CAPITAL CONTROLS AND OPTIMAL CHINESE MONETARY POLICY

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Abstract. We examine optimal monetary policy under prevailing Chinese policies – including capital controls, nominal exchange rate targets, and costly sterilization of foreign capital inflows. China's combination of capital controls and exchange rate pegs disrupts its monetary policy, precluding adjustments that could maintain macroeconomic stability following a set of shocks that mirror its experience during the global financial crisis. However, comparing different policy regimes in a consistent DSGE framework, we find that the bulk of welfare gains achieved under full liberalization can be obtained by liberalizing either the capital account or the exchange rate.

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I. Introduction

China has experienced substantive current account surpluses and large capital inflows in the past decade. Under its current policy regime, however, China's capital account is effectively closed. The combination of current account surpluses and restrictions on domestic citizens' access to foreign asset markets necessitates intervention by the People's Bank of China (PBOC)—China's central bank—to absorb foreign capital inflows. Exporters swap their foreign-currency revenues with the PBOC at the ongoing exchange rates for either domestic currency or bonds.[1] The portion of foreign asset purchases 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.

In this paper, we evaluate optimal sterilization policy in China —consistent with other maintained Chinese policies— in a dynamic stochastic general equilibrium (DSGE) model with microeconomic foundations. The maintained policies that we incorporate in the model include capital account restrictions, an exchange rate target, and a desire to maintain the stability of the real exchange rate.[2]

Given these constraints, we investigate optimal Chinese monetary policy in response to external shocks. In particular, we focus on studying optimal policy responses to the sudden declines in foreign interest rates subsequent to 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

[1]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 fiscal policies as given, including taxing the banking sector through reserve requirements and quantitative restrictions on capital movements, such as administrative controls.

[2]The PBOC's stated objective of monetary policy is to "maintain the stability of the value of the currency and thereby promote economic growth." Since the PBOC has kept the nominal exchange rate under tight controls, we interpret the stated objective of monetary policy as a desire to maintain the stability of the real exchange rate (e.g., against fluctuations in the terms of trade).

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 (see Figure 1).

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 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.[3]

Sterilization becomes even more challenging when countries run large trade surpluses and foreign reserves accumulate rapidly. Figure 2 shows that the share of foreign currency reserves in total PBOC assets has grown from just over 40 percent in 2002 to more than 80 percent in 2011. 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)].

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: The government maintains a closed capital account, so that private

[3]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. The literature was aware of this issue, and therefore referred to these costs as "quasi-fiscal costs." In contrast, China's closed capital account allows deviations from UIP, so that observed deviations in bond yields represent true expected costs of sterilization as expected default risk is minimal for both Chinese government bonds and US Treasuries.

agents are restricted to hold a very small share of China's foreign currency assets. In addition, domestic bonds and foreign bonds are imperfect substitutes so that the standard uncovered interest rate parity (UIP) condition does not hold. The government also controls the pace of appreciation (or depreciation) of the nominal exchange rate. The central bank takes these institutional restrictions as given in formulating its monetary policy.[4]

The central bank can sterilize its foreign asset purchases by exchanging domestic-currency bonds for these assets at the prevailing exchange rate. We assume that the government seeks to stabilize fluctuations in domestic inflation and real GDP. In addition, to stay consistent with the stated objective of China's monetary policy, we assume that the government is committed to avoiding excessive fluctuations in the real exchange 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. The government responds to this increase in the cost of sterilization by reducing its sales of domestic assets and financing a greater portion of its foreign reserve purchases through money creation. As a result, inflation rises.

We then study the implications for macroeconomic stability under external shocks (including a foreign interest rate shock, an export demand shock, and a terms of trade shock) under three alternative liberalizations: (i) Opening the capital account 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 an open capital account. Our unified DSGE framework allows for consistent comparison across these regimes.

Not surprisingly, full reform performs the best in terms of macroeconomic stability. However, we also find that either partial reform – lifting capital controls or releasing exchange rate pegs while leaving the other restriction intact – can achieve most of the stability gains. Under a regime with an open capital account, the PBOC faces no requirement to manage foreign export revenues. As we assume imperfect asset substitutability, it can conduct independent monetary policy for stabilizing macroeconomic fluctuations even if the nominal exchange rate is kept fixed. Under a floating exchange

[4]Despite the exchange rate management, the well-known "trilemma" argument suggests that China's central bank can conduct independent monetary policy to the extent that the capital account remains closed.

rate regime, on the other hand, the central bank gains the flexibility of adjusting the exchange rate to reduce external imbalances, and thus is better able to respond to external shocks, even though the capital account remains relatively closed.

The remainder of this paper is divided into five sections. Section II provides a brief review of the literature on optimal monetary policy in a DSGE framework. Section III introduces the benchmark DSGE model with pegged exchange rates and a closed capital account. Section IV 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 V examines the optimal policy under the three alternative liberalizations and compare welfare implications of each regime. Section VI provides some concluding remarks.

II. Literature on Optimal Monetary Policy

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 the divine coincidence breaks down in more general environments, such as one with multiple sources of nominal rigidities. 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).[5]

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 restricted 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

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

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.[6]

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, Chamon, Qureshi, and Reinhart (2010)], as it is unclear that financial integration reduces macroeconomic volatility.[7] 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 that those policies imply for an optimizing central bank faced with a persistent current account surplus.

