

Date: May 28, 2020.

Key words and phrases. Capital controls, financial repression, China, sequencing of reforms, welfare.

JEL classification: F38, G18, O41

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I. Elasticity of substitution between SOE and POE products

In the benchmark model, we assume that final goods are a constant elasticity of substitution (CES) aggregate of intermediate goods produced by the SOEs and POEs, with the elasticity of substitution calibrated to $\sigma_m = 3$ based on the empirical estimates of Chang et al. (2016). We have also shown, through analytical solutions, that the results are qualitatively the same if the elasticity parameter is $\sigma_m = 1$ (corresponding to Cobb-Douglas aggregation). In the literature, however, some authors have considered much larger elasticities [e.g., Song et al. (2011) and Liu et al. (2020) assume perfect substitution between SOE and POE products]. To examine the robustness of our results to larger values of the elasticity parameter, we consider an alternative calibration with a larger value of the elasticity. In particular, we consider $\sigma_m = 10$, while keeping the other parameters at their calibrated values.

Figure 1 displays the steady-state relations between a few macro variables and the capital outflow tax rate τ_d. As in the benchmark model, a reduction in τ_d leads to an increase in capital outflows. No arbitrage implies that the domestic deposit interest rate rises to the level of the after-tax returns on foreign assets. The increased asset returns alleviate the distortion on the householdsâĂŹ consumption-savings decisions. However, since the bank passes through increases in the deposit rate to the domestic loan rate, the POEs face higher funding costs, leading to reallocation toward SOEs and reducing aggregate TFP. The tradeoff between productive efficiency and intertemporal efficiency results in an interior optimum, as in the benchmark model.

Figure 2 displays the steady-state relationship between the capital inflow tax rate (τ_l) and several macroeconomic variables. Liberalizing inflow controls induces capital inflows, reducing the domestic market lending rate and benefiting POEs more than SOEs. This would reallocate resources toward productive POEs, raising aggregate productivity. Under directed lending, banks must reduce deposit interest rates to remain solvent, exacerbating the distortion on the households' intertemporal consumption-savings decision. Again, as in the benchmark model, the tradeoff between productive efficiency and intertemporal efficiency leads to an interior optimum of capital inflow controls at the given level of financial repression.

Figure 3 shows that more severe financial repression raises optimal restrictions on both capital inflows and outflows. An increase in γ requires an increase in the market lending rate to keep banks solvent. This is partially achieved through an increase in inflow taxes (τ_l). The increased market lending rates reallocate activity towards the less productive SOE sector, lowering TFP. The planner therefore also

TABLE 1. Liberalization of capital account following a decline in SOE share

	Benchmark	Inflow only	Outflow only	Full liberalization
Case	0	1	2	3
τ_d	15.84%	15.84%	-1.08%	-0.72%
α_d	-	-	51.49%	48.72%
τ_l	6.47%	-6.20%	6.47%	4.26%
α_l	-	16.69%	-	90.48%
γ	50.00%	0.00%	0.00%	0.00%
α_γ	-	99.99%	100.00%	100.00%
Welfare gains	0.00%	0.15%	1.91%	1.94%

Note: Welfare gains are expressed in terms of consumption equivalent per period. Case 0 is the baseline where all policy parameters are kept constant at its initial steady state level. In Case 1, the planner chooses the capital inflow parameters (τ_{l1} and α_l) and the financial repression parameters (γ_1 and α_γ) to maximize the transition welfare, holding the capital outflow parameters (τ_{d1} and α_d) constant. In Case 2, the planner keeps the inflow control parameters at their initial steady state levels and chooses the outflow control parameters and the financial repression parameters to maximize the transition welfare. In Case 3, the planner implements a full reform by choosing all policy parameters to maximize the transition welfare.

raises the capital outflow tax (τ_d) to partly undo this misallocation effect, because more restrictive capital outflow controls help retain domestic household deposits and contain domestic lending rates. However, the increase in the market interest rate also increases borrowing from abroad, raising the risk premium and the over-borrowing externality. The planner partly addresses this source of inefficiency by also raising the capital inflow tax rate τ_l. These results are also very similar to the benchmark model.

Table 1 shows the configurations of optimal liberalization policies along the transition paths toward a new steady state with a smaller share of the SOE sector for the economy with a large elasticity parameter ($\sigma_m = 10$). The results are qualitatively the same as in our benchmark model. Specifically, optimal policy calls for immediately removal of directed lending but gradual liberalization of capital controls.

II. The model with SOE bailout guarantees

We focus on describing the intermediate goods sector and the banking sector. The remaining components of the model are the same as in the benchmark model.

II.1. **The intermediate goods sectors.** Intermediate goods are produced in both the SOE sector and the POE sector. We focus on describing the optimizing decisions of a representative firm in each sector $j \in \{s, p\}$, where s denotes the SOE sector and p denotes the POE sector.

