MONETARY POLICY IN A DSGE MODEL WITH "CHINESE CHARACTERISTICS"

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Abstract. We examine optimal monetary policy under prevailing Chinese policy – including capital controls and nominal exchange rate targets – in a DSGE model calibrated to Chinese and global data. Under the closed capital account, domestic citizens are prohibited from holding foreign assets. Foreign currency revenues are sold to the central bank, which then sterilizes these purchases by issuing domestic debt. Uncovered interest parity conditions do not hold, so sterilization results in transfers between the private sector and the government. Given a negative shock to relative foreign interest rates, similar to that which occurred during the global financial crisis, sterilization costs increase and optimal policy calls for a reduction in sterilization activity, resulting in an easing of monetary policy and an increase in Chinese inflation.

We then compare these dynamics to three alternative liberalizations: A partial opening of the capital account, removing the exchange rate peg, or doing both simultaneously. The regime with liberalized capital accounts and floating exchange rate yields the lowest losses to the central bank under the foreign interest rate shock. However, intermediate reforms do less well. In particular, letting the exchange rate float without opening the capital account results in higher losses following the interest rate shock than the benchmark case of no liberalization.

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I. Introduction

As China's importance in global trade has increased, so has scrutiny about its capital account and exchange rate policies. Estimates of the severity of undervaluation of the Chinese renminbi relative to the dollar have been as high as 20 to 40 percent [Goldstein and Lardy (2006)]. While the renminbi has appreciated somewhat against the dollar since its initial move to a crawling peg in 2005, further appreciation is widely expected. This expectation, combined with China's substantive current account surplus, has resulted in substantial pressure for capital flows into China.

Despite its exchange rate management, the well-known "trilemma" argument suggests that China's central bank, the People's Bank of China (PBOC), can conduct independent monetary policy to the extent that it can maintain a closed capital account.[1] Since the capital account is closed, Chinese nationals are prohibited from holding foreign assets. The PBOC intervenes to absorb foreign capital inflows. Under capital controls, Chinese exporters are prohibited from repatriating their profits in foreign currency. Instead, these exporters are required to swap their foreign-currency revenues with the central bank at market rates of exchange for either domestic currency or bonds.[2] The subset of purchases of foreign assets that are financed by selling domestic bonds are said to be "sterilized," in that they do not result in an expansion of the domestic money supply in China.

By varying the intensity of sterilization activity, the PBOC influences monetary conditions. The intensity of sterilization activity appears to have varied widely over time. For example, Goodfriend and Prasad (2007) report that private-sector estimates of the share of total net foreign exchange inflows sterilized by the PBOC ranged from 20 to 48 percent for 2004-2005.

In this paper, we evaluate optimal sterilization policy in China —consistent with other maintained Chinese policies— in a fully specified DSGE model. The maintained policies we include are closed capital accounts, an exchange rate target, and the

[1]The trilemma argument says that a country cannot simultaneously maintain monetary policy and exchange rate targets while maintaining an open capital account [e.g., Obstfeld, Shambaugh, and Taylor (2005)].

[2]The PBOC has also limited capital movements in other ways, such as imposing administrative controls that limit bank credit creation [e.g., Goldstein and Lardy (2006)], or by taxing the movement of capital through the banking sector by raising reserve requirements. In this paper, we concentrate on monetary policy and take as given fiscal policy, including taxing the banking sector through reserve requirements, as well as quantitative restrictions on capital movements such as administrative controls.

desire to avoid abrupt changes in interest rates and central bank portfolio holdings. Given these constraints, we investigate optimal Chinese monetary policy in response to external shocks.

In particular, we evaluate the optimal monetary policy response to the sudden declines in foreign interest rates following the onset of the 2008-2009 global financial crisis. Following the sharp spikes of uncertainty in the financial markets during the crisis period, investors shifted their portfolio allocations toward low-risk and high-liquidity assets, such as U.S. Treasuries, in a "flight to liquidity." Moreover, the Federal Reserve and other central banks in the developed economies responded to the crisis aggressively by lowering overnight rates close to the zero bound and by adopting quantitative easing and other unconventional monetary policies. These responses combined to substantially reduce yields on China's foreign reserves. In contrast, nominal interest rates on China's domestic assets, such as the Central Bank (CB) bills rates and the Shanghai Interbank Offer Rate (SHIBOR), remained high throughout the crisis period.

The global financial crisis therefore triggered a reversal in the sign of the spread between China's domestic and foreign interest rates. In the earlier part of the previous decade, China's low domestic interest rates were often below those earned on foreign bonds, implying net marginal benefits to sterilization [e.g., Prasad and Wei (2007)]. However, since the global financial crisis, elevated nominal Chinese rates, combined with the low rates prevailing in foreign economies have reversed this pattern, leaving a positive spread between Chinese domestic interest rates and yields on foreign assets.

As shown in Figure 1, Chinese domestic interest rates, as measured by the three-month CB bills rate, were lower than the three-month interest rates on US Treasuries in 2006 and 2007. Since 2008, however, the aggressive policy easing by monetary authorities in the advanced economies (including the U.S. Federal Reserve) has reduced foreign interest rates to lower levels, inverting the sign of the interest rate spread. Most recently, the spread of China's interest rates over Treasuries of comparable maturities has increased to over 300 basis points.[3]

The reversal of yield spreads leaves the Chinese situation closer to the experience of emerging market economies facing capital inflow surges. Under these conditions, sterilization of foreign capital inflows is likely to be costly, due to the possibility of the quasi-fiscal costs associated with the interest rate premia paid on domestic debt

[3]The spread between the SHIBOR rates and U.S. Treasury yields increased to over 500 basis points during the same period.

relative to interest earned on foreign bonds [e.g., Calvo (1991)]. Existing studies suggest that the fiscal costs of sterilization can be substantial. Calvo, Leiderman, and Reinhart (1996) report estimates for Latin American nations between 0.25 and 0.5 percent of GDP. Kletzer and Spiegel (1998) report similar magnitudes for a group of small Pacific Basin countries.

However, the estimated fiscal costs of sterilization in the literature are typically calculated ex post in the absence of default. Ex ante, under efficient capital markets and open capital accounts, uncovered interest rate parity (UIP) should ensure that expected returns on domestic and foreign assets are equal net of risk premia.[4] In contrast, China's closed capital account removes the capacity to arbitrage deviations from UIP, so that observed deviations from uncovered interest parity between domestic Chinese and foreign bonds represent true expected costs of sterilization.[5]

Sterilization becomes even more challenging when countries run large trade surpluses and foreign reserves accumulate rapidly. Figure 2 shows that foreign exchange reserves as a share of total PBOC assets have grown from just over 40 percent in 2002 to more than 80 percent. Ouyang, Rajan, and Willett (2010) find that the offset coefficient—the fraction of changes in the autonomous monetary base that are offset by international capital movements, which is likely an indicator of the openness of the Chinese capital account—has grown over time. This trend implies that, over time, current account surpluses run by China require increasingly intensive sterilization to maintain the exchange rate goals [e.g., Glick and Hutchison (2009)].

In this paper, we examine optimal monetary policy responses to changes in world interest rates in a DSGE framework with a few key characteristics unique to the Chinese economy. The model economy consists of China and the rest of the world. We assume that world interest rates do not respond to Chinese economic conditions. However, variations in the real exchange rate do affect world demand for China's exported goods. The main friction in the private sector in the model takes the form of sticky goods prices and sticky nominal wages, which is a standard feature in many DSGE models [e.g., Christiano, Eichenbaum, and Evans (2005) and Smets and Wouters (2007)].

Our benchmark model contains a few nonstandard features to mimic China's current policy regime. Specifically, we assume that the government maintains a closed capital account, so that private agents are precluded from holding foreign assets. The government also pegs the nominal exchange rate to the foreign currency (dollars). If

[4]The literature was aware of this issue, and therefore referred to these costs as "quasi-fiscal costs."

[5]This is net of differences in expected default risk, which are likely minimal for both assets.

the country runs a current account surplus, the government sterilizes the inflow of foreign assets by exchanging nominal domestic-currency bonds for foreign-currency bonds at prevailing market prices. We assume that the government seeks to stabilize fluctuations in domestic inflation and real GDP. In addition, to stay consistent with recent behavior of the Chinese government, we assume that the government is committed to avoiding excessive fluctuations in domestic interest rate and disruptive changes in its holdings of foreign assets.

Given these institutional features, we investigate how optimal monetary policy should react to a persistent decline in foreign interest rates, similar to what we observe in Western economies during and after the global financial crisis. As the persistent increases in the spread between domestic and foreign interest rates raise the cost of sterilization, the government reduces its sales of domestic assets, financing a greater portion of its foreign reserve purchases through money creation. Under this policy response, inflation rises.

We then study the implications of several alternative policy regimes involving opening the capital account or abandoning the exchange rate peg. We compare the implications of the same foreign interest rate shock under three alternative liberalizations: (i) A partial lifting of capital controls while maintaining the exchange rate peg, (ii) allowing the exchange rate to float while maintaining a closed capital account, and (iii) combining a floating exchange rate with a partial lift of the capital controls. Our unified DSGE framework allows for consistent comparison of these alternative regimes.

We find that the best-performing regime is the one with both a floating exchange rate and a partial lift of capital controls. The worst-performing regime is the one with a floating exchange rate but a closed capital account. The welfare performances of the benchmark regime with no liberalization and the regime with a partial lift of capital controls while maintaining the exchange rate pegs lie somewhere in between.

The superior performance of the full liberalization regime stems from the central bank's ability under full liberalization to use the nominal exchange rate to adjust to the foreign interest rate shock without concerns about the implications of such policy for its costs of sterilization. Indeed, given an open capital account, foreign capital inflows need not be absorbed by the central bank. In contrast, when the exchange rate peg is lifted without opening the capital account, the adjustment process includes a costly change in the central bank's portfolio of domestic and foreign assets.

The DSGE model that we examine here provides a coherent theoretical framework for studying optimal monetary policy and for evaluating welfare performances of alternative policy regimes for China. Our work adds to the literature on optimal monetary policy in a New Keynesian DSGE framework. In the standard DSGE model of a closed economy, monetary policy faces no trade off between stabilizing inflation and stabilizing the output gap (Blanchard and Galí, 2007). This "divine coincidence," which is obtained from a closed economy model, can be carried over to a small open economy with perfect international capital flows and flexible exchange rates (Clarida, Galí, and Gertler, 2002). Subsequent literature shows that divine coincidence breaks down in more general environments. For example, when there are multiple sources of nominal rigidities, monetary policy in general faces a tradeoff between stabilizing inflation and stabilizing output gap. Examples include a model with sticky prices and sticky nominal wages (Erceg, Henderson, and Levin, 2000), a model with sticky prices in multiple sectors (Mankiw and Reis, 2003; Huang and Liu, 2005), and a model with multiple countries (Benigno, 2004; Liu and Pappa, 2008).[6]

In our benchmark model with a closed capital account and a pegged exchange rate, monetary policy faces additional constraints in stabilizing inflation and output fluctuations. Since private agents in the economy are precluded from trading foreign assets, the country is effectively in financial autarky and international risk-sharing becomes infeasible. Because the nominal exchange rate is pegged to foreign currency, adjustments in the terms of trade (or the real exchange rate) cannot be used as an effective instrument to mitigate the impact of external shocks. Under such a regime, increases in the cost of sterilization following a sudden decline in foreign interest rates further constrain the central bank's ability to stabilize domestic price inflation. To our knowledge, this source of tradeoff for monetary policy (from capital controls and exchange-rate pegs) is new to the literature.[7]

The recent global financial crisis has generated a renewed interest in the implications of capital controls and exchange-rate pegs. Policy makers have become more amenable to capital controls under certain conditions [e.g., Ostry, Ghosh, Habermeier,

[6]For a survey of the literature on optimal monetary policy in open economies, see, for example, Corsetti, Dedola, and Leduc (forthcoming).

[7]Despite the popularity of DSGE models in the recent macroeconomics and open economy literature and despite the clear advantage of using the DSGE framework for studying optimal policy issues in China, there are very few studies that use the DSGE framework in the context of the Chinese economy. Two exceptions include Miao and Peng (2011) and Chen, Funke, and Paetz (2012), who present closed-economy DSGE models with financial frictions to study China's credit policy.

Chamon, Qureshi, and Reinhart (2010)], as it is unclear that financial integration reduces macroeconomic volatility.[8] Farhi and Werning (2012) also argue that capital controls can mitigate the effects of excess international capital movements caused by risk premium shocks. Our paper investigates the benefits and costs of capital account policies, but focus on the constraints those policies imply for an optimizing central bank faced with a persistent current account surplus.