III. 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 describing the home country and make explicit assumptions about the foreign country where necessary.

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 that the markets for differentiated labor skills and retail goods are monopolistically competitive. Each retailer takes all prices but its own as given and sets a price

[6]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.

[7]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.

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.

The representative household faces a segmented asset market, where she has limited access to the foreign bond market. The household is allowed to choose a portfolio of holdings of domestic and foreign currency bonds subject to a quadratic portfolio adjustment cost. With capital controls, however, the household can hold, on average, only a small fraction of the country's total foreign-currency asset. This last assumption captures the relatively closed capital account under China's currency policy regime, while allowing for small "leakages" of foreign assets to be held by the private sector.[8]

We characterize government behavior in a manner broadly consistent with current Chinese institutional features. We assume that the government maintains an exchange rate peg to the foreign currency and sterilizes its current account surplus by exchanging nominal bonds denominated in domestic currency for bonds denominated in foreign currency. We study optimal monetary policy, under which the central bank wishes to smooth fluctuations in inflation, real GDP, and the real exchange rate. In addition, to minimize portfolio adjustment costs for the household, the central bank desires to also smooth fluctuations in the private holdings of foreign assets relative to GDP.

III.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

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

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

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.

[8]Under our calibration, the bulk of the foreign assets (95% on average) is held by the central bank.

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

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

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

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 $W_t = \left[\int_0^1 W_t(i)^{1-\theta_w} di\right]^{\frac{1}{1-\theta_w}}$.

III.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.

The household chooses consumption C_t, money balances M_t, the nominal wage $W(i)_t$, and the holdings of a nominal domestic bond B_t and a foreign 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

$$\begin{aligned} C_t + \frac{M_t}{P_t} + \frac{B_t + e_t B_{pt}^*}{P_t}\left[1 + \frac{\Omega_b}{2}\left(\frac{B_t}{B_t + e_t B_{pt}^*} - \bar{\psi}\right)^2\right] \leq \frac{W_t(i)}{P_t} L_t^d(i) \\ -\frac{\Omega_w}{2}\left(\frac{W_t(i)}{\pi^w W_{t-1}(i)} - 1\right)^2 C_t + \frac{M_{t-1}}{P_t} + \frac{R_{t-1}B_{t-1} + e_t R_{t-1}^* B_{p,t-1}^*}{P_t} + \frac{D_t}{P_t}, \end{aligned} \tag{6}$$

where e_t denotes the nominal exchange rate; Bt and B_{pt}^* denote the household's holdings of domestic and foreign bonds, respectively; R_t and R_t^* denote the nominal interest rates for domestic and foreign bonds, respectively; and D_t denotes the nominal dividends received by the household from her ownership of retail firms. The term E is an expectation operator. The parameter $\beta \in (0,1)$ 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. The parameters Ω_b and Ω_w measure the size of the adjustment costs for the bond portfolio and the nominal wage rate. The parameter $\bar{\psi}$ denotes the steady-state portfolio share of domestic bond in the total value of private bond holdings and the parameter π^w denotes steady-state wage inflation.[9]

Denote by Λ_t the Lagrangian multiplier for the budget constraint (6) and by $m_t \equiv \frac{M_t}{P_t}$ the quantity of real money balances. The optimal money demand equation is given by

$$\frac{\Phi_m}{\Lambda_t m_t} = \frac{R_t - 1}{R_t}. \tag{7}$$

Denote by $\psi_t = \frac{B_t}{B_t + e_t B^*_{pt}}$ the portfolio share of domestic bond in total bond holdings. The optimal choices of B_t and B^*_{pt} imply that

$$\Omega_b(\psi_t - \bar{\psi}) = \mathrm{E}_t \frac{\beta \Lambda_{t+1}}{\Lambda_t} \frac{1}{\pi_{t+1}} \left[R_t - R^*_t \frac{e_{t+1}}{e_t} \right], \tag{8}$$

where $\pi_{t+1} \equiv \frac{P_{t+1}}{P_t}$ denotes the inflation rate from period t to $t+1$.

This equation represents a generalized uncovered interest rate parity (UIP) condition. Absent portfolio adjustment costs (i.e., $\Omega_b = 1$), this equation reduces to the standard UIP condition

$$0 = \mathrm{E}_t \frac{\beta \Lambda_{t+1}}{\Lambda_t} \frac{1}{\pi_{t+1}} \left[R_t - R^*_t \frac{e_{t+1}}{e_t} \right], \tag{9}$$

which equates the relative interest rate $\frac{R_t}{R^*_t}$ to the expected rate of currency depreciation. With the portfolio adjustment costs, however, domestic and foreign bonds are no longer perfect substitutes and the UIP condition needs to be modified to include a new term that depends on the portfolio share of domestic bonds ψ_t. As revealed by equation (8), the portfolio share of domestic bonds depends positively on the spread between domestic interest rate and the exchange-rate adjusted foreign interest rate. Thus, this equation represents a downward-sloping demand curve for domestic bonds: when the relative price of domestic bonds falls (i.e., when the relative nominal interest rate increases), the household's optimal share of domestic bond holdings increases.