A firm in sector j produces a homogeneous intermediate good Y_{jt} using capital K_{jt} and labor H_{jt} as inputs, with the production function

$$Y_{jt} = A_j \omega_{jt} (K_{jt})^{1-\alpha} (H_{jt})^{\alpha}, \tag{1}$$

where A_j denotes a sector-specific productivity facing all firms in sector j, and the parameter $\alpha \in (0, 1)$ is the labor input elasticity in the production function. The term ω_{jt} is an idiosyncratic productivity shock that is i.i.d. across firms and time, and is drawn from the distribution $F(\cdot)$ with a nonnegative support. We assume that the idiosyncratic productivity shocks are drawn from a Pareto distribution with the cumulative density function $F(\omega) = 1 - (\frac{\omega_m}{\omega})^k$ over the range $[\omega_m, \infty)$, where $\omega_m > 0$ is the scale parameter and k is the shape parameter.

Firms face working capital constraints. Before production takes place, a firm needs to pay wages and capital rents with working capital loans B_{jt} obtained from banks. The firm repays the loans at the end of the period when production is completed. The working capital constraint for a firm in sector $j \in \{s, p\}$ is given by

$$B_{jt} = w_t H_{jt} + r_t^k K_{jt}. \tag{2}$$

We assume that all firms face perfect competition in both input and product markets. A firm's cost-minimizing decisions in sector j imply the production factor demand functions

$$w_t H_{jt} = \alpha B_{jt}, \tag{3}$$

and

$$r_t^k K_{jt} = (1 - \alpha) B_{jt}. \tag{4}$$

Denote $\tilde{A}_{jt} \equiv \frac{p_{jt} Y_{jt}}{B_{jt}}$ as the rate of return on the firm's investment financed by bank loans, which, under cost-minimizing decisions, is given by

$$\tilde{A}_{jt} = p_{jt} A_j \left(\frac{1 - \alpha}{r_t^k} \right)^{1-\alpha} \left(\frac{\alpha}{w_t} \right)^{\alpha}. \tag{5}$$

II.2. **Banks.** There is a continuum of competitive banks. The representative bank takes deposits D_t from households at the deposit interest rate R_t and lends to firms in the SOE and POE sectors, with the amount B_{st}^d and B_{pt}^d, respectively. The flow of funds constraint of the bank is then given by,

$$D_t \geq B_{st}^d + B_{pt}^d. \tag{6}$$

To capture financial repression in China, we assume that the government provides guarantees on a fraction γ of total bank loans but requires these loans to be lent to the SOEs. This directed lending policy implies that,

$$B_{gt} \geq \min[\gamma(B_{st}^d + B_{pt}^d), B_{st}^d], \tag{7}$$

where B_{gt} denotes the amount of the directed loans, and the bank does not face default risk on these loans. (7) requires that the amount of the directed loans must not exceed the amount of the SOE loans.

Assume that the bank charges a gross loan interest rate Z_{jt} $(j = s, p)$ to firms in sector j. Under this financial arrangement, firms with sufficiently low levels of realized productivity will not be able to make repayments. There is therefore a cut-off level of productivity $\bar{\omega}_{jt}$ such that firms with $\omega_{jt} < \bar{\omega}_{jt}$ choose to default, where $\bar{\omega}_{jt}$ satisfies

$$\bar{\omega}_{jt} \equiv \frac{Z_{jt}}{\tilde{A}_{jt}}, \tag{8}$$

where the term $\tilde{A}_{jt}$ denotes the rate of return on the firm's investment financed by bank loans, given by (5).

If an POE defaults, the bank takes over and obtains the residual revenues. The expected income for the bank in case of POE lending is given by,

$$\begin{aligned} & [1 - F(\overline{\omega}_{pt})]Z_{pt}B_{pt}^d + \int_0^{\overline{\omega}_{pt}} \omega \tilde{A}_{pt} B_{pt}^d dF(\omega) \\ = \; & \tilde{A}_{pt} B_{pt}^d \{[1 - F(\overline{\omega}_{pt})]\bar{\omega}_{pt} + \int_0^{\overline{\omega}_t} \omega dF(\omega)\} \\ \equiv \; & \tilde{A}_{pt} B_{pt}^d g_{pt}(\overline{\omega}_{pt}), \end{aligned} \tag{9}$$

where $g_p(\overline{\omega}_{pt})$ is the share of production revenues going to the bank in the case of POE lending.

When an SOE defaults, the bank still takes over and obtains the residual revenues. Meanwhile, the government covers a fraction $\frac{B_{gt}}{B^d_{st}}$ of the SOE loan losses.[1] The expected income for the bank in the case of SOE lending is then given by,

$$
\begin{aligned}
& [1-F(\overline{\omega}_{st})]Z_{st}B^d_{st} + \int_0^{\overline{\omega}_{st}} \{\omega \tilde{A}_{st}B^d_{st} + \frac{B_{gt}}{B^d_{st}}(Z_{st}B^d_{st} - \tilde{A}_{st}\omega B^d_{st})\} dF(\omega) \\
= \;& \tilde{A}_{st}B^d_{st}\{[1-(1-\frac{B_{gt}}{B^d_{st}})F(\overline{\omega}_{st})]\bar{\omega}_{st} + (1-\frac{B_{gt}}{B^d_{st}})\int_0^{\overline{\omega}_t} \omega dF(\omega)\} \\
\equiv \;& \tilde{A}_{st}B^d_{st}g_{st}(\overline{\omega}_{jt}),
\end{aligned}
\tag{10}
$$

where $g_s(\overline{\omega}_{st})$ is the share of production revenues going to the bank in the case of SOE lending.