The remainder of this paper is divided into four sections. Section II introduces the benchmark DSGE model with pegged exchange rates and a closed capital account. Section III examines optimal monetary policy under the benchmark model in the wake of a negative shock to foreign interest rates comparable to that which occurred during the global financial crisis. Section IV examines the policy responses to the same shock under the three alternative liberalizations. Section V provides some concluding remarks.

II. Benchmark model

This section introduces our benchmark model with capital controls and exchange rate targeting. We consider a global economy with two countries—home and foreign. We focus on the home country and assume that the foreign country is passive. The home country is populated by a continuum of infinitely lived households. The representative household consumes a final good, holds real money balances, and supplies differentiated skills to firms. The final good is a composite of differentiated retail products, each of which is produced using a composite of labor skills and intermediate goods. Intermediate goods are in turn a composite of domestic goods and imported materials. Final goods can be used for consumption, as an intermediate input for production, or exported to the foreign country. All markets are perfectly competitive, except the markets for labor skills and for retail products, which are monopolistically competitive. Each retailer takes all prices but its own as given and sets a price for its differentiated product. Each worker takes all prices and wages but his own as given and sets a nominal wage for his differentiated labor skill. Wage and price adjustments are costly.

We characterize government behavior in a manner broadly consistent with current Chinese institutional features. In the benchmark model, we assume that the government maintains an exchange rate peg to the foreign currency and sterilizes its current

[8] Prasad, Rumbaugh, and Wang (2005) have argued that China's closed capital account regime facilitates its ability to allow for some additional flexibility in the renminbi.

account surplus by exchanging nominal bonds denominated in domestic currency for bonds denominated in foreign currency. As the capital account is closed, the private sector is not allowed to hold foreign assets. Instead, exporters swap their foreign-currency proceeds for domestic bonds with the central bank at par market values. Finally, we assume that the central bank wishes to smooth domestic interest rates and avoid abrupt changes in its foreign exchange holdings.[9]

II.1. **The aggregation sector.** The aggregation sector produces a composite final good Y_t, using a continuum of differentiated retail products $Y_t(j)$ for $j \in [0,1]$, and composite labor L_t, using differentiated labor skills $L_t(i)$ for $i \in [0,1]$ with the aggregation technology

$$Y_t = \left[\int_0^1 Y_t(j)^{\frac{\theta_p-1}{\theta_p}} dj\right]^{\frac{\theta_p}{\theta_p-1}}, \qquad (1)$$

$$L_t = \left[\int_0^1 L_t(i)^{\frac{\theta_w-1}{\theta_w}} di\right]^{\frac{\theta_w}{\theta_w-1}}, \qquad (2)$$

where $\theta_p > 1$ is the elasticity of substitution between differentiated retail goods and $\theta_w > 1$ is the elasticity of substitution between differentiated labor skills.

The demand functions for retail good j and labor skill i are derived from optimization in the aggregation sector, and are given by

$$Y_t^d(j) = \left[\frac{P_t(j)}{P_t}\right]^{-\theta_p} Y_t, \qquad (3)$$

$$L_t^d(i) = \left[\frac{W_t(i)}{W_t}\right]^{-\theta_w} L_t, \qquad (4)$$

where the price index P_t is related to the prices $\{P_t(j)\}_{j\in[0,1]}$ of the differentiated goods by $P_t = \left[\int_0^1 P_t(j)^{1-\theta_p} dj\right]^{\frac{1}{1-\theta_p}}$, and the wage index W_t is related to the prices $\{W_t(i)\}_{i\in[0,1]}$ of the differentiated skills by $W_t = \left[\int_0^1 W_t(i)^{1-\theta_w} di\right]^{\frac{1}{1-\theta_w}}$.

II.2. **The household sector.** The representative household is a monopolistic competitor in its differentiated labor skills, as in Blanchard and Kiyotaki (1987), and owns a share of the retail firms. Wages are assumed to be sticky, due to a quadratic cost of adjustment.

[9]In the absence of these assumptions, the government could avoid sterilization costs altogether through discrete offsetting movements in the nominal interest rate or in foreign asset holdings. Clearly, neither of these responses was pursued by the Chinese government subsequent to the reduction in global interest rates experienced during the financial crisis.

The household takes as given the price level P_t and the risk-free nominal interest rate R_{t-1} (for the one-period bond held from $t-1$ to t). The household chooses consumption C_t, money balances M_t, the nominal wage $W(i)_t$, and holdings of a nominal domestic bond B_t to maximize its lifetime expected utility function:

$$U = \mathrm{E}\sum_{t=0}^{\infty}\beta^t\left\{\ln C_t + \Phi_m \ln\frac{M_t}{P_t} - \Phi_l\frac{\left(L_t^d(i)\right)^{1+\eta}}{1+\eta}\right\}, \tag{5}$$

subject to the demand schedule for labor (4) and the sequence of budget constraints

$$C_t+\frac{M_t}{P_t}+\frac{B_t}{P_t}\leq\frac{W_t(i)}{P_t}L_t^d(i)+\frac{M_{t-1}}{P_t}+R_{t-1}\frac{B_{t-1}}{P_t}+\frac{D_t}{P_t}-\frac{\Omega_w}{2}\left(\frac{W_t(i)}{\pi^w W_{t-1}(i)}-1\right)^2 C_t, \tag{6}$$

where Ω_w represents the average cost of wage adjustment and π^w denotes steady-state wage inflation.[10] The term D_t represents the nominal dividend received by the household from its retail firms. The term E is an expectation operator, $\beta \in (0,1)$ is a subjective discount factor, $\Phi_m > 0$ is the utility weight for real money balances, $\Phi_l > 0$ is the utility weight for leisure, and $\eta > 0$ is the inverse Frisch elasticity of hours worked.

Let Λ_t represent the Lagrangian multiplier for the budget constraint (6). The representative household's optimizing decisions are summarized by the following first-order conditions:

$$1 = \mathrm{E}_t\beta\frac{\Lambda_{t+1}}{\Lambda_t}\frac{R_t}{\pi_{t+1}}, \tag{7}$$

$$\frac{\Phi_m}{\Lambda_t m_t} = \frac{R_t-1}{R_t}, \tag{8}$$

$$\Lambda_t = \frac{1}{C_t}, \tag{9}$$

where $\pi_{t+1} \equiv \frac{P_{t+1}}{P_t}$ denotes the inflation rate from period t to $t+1$ and $m_t \equiv \frac{M_t}{P_t}$ denotes the quantity of real money balances at time t.

In a symmetric equilibrium, all households set identical nominal wages. The wage-setting rule is described by the wage Phillips curve relation

$$w_t = \frac{\theta_w}{\theta_w-1}\Phi_l L_t^\eta C_t - \frac{\Omega_w}{\theta_w-1}\frac{C_t}{L_t}\left[\left(\frac{\pi_t^w}{\pi^w}-1\right)\frac{\pi_t^w}{\pi^w} - \beta\mathrm{E}_t\left(\frac{\pi_{t+1}^w}{\pi^w}-1\right)\frac{\pi_{t+1}^w}{\pi^w}\right], \tag{10}$$

where $w_t = \frac{W_t}{P_t}$ denotes the real wage, $\pi_t^w = \frac{W_t}{W_{t-1}}$ denotes nominal wage inflation, and we have substituted out for marginal utility Λ_t using equation (9). Absent wage

[10]We assume the existence of an implicit insurance market so that all workers receive the same consumption and real money balances independent of their skill types, as in Huang and Liu (2002), Woodford (2003), and Christiano, Eichenbaum, and Evans (2005).

adjustment cost (i.e., with $\Omega_w = 0$), the real wage is a constant markup over the marginal rate of substitution (MRS) between leisure and consumption. With nominal wage rigidities, the real wage will deviate from a constant markup in the short run, according to the wage-setting rule (10).

II.3. **The retail sector.** There is a continuum of retailers, each producing a differentiated product $Y_t(j)$ using the constant returns technology

$$Y_t(j) = \Gamma_t(j)^{\phi}(Z_t L_t(j))^{1-\phi}, \tag{11}$$

where Z_t is a labor-augmenting technology shock, $\Gamma_t(j)$ denotes the input of intermediate goods, and $L_t(j)$ denotes the input of labor. The parameter $\phi \in [0, 1]$ is the cost share of the intermediate input.

We assume that the technology shock Z_t satisfies $Z_t = Z_t^p Z_t^m$, where Z_t^p represents a permanent component and Z_t^m represents a transitory component. Z_t^p follows a random walk process with a drift λ_{zt}, while the transitory component Z_t^m is a stationary (mean-reverting) stochastic process. In particular, $Z_t^p = Z_{t-1}^p \lambda_{zt}$, where λ_{zt} satisfies

$$\ln \lambda_{zt} = (1 - \rho_{z^p}) \ln \bar{\lambda}_z + \rho_{z^p} \ln \lambda_{z,t-1} + \sigma_{z^p} \varepsilon_{z^p t}, \tag{12}$$

where ρ_{z^p} is a persistence parameter and σ_{z^p} is the standard deviation of the innovation $\varepsilon_{z^p t}$, which itself follows an i.i.d. standard normal process.

The transitory component, Z_t^m, follows the stochastic process

$$\ln Z_t^m = \rho_{z^m} \ln Z_{m,t-1} + \sigma_{z^m} \varepsilon_{z^m t}, \tag{13}$$

where ρ_{z^m} is a persistence parameter, σ_{z^m} is the standard deviation of the innovation, and $\varepsilon_{z^m t}$ is again an i.i.d. standard normal process.

Denote by v_t the real marginal cost for firms. Cost-minimizing implies that

$$v_t = \tilde{\phi} q_{mt}^{\phi} \left(\frac{w_t}{Z_t} \right)^{1-\phi}, \tag{14}$$

where q_{mt} denotes the relative price of intermediate goods and $\tilde{\phi} \equiv \phi^{-\phi}(1-\phi)^{\phi-1}$ is a constant. The conditional factor demand derived from the cost-minimization problem implies

$$\frac{w_t}{q_{mt}} = \frac{1-\phi}{\phi} \frac{\Gamma_t(j)}{L_t(j)}. \tag{15}$$

Given that input factors are perfectly mobile across all retail firms, the wage rate and the relative price of intermediate goods are identical for each firm, as is the real marginal cost.

Retailers face competitive input markets and a monopolistically competitive product market. Retailer j takes the input prices q_t and w_t, the price level P_t, and the demand schedule for its product described in equation (3) as given, and sets a price $P_t(j)$ for its own differentiated product to maximize expected discounted dividend flows. Price adjustment is assumed to be costly. Following Rotemberg (1982), retailers face a quadratic price adjustment cost

$$\frac{\Omega}{2}\left(\frac{P_t(j)}{\pi P_{t-1}(j)}-1\right)^2 C_t,$$

where Ω is the average size of adjustment costs and π is the steady-state inflation rate.[11] In particular, the retailer solves the problem

$$\text{Max}_{P_t(j)} \quad E_t\sum_{k=0}^{\infty}\beta^k\frac{C_t}{C_{t+k}}\left[\left(\frac{P_{t+k}(j)}{P_{t+k}}-\upsilon_{t+k}\right)Y_{t+k}^d(j)-\frac{\Omega}{2}\left(\frac{P_{t+k}(j)}{\pi P_{t+k-1}(j)}-1\right)^2 C_{t+k}\right], \tag{16}$$

where $Y_t^d(j)$ is given by equation (3).

The optimal price-setting decision implies that, in a symmetric equilibrium with $P_t(j)=P_t$ for all j, we have

$$\upsilon_t=\frac{\theta_p-1}{\theta_p}+\frac{\Omega}{\theta_p}\frac{C_t}{Y_t}\left[\left(\frac{\pi_t}{\pi}-1\right)\frac{\pi_t}{\pi}-\beta \text{E}_t\left(\frac{\pi_{t+1}}{\pi}-1\right)\frac{\pi_{t+1}}{\pi}\right]. \tag{17}$$

Absent price adjustment costs (i.e., when $\Omega=0$), the optimal pricing rule would imply that the real marginal cost υ_t equals the inverse markup.

II.4. **The intermediate goods sector.** The intermediate goods used by the retail sector for production are a composite of domestically produced and imported goods

$$\Gamma_t=\Gamma_{ht}^{\alpha}\Gamma_{ft}^{1-\alpha}, \tag{18}$$

where Γ_{ht} and Γ_{ft} denote the quantities of domestically produced and imported goods, respectively, and α is domestic good expenditure share.