The household's optimal wage-setting decisions imply the wage Phillips curve

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

where $w_t = \frac{W_t}{P_t}$ denotes the real wage and $\pi^w_t = \frac{W_t}{W_{t-1}}$ denotes nominal wage inflation. Absent wage 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

[9] Following Huang and Liu (2002), Woodford (2003), and Christiano, Eichenbaum, and Evans (2005), 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.

nominal wage rigidities, the real wage deviates from a constant markup in the short run, according to the wage-setting rule (10).

III.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 follows a random walk process with a drift λ_{zt}, where λ_{zt} satisfies

$$\ln \lambda_{zt} = (1 - \rho_z) \ln \bar{\lambda}_z + \rho_z \ln \lambda_{z,t-1} + \sigma_z \varepsilon_{zt}, \tag{12}$$

where ρ_z is a persistence parameter and σ_z is the standard deviation of the innovation ε_{zt}, which itself follows an i.i.d. standard normal process.

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

$$v_t = \tilde{\phi} q_{mt}^{\phi} \left(\frac{w_t}{Z_t}\right)^{1-\phi}, \tag{13}$$

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

$$\frac{w_t}{q_{mt}} = \frac{1-\phi}{\phi} \frac{\Gamma_t(j)}{L_t(j)}. \tag{14}$$

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

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

where Ω_p measures the size of the price adjustment costs and π is the steady-state inflation rate.[10] In particular, the retailer solves the problem

$$\mathrm{Max}_{P_t(j)} \quad E_t \sum_{k=0}^{\infty} \beta^k \frac{C_t}{C_{t+k}} \left[\left(\frac{P_{t+k}(j)}{P_{t+k}} - v_{t+k} \right) Y^d_{t+k}(j) - \frac{\Omega}{2} \left(\frac{P_{t+k}(j)}{\pi P_{t+k-1}(j)} - 1 \right)^2 C_{t+k} \right], \tag{15}$$

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

$$v_t = \frac{\theta_p - 1}{\theta_p} + \frac{\Omega_p}{\theta_p} \frac{C_t}{Y_t} \left[\left(\frac{\pi_t}{\pi} - 1 \right) \frac{\pi_t}{\pi} - \beta \mathrm{E}_t \left(\frac{\pi_{t+1}}{\pi} - 1 \right) \frac{\pi_{t+1}}{\pi} \right]. \tag{16}$$

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

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

$$\Gamma_t = \Gamma_{ht}^{\alpha} \Gamma_{ft}^{1-\alpha}, \tag{17}$$

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

$$q_{mt} = \tilde{\alpha} \left(\frac{e_t P_t^*}{P_t} \right)^{1-\alpha}, \tag{18}$$

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

$$q_t \equiv \frac{e_t P_t^*}{P_t} = \frac{1-\alpha}{\alpha} \frac{\Gamma_{ht}}{\Gamma_{ft}}, \tag{19}$$

where q_t is the real exchange rate.

III.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

$$ca_t = X_t - q_t \Gamma_{ft} + \frac{e_t (R_{t-1}^* - 1) B_{t-1}^*}{P_t}, \tag{20}$$

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

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

$$\ln R^*_t = (1-\rho_r)\ln R^* + \rho_r \ln R^*_{t-1} + \sigma_r \varepsilon_{rt}, \tag{21}$$

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

$$X_t = \left(\frac{P_t}{e_t P^*_t}\right)^{-\theta} \tilde{X}^*_t Z_t = q_t^{\theta} \tilde{X}^*_t Z_t, \tag{22}$$

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

$$\ln \tilde{X}^*_t = (1-\rho_x)\ln \tilde{X}^* + \rho_x \ln \tilde{X}^*_{t-1} + \sigma_x \varepsilon_{xt}, \tag{23}$$

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.

III.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 allowed to hold a small share of foreign assets. The government buys up most of the net inflow of foreign assets from the private sector using domestic currency.

Left alone, this would require the central bank to increase the 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

$$ca_t = e_t \frac{B^*_t - B^*_{t-1}}{P_t}. \tag{24}$$

Given full sterilization, we would have

$$B_t - B_{t-1} = e_t(B^*_t - B^*_{t-1}) = P_t ca_t, \tag{25}$$

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.[11]

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

$$e_t(B^*_{gt} - R^*_{t-1}B^*_{g,t-1}) \leq B_t - R_{t-1}B_{t-1} + M^s_t - M^s_{t-1}, \tag{26}$$

where B^*_{gt} denotes the central bank's holdings of the foreign bond. 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 matured foreign bonds, and seigniorage revenue.[12]

III.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 $\{C_t, Y_t, \Gamma_t, \Gamma_{ht}, \Gamma_{ft}, X_t, L_t, M_t, M^s_t, B_t, B^*_{pt}, B^*_{gt}, B^*_t\}$, 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 $L^d_t(i)$ 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, the

[11]The fiscal costs of holding foreign assets can be affected by exchange rate fluctuations. 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.

[12]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 which we leave for future research.