Denote R_{lt} as the risk adjusted rate of return that the bank requires on its loans. The bank's participation constraint is then given by,

$$g_j(\overline{\omega}_{jt})\tilde{A}_{jt}B^d_{jt} \geq R_{lt}B^d_{jt}. \tag{11}$$

The government finances its spending on SOE bailout costs through taxes on domestic banking activities. Since banks are risk neutral and there is free entry, the representative bank earns zero profits in equilibrium, which implies,

$$(R_{lt} - R_t)D_t = B_{gt}\tilde{A}_{st}\int_0^{\overline{\omega}_{st}} (\overline{\omega}_{st} - \omega) dF(\omega). \tag{12}$$

The above zero-profit condition suggests that the bank must charge an interest rate R_{lt} on market lending that exceeds the deposit interest rate R_t to pay for the taxes used to finance SOE bailout costs. As a result, financial repression drives a wedge between the loan rate and the deposit rate.

We assume that, at the beginning each period, individual firms obtains start-up funds from their shareholders (the household) to pay a fixed cost that is proportional to the aggregate production cost of all firms in sector j.[2] Perfect competition among

[1]Here we assume that an SOE is entitled to $\frac{B_{gt}}{B^d_{st}}$ amount of directed loans for each unit of funds it borrows from domestic banks. In other words, the ratio of SOE loans guaranteed by the government is equal across all SOEs.

[2]This fixed cost is taken as given by individual firms when making production decisions. Without this fixed cost, firms' zero profit condition requires that $f(\overline{\omega}_{jt}) = 0$, which implies that all firms must default ($\overline{\omega}_{jt} = +\infty$). In the standard BGG framework, a credit spread (or external financing premium) arises from costly state verifications ($f(\overline{\omega}_{jt}) > 0$). The existence of fixed costs in our model is a simpler approach to ensure a positive external financing premium, and it does not drive our main results.

firms implies the profit net of fixed cost is zero for all individual firms, so that,

$$f(\overline{\omega}_{jt})\tilde{A}_{jt}B_{jt} - \theta(w_t H_{jt} + r_t^k K_{jt}) = 0. \tag{13}$$

where θ denotes the ratio of the fixed cost to the aggregate production cost of all firms in sector j. $f(\overline{\omega}_{jt})$ denotes the share of the production revenues going to the type-j firm under the loan contract featured by $\bar{\omega}_{jt}$ and B_{jt}^d. In particular, the expected income for the type-j firm is given by,

$$\begin{aligned}
&\int_{\overline{\omega}_{jt}}^{\infty} \tilde{A}_{jt}\omega_{jt}B_{jt}^d dF(\omega) - (1 - F(\overline{\omega}_{jt}))Z_{jt}B_{jt}^d \\
&= \tilde{A}_{jt}B_{jt}^d[\int_{\overline{\omega}_{jt}}^{\infty} \omega dF(\omega) - (1 - F(\overline{\omega}_{jt}))\overline{\omega}_{jt}] \\
&\equiv \tilde{A}_{jt}B_{jt}^d f(\overline{\omega}_{jt}),
\end{aligned}$$

The rest of the model (the households, the final goods sector, and the foreign sector) are the same as in the benchmark model.

II.3. **Market clearing and equilibrium.** An equilibrium consists of sequences of allocations $\{C_t^y, C_t^o, I_t, K_t^o, Y_t, K_{st}, K_{pt}, H_{st}, H_{pt}, K_t, H_t, B_{st}, B_{pt}, B_{st}^d, B_{pt}^d, B_{gt}, B_{ft}^l, NX_t\}$ and prices $\{w_t, R_t, q_t^k, r_t^k, p_{st}, p_{pt}, R_{lt}\}$ that solve the optimizing problems for the households, the firms, and the banks. In the equilibrium, the markets for the loanable funds, capital, labor, and goods all clear.

Since SOE firms enjoy government guarantees on directed loans from domestic banks, they do not borrow from foreign investors. Meanwhile, POEs are indifferent between domestic lending and foreign lending. The loan market clearing condition is given by,

$$B_{st} = B_{st}^d, \quad B_{pt} = B_{pt}^d + B_{ft}^l. \tag{14}$$

Capital and labor are both perfectly mobile across sectors. Labor and capital market clearing implies that

$$H_t = H_{st} + H_{pt}, \tag{15}$$

and

$$K_{t-1} = K_{st} + K_{pt}. \tag{16}$$

Final goods market clearing implies that the trade surplus is given by

$$NX_t = Y_t - C_t^y - C_t^o - I_t - \frac{\Omega_k}{2}\left(\frac{I_t}{K_t^o} - \frac{\bar{I}}{\bar{K^o}}\right)^2 K_t^o - \theta(w_t H_{st} + r_t^k K_{st}) - \theta(w_t H_{pt} + r_t^k K_{pt}). \tag{17}$$

In addition, by summing up all sectors' budget constraints, we obtain the balance of payments condition

$$NX_t+(R^*_{t-1}-1)B^d_{f,t-1}-\left[R^*_{t-1}\Phi\left(\frac{B^l_{f,t-1}}{Y_{t-1}}\right)-1\right]B^l_{f,t-1}=(B^d_{ft}-B^l_{ft})-(B^d_{f,t-1}-B^l_{f,t-1})+\Delta_t. \tag{18}$$

Note that the last term $\Delta_t = (R_{st}B_{st} + R_{pt}B_{pt} - R_{s,t-1}B_{s,t-1} - R_{p,t-1}B_{p,t-1})$ emerges because banks receive repayments on their working capital loans at the end of the same period, whereas they repay deposits to the households at the beginning of the next period.