Cost-minimizing implies that the relative price of intermediate goods is given by

$$q_{mt}=\tilde{\alpha}\left(\frac{e_t P_t^*}{P_t}\right)^{1-\alpha}, \tag{19}$$

where e_t denotes the nominal exchange rate and P_t^* denotes the foreign price level. This relation suggests that the cost of intermediate goods is a monotonic function of

[11] For convenience, we normalize the adjustment cost in aggregate consumption units. The results do not change if we normalize using aggregate output units.

the real exchange rate or the terms of trade. Cost-minimizing also implies that

$$q_t \equiv \frac{e_t P_t^*}{P_t} = \frac{1-\alpha}{\alpha} \frac{\Gamma_{ht}}{\Gamma_{ft}}, \tag{20}$$

where q_t is the real exchange rate.

II.5. **The external sector and current account.** The home country imports materials and exports final goods. Its current account surplus equals the trade surplus plus net interest income received from holdings of foreign assets

$$ca_t = X_t - q_t \Gamma_{ft} + \frac{e_t (R_{t-1}^* - 1) B_{t-1}^*}{P_t}, \tag{21}$$

where X_t represents the quantity of exports, B_{t-1}^* denotes the country's holdings of foreign-currency bonds at the beginning of period t, and R_{t-1}^* denotes the gross nominal interest rate on foreign bonds from period $t-1$ to period t. We assume that the foreign interest rate R_t^* is exogenous and follows the stationary stochastic process

$$\ln R_t^* = (1-\rho_r) \ln R^* + \rho_r \ln R_{t-1}^* + \sigma_r \varepsilon_{rt}, \tag{22}$$

where $\rho_r \in (0,1)$ is a persistence parameter, σ_r is the standard deviation of the shock, and ε_{rt} is an i.i.d. standard normal process.

We assume that foreign demand is inversely related to the relative price of home exported goods and positively related to aggregate demand in the foreign country. The export demand schedule is given by

$$X_t = \left(\frac{P_t}{e_t P_t^*} \right)^{-\theta} \tilde{X}_t^* Z_t^p = q_t^\theta \tilde{X}_t^* Z_t^p, \tag{23}$$

where, to obtain balanced growth, we assume that export demand is augmented by the permanent component of the domestic technology shock, Z_t^p. The term $\tilde{X}_t^*$ is foreign aggregate demand, which follows the exogenous process

$$\ln \tilde{X}_t^* = (1-\rho_x) \ln \tilde{X}^* + \rho_x \ln \tilde{X}_{t-1}^* + \sigma_x \varepsilon_{xt}, \tag{24}$$

where $\rho_x \in (0,1)$ is a persistence parameter, σ_x is the standard deviation of the foreign demand shock, and ε_{xt} is an i.i.d. standard normal process.

II.6. **Central bank policy and sterilized intervention.** The government issues domestic-currency bonds and currency, and holds foreign-currency reserves. In the benchmark model, the central bank allows the nominal exchange rate to appreciate at a constant rate γ_e and maintains a closed capital account. The private sector is not allowed to hold foreign assets. The government buys up any net inflow of foreign assets from the private sector using domestic currency.

Left alone, this would require the central bank to increase domestic money supply. We assume that the central bank engages in sterilization activity by swapping domestic-currency bonds for money with the private sector.

Specifically, the amount of foreign capital inflows equals the current account surplus, so that

$$ca_t = e_t \frac{B_t^* - B_{t-1}^*}{P_t}. \tag{25}$$

Given full sterilization, we would have

$$B_t - B_{t-1} = e_t(B_t^* - B_{t-1}^*) = P_t ca_t, \tag{26}$$

where B_t denotes the outstanding domestic debt issued by the government (which equals household savings). Thus, the government changes its portfolio composition by exchanging domestic debt for foreign capital inflows at par.

However, when sterilization is costly (e.g., when the yield on domestic debt exceeds that on foreign bonds), the central bank may not wish to fully sterilize. Instead, the central bank can partially sterilize the foreign capital inflow and expand the domestic money supply sufficiently to accommodate excess inflows. Intuitively, the fiscal costs of sterilization will be equal to the difference between the return on foreign bonds acquired and that on the domestic bonds that were swapped with the private sector in exchange.[12]

The central bank's flow-of-funds constraint satisfies

$$e_t(B_t^* - R_{t-1}^* B_{t-1}^*) \leq B_t - R_{t-1}B_{t-1} + M_t^s - M_{t-1}^s, \tag{27}$$

where R_{t-1}^* is the nominal interest rate for holding foreign-currency bonds from period $t-1$ to t. The central bank finances interest payments for mature domestic debt and increases in foreign bond holdings by a combination of new domestic debt issues, interest payments on mature foreign bonds, and seigniorage revenue.[13]

[12]The fiscal costs of holding foreign assets can be affected by capital gains or losses on foreign asset values when the foreign interest rates or exchange rates fluctuate. However, this would affect the value of foreign bonds (in domestic current units) already held, B_{t-1}^*, and not the flow costs of holding foreign assets over period t. As such, capital gains or losses on foreign assets do not affect the government's sterilization decision.

[13]To concentrate on monetary policy issues, we take all fiscal policies as given. This includes implicit taxes that may be levied by the central bank, such as reserve requirements that force banks to hold assets at the central bank at below-market interest rates, and the practice of handing over the central bank budget surplus to the general Treasury for fiscal spending. Proper analysis of these fiscal policies would require a fuller model of both government and the local banking sector. We leave these policy considerations for future research.

II.7. **Market clearing and equilibrium.** Given government policy, an equilibrium in this economy is a sequence of prices $\{P_t, w_t, q_{mt}, e_t, R_t\}$ and aggregate quantities $\{C_t, Y_t, \Gamma_t, \Gamma_{ht}, \Gamma_{ft}, X_t, L_t, M_t, M_t^s, B_t\}$, as well as the prices $P_t(j)$ and quantities $\{Y_t(j), L_t(j), \Gamma_t(j)\}$ for each retail firm $j \in [0,1]$ and the wage $W_t(i)$ and labor demand $L_t^d(i)$ for each worker with skill $i \in [0,1]$, such that (i) taking all prices but its own as given, the price and allocations for each retail firm solves its profit maximizing problem, (ii) taking all prices and wages but his own as given, both the wage for each individual worker and the allocations for the households solve the utility maximizing problems, and (iii) markets for the final goods, intermediate goods, composite labor, money balances, and bond holdings all clear.

The market-clearing conditions are summarized below.

$$Y_t = C_t + \Gamma_{ht} + X_t + \left[\frac{\Omega_p}{2}\left(\frac{\pi_t}{\pi} - 1\right)^2 + \frac{\Omega_w}{2}\left(\frac{\pi_t^w}{\pi^w} - 1\right)^2\right] C_t, \tag{28}$$

$$L_t = \int_0^1 L_t(j)dj, \tag{29}$$

$$\Gamma_t = \int_0^1 \Gamma_t(j)dj. \tag{30}$$

$$M_t = M_t^s, \tag{31}$$

where equation (28) is the final goods market-clearing condition, (29) is the labor market-clearing condition, (30) is the intermediate-goods market-clearing condition, and (31) is the money market-clearing condition.

We define real GDP as the sum of consumption and net exports, which is given by

$$GDP_t = C_t + X_t - q_t\Gamma_{ft}. \tag{32}$$

Note that the definition of real GDP in (32) uses the expenditure approach. We can also obtain real GDP using the income approach. Adding up the household's budget constraint (6) and the government's flow-of-funds constraint (27), and using both the definition of current account in (21) and the relation between current account and foreign capital inflows in (25), we obtain

$$GDP_t \equiv C_t + X_t - q_t\Gamma_{ft} = w_t L_t + \frac{D_t}{P_t} - \frac{\Omega_w}{2}\left(\frac{\pi_t^w}{\pi^w} - 1\right)^2 C_t, \tag{33}$$

which equates real GDP to total domestic factor income—including wage income and profit income—net of wage adjustment costs, where profit income is net of price adjustment costs.

III. Optimal monetary policy

We now examine optimal monetary policy in the benchmark model with capital controls and exchange rate pegs. We assume that the policymaker minimizes a quadratic loss function subject to the private sector's optimizing conditions. We consider the loss function

$$\mathcal{L} = \sum_{t}^{\infty} L_t, \quad L_t = \lambda_\pi \hat{\pi}_t^2 + \lambda_y \widehat{gdp}_t^2 + \lambda_r \hat{R}_t^2 + \lambda_b \hat{b}_{yt}^{*2}, \tag{34}$$

where $\hat{\pi}_t$ and $\hat{R}_t$ denote deviations of inflation and the nominal interest rate from their steady-state levels, $\widehat{gdp}_t$ denotes deviations of real GDP from the balanced growth paths, and $\hat{b}_{yt}^*$ denotes deviations of the ratio of foreign-assets to GDP from steady state. The parameters λ_π, λ_y, λ_r, and λ_b determine the relative importance of the four variables in the planner's objective function.

The quadratic terms involving inflation, output, and the nominal interest rate in the loss function are standard in the optimal monetary policy literature. They can be derived from second-order approximations to the representative household's utility function [e.g., Woodford (2003)]. The interest rate smoothing term appears in the policy objective in the presence of transaction frictions, such as money in the utility function.

The term involving $\hat{b}_{yt}^*$ is not standard and deserves some explanation. Including $\hat{b}_{yt}^*$ in the loss function implies that the central bank wishes to avoid large fluctuations in its foreign reserve holdings relative to GDP. The PBOC's foreign reserve holdings, especially its holdings of U.S. Treasuries, makes it hard for the Chinese central bank to sell or buy foreign assets without affecting world prices. As shown in Figure 2, China has accumulated large foreign reserves as it ran large current account surpluses and sterilized its foreign capital inflows. Failure to include this term would eliminate all of the dynamics in the interest rate shock that we consider below, since the central bank would be able respond to the shock with an abrupt portfolio change and to restore the steady state immediately. Empirically, we do not observe such abrupt adjustments in the PBOC's foreign reserve holdings relative to GDP. In particular, China's central bank did not sell off its foreign reserves during the recent crisis period when returns on foreign assets declined substantially.

The Ramsey planner minimizes the quadratic loss in (34) subject to log-linearized optimizing conditions. We describe the stationary equilibrium, the steady state, and the log-linearized conditions in Appendix A.

III.1. **Parameter calibration.** We solve the optimal policy problem using numerical methods. For this purpose, there are five sets of parameters to be calibrated. These include the parameters in the representative household's utility function, those in the representative firm's production function, those that characterize nominal rigidities, those that characterize international trade, and those in the Ramsey planner's objective function.

For the utility function parameters, we set the subjective discount factor in our quarterly model to $\beta = 0.998$. Based on the money demand regression by Chari, Kehoe, and McGrattan (2000), we set $\Phi_m = 0.06$. We set $\eta = 10$, so that the Frisch elasticity of labor supply is 0.01, consistent with microeconomic evidence (Pencavel, 1986). We calibrate Φ_l so that the steady-state labor hours are about 40 percent of time endowment.

For the technology parameters, we set the cost share of intermediate goods to $\phi = 0.5$. We set the mean technology growth rate to $\bar{\lambda}_z = 1.02$, so that real per capita GDP grows at an annual rate of 8 percent on average, similar to China's experience over the last two decades.

For the nominal rigidity parameters, we set $\theta_p = 10$, so that the steady-state price markup is about 11 percent, consistent with the estimate reported by Basu and Fernald (1997). We set $\Omega_p = 30$, which is consistent with an average duration of price contracts of about three quarters, in line with empirical evidence on price rigidities (Nakamura and Steinsson, 2008).[14]

Estimated DSGE models imply that the duration of nominal wage contracts is between three and four quarters (Smets and Wouters, 2007). A recent study by Barattieri, Basu, and Gottschalk (2010) uses micro-level wage data and reports that, after controlling for measurement errors, nominal wages are stickier than those found in DSGE models. They find that the probability of wage changes for hourly workers is about 18 percent per quarter, implying an average duration of wage contracts of about

[14]The slope of the Phillips curve in our model is given by $\kappa_p \equiv \frac{\theta_p - 1}{\Omega_p}\frac{C}{Y}$, where the steady-state ratio of consumption to gross output is about 0.53. The values of $\theta_p = 10$ and $\Omega_p = 30$ imply that $\kappa_p = 0.16$. In an economy with Calvo (1983) price contracts, the slope of the Phillips curve is given by $\frac{(1-\beta\alpha_p)(1-\alpha_p)}{\alpha_p}$, where α_p is the probability that a firm cannot reoptimize prices. To obtain a slope of 0.16 for the Phillips curve in the Calvo model, we need to have $\alpha_p = 0.66$ (taking $\beta = 0.998$ as given), which corresponds to an average price contract duration of $\frac{1}{1-\alpha_p} = 3$ quarters. The study by Nakamura and Steinsson (2008) shows that the median price contract duration is between 8 and 12 months. This contract duration is longer than that found by Bils and Klenow (2004) because temporary sales are excluded from the sample.