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.

$$\begin{aligned} Y_t &= C_t + \Gamma_{ht} + X_t + \left[\frac{\Omega_p}{2}\left(\frac{\pi_t}{\pi} - 1\right)^2 + \frac{\Omega_w}{2}\left(\frac{\pi_t^w}{\pi^w} - 1\right)^2\right] C_t \\ &+ \frac{B_t + e_t B_{pt}^*}{P_t}\frac{\Omega_b}{2}\left(\psi_t - \bar{\psi}\right)^2, && (27) \\ L_t &= \int_0^1 L_t(j)dj, && (28) \\ \Gamma_t &= \int_0^1 \Gamma_t(j)dj. && (29) \\ M_t &= M_t^s, && (30) \\ B_t^* &= B_{pt}^* + B_{gt}^*, && (31) \end{aligned}$$

where equation (27) is the final goods market-clearing condition, (28) is the labor market-clearing condition, (29) is the intermediate-goods market-clearing condition, (30) is the money market-clearing condition, and (31) is the foreign bond 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 (26), and using both the definition of current account in (20) and the relation between current account and foreign capital inflows in (24), we obtain

$$GDP_t \equiv C_t + X_t - q_t \Gamma_{ft} = w_t L_t + \frac{D_t}{P_t} - \frac{\Omega_w}{2}\left(\frac{\pi_t^w}{\pi^w} - 1\right)^2 C_t - \frac{B_t + e_t B_{pt}^*}{P_t}\frac{\Omega_b}{2}\left(\psi_t - \bar{\psi}\right)^2, \tag{33}$$

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

IV. 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

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

where $\hat{\pi}_t$ and $\hat{q}_t$ denote deviations of inflation and the real exchange 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 privately held foreign assets to GDP from steady state. The parameters λ_y, λ_q, and λ_b determine the importance of the last 3 variables relative to inflation stabilization in the planner's objective function.

The loss function reflects the desire of the central bank to stabilization inflation and output fluctuations, as in the literature of optimal flexible inflation-targeting policy [e.g., Svensson (2010)]. These quadratic terms can be derived from microeconomic foundation in a model with sticky prices [e.g., Woodford (2003)].[13]

The term involving the real exchange rate fluctuations in the loss function (34) reflects the PBOC stated policy objective that the central bank should "maintain stability of the value of the currency."

The loss function also implies that the central bank desires to smooth fluctuations in the ratio of privately held foreign bonds to real GDP, since large swings in private holdings of foreign assets would incur large portfolio adjustment costs and potential welfare losses. We interpret the last term in the loss function as a desire of the central bank to maintain financial stability.[14]

[13]In our model with both sticky prices and sticky nominal wages, the loss function derived from quadratic approximations to the representative household's utility function typically contains the output gap, price inflation, and nominal wage inflation, as shown, for example, by Erceg, Henderson, and Levin (2000). For our purpose, however, we focus on price inflation. We have examined an alternative loss function that includes, in addition to the 4 variables in equation (34), nominal wage inflation with a welfare weight equal to that of price inflation. The qualitative results do not change.

[14]Failure to include the $\hat{b}_{yt}^{*2}$ term would eliminate all of the dynamics in the interest rate shock that we consider below, since the central bank would be able to respond to shocks with an abrupt portfolio change that would restore the steady state allocations immediately. Empirically, we do not observe such abrupt adjustments in the foreign reserve holdings relative to GDP. In particular, China 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.

IV.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 utility function, those in the production function, those that characterize real and nominal rigidities, those that are related to 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).[15]

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

[15]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.

about 18 percent per quarter, implying an average duration of wage contracts of about 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.[16]

IV.2. **Calibrating financial friction parameters.** To calibrate the parameters in the portfolio adjustment cost functions and the steady-state share of foreign bonds held by the private sector, we log-linearize the modified UIP condition (8) and obtain

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

where $\hat{\psi}_t$ is the deviation of the portfolio share of domestic bonds from the steady-state level. This equation reveals that an increase in the interest rate differential $\hat{R}_t - \hat{R}_t^*$, holding expected exchange rate movements constant, raises the private demand for domestic bonds relative to that for foreign bonds.[17]

[16]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.

[17]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 also need to calibrate the steady-state portfolio share $\bar{\psi}$ and the portfolio adjustment cost parameter Ω_b. Since we have yet to observe China with an open capital account, we calibrate these using evidence from other emerging market economies. We set $\bar{\psi} = 0.90$, which lies in the range of empirical studies such as Coeurdacier and Rey (2011).[18]

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 (8) using panel data from emerging market economies. The empirical model is given by

$$\log \frac{S_{it}}{S_{i,t-1}} - (R_{i,t-1} - R^*_{t-1}) = a_i - b \log(\psi_{i,t-1}), \tag{36}$$

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.[19] The point estimate of b in equation (36) is about 0.2.[20] 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.

Finally, we need to set a value for the parameter ϑ, which 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

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[18] 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.

[19] 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).

[20] 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.

bonds in 2010 (so that ϑ is about 0.97 for the U.S.). For China, however, the share of privately held foreign bonds is likely much smaller, especially under the current regime with a relatively closed capital account. We set $\vartheta = 0.05$ for our benchmark model with capital controls. We set $\vartheta = 0.95$ in the alternative hypothetical model with an open capital account. 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.

IV.3. **Dynamic responses to a foreign interest rate shock 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.

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 a few key macroeconomic variables following a negative shock to the foreign interest rate.