II.4. **Calibration.** We calibrate our model based on values from the Chinese economy where possible. We use the same calibrated values from our benchmark model, except for the policy parameters on financial repression and capital controls. These policy parameters are recalibrated to match Chinese data. The calibrated parameters specific to the model with SOE bailouts are shown in Table 2.

We assume that the idiosyncratic productivity shocks are drawn from a Pareto distribution with the cumulative density function $F(\omega) = 1 - (\frac{\omega_m}{\omega})^k$ over the range $[\omega_m, \infty)$. We calibrate the scale parameter ω_m and the shape parameter k to match empirical estimates of cross-firm dispersions of TFP in China's data. In particular, Hsieh and Klenow (2009) estimated that the annualized standard deviation of the logarithm of TFP across firms is about 0.63 in 2005. Since ω is drawn from a Pareto distribution, the logarithm of ω (scaled by ω_m) follows an exponential distribution with a standard deviation of $1/k$. To match the empirical dispersion of TFP estimated by Hsieh and Klenow (2009), we set $k = 1/0.63/\sqrt{10}$. To keep the mean of ω at one then requires $\omega_m = \frac{k-1}{k}$. These results in $k = 5.02$ and $\omega_m = 0.80$.

The parameters θ, τ_d and τ_l are calibrated so that the interest rate spread between market loans and deposits $\frac{R_l}{R} - 1$ is around 2.5% per annum, the outflows to output ratio $\frac{B^f_d}{Y} = 0.06$, and the inflows to output ratio $\frac{B^f_l}{Y} = 0.04$.

II.5. **Capital account liberalization: Comparative statics.** We now use the calibrated model to examine the implications of alternative liberalization policies for equilibrium allocations and welfare. We highlight that the presence of government guarantee plays an important role in affecting the credit spreads faced by SOEs and POEs and therefore the resource allocation between these two types of firms.

We first take financial repression as given, and consider three alternative capital account liberalization policies: (i) a one-way liberalization of capital outflows, (ii)

Table 2. Calibrated parameters specific to the model with SOE bailout guarantees

Parameter	Description	Value
k	Shape parameter in idiosyncratic shocks	5.02
ω_m	Scale parameter in idiosyncratic shocks	0.80
θ	Relative size of fixed cost of entry	0.015
τ_d	Tax rate on foreign asset	15.82%
τ_l	Tax rate on foreign debt	5.87%

a one-way liberalization of capital inflows, and (iii) liberalizing controls over both capital outflows and inflows. We then examine the implications of joint liberalization of both financial repression and capital controls. We focus on the steady state analysis throughout this section.

II.5.1. *Liberalizing capital outflow controls.* Figure 4 shows the steady-state relation between several macro variables (the vertical axes) and the capital outflow tax rate (τ_d), holding the capital inflow tax rate (τ_l) and the financial repression parameter (γ) constant. The figure shows that a permanent decline in the outflow tax rate induces more capital outflows, raising the domestic deposit interest rate that the bank needs to pay to the households. This effect alleviates the intertemporal distortions for the household.

To cover the SOE bailout costs, the bank raises the interest rate on domestic market loans, attracting more capital inflows. The increase in market loan rates leads to an increase in the credit spread facing POEs. The credit spread facing SOEs also increases, but to a lesser extent, because SOEs borrow a fraction of their loans at the lower rate under the government's bailout guarantees. The increase in capital inflows reallocates capital and labor to POEs, improving aggregate productivity. However, the larger increase in the credit spread facing POEs raises the funding costs for POEs relative to SOEs, partially offsetting the positive effects on aggregate productivity through reallocation. Thus, the net effect on TFP is ambiguous. If the initial outflow tax rate is relatively high, then cutting the outflow taxes would reduce TFP; if the initial outflow tax rate is sufficiently low, then further reduction in outflow taxes would raise TFP. In addition, the increase in foreign capital inflows would exacerbate the over-borrowing externality.

Overall, capital outflow liberalization improves the intertemporal consumption-saving tradeoff for the household, but exacerbates the over-borrowing externality and generates ambiguous effects on aggregate productivity. Thus, the net effect of outflow liberalization on welfare is nonlinear, as shown in the figure. These results are similar to those obtained in the benchmark model.

II.5.2. *Liberalizing capital inflow controls.* Consider now the effects of liberalizing capital inflow controls by reducing the tax rate τ_l on foreign investors' earnings. Figure 5 displays the steady-state relations between the capital inflow tax rate (τ_l) and several macroeconomic variables. If the inflow tax rate is sufficiently high, then foreign investors do not enter the domestic market. Liberalizing inflow controls sufficiently raises foreign investors' after-tax returns and induces foreign inflows. These foreign inflows reduce domestic market lending rates. In response, banks can remain solvent only if they cut their deposit interest rates, exacerbating the distortion on the households' intertemporal consumption-savings decision. When the domestic deposit rate falls sufficiently, the household would start to purchase foreign assets, leading to capital outflows, which partially mitigate the intertemporal distortion.