5.6 quarters. In light of these studies, we set $\theta_w = 10$ and $\Omega_w = 100$, corresponding to a Calvo model with an average duration of four quarters for nominal wage contracts.

For the parameters in the external sector, we set $\alpha = 0.7$ so that the model implies an import-to-GDP ratio of 20 percent in the steady state, equal to the average import-to-GDP ratio in China between 1990 and 2009. The export demand elasticity θ captures the elasticity of substitution between goods made in China and those made in their domestic country for foreign consumers. Empirical studies suggest that the elasticity estimates are typically larger at the micro levels than at the macro levels when sectoral heterogeneity is important (Imbs and Méjean, 2011). We have an aggregate model. Thus, we calibrate θ based on the estimated elasticity of substitution between domestic and foreign goods at the macro level, which lies in the range between 1 and 2 (Feenstra, Obstfeld, and Russ, 2012). Specifically, we set $\theta = 1.5$.

This leaves the parameters in the Ramsey planner's objective function (34). We follow Woodford (2003) by setting $\lambda_\pi = 1$ and $\lambda_y = 0.05$. The greater weight on inflation than on GDP reflects the planner's stronger desire for price stability. We have less guidance on the values of λ_r and λ_b. We assign a small weight to foreign bond positions ($\lambda_b = 0.01$), so that the planner is mainly concerned about stabilizing inflation and output. We set a relatively large value for the interest rate smoothing parameter ($\lambda_r = 5$), so that the domestic nominal interest rate does not decline too much following a large and persistent negative shock to the foreign interest rate.[15]

III.2. **Dynamics under optimal policy.** In this section, we examine the dynamic responses of several key macroeconomic variables under optimal policy with capital controls and nominal exchange rate pegs following a negative shock to the foreign interest rate, similar to the decline in short-term nominal interest rates in foreign countries (and specifically in the United States) during the 2008-2009 financial crisis.

In response to the crisis, the Federal Reserve lowered its interest rate target to near-zero levels in early 2009 and later signaled its intention to maintain the extremely low levels of the target at least through the end of 2014. To capture this high degree of persistence in the decline of the foreign interest rates, we set $\rho_r = 0.98$, so that the decline in foreign interest rates has a half life of about three years, which appears to be a conservative assumption in light of the Federal Reserve's expressed commitment to keep interest rates low for an extended period. We set the standard deviation of the interest-rate shock to one percent.

[15]We have examined the robustness of our results for different values of λ_b and λ_r. We find that the qualitative results do not change.

The equilibrium dynamics are deviations from an initial steady state, in which the domestic nominal interest rate is slightly lower than the foreign nominal interest rate. In particular, we set $R = 1.0075$ and $R^* = 1.01$, corresponding to annual rates of returns of 3 percent on domestic bonds and 4 percent on foreign bonds. This interest-rate differential captures the positive spread of foreign asset yields that prevailed over yields on Chinese assets prior to the financial crisis [e.g., (Prasad and Wei, 2007)]. Also matching Chinese data, we model the steady state as exhibiting a positive trade surplus, generating increases in Chinese holdings of foreign assets. We calibrate the steady state so that net exports are about 3 percent of GDP, matching the average in Chinese data from 1990 to 2009.

We examine a one percent decline (instead of an increase) in R^* to capture the effects of the recent global financial crisis that has pushed down the yields on U.S. Treasuries substantially. Figure 3 shows the impulse responses of the four variables in the central bank's loss function to a negative shock to the foreign interest rate.

The decline in the foreign interest rate directly lowers the country's earnings on foreign assets and thus reduces the current account surplus. This leads to a lower national income and lower aggregate demand. This effect, in itself, is disinflationary. However, the decline in the foreign interest rate relative to the domestic interest rate also raises the cost of sterilization. In response, the planner relies less on swapping domestic bonds for foreign assets and more on increasing the domestic money supply to absorb current account surpluses, which results in an initial upturn in inflation and a decline in the nominal interest rate, as well as a decline in the Foreign bond to GDP ratio. With nominal rigidities, the increase in the money supply raises aggregate demand and offsets the initial recessionary effects following the decline in the current account surplus. Under our calibrated parameters, the net effect of a negative foreign interest rate shock is an increase in real GDP.

Figure 4 shows the impulse responses of a few other macroeconomic variables in our model. The nominal exchange rate does not respond to the shock because it is pegged by the central bank (the movements in the nominal exchange rate in the figure reflect computer rounding errors). The short-run increase in inflation appreciates the real exchange rates, which mitigates the magnitude of capital inflows and reduces the need for sterilization. The effort to mitigate sterilization costs results in a decline in the holdings of domestic bonds by the private sector. Over time, as the foreign interest rate rises towards the steady state and the interest rate spread shrinks, so that the cost of sterilization declines. The planner then reduces the money supply and increases debt issuance to absorb the foreign export earnings. Thus, inflation declines and the real exchange rate depreciates, returning the current account to its steady-state level.

IV. Policy reforms

In this section, we evaluate the dynamics of responses to the same interest shock relative to a steady state where partial liberalization has taken place. We consider three alternative liberalizations: A partial lifting of capital controls with maintenance of the exchange rate peg, allowing the exchange rate to float while maintaining a closed capital account, and the combination of allowing a floating exchange rate and a partial lift of the capital controls. We compare the dynamics and welfare losses under these alternative policy regimes to those in our benchmark case.

IV.1. **Opening the capital account.** We begin with a partial liberalization of the capital account while maintaining a fixed exchange rate. We assume that the private sector is allowed to hold, on average, up to $\vartheta < 1$ fraction of total foreign assets (while the government holds the remaining $1 - \vartheta$ fraction).

Under a regime with perfect capital mobility, a variant of the UIP condition would hold. Thus, to a first-order approximation, we have

$$\hat{R}_t - \hat{R}_t^* = \mathrm{E}_t \hat{\gamma}_{e,t+1}, \tag{35}$$

where $\hat{R}_t$ and $\hat{R}_t^*$ denote the deviations of domestic and foreign interest rates from steady-state levels and $\mathrm{E}_t \hat{\gamma}_{e,t+1}$ denotes the expected nominal exchange rate devaluation.

If the central bank continues to peg the nominal exchange rate, then the UIP condition implies that $\hat{R}_t = \hat{R}_t^*$ for all periods t. Thus, allowing perfect capital mobility while maintaining an exchange rate peg would force the central bank to give up independent monetary policy, as implied by the trilemma argument. Even with a managed floating exchange rate, domestic monetary policy would be tied to exchange rate policy through the UIP condition.

We assume that the central bank would like to retain some capacity for sterilization even after the capital account is opened. This assumption captures home bias, which prevails even in the most advanced economies [e.g., Coval and Moskovitz (1999)]. We therefore study imperfect capital mobility by assuming that domestic private agents are allowed to hold both domestic bonds and foreign bonds, but the two types of assets are imperfect substitutes. We assume that it is costly to adjust the share of domestic bonds in the household's portfolio of domestic and foreign bonds away from the steady-state allocation, which is assumed to be the first best given the household's preferences. The central bank does not face such a portfolio adjustment cost.

Let B^*_{pt} represent the private sector's holdings of foreign bonds and B^*_{gt} the government's holdings. Denote by $\psi_t \equiv \frac{B_t}{B_t+e_tB^*_{pt}}$ the household's portfolio share of domestic bonds. Given a partially open capital account, the household's budget constraint (6) is replaced by

$$C_t + \frac{M_t}{P_t} + \frac{B_t + e_tB^*_{pt}}{P_t}\left[1 + \frac{\Omega_b}{2}\left(\frac{B_t}{B_t + e_tB^*_{pt}} - \bar{\psi}\right)^2\right] \leq \frac{W_t(i)}{P_t}L^d_t(i)$$
$$-\frac{\Omega_w}{2}\left(\frac{W_t(i)}{\pi^w W_{t-1}(i)} - 1\right)^2 C_t + \frac{M_{t-1}}{P_t} + \frac{R_{t-1}B_{t-1} + e_tR^*_{t-1}B^*_{p,t-1}}{P_t} + \frac{D_t}{P_t}, \quad (36)$$

where Ω_b is a parameter measuring the size of the portfolio adjustment costs and $\bar{\psi}$ is the steady-state portfolio share of domestic bonds held by the private sector (i.e., the household).

We assume that the opening of the capital account is one-sided, as domestic bonds are held by domestic residents only. These bonds are traded between the household and the government, but not in the world financial market. The foreign bonds are held by both the government and the household and the sum of private and public holdings of foreign bonds equals the country's foreign reserves:

$$B^*_t = B^*_{pt} + B^*_{gt}. \quad (37)$$

Accordingly, the central bank's budget constraint is replaced by

$$e_t(B^*_{gt} - R^*_{t-1}B^*_{g,t-1}) \leq B_t - R_{t-1}B_{t-1} + M^s_t - M^s_{t-1}. \quad (38)$$

The first-order conditions with respect to the optimal choices of B_t and B^*_{pt} for the representative household are given by

$$1 + \frac{\Omega_b}{2}\left(\psi_t - \bar{\psi}\right)^2 + \Omega_b(\psi_t - \bar{\psi})(1 - \psi_t) = \beta \mathrm{E}_t \frac{\Lambda_{t+1}}{\Lambda_t}\frac{R_t}{\pi_{t+1}}, \quad (39)$$
$$1 + \frac{\Omega_b}{2}\left(\psi_t - \bar{\psi}\right)^2 - \Omega_b(\psi_t - \bar{\psi})\psi_t = \beta \mathrm{E}_t \frac{\Lambda_{t+1}}{\Lambda_t}\frac{R^*_t}{\pi_{t+1}}\frac{e_{t+1}}{e_t}. \quad (40)$$

Log-linearizing these intertemporal Euler equations and combining terms leads to the equilibrium condition

$$\hat{R}_t - \hat{R}^*_t = \mathrm{E}_t\hat{\gamma}_{e,t+1} + \Omega_b\bar{\psi}\hat{\psi}_t, \quad (41)$$

where $\hat{\psi}_t$ is the deviation of the portfolio share of domestic bonds from the steady-state level. This is an additional Euler equation for the household's optimizing decisions resulting from optimal choices of foreign bond holdings.

Equation (41) is a modified UIP condition, under which the yield spread on domestic versus foreign bonds is related not just to the expected depreciation of the domestic currency, but also to changes in the portfolio share. Since deviations of the portfolio share from the steady state are costly, the household needs to be compensated with a higher relative interest rate to be willing to increase the share of domestic bonds in its portfolio (i.e., the interest rate differential $\hat{R}_t - \hat{R}_t^*$ increases with $\hat{\psi}_t$). Equivalently, to induce the domestic household to hold more foreign bonds the interest rate on domestic bonds must fall. In this sense, domestic and foreign bonds are imperfect substitutes.[16] Changes in the portfolio share therefore affect relative domestic and foreign interest rates.

Indeed, equation (41) represents a downward-sloping demand curve for domestic bonds relative to foreign bonds. To see this, we log-linearize the definition of the portfolio share ψ_t to obtain

$$\hat{\psi}_t = (1 - \bar{\psi})(\hat{b}_t - \hat{q}_t - \hat{b}_{pt}^*). \tag{42}$$

Substituting this expression in equation (41), we get

$$\Omega_b \bar{\psi}(1 - \bar{\psi})(\hat{b}_t - \hat{q}_t - \hat{b}_{pt}^*) = \hat{R}_t - \hat{R}_t^* - \mathrm{E}_t \hat{\gamma}_{e,t+1}. \tag{43}$$

Thus, an increase in the interest rate differential $\hat{R}_t - \hat{R}_t^*$, holding expected exchange rate movements constant, raises the demand for domestic bonds relative to foreign bonds. Since the interest rates are inversely related to the bond prices, this relation represents a downward-sloping relation between the relative quantity of domestic bond holdings and the relative price.