The decline in the foreign interest rate relative to the domestic interest rate creates an incentive for the household to hold more domestic bonds relative to foreign bonds (see the modified UIP condition (35)). Indeed, as shown in the figure, the quantity of privately held foreign bonds (relative to GDP) declines following the foreign interest rate shock. The increased demand for domestic bonds bids up their price and lowers the domestic interest rate (see the figure). With sticky prices and wages, the decline in the nominal interest rate leads to an expansion in aggregate demand through intertemporal substitution (the household desires to consume more and save less). Thus, real GDP and domestic inflation both rise in the short run, as shown in the figure.

Under capital controls, the central bank's response to the shock reinforces these aggregate dynamics. In the steady state, the central bank holds the bulk of foreign assets (95% of them with our calibration) and it sterilizes the purchases of foreign assets by issuing domestic bonds. If lump-sum taxes or transfers are possible, then changes in the relative yields on foreign assets would have been internalized within the country and would have no consequences on the country's welfare. However, if lump-sum taxes are not available, as we assume in our model (which is a realistic characterization of China's economy), the decline in the foreign interest rate and the rise in the fiscal costs of sterilization cannot be internalized with the private sector. Facing an increase in sterilization costs, the central bank chooses to sterilize less and rely more on increasing money supply to finance the purchases of foreign assets. This expansionary monetary policy reinforces the decline in the domestic interest rate and further boosts aggregate demand and inflation.

These expansionary effects are partly offset by an expected drop in the current account surplus associated with a decrease in foreign asset earnings. In particular, a decline in today's foreign interest rate R_t^* reduces tomorrow's earnings on foreign assets (see the current account relation (20)). The expectations of a lower current account surplus and thus lower national income in period $t+1$ create a negative wealth effect on today's consumption. Furthermore, since the nominal exchange rate is fixed, the rise in domestic inflation leads to a real appreciation of the country's currency (i.e., the real exchange rate falls, as shown in the figure). The real appreciation, along with the expected declines in foreign asset earnings, generate a short-run decline in the country's current account surplus (see the figure).

Under our parameter calibration, the expansionary monetary policy together with the intertemporal substitution effect dominates the negative wealth effect and the real appreciation effect, leading to short-run increases in both inflation and real GDP.

Why doesn't the Ramsey planner allow the domestic interest rate to fall sufficiently to close the gap with the foreign interest rate? The reason is that, under optimal policy, the central bank desires to smooth fluctuations in inflation and real GDP. A large decline in the nominal interest rate would lead to large upward swings in inflation and GDP—a consequence that the planner would like to avoid. Thus, the rise in the interest rate spread and thus the fiscal cost of sterilization is a natural consequence of optimal stabilization policy. As we show below, sterilization costs would be less of a constraint on optimal policy under a more open capital account.

V. Policy reforms

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

We first consider a regime with an open capital account and a fixed nominal exchange rate. We assume that the private sector is allowed to hold, on average, up to $\vartheta = 0.95$ fraction of total foreign assets (much larger than that in the benchmark model, where we assume $\vartheta = 0.05$). We assume that the central bank retains some capacity for sterilization even after the capital account is opened. This assumption allows for the existence of home bias, which prevails even in the most advanced economies [e.g., Coval and Moskovitz (1999)].

We then examine a regime with a floating exchange rate but a relatively closed capital account. 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.

Finally, we study a regime that features a full reform, in which the government eases capital controls and allows the exchange rate to freely float.

During the global financial crisis that started in 2007-08, many advanced economies experienced large recessions, implying substantially weakened export demand for goods made in China. In addition, there were large disruptions in the world commodity markets, leading to large fluctuations in import prices for China. In light of these events, we consider three types of shocks in evaluating the welfare implications of the alternative policy regimes: a shock to the foreign interest rate, a shock to export demand, and a shock to the foreign price level (i.e., a terms-of-trade shock).

V.1. **Dynamic effects of foreign interest rate shocks under alternative policy regimes.** We next examine the dynamic responses of the macroeconomic variables following the same foreign interest rate shock under each alternative regime. This is a counterfactual thought experiment, which asks the question: What would have happened to China's macroeconomic fluctuations had a different policy regime been in place at a time when the foreign interest rate drops?

Figure 4 displays the impulse responses of the key macroeconomic variables following 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 one with an open capital account but a fixed exchange rate (labeled "Open capital account"), the one with a floating exchange rate but a relatively closed capital account (labeled "Flex exchange rate"), and the one with an capital account and a floating exchange rate (labeled "Full reform").

Consider first the regime with an open capital account and a fixed exchange rate(the dashed lines). Similar to the benchmark case (the solid lines), the decline in the foreign interest rate leads to a portfolio reallocation and a decline in the domestic interest rate, which tends to raise aggregate demand through intertemporal substitution. However, unlike the benchmark economy, the central bank under a regime with an open capital account does not need to sterilize inflows of foreign assets. Thus, optimal monetary policy does not respond to changes in the relative yields on domestic and foreign assets. Absent monetary policy expansion, the decline in the domestic interest rate under this policy regime is more muted than that in the benchmark economy.

However, the fall in the foreign interest rate leads to an expected decline in the current account surplus in the next period. This represents an expected loss in national income, which generates a negative wealth effect on current consumption. This wealth effect dominates the intertemporal substitution effect, leading to a short-run decline in both real GDP and inflation, as shown in the figure.