The decline in the market lending rate disproportionately benefits the POEs because it lowers POEs' funding costs, reducing the POE default probability and thus their credit spread. However, the credit spread facing SOEs increases because capital inflows crowd out domestic bank loans, reducing the amount of directed loans available to SOEs. As a result, relative POE activity expands, improving aggregate productivity. This positive reallocation effect, however, is partly offset by the over-borrowing externality, because the risk premium on foreign debt increases.

Overall, liberalizing capital inflow controls improves aggregate productivity, but it exacerbates intertemporal misallocation and the over-borrowing externality. The net effect on welfare is thus ambiguous. As shown in Figure 5 there is an interior optimum of the level of capital inflow tax rate that maximizes the representative household's welfare.

II.5.3. *Two-way capital account liberalization.* We next examine the steady-state implications of liberalizing capital controls for both inflows and outflows (parameterized by τ_l and τ_d), taking different values of financial repression (γ) as given.

Figure 6 shows that more severe financial repression raises optimal restrictions on both capital inflows and outflows. An increase in γ leads to an increase in the bailout cost on SOE loans and requires an increase in the market lending rate to keep banks solvent. The increased market lending rates makes firms more likely to default and raises the credit spread faced by POEs. Meanwhile, SOEs face lower credit spread as a higher fraction of SOE loans are guaranteed. Therefore, the increase in γ reallocates activity towards the less productive SOE sector, lowering TFP. The planner therefore raises the capital outflow tax (τ_d) to partly undo this misallocation effect, because more restrictive capital outflow controls help retain domestic household deposits and contain domestic lending rates. However, the increase in the market interest rate also increases borrowing from abroad, raising the risk premium and the over-borrowing externality. The planner partly addresses this source of inefficiency by also raising the capital inflow tax rate τ_l, as shown in Figure 6.

Under optimal steady-state capital controls, reducing the degree of financial repression γ improves the obtainable welfare under optimal capital control policy. Lowering the share of directed lending increases aggregate TFP through reallocation across sectors. Reducing directed lending also benefits households because they receive higher returns on savings at domestic banks. In addition, the planner optimally lowers the taxes on capital inflows and outflows. Thus, reducing financial repression raises welfare.

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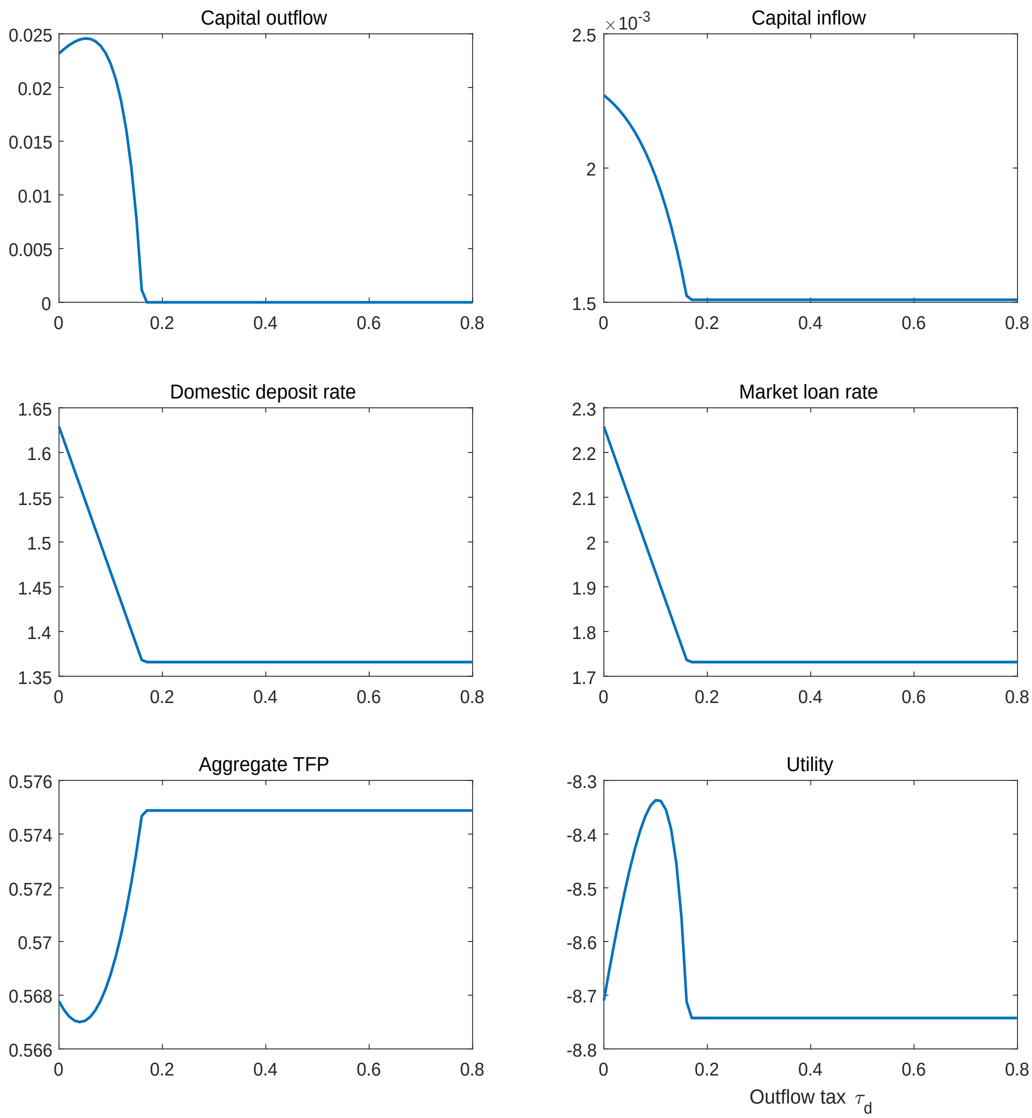