We first study optimal monetary policy under this regime with partial capital controls and exchange rate pegs. The Ramsey planner minimizes the loss in equation (34), subject to the private sector's optimizing conditions, augmented with the modified UIP condition (41). As in the benchmark model, we focus on the dynamic effects of shocks to the foreign interest rate and foreign demand for exported goods.

To solve the model with partial capital controls, we need to calibrate the steady-state portfolio share $\bar{\psi}$, the portfolio adjustment cost parameter Ω_b, and the steady-state fraction of foreign bonds held by the private sector $\vartheta \equiv \frac{\bar{b}_p^*}{\bar{b}^*}$. Since we have yet to

[16]For a broader review of recent innovations in imperfect asset substitutability in international capital markets, see Coeurdacier and Rey (2011).

observe China with an open capital account, we calibrate these two parameters using evidence from other emerging market economies.

The portfolio share $\bar{\psi}$ reflects home bias in asset holdings. We set $\bar{\psi} = 0.90$, which lies in the range of empirical studies such as Coeurdacier and Rey (2011).[17]

We calibrate Ω_b to capture the average deviations of interest rate differentials from the UIP conditions. Specifically, we estimate a simple empirical model based on the modified UIP condition (41) using panel data from emerging market economies. The empirical model is given by

$$\log \frac{S_{it}}{S_{i,t-1}} - (R_{i,t-1} - R^*_{t-1}) = a_i - b \log(\psi_{i,t-1}), \tag{44}$$

where S_{it} is the nominal exchange rate for country i relative to the U.S. dollar (units of local currency per U.S. dollar) at the end of year t, $R_{i,t-1} - R^*_{t-1}$ is the difference between country i's nominal interest rate and the U.S. three-month T-bill rate at the end of year $t-1$, and $\psi_{i,t-1}$ is the share of domestic bonds held by country i residents relative to the country's total bond holdings (including domestic and foreign bonds) at the end of year $t-1$. We consider a balanced panel of 22 emerging market economies with a sample period from 2001 to 2011.[18] The point estimate of b in equation (44) is about 0.2.[19] Given our calibration that $\bar{\psi} = 0.9$, the value of $b = 0.2$ implies that $\Omega_b = 0.22$, which is the value we use in our simulation of optimal policy.

The parameter ϑ corresponds to the steady-state share of foreign bonds held by the private sector. According to the Bureau of Economic Analysis, the U.S. government holds only about 3.4 percent of foreign bonds in 2010. For China, however, the government sector has a much larger share in both production and asset holdings than that of the government in the United States. Thus, we set $\vartheta = 0.55$ as a

[17]Coeurdacier and Rey (2011) find that average bond home bias worldwide in 2008 is equal to 0.75. Earlier studies reported values for equity home bias around 0.80 (Aviat and Coeurdacier, 2007). Emerging markets tend to have even higher levels of home bias in bonds on average, above 0.9. Home bias figures for emerging Asia are even higher than those for emerging economies from the rest of the world, around 0.97. We therefore set $\bar{\psi} = 0.90$ for China subsequent to opening its capital account.

[18]For the period up to 2008, we use the portfolio share data from Coeurdacier and Rey (2011). We extend their sample through 2011 by merging data from the International Financial Statistics (IFS) and from the Bank for International Settlements (BIS).

[19]In keeping with poor empirical performances of UIP-related conditions in the literature, this coefficient was marginally significant at a 15 percent level. However, we use the point estimate from this exercise for our calibration rather than asserting a value for this relatively free parameter. See Carneiro and Wu (2010) for empirical evidence that UIP-based exchange rate conditions hold at statistically significant levels for samples of emerging market economies.

benchmark. We also experiment with a few alternative values of ϑ to see how the simulation results depend on the share of private sector's holdings of foreign assets.

Figure 5 displays the impulse responses of the four variables in the central bank's loss function to a negative shock to the foreign interest rate. In addition to the responses in the benchmark model that we have discussed (labeled "Benchmark"), the figure shows the impulse responses under three alternative policy regimes. The first alternative regime that we consider features a partial lift of capital controls (labeled "Open capital account"), the second alternative regime features a floating exchange rate (labeled "Flex exchange rate"), and the third alternative regime features a combination of opening the capital account and letting the exchange rate to float (labeled "Full reform").

Consider first the regime with an open capital account (the dashed lines). Similar to the benchmark case (the solid lines), the decline in the foreign interest rate reduces the country's earnings on foreign assets and thus lowers the current account surplus. This effect leads to lowered national income and aggregate demand and is thus disinflationary. However, since the capital account is open, the central bank does not need to sterilize, and hence does not respond to an increase in the cost of sterilization. As a result, the holdings of domestic bonds by the private sector rise relative to the steady state, rather than falling as in the benchmark case; and the drop in domestic interest rates is quite modest as well. Because the central bank does not respond aggressively, inflation no longer rises in the short run; instead, there is some modest disinflation following a negative shock to the foreign interest rate. There is also a fall in GDP, but the deviation from the steady state is smaller in absolute value than in the benchmark case.

Figure 6 shows the impulse responses for a few other macroeconomic variables in our model. Consider again the impulse responses under the "Open capital account" regime (the dashed lines). As in the benchmark case, the exchange rate peg is maintained, so the nominal exchange rate remains at its steady-state level throughout. The short-run decrease in inflation, combined with the constant nominal exchange rate, results in a real exchange rate depreciation (i.e., the real exchange rate rises above the steady-state level) and a short-run movement of the current account into surplus, despite the decline in interest earnings on foreign assets. This stimulates exports and over time – combined with the return of foreign interest rates to their steady state levels – helps to bring GDP and the other variables back to their steady-state levels as well.

IV.2. **Exchange rate floating.** We next turn to the alternative regime where the central bank lifts its exchange rate peg but maintains capital controls. Relative to the benchmark case, all of the equations remain the same. The only distinction is that instead of the exchange rate being fixed at its steady-state level, the nominal anchor is provided by a money growth rule.

The impulse responses of macroeconomic variables under the floating exchange rate regime following a negative shock to the foreign interest rate are shown in Figures 5 and 6 (see the dashed and dotted lines, labeled "Flex exchange rate"). The decline in the foreign interest rate again directly lowers the country's earnings on foreign assets and reduces the current account surplus, leading to lower national income and aggregate demand. Similar to the benchmark case, the central bank maintains a closed capital account and sterilizes its purchases of foreign capital inflows. Since the foreign interest rate shock raises the cost of sterilization, the central bank responds by appreciating the nominal exchange rate and therefore reducing the amount of foreign capital inflows through current account surpluses. Since prices are sticky, the nominal appreciation leads a substantial real appreciation and a large reduction in current account surpluses relative to the steady-state level (see Figure 6). Persistent declines in the current account surplus lead to a reduction in the holdings of foreign bond relative to GDP (see the lower-right panel in Figure 5), which mitigates the costs of sterilization. The decline in the current account surpluses leads to a short-run recession and disinflation (see the two top panels in Figure 5).

Different from the benchmark case, however, letting the exchange rate to float does not give rise to inflation when the foreign interest rate declines. The central bank can rely on exchange rate appreciation instead of money-supply increases to mitigate the increased costs of sterilization.

IV.3. **Floating exchange rate and liberalized capital account.** Finally, we consider the case where both the exchange rate is allowed to float and the capital account is liberalized. The impulse responses under this regime are shown in Figures 5 and 6 (see the dotted lines, labeled "Full reform").

Because the capital account is open, there is no sterilization taking place, and therefore almost no adjustment in the ratio of domestic bonds to GDP. There is also almost no movement in the domestic interest rate. We do see a modest rise in inflation and a modest initial increase in real GDP followed by a persistent decline relative to its steady state value.

Because of the decline in interest earnings on foreign bonds associated with the foreign interest rate shock, there would be an initial decline in the current account, which puts a drag on real GDP. However, the central bank mitigates the effects of this shock by depreciating the nominal exchange rate which, with sticky prices, results in a real exchange rate depreciation.[20] This real exchange rate depreciation stabilizes the current account relative to the benchmark case, as happened with the floating exchange rate regime, but does so without the initial decline in GDP suffered under that regime.

IV.4. **Welfare outcomes.** We compute the welfare losses under each of the four policy regimes. We evaluate the welfare loss under each regime using the loss function in equation (34). In particular, for each regime, we simulate the model under optimal policy and compute the variances of the four variables in the loss function, including inflation, real GDP, domestic interest rate, and the ratio of foreign bond holdings to GDP. We then use the calibrated welfare weights to evaluate the welfare loss for a particular regime.

Table 2 displays the welfare loss and the components for each of the four loss function variables. The regime with a floating exchange rate and an open capital account incurs the smallest welfare loss among the four regimes. The regime with a floating exchange rate but with a closed capital account results in the highest welfare loss, with the loss stemming mainly from fluctuations in the ratio of foreign bond holdings to GDP. Under that regime, the central bank responds to the increase in sterilization costs from a foreign interest rate shock by substantially appreciating its currency. The policy response leads to a large and persistent reduction in current account surpluses and thus a large and persistent decline in foreign bond holdings relative to GDP. Although the central bank assigns a small weight to the variance of foreign bond to GDP ratio, the large fluctuations in that variable result in a large welfare loss relative to the other three regimes.

The benchmark regime with both a fixed exchange rate and a closed capital account implies a larger welfare loss than the regimes with an open capital account (with or without floating exchange rates). The largest welfare gains come from liberalizing the capital account. Comparing the partial-liberalization open capital account and fixed exchange rate regime with full reform, the reduction in welfare losses stemming from letting exchange rate float appears small relative to the reduction in welfare losses

[20]Note that the nominal exchange rate adjustment is possible given our money growth rule and open capital account because of imperfect asset substitutability.

when the central bank moves from the benchmark regime to the one with an open capital account. This result is not surprising since removing capital controls eliminates the costs of sterilization. In this sense, our finding suggests that costly sterilization is an important constraint for the central bank's optimal stabilizing policy.

Our results are in contrast with some of the literature, such as (Prasad, Rumbaugh, and Wang, 2005) who advocate allowing the exchange rate to float in China, even if capital account liberalization is not pursued. Indeed, they argue that exchange rate liberalization should be a prerequisite for undertaking successful capital account liberalization.

The distinction between their policy prescription and ours is the consideration of sterilization costs under the closed capital account. Recall that in the steady state these costs are actually negative, implying that the government received a benefit from its sterilization activities. However, the sharp declines in global interest rates after the financial crisis reversed the sign of this spread, and in so doing, also reduced markedly the desirability of allowing the nominal exchange rate to float in isolation. Nevertheless, it is important to remember that the best policy outcome in our framework was achieved by letting the exchange rate float and opening the capital account, so the results here do not really argue against exchange rate flexibility in China. Indeed, our results appear sympathetic to the contention in (Prasad, Rumbaugh, and Wang, 2005) that a fixed exchange rate regime masks underlying policy and institutional weaknesses. In particular, the difficulties with exchange rate flexibility that we encounter are associated with the closed capital account. That is why the best policy option is to open both simultaneously.

V. Conclusion

In this paper, we examine optimal monetary policy under a set of currently prevailing Chinese policies – including capital controls, swaps of domestic for foreign assets with exporters at favorable terms, and exchange rate targets – in a DSGE model calibrated to Chinese and global data.

We find that optimal Chinese monetary policy responds to sterilization costs. In particular, given a negative shock to relative foreign interest rates, similar to that which occurred during the global financial crisis, optimal policy calls for a reduction in sterilization activity, resulting in an easing of monetary policy and an increase in Chinese inflation.

We then examine three alternative liberalization policies: opening the capital account, letting the exchange rate float, or doing both simultaneously. We evaluate the welfare performances of these three alternative regimes under the same foreign interest shock. Our results suggest that the regime that combines an open capital account with a floating exchange rate performs best in weathering the foreign interest rate shock and results in the lowest losses to the central bank. Intermediate reforms do less well, with the regime with a pegged exchange rate and an open capital account outperforming that with a floating exchange rate and a closed capital account. We further show that opening the capital account results in large welfare gains even if the central bank continues to peg the exchange rate. Opening the capital account eliminates the need for sterilization. Thus, increases in the costs of sterilization following a negative foreign interest rate shock are no longer a constraint for optimal monetary policy.

As we focus on a stylized model for China, we do not want to push the numerical differences too aggressively. Nevertheless, the qualitative differences across the alternative liberalizations do illustrate intuitive reasons for our preference for liberalizing both the exchange rate and the capital account. Such policy reform would allow the central bank to adjust the exchange rate to respond to external shocks without concerns about the potential costs of sterilizing capital inflows, because the capital account liberalization eliminates the need to sterilize entirely. Under this regime, the central bank would be able to stabilize fluctuations in inflation and real GDP without costly abrupt changes in either its foreign asset portfolio or domestic nominal interest rates.