Since the nominal exchange rate is fixed, disinflation implies a real depreciation, which helps boost net exports and raise current account balances. As revealed in the figure, the current account shows a small increase in the first period, but a subsequent decline in the second period because of the reduction in foreign interest earnings in that period.

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Next, consider the regime with a floating exchange rate and a closed capital account ("Flex exchange rate", shown by the dashed and dotted lines in the figure). As in the benchmark model, the central bank faces a rise in the cost of sterilization when the foreign interest rate falls. However, since it needs to maintain the money supply to have a nominal anchor when the exchange rate is freely floating, the central bank cannot rely on money supply expansion to finance the purchases of foreign assets from exporters. Indeed, with a constant money supply growth, our model implies a constant nominal interest rate under the logarithmic utility function in consumption and real money balances (see the figure). The central bank responds to the rise in sterilization costs by sharply appreciating the currency and thereby reducing the current account surplus and cutting down further inflows of foreign assets. As shown in the figure, this policy leads to a large decline in the real exchange rate (i.e., a large real appreciation) and in the current account surplus. This policy leads to a short-run contraction in aggregate demand and thus declines in both real GDP and inflation.

Finally, consider the case where both capital controls and exchange rate pegs are relaxed ("Full reform", represented by the dotted lines in the figure). With a floating exchange rate, the central bank targets money supply as a nominal anchor and cannot expand money supply or lower the nominal interest. However, since the capital account is open, the central bank does not need to expand money supply to sterilize foreign asset purchases following the decline in the foreign interest rate. Neither does it need to engineer a sharp appreciation of its currency to cut down further inflows of foreign assets. These flexibilities gained from the full reform lead to better macroeconomic stability, not just in response to a foreign interest rate shock, but also to other external shocks such as those to export demand or terms of trade, as we show in the next section.

V.2. **Welfare outcomes.** We compute the welfare losses under each of the four policy regimes conditional on three shocks: a shock to the foreign interest rate, a shock to foreign export demand, and a shock to the foreign price level (or terms of trade). 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. We then compute the variances of the four variables in the loss function and use the 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 full-reform regime incurs, not surprisingly, the smallest welfare loss among the four regimes. What does seem interesting is the finding that liberalizing either capital controls or exchange rate pegs goes a long way in bringing down the welfare losses to levels close to that under the full-reform regime.

This suggests that the constraints associated with these restrictions exacerbate each other. For example, under a liberalized the capital account alone, the central bank is not as much constrained by concerns of sterilization costs and thus gains some flexibility in responding to external shocks through portfolio adjustments even though it must respect the nominal exchange rate peg. Similarly, by letting the exchange rate float under the closed capital account the central bank gains the ability to use exchange-rate adjustments to restore external balance even as it responds to the changes in the costs of sterilization implied by the foreign interest rate shock. Either reform provides a channel for adjustment through which the welfare loss incurred from the external shocks is substantially lowered relative to the benchmark regime.

VI. Conclusion

In this paper, we examine optimal monetary policy under a set of currently prevailing Chinese policies – including capital controls 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 several external shocks, including a shock to the foreign interest rate, a shock to export demand, and a shock to the terms of trade—mirroring the experience of China during the recent global crisis.

We find that the regime that combines an open capital account with a floating exchange rate performs best in achieving macroeconomic stability in response to external shocks. Intermediate reforms—either opening the capital account or allowing the exchange rate to float alone—can go a long way in bringing down the losses to the central bank. By partially opening the capital account, the central bank is less concerned about the cost of sterilization associated with a reduction in the relative foreign interest rate and can thus achieve better domestic macroeconomic stability even if the nominal exchange rate stays fixed. On the other hand, by allowing the exchange rate to float, the central bank is able to respond to external shocks by adjusting the exchange rate; such exchange-rate adjustments help reduce external imbalances and shield the country from the adverse impact of fluctuations in foreign capital flows, even though the capital account remains relatively closed. These alternative adjustment channels are substitutes that can improve macroeconomic stability in the face of the shocks we consider with the proper partial liberalization.

Consequently, while the DSGE model that we have studied is quite stylized and we do not want to push the relative numerical rankings too aggressively, our findings suggest that even partial reform of China's existing trade policy regime–either through opening the capital account or by letting exchange rate float—can substantively improve the Chinese central bank's ability to weather external shocks and achieve better macroeconomic stability. Full liberalization is still best, but partial reform of either type implies substantial welfare gains.

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
	Portfolio adjustment	
Ω_b	Portfolio adjustment cost parameter	0.22
$\bar{\psi}$	Average portfolio share of domestic bonds	0.90
ϑ	Average share of privately held foreign bonds	0.05 or 0.95
	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	0.5
λ_q	Weight on interest rate	0.5
λ_b	Weight on foreign bond	0.01

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

Regime	Welfare Loss	Welfare components			
		$var(\hat{\pi}_t)$	$0.5var(\hat{gdp}_t)$	$0.5var(\hat{q}_t)$	$0.01var(\hat{b}^*_{yt})$
Benchmark	0.0781	0.0011	0.0007	0.0009	0.0753
Open capital	0.0537	0.0010	0.0004	0.0055	0.0468
Flex ex rate	0.0569	0.0002	0.0002	0.0111	0.0454
Full reform	0.0503	0.0000	0.0002	0.0060	0.0440

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 to the losses from fluctuations in inflation, real GDP, the real exchange rate, and the ratio of privately held foreign bonds to GDP.

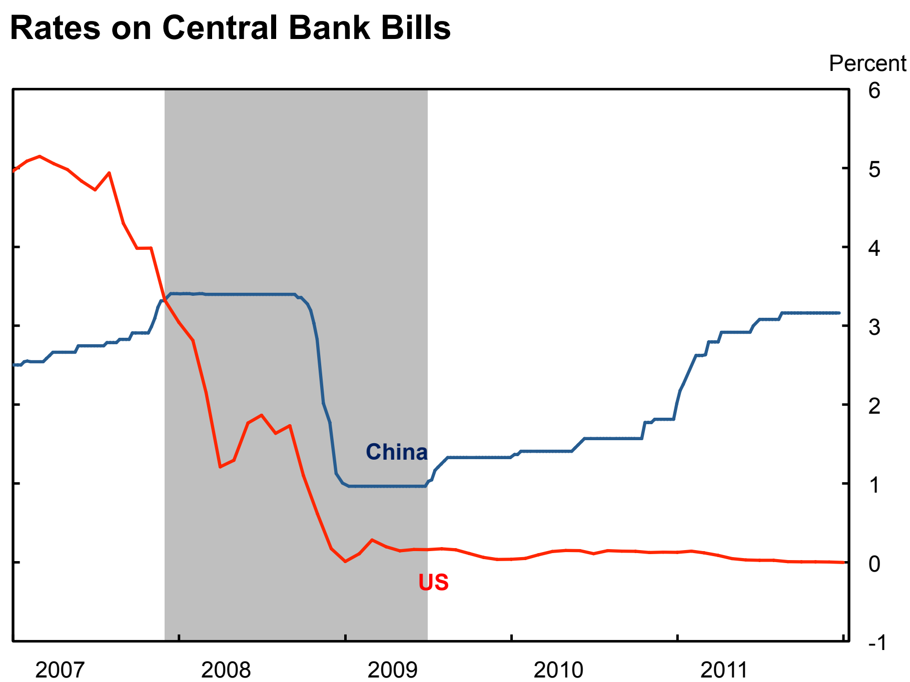

Figure 1. China's three-month central bank bills rate vs. U.S. three-month Treasury bills rate. The grey area indicates the Great Recession period in the United States.

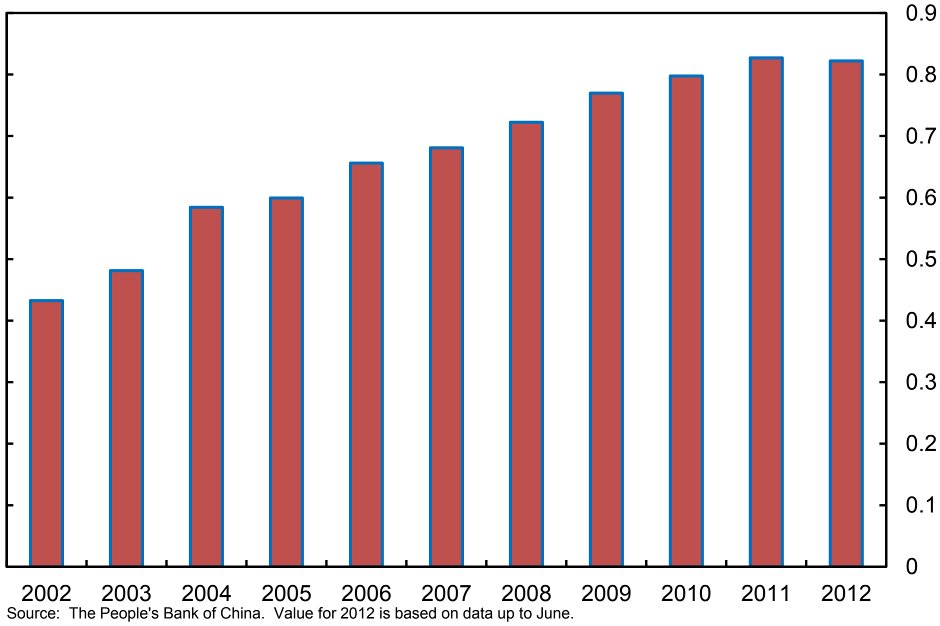

FIGURE 2. Foreign reserves as a share of total assets for the People's Bank of China.