FIGURE 1. Steady-state implications of a one-way liberalization of capital outflow controls: the general case with capital inflows allowed ($\tau_l = 6.47\%$). The horizontal axis shows the range of the capital outflow tax rate τ_d.

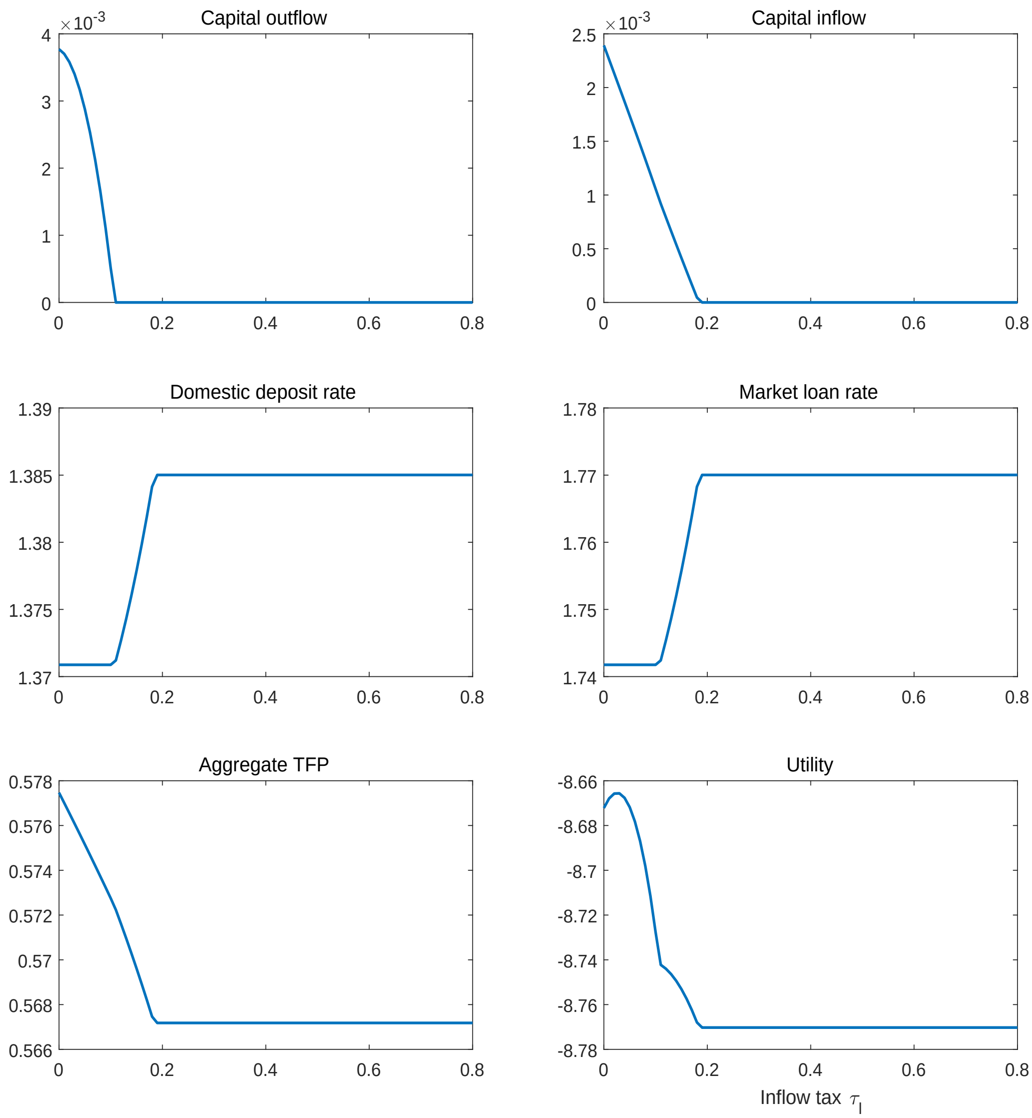

FIGURE 2. Steady-state implications of a one-way liberalization of capital inflow controls: the general case with capital outflows allowed ($\tau_d = 15.84\%$). The horizontal axis shows the range of the capital inflow tax rate τ_l.