Appendix A. Equilibrium conditions

In this appendix, we summarize the stationary equilibrium conditions on the balanced growth path, define the steady-state equilibrium, and characterize the equilibrium dynamics.

A.1. **The balanced growth path.**

On a balanced growth path, output, intermediate inputs, consumption, real money balances, current account balances, real domestic debt, real foreign asset holdings, and the real wage rate all grow at a constant rate. To obtain balanced growth, we make the stationary transformations

$$\tilde{Y}_t = \frac{Y_t}{Z_t^p}, \quad \tilde{\Gamma}_{ht} = \frac{\Gamma_{ht}}{Z_t^p}, \quad \tilde{\Gamma}_{ft} = \frac{\Gamma_{ft}}{Z_t^p}, \quad \tilde{C}_t = \frac{C_t}{Z_t^p}, \quad \tilde{ca}_t = \frac{ca_t}{Z_t^p},$$
$$\tilde{m}_t = \frac{M_t}{\bar{P}_t Z_t^p}, \quad \tilde{b}_t = \frac{B_t}{P_t Z_t^p}, \quad \tilde{b}_t^* = \frac{B_t^*}{P_t^* Z_t^p}, \quad \tilde{w}_t = \frac{w_t}{Z_t^p}.$$

On the balanced growth path, the transformed variables (e.g., $\tilde{Y}_t$), the interest rate, the inflation rate, and the real exchange rate are all constant.

The balanced growth equilibrium is summarized by the following equations:

$$\frac{\theta_w}{\theta_w - 1}\Phi_l L_t^\eta \tilde{C}_t = \tilde{w}_t - \frac{\Omega_w}{\theta_w - 1}\frac{\tilde{C}_t}{L_t}\left[\left(\frac{\pi_t^w}{\pi^w} - 1\right)\frac{\pi_t^w}{\pi^w} - \beta \mathrm{E}_t\left(\frac{\pi_{t+1}^w}{\pi^w} - 1\right)\frac{\pi_{t+1}^w}{\pi^w}\right] \tag{45}$$

$$1 = \mathrm{E_t}\beta\frac{\tilde{\Lambda}_{\mathrm{t+1}}}{\tilde{\Lambda}_{\mathrm{t}}\lambda_{\mathrm{z,t+1}}}\frac{\mathrm{R_t}}{\pi_{\mathrm{t+1}}}, \tag{46}$$

$$\frac{\Phi_m}{\tilde{m}_t\tilde{\Lambda}_t} = \frac{R_t - 1}{R_t}, \tag{47}$$

$$\tilde{\Lambda}_t = \frac{1}{\tilde{C}_t - \chi\tilde{C}_{t-1}/\lambda_{zt}} - \mathrm{E_t}\frac{\beta\chi}{\tilde{\mathrm{C}}_{\mathrm{t+1}}\lambda_{\mathrm{z,t+1}} - \chi\tilde{\mathrm{C}}_{\mathrm{t}}}, \tag{48}$$

$$v_t = \tilde{\phi} q_{mt}^\phi \left(\frac{\tilde{w}_t}{Z_t^m}\right)^{1-\phi}, \tag{49}$$

$$\tilde{w}_t = (1-\phi)\frac{v_t\tilde{Y}_t}{L_t}, \tag{50}$$

$$\tilde{\Gamma}_t = \tilde{\Gamma}_{ht}^\alpha \tilde{\Gamma}_{ft}^{1-\alpha}, \tag{51}$$

$$q_{mt} = \tilde{\alpha} q_t^{1-\alpha}, \tag{52}$$

$$q_t = \frac{1-\alpha}{\alpha}\frac{\tilde{\Gamma}_{ht}}{\tilde{\Gamma}_{ft}}, \tag{53}$$

$$\frac{q_t}{q_{t-1}} = \gamma_{et}\frac{\pi_t^*}{\pi_t}, \tag{54}$$

$$\frac{\theta_p - 1}{\theta_p} = v_t - \frac{\Omega}{\theta_p}\frac{\tilde{C}_t}{\tilde{Y}_t}\left[\left(\frac{\pi_t}{\pi} - 1\right)\frac{\pi_t}{\pi} - \beta \mathrm{E_t}\left(\frac{\pi_{\mathrm{t+1}}}{\pi} - 1\right)\frac{\pi_{\mathrm{t+1}}}{\pi}\right], \quad (55)$$

$$\tilde{ca}_t = \tilde{X}_t - q_t\tilde{\Gamma}_{ft} + q_t(R^*_{t-1} - 1)\frac{\tilde{b}^*_{t-1}}{\pi^*_t\lambda_{zt}}, \quad (56)$$

$$\tilde{X}_t = q_t^{\theta}\tilde{X}^*_t, \quad (57)$$

$$\tilde{ca}_t = q_t\left[\tilde{b}^*_t - \frac{\tilde{b}^*_{t-1}}{\pi^*_t\lambda_{zt}}\right], \quad (58)$$

$$q_t\left[\tilde{b}^*_t - \frac{\tilde{b}^*_{t-1}R^*_{t-1}}{\pi^*_t\lambda_{zt}}\right] = \tilde{b}_t - \frac{\tilde{b}_{t-1}R_{t-1}}{\pi_t\lambda_{zt}} + \tilde{m}_t - \frac{\tilde{m}_{t-1}}{\pi_t\lambda_{zt}}, \quad (59)$$

$$\tilde{Y}_t = \tilde{C}_t + \tilde{\Gamma}_{ht} + \tilde{X}_t + \left[\frac{\Omega_p}{2}\left(\frac{\pi_t}{\pi} - 1\right)^2 + \frac{\Omega_w}{2}\left(\frac{\pi^w_t}{\pi^w} - 1\right)^2\right]\tilde{C}_t, \quad (60)$$

$$\tilde{Y}_t = \tilde{\Gamma}^{\phi}_t\left(Z^m_t L_t\right)^{1-\phi}, \quad (61)$$

$$\frac{\tilde{m}_t}{\tilde{m}_{t-1}} = \frac{\mu_t}{\pi_t\lambda_{zt}}, \quad (62)$$

$$G\tilde{D}P_t = \tilde{C}_t + \tilde{X}_t - q_t\tilde{\Gamma}_{ft}. \quad (63)$$

$$\frac{\tilde{w}_t}{\tilde{w}_{t-1}} = \frac{\pi^w_t}{\pi_t\lambda_{zt}}, \quad (64)$$

Under the benchmark policy, the central bank controls the pace at which the nominal exchange rate changes (i.e., it controls $\gamma_{et} = e_t/e_{t-1}$). With perfect capital control, the central bank can maintain an exchange rate peg and simultaneously set domestic monetary policy. In principle, the central bank can use either the money growth rate μ_t or the nominal interest rate R_t as a policy instrument. We focus on the money growth rate as a domestic monetary policy instrument since it better describes Chinese monetary policy. We also consider a type of Taylor rule under which the central bank sets the nominal interest rate in response to deviations of domestic inflation from a target and deviations of real GDP from its trend growth path.

Given that the nominal exchange rate growth γ_{et} and the money growth rate μ_t are both set by the central bank, the system of 19 equations from (45) to (64) determine the equilibrium solution for the 20 endogenous variables summarized in the vector

$$[\tilde{C}_t, L_t, \tilde{w}_t, R_t, \pi_t, \tilde{\Lambda}_t, \tilde{m}_t, q_{mt}, v_t, \tilde{\Gamma}_t, \tilde{\Gamma}_{ht}, \tilde{\Gamma}_{ft}, q_t, \tilde{ca}_t, \tilde{X}_t, \tilde{b}^*_t, \tilde{b}_t, \tilde{Y}_t, G\tilde{D}P_t, \pi^w_t].$$

A.2. **Steady state.** A deterministic steady state is a balanced growth path without any shocks. In particular, the steady-state equilibrium is a solution to the following system of equations:

$$\tilde{w} = \frac{\theta_w}{\theta_w - 1}\Phi_l L^{\eta}\tilde{C}, \quad (65)$$

$$\frac{\lambda_z}{\beta} = \frac{R}{\pi}, \quad (66)$$

$$\frac{\Phi_m}{\tilde{m}\tilde{\Lambda}} = \frac{R-1}{R}, \quad (67)$$

$$\tilde{\Lambda} = \frac{1}{\tilde{C}}\frac{\lambda_z - \beta\chi}{\lambda_z - \chi}, \quad (68)$$

$$v = \tilde{\phi} q_m^{\phi} \tilde{w}^{1-\phi}, \quad (69)$$

$$\tilde{w} = (1-\phi)\frac{v\tilde{Y}}{L}, \quad (70)$$

$$\tilde{\Gamma} = \tilde{\Gamma}_h^{\alpha}\tilde{\Gamma}_f^{1-\alpha}, \quad (71)$$

$$q_m = \tilde{\alpha} q^{1-\alpha}, \quad (72)$$

$$q = \frac{1-\alpha}{\alpha}\frac{\tilde{\Gamma}_h}{\tilde{\Gamma}_f}, \quad (73)$$

$$1 = \frac{\gamma_e \pi^*}{\pi}, \quad (74)$$

$$\frac{\theta_p - 1}{\theta_p} = v, \quad (75)$$

$$\tilde{ca} = \tilde{X} - q\tilde{\Gamma}_f + \frac{q(R^* - 1)\tilde{b}^*}{\pi^* \lambda_z}, \quad (76)$$

$$\tilde{X} = q^{\theta}\tilde{X}^*, \quad (77)$$

$$\tilde{ca} = q\tilde{b}^*\left[1 - \frac{1}{\pi^*\lambda_z}\right], \quad (78)$$

$$q\tilde{b}^*\left[1 - \frac{R^*}{\pi^*\lambda_z}\right] = \tilde{b}\left[1 - \frac{1}{\beta}\right] + \tilde{m}\left[1 - \frac{1}{\mu}\right], \quad (79)$$

$$\tilde{Y} = \tilde{C} + \tilde{\Gamma}_h + \tilde{X}, \quad (80)$$

$$\tilde{Y} = \tilde{\Gamma}^{\phi}\left(\bar{Z}^m L\right)^{1-\phi}, \quad (81)$$

$$1 = \frac{\mu}{\pi\lambda_z}, \quad (82)$$

$$\tilde{GDP} = \tilde{C} + \tilde{X} - q\tilde{\Gamma}_f, \quad (83)$$

$$\pi^w = \pi\lambda_z. \quad (84)$$

A.3. **Log-linearized equilibrium conditions.** To characterize equilibrium dynamics under given monetary policy, we log-linearize the equilibrium conditions around the balanced growth path. The equilibrium dynamics are summarized in the following set of equations.