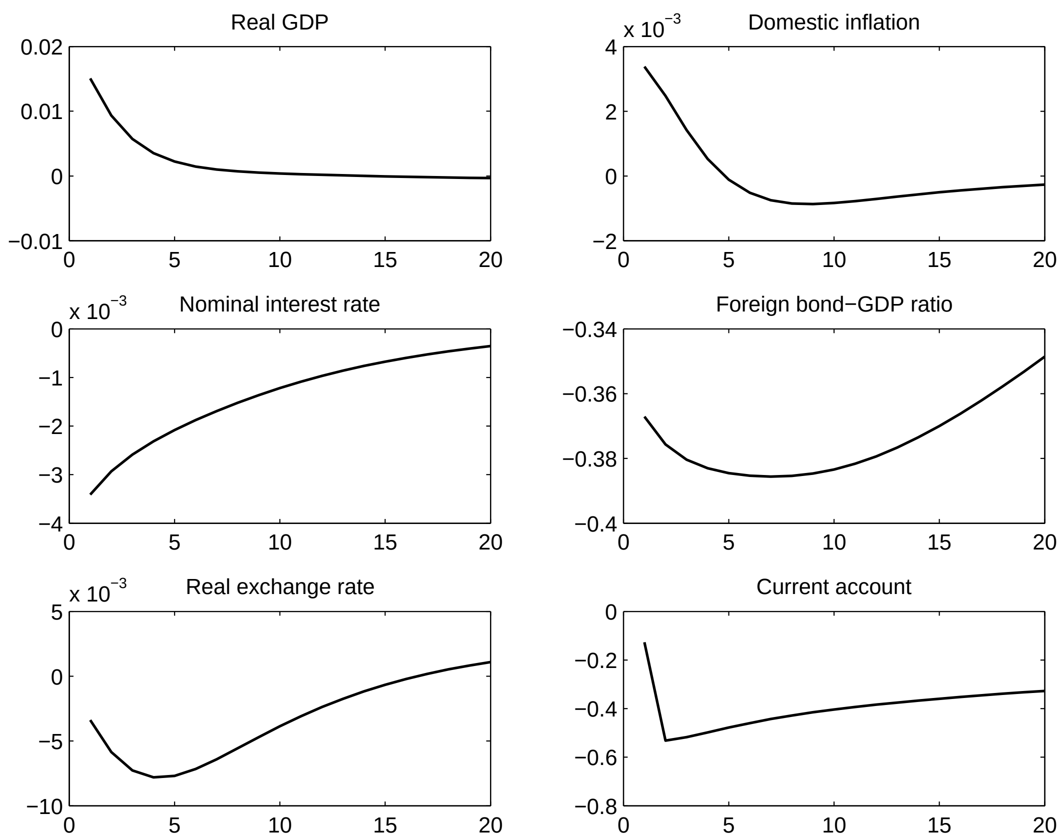

FIGURE 3. Impulse responses of policy variables following a persistent decline in the foreign interest rate in the benchmark model.

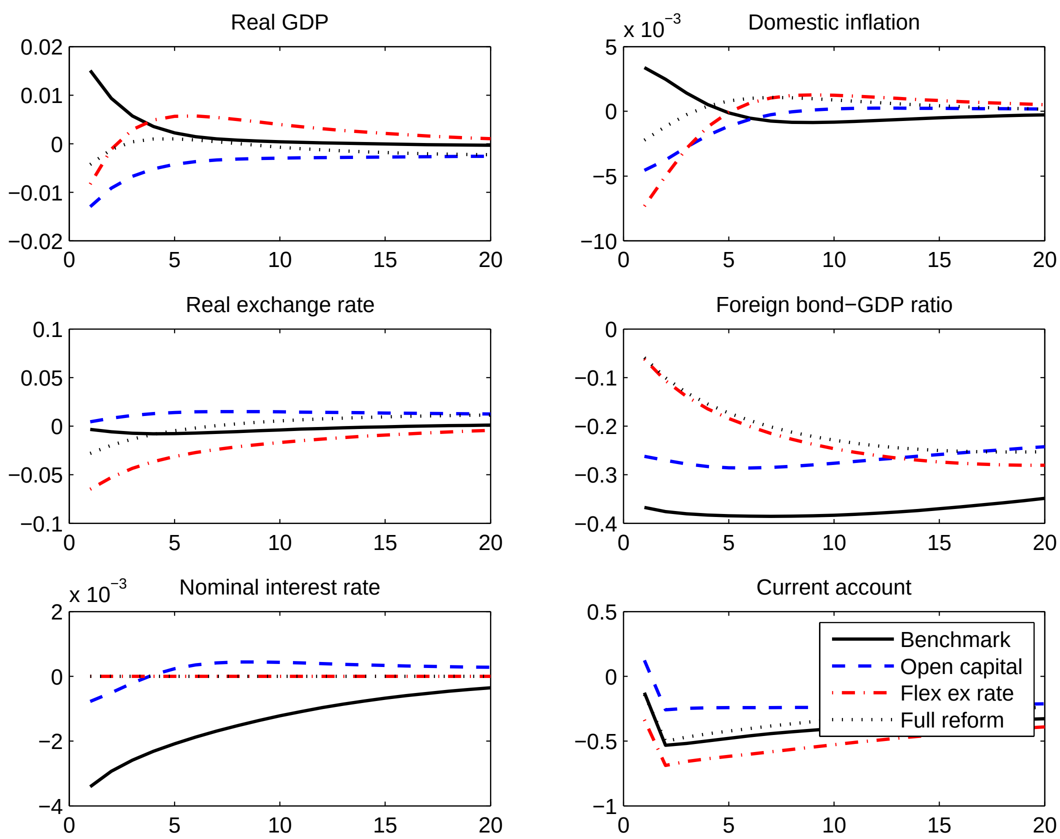

FIGURE 4. Impulse responses of policy variables following a persistent decline in the foreign interest rate: Alternative policy regimes

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