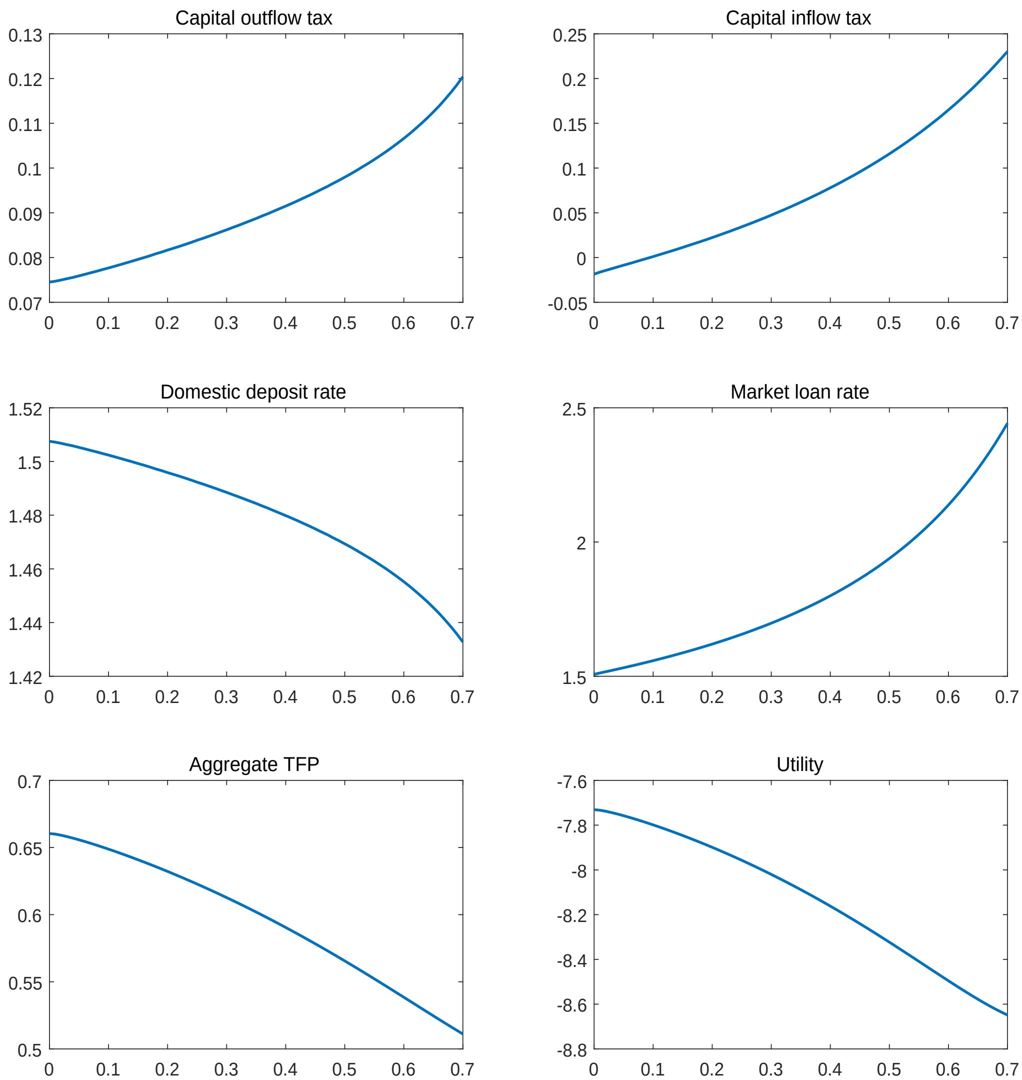

FIGURE 3. Optimal capital control policies under different degree of financial repression γ. The horizontal axis shows the range of the financial repression parameter γ.

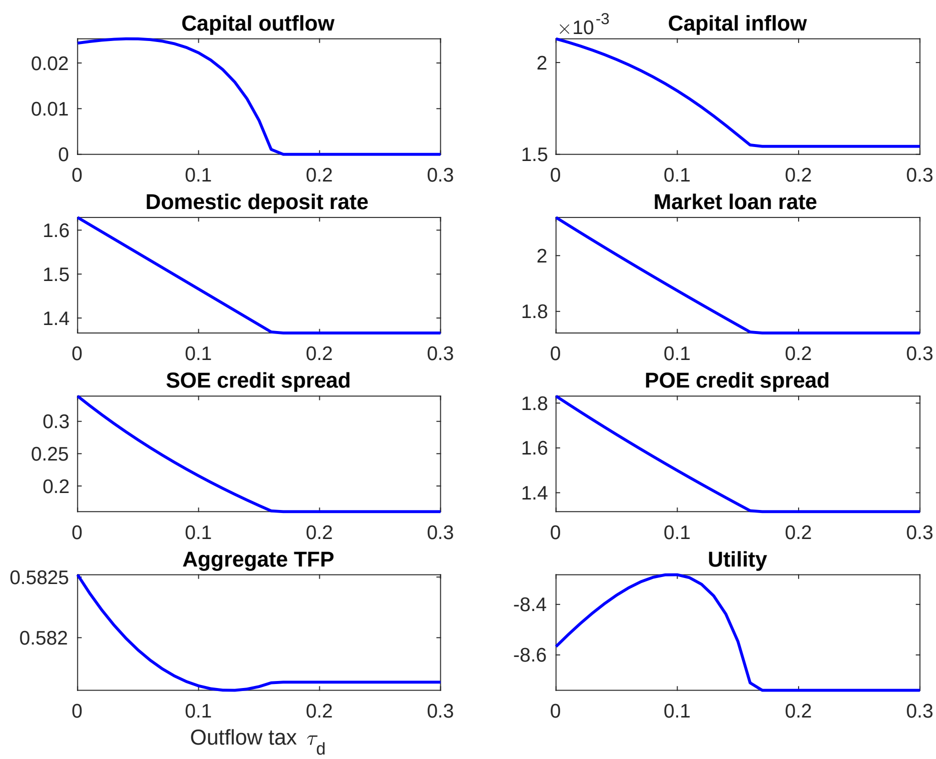

FIGURE 4. Steady-state implications of a one-way liberalization of capital outflow controls in the alternative model with SOE bailouts.

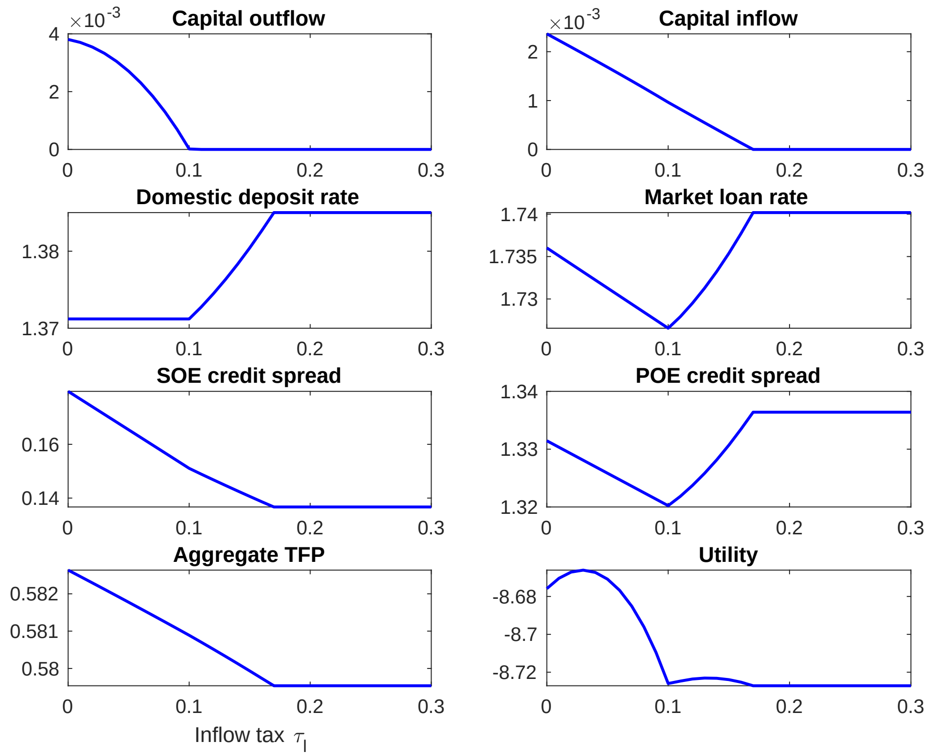

FIGURE 5. Steady-state implications of a one-way liberalization of capital inflow controls in the alternative model with SOE bailouts.

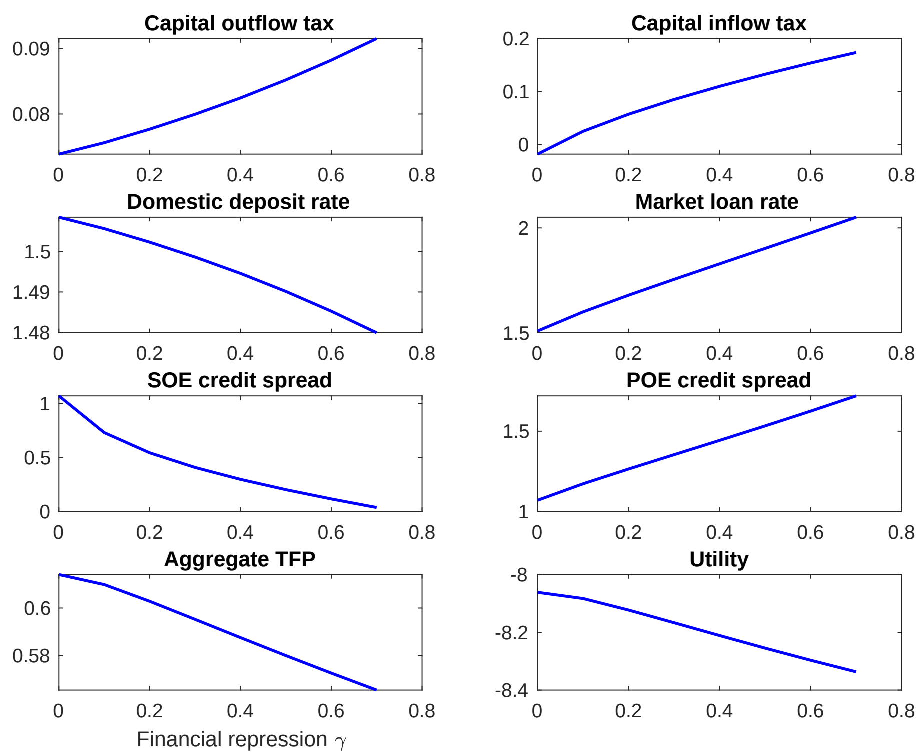

FIGURE 6. Optimal capital control policies under different degree of financial repression γ in the alternative model with SOE bailouts.