$$\hat{\pi}_t^w = \kappa_w\left(\eta\hat{L}_t + \hat{C}_t - \hat{w}_t\right) + \beta \mathrm{E}_t\hat{\pi}_{t+1}^w, \tag{85}$$

$$0 = \mathrm{E_t}\left[\hat{\Lambda}_{t+1} - \hat{\Lambda}_t - \hat{\lambda}_{z,t+1} + \hat{R}_t - \hat{\pi}_{t+1}\right], \tag{86}$$

$$\hat{m}_t + \hat{\Lambda}_t = -\frac{1}{R-1}\hat{R}_t, \tag{87}$$

$$\Omega_c\hat{\Lambda}_t = -(\lambda_z^2 + \beta\chi^2)\hat{C}_t + \lambda_z\chi\hat{C}_{t-1} + \beta\chi\lambda_z \mathrm{E_t}\hat{C}_{t+1} - \lambda_z\chi(1-\beta\rho_{z^p})\hat{\lambda}_{zt}, \tag{88}$$

$$\hat{v}_t = \phi\hat{q}_{mt} + (1-\phi)(\hat{w}_t - \hat{Z}_t^m), \tag{89}$$

$$\hat{w}_t = \hat{v}_t + \hat{Y}_t - \hat{L}_t, \tag{90}$$

$$\hat{\Gamma}_t = \alpha\hat{\Gamma}_{ht} + (1-\alpha)\hat{\Gamma}_{ft}, \tag{91}$$

$$\hat{q}_{mt} = (1-\alpha)\hat{q}_t, \tag{92}$$

$$\hat{q}_t = \hat{\Gamma}_{ht} - \hat{\Gamma}_{ft}, \tag{93}$$

$$\hat{q}_t = \hat{q}_{t-1} + \hat{\gamma}_{et} + \hat{\pi}_t^* - \hat{\pi}_t, \tag{94}$$

$$\hat{\pi}_t = \beta \mathrm{E_t}\hat{\pi}_{t+1} + \frac{\theta_p - 1}{\Omega}\frac{\tilde{C}}{\tilde{Y}}\hat{v}_t, \tag{95}$$

$$\tilde{ca}\hat{ca}_t = \tilde{X}\hat{X}_t - q\tilde{\Gamma}_f(\hat{q}_t + \hat{\Gamma}_{ft}) + \frac{q(R^*-1)\tilde{b}^*}{\pi^*\lambda_z}\left(\hat{q}_t + \frac{R^*}{R^*-1}\hat{R}_{t-1}^* + \hat{b}_{t-1}^* - \hat{\pi}_t^* - \hat{\lambda}_{zt}\right), \tag{96}$$

$$\hat{X}_t = \theta\hat{q}_t + \hat{X}_t^*, \tag{97}$$

$$\frac{\tilde{ca}}{q\tilde{b}^*}\hat{ca}_t = \left(1 - \frac{1}{\pi^*\bar{\lambda}_z}\right)\hat{q}_t + \hat{b}_t^* - \frac{1}{\pi^*\bar{\lambda}_z}\left(\hat{b}_{t-1}^* - \hat{\pi}_t^* - \hat{\lambda}_{zt}\right), \tag{98}$$

$$\begin{aligned}\hat{m}_t = {} & \frac{1}{\pi\bar{\lambda}_z}(\hat{m}_{t-1} - \hat{\pi}_t - \hat{\lambda}_{zt}) - \frac{\tilde{b}}{\tilde{m}}\left[\hat{b}_t - \frac{R}{\pi\bar{\lambda}_z}(\hat{b}_{t-1} + \hat{R}_{t-1} - \hat{\pi}_t - \hat{\lambda}_{zt})\right] \\ & + \frac{q\tilde{b}^*}{\tilde{m}}\left[\left(1 - \frac{R^*}{\pi^*\bar{\lambda}_z}\right)\hat{q}_t + \hat{b}_t^* - \frac{R^*}{\pi^*\bar{\lambda}_z}(\hat{b}_{t-1}^* + \hat{R}_{t-1}^* - \hat{\pi}_t^* - \hat{\lambda}_{zt})\right],\end{aligned} \tag{99}$$

$$\hat{Y}_t = \frac{\tilde{C}}{\tilde{Y}}\hat{C}_t + \frac{\tilde{\Gamma}_h}{\tilde{Y}}\hat{\Gamma}_{ht} + \frac{\tilde{X}}{\tilde{Y}}\hat{X}_t, \tag{100}$$

$$\hat{Y}_t = \phi\hat{\Gamma}_t + (1-\phi)(\hat{Z}_t^m + \hat{L}_t), \tag{101}$$

$$\hat{m}_t = \hat{m}_{t-1} + \hat{\mu}_t - \hat{\pi}_t - \hat{\lambda}_{zt}, \tag{102}$$

$$\hat{GDP}_t = \frac{\tilde{C}}{\tilde{GDP}}\hat{C}_t + \frac{\tilde{X}}{\tilde{GDP}}\hat{X}_t - \frac{q\tilde{\Gamma}_f}{\tilde{GDP}}(\hat{q}_t + \hat{\Gamma}_{ft}), \tag{103}$$

$$\hat{w}_t = \hat{w}_{t-1} + \hat{\pi}_t^w - \hat{\pi}_t - \lambda_{zt}, \tag{104}$$

where, in (88), the term Ω_c is given by $\Omega_c = (\bar{\lambda}_z - \chi)(\bar{\lambda}_z - \beta\chi)$.

A.4. **Equilibrium conditions under partial capital controls.** The log-linearized equilibrium conditions are identical to those in the benchmark economy except for the following.

First, a modified UIP condition needs to be added:

$$\hat{R}_t - \hat{R}_t^* = \mathrm{E}_t \hat{\gamma}_{e,t+1} + \Omega_b \bar{\psi} \hat{\psi}_t, \tag{105}$$

Second, the portfolio share $\hat{\psi}_t$ is defined:

$$\hat{\psi}_t = (1 - \bar{\psi})(\hat{b}_t - \hat{q}_t - \hat{b}_{pt}^*). \tag{106}$$

Third, since foreign bonds are held by both the government and the private sector, the total holdings of foreign bonds are given by

$$\hat{b}_t^* = \frac{\tilde{b}_p^*}{\tilde{b}^*} \hat{b}_{pt}^* + \frac{\tilde{b}_g^*}{\tilde{b}^*} \hat{b}_{gt}^*. \tag{107}$$

Finally, the government budget equation (99) is replaced by

$$\begin{aligned} \hat{m}_t \quad = \quad & \frac{1}{\pi \bar{\lambda}_z}(\hat{m}_{t-1} - \hat{\pi}_t - \hat{\lambda}_{zt}) - \frac{\tilde{b}}{\tilde{m}} \left[\hat{b}_t - \frac{R}{\pi \bar{\lambda}_z} (\hat{b}_{t-1} + \hat{R}_{t-1} - \hat{\pi}_t - \hat{\lambda}_{zt}) \right] \\ & + \frac{q \tilde{b}_g^*}{\tilde{m}} \left[\left(1 - \frac{R^*}{\pi^* \bar{\lambda}_z} \right) \hat{q}_t + \hat{b}_{gt}^* - \frac{R^*}{\pi^* \bar{\lambda}_z} (\hat{b}_{g,t-1}^* + \hat{R}_{t-1}^* - \hat{\pi}_t^* - \hat{\lambda}_{zt}) \right]. \end{aligned} \tag{108}$$

Table 1. Calibrated parameters

Parameter	Description	value
	Preferences	
β	Subjective discount factor	0.998
Φ_m	Utility weight on money balances	0.06
η	Inverse Frisch elasticity	10
	Technologies	
ϕ	Cost share of intermediate goods	0.50
$\bar{\lambda}_z$	Mean productivity growth rate	1.02
	Nominal rigidities	
θ_p	Elasticity of substitution between differentiated goods	10
Ω_p	Price adjustment cost	30
θ_w	Elasticity of substitution between differentiated labor skills	10
Ω_w	Nominal wage adjustment cost	100
	International trade	
α	Share of domestic intermediate goods	0.70
θ	Export demand elasticity	1.5
	Loss function	
λ_π	Weight on inflation	1
λ_y	Weight on GDP	0.05
λ_b	Weight on foreign bond	0.01
λ_r	Weight on interest rate	5
	Parameters specific to partial lifts of capital controls	
Ω_b	Portfolio adjustment cost parameter	0.22
$\bar{\psi}$	Average portfolio share of domestic bonds	0.90
ϑ	Average share of foreign bonds held by private sector	0.55

Table 2. Stabilization effects and welfare losses under alternative policy regimes

Regime	Welfare Loss	Welfare components: Inflation	GDP	Interest rate	Foreign bond
Benchmark regime	0.98	0.02	0.20	0.37	0.40
Capital controls lifted	0.24	0.02	0.16	0.02	0.03
Exchange rate pegs removed	2.97	0.01	0.06	0.00	2.91
Full reform	0.16	0.01	0.14	0.00	0.01

Note: All numbers are percentage points. Welfare is a weighted average of the variances of the term terms in the planner's objective function. The last four columns display the contributions of each of the four terms to the welfare loss under each regime (so that the sum of the four terms should equal the total welfare loss). Benchmark regime features both capital controls and nominal exchange rate pegs. The regime with capital controls lifted keeps nominal exchange rate pegs; the regime with exchange rate pegs lifted keeps capital controls in place; and the regime with full reform removes both capital controls and exchange rate pegs.

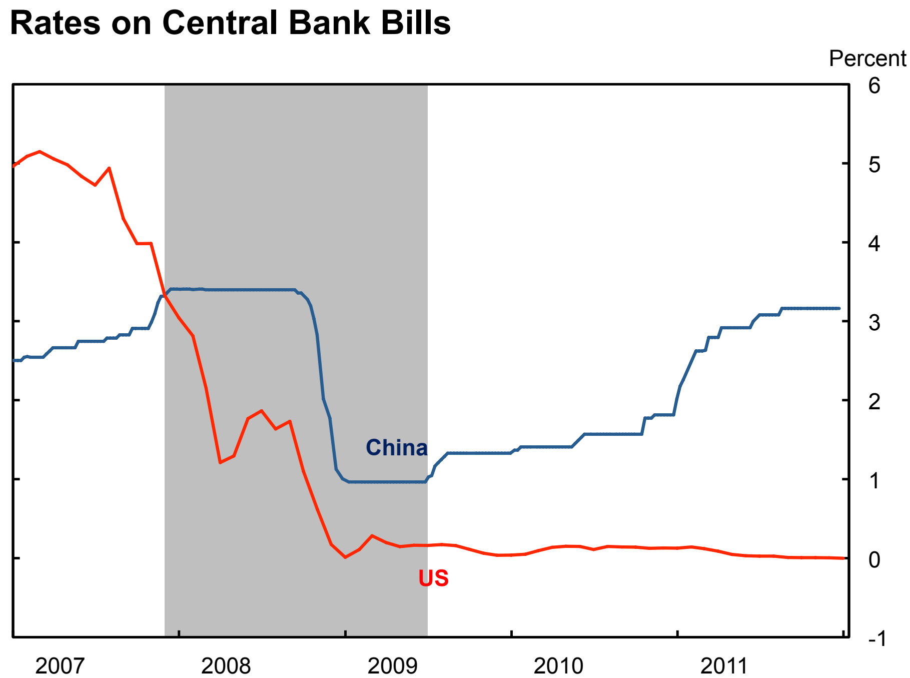

FIGURE 1. China's three-month central bank bills rate vs. U.S. three-month Treasury bills rate.

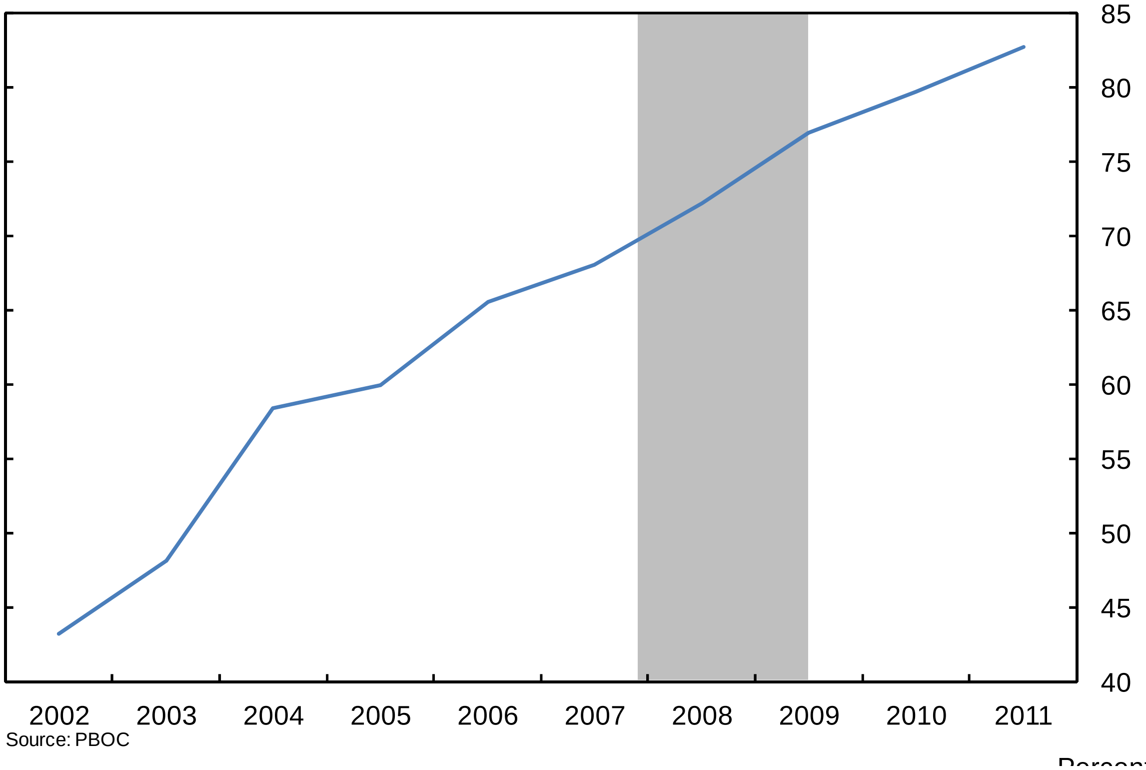

Figure 2. Foreign reserves as a share of total assets for the People's Bank of China.

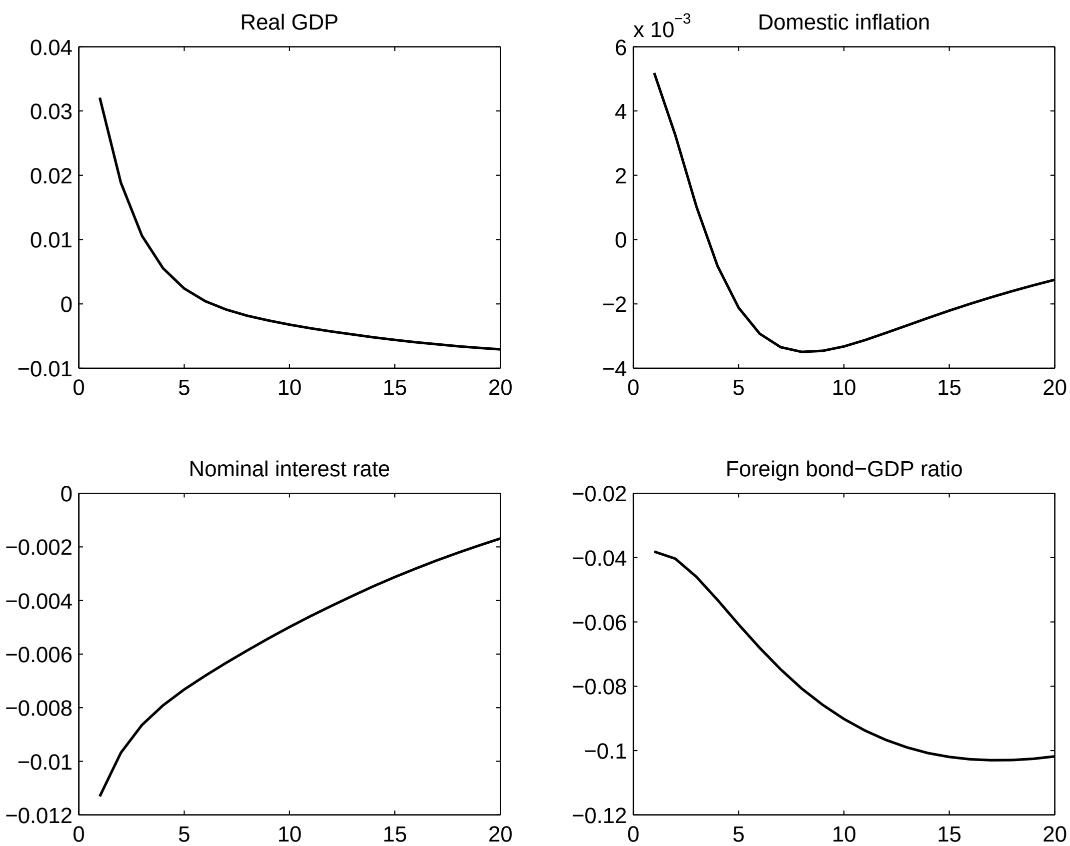

FIGURE 3. Impulse responses of policy variables following a persistent decline in the foreign interest rate in the benchmark model.

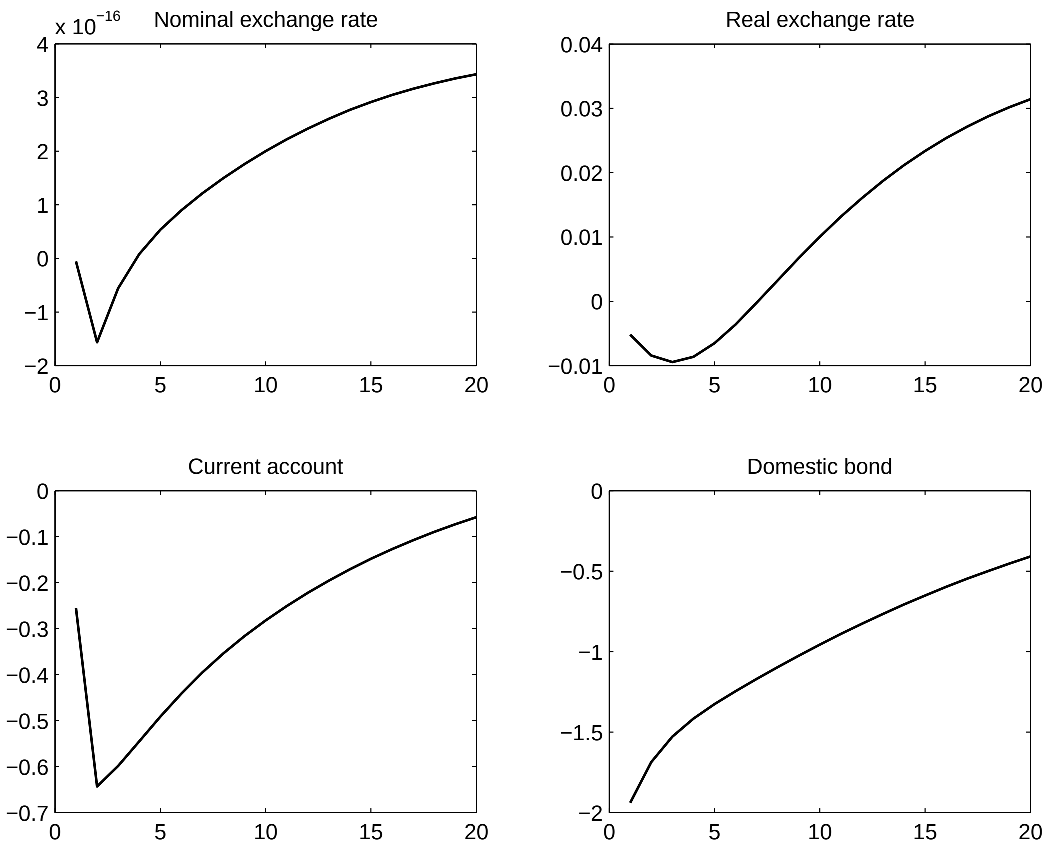

FIGURE 4. Impulse responses of other macroeconomic variables following a persistent decline in the foreign interest rate in the benchmark model.

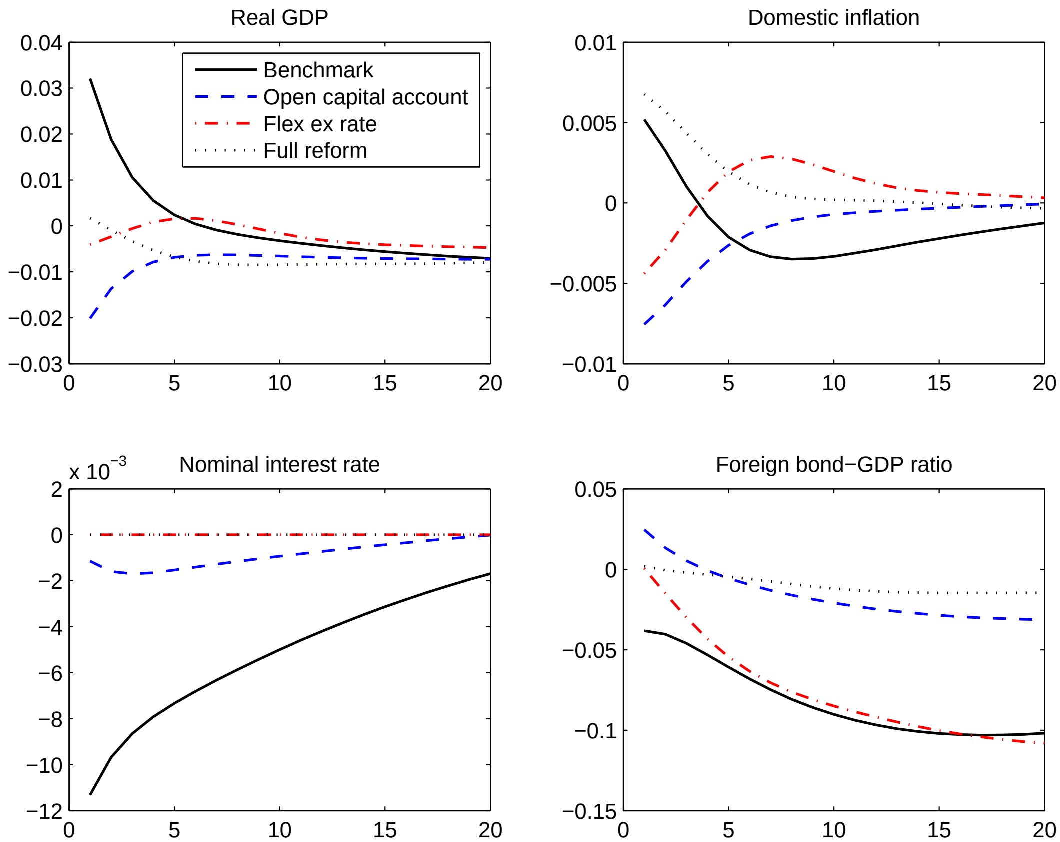

FIGURE 5. Impulse responses of policy variables following a persistent decline in the foreign interest rate: Alternative policy regimes

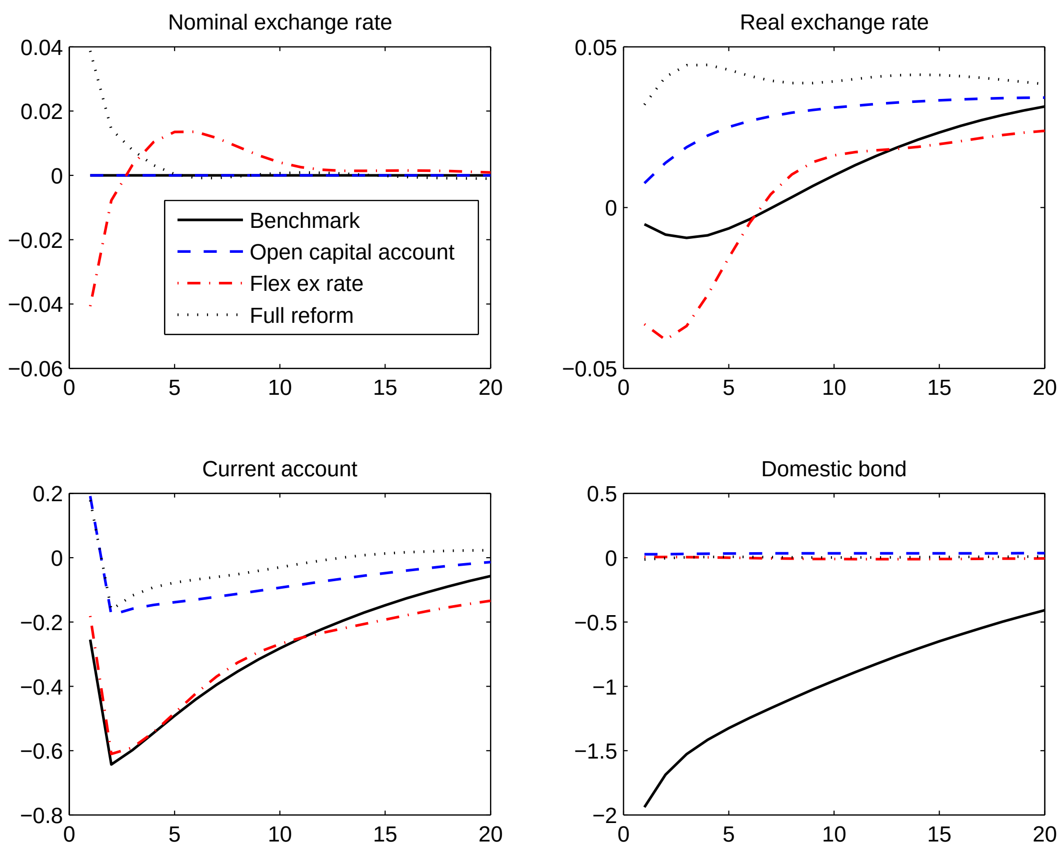

FIGURE 6. Impulse responses of other macroeconomic variables following a persistent decline in the foreign interest rate: Alternative policy regimes

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