MONETARY POLICY REGIMES AND CAPITAL ACCOUNT RESTRICTIONS IN A SMALL OPEN ECONOMY

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Abstract. The recent financial crisis has led to large declines in world interest rates and surges of capital flows to emerging market economies. We examine the effectiveness and welfare implications of capital control policies in the face of such external shocks in a monetary DSGE model of a small open economy. We consider both optimal, time-varying restrictions on capital inflows and a simple capital account restriction, such as a constant tax on foreign debt holdings. We then compare the effectiveness of such capital account restrictions under alternative monetary regimes. We find that the optimal time-varying capital control policy is very effective in mitigating foreign interest rate shocks. However, under a simple and more practical capital control policy, macroeconomic stability and welfare depend on which monetary policy regime is put in place. A hawkish regime that places a relatively large weight on inflation leads to additional gains in macroeconomic stability, although such gains are small relative to having a central banker that desires to smooth the real exchange rate. Our findings suggest that, while macroeconomic stability and welfare outcomes may depend on the types of capital account policies in place, targeting the real exchange rate is a robust and effective monetary policy to help weather external shocks.

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I. Introduction

In the wake of the recent global financial crisis, central banks in Western countries reduced global interest rates dramatically. Small open economies, particularly those in Asia that were perceived as having desirable growth opportunities going forward, experienced surges of foreign capital inflows [e.g. Ghosh and Qureshi (2012)]. These capital inflows posed potential threats of rising inflation or sudden reversals in flows for the recipient countries and led to criticism of the easy Western policies. However, Western central bankers maintained that the policies were appropriate for stimulating their domestic economies, and that ensuring the recovery of the advanced economies was also in the interest of the emerging economies [e.g. Bernanke (2012)].

These surges in capital flows also led to reconsideration of the merits of restricting capital flows (Ostry, Ghosh, Habermeier, Chamon, Qureshi, and Reinhart, 2010). Some studies argue that by using a combination of restrictions on capital flows and increases in the pace of sterilization of inward flows by the central bank, a nation can mitigate the effects of excess international capital flows caused by external shocks [e.g. Fernandez-Arias and Montiel (1996), Farhi and Werning (2012) and Unsal (2013)].

Nevertheless, capital controls and sterilization policies are not without costs, particularly in an environment with low prevailing global interest rates. For example, Chang, Liu, and Spiegel (2012) examine the policy problem faced by the People's Bank of China (PBOC) — with that country's closed capital account and crawling exchange rate peg — subsequent to the global financial crisis. They show that the large increases in the spread between domestic and foreign interest rates following the crisis raise substantially the cost of sterilization for the PBOC and therefore present a tradeoff between sterilization costs and inflation stability. Chang, Liu, and Spiegel (2012) derive the optimal monetary policy decision in an open-economy DSGE model with nominal rigidities and imperfect asset substitutability, taking the closed capital account policy as given. They find that optimal monetary policy response to a downward foreign interest rate shock includes reducing the pace of sterilization and allowing for increased inflation. Moreover, had China liberalized both its capital account and exchange rate policies, the PBOC's optimal monetary policy response would have been able to substantively mitigate Chinese macroeconomic volatility subsequent to the global financial crisis.

While China's situation is unique, primarily because of its largely closed capital account, many similarities exist for the central banks of Asia's small open economies. These economies also are subject to capital account pressures associated with lower foreign interest rates; in their case, these pressures manifest themselves in surges in capital inflows. In small open economies with open capital accounts, monetary policy is likely to be less effective in mitigating surges in capital inflows as raising interest rates can be counterproductive by raising the attractiveness of a nation as a destination for foreign investment. Still, if assets are imperfect substitutes, sterilization can be effectively used as a policy response.

In this paper, we study monetary policy tradeoffs for a central bank in a small open economy DSGE model with incomplete capital mobility faced with external shocks. We examine these tradeoffs in a monetary model to allow for consideration for the effects of sterilization decisions on domestic monetary policy.

We focus on the tradeoff between inflation stability and capital account volatility. Given a large capital inflow, a central bank would engage in sterilization activity to alleviate inflation pressure in the domestic economy. However, if the source of capital inflows is associated with a large decline in foreign interest rates, then the shock that led to the incipient surge in inflows also raises the cost of sterilization.[1] To allow the central bank to engage in sterilization activity, we incorporate a partially open capital account by assuming that foreign capital and domestic assets are imperfect substitutes, and that external demand for the home country's bonds increases with deviations from uncovered interest parity.

The central bank in our model optimizes welfare according to a simple loss function, in a form of "flexible inflation targeting" (Svensson, 2000). Our analysis also follows Galí and Monacelli (2005), who demonstrate that the equilibrium dynamics of a Calvo sticky price small open economy can be reduced to a representation in domestic inflation and the output gap. As in Chang, Liu, and Spiegel (2012), our model demonstrates that consideration of the costs of sterilization add an additional argument for "flexibility" in the pursuit of inflation targeting. In particular, the response to negative interest rate shock is less aggressive, as the central bank engages in less sterilization activity than it would absent the consideration of sterilization costs.

We then examine the implications of capital controls in the form of taxes on foreign borrowing. We consider two types of capital controls: One is a simple capital account restriction that remains at a constant level in the steady state and through the course of a business cycle. This simple capital account restriction is in keeping with those

[1]We also consider shocks to external demand and domestic productivity shocks.

that we observe empirically, which tend to be infrequently adjusted [e.g. Chinn and Ito (2002) and Magud, Reinhart, and Rogoff (2011)].[2]

We also consider a time-varying tax that is at the same low levels as our simple controls in the steady state, but then is set optimally over the course of the cycle. Keeping the taxes equal across these control policies in the steady state allows for consistent comparison of the two policy regimes in terms of welfare losses attributable to deviations from the first-best steady state subsequent to the interest rate shock. We compare the welfare outcomes under these capital control regimes by calibrating our model to parameters that fit representative small Asian economies when available, and standard parameters in the literature otherwise. While changes in tax rates are likely to be infrequent in practice, the optimal time-varying tax on foreign borrowing provides a good benchmark which can be approximated by a small number of discrete changes in capital controls over the course of a cycle. Such time varying capital flow restrictions have been considered elsewhere [e.g. Jeanne and Korinek (2010) and Korinek (2013)].

Our results confirm that a policy that taxes capital inflows subsequent to the interest rate shock can mitigate output volatility and improve welfare relative to the benchmark case. Moreover, a time-varying capital account policy almost perfectly smooths the effects of the shocks.

We also consider the implications of the same foreign interest rate shock under two alternative rule-based policies reflecting differences in the preferences of the central banker: A "conservative" central banker whose loss function places a relatively high weight on avoiding inflation, and a central banker who places higher weight on real exchange rate stabilization. We examine these alternative preferences with both varieties of capital controls.

Our results demonstrate that a conservative central banker can also improve welfare relative to our benchmark model. However, the greatest improvement is found when the central banker's loss function is geared towards smoothing the real exchange rate. A central banker with preferences aimed towards real exchange rate smoothing pursues policies that almost completely smooth the impact of the interest rate shock.

[2]As we show below, the optimal time-varying capital control tends to taper off over the course of the cycle as shocks diminish. In contrast, the capital control adjustments that are documented in Magud, Reinhart, and Rogoff (2011) tend to exhibit infrequent increases in restrictiveness over the cycle, as additional restrictions are brought into law.

Overall, our results suggest that either the optimal time-varying capital control policy or the real-exchange rate smoothing central banker does quite well in mitigating macroeconomic volatility. However, the simple capital control policy with the benchmark central banker is dominated by optimal monetary policy under the exchange-rate-smoothing central banker, and roughly equalled under the conservative central banker. To some extent, this is not surprising, as it has long been established that the gains from international policy coordination may be limited relative to welfare attainable given "self-oriented" monetary policies geared towards national macroeconomic goals [Obstfeld and Rogoff (2002)].[3]

The relative merits of using monetary policy are then likely to depend on the practical flexibility of available capital account policies. While capital account policies have the advantage of being directed precisely at external shocks, monetary policy actions lend themselves more easily to changes over the course of the business cycle. As such, the superiority of one policy over another is unclear. In the end, we find that a monetary policy aimed at smoothing the real exchange rate does almost as well with either form of capital controls.[4]

The remainder of this paper is divided into four sections. Section 2 considers where we place the contributions of this paper in the burgeoning literature on this topic. Section 3 introduces the benchmark DSGE model. Section 4 introduces the loss function of the monetary authority and considers optimal policy under the aforementioned optimal capital account policies, examining the welfare implications of alternative policy stances of the monetary authority. Lastly, section 5 concludes.

II. Related Literature

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. In the standard DSGE model of a closed economy, monetary policy faces no trade off between stabilizing inflation and stabilizing the output gap

[3]However, scope for welfare-enhancing monetary policy coordination has been generated through a variety of extensions of the basic open-economy DSGE model, including differences in exchange rate pass-through Devereux and Engel (2003), asymmetric information (Dellas (2006)), or through cross-country differences in trading patterns (Liu and Pappa (2008)).

[4]However, this does not imply that one might not do better using a combination of macro-prudential and monetary policies when one is also facing other frictions, such as the financial frictions in Unsal (2013), where monetary policies are targeted towards stabilizing macroeconomic conditions and macro-prudential policies are targeted towards achieving financial stability.

(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; Monacelli, 2013).[5]

In our benchmark open-economy model with imperfect international asset substitutability, monetary policy faces additional constraints in stabilizing inflation and output fluctuations. In particular, our analysis follows a growing literature that argues that capital controls may be welfare-enhancing under credit market imperfections. In a recent paper, Jeanne and Korinek (2010) demonstrate that a time-varying Pigouvian tax on borrowing can induce borrowers to internalize the externalities associated with international borrowing. Korinek (2013) finds that if such taxes are addressed at neutralizing domestic distortions, outcomes are Pareto efficient and there are no gains from global policy coordination.[6] Bianchi (2011) also introduces a model with financial frictions and finds that constrained-efficient allocations can be recovered through appropriate state-contingent capital controls, reserve requirements, or margin requirements on borrowing. Of course, the growing acceptance of capital controls as a tool for maintaining macroeconomic stability has been mirrored in policy circles, where policy makers have become more amenable to capital controls under certain conditions [e.g., Ostry, Ghosh, Habermeier, Chamon, Qureshi, and Reinhart (2010)]. 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.

To our knowledge, however, our paper is the first to examine the interactions between capital account and monetary policies in a DSGE model in which the mix of

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

[6]Capital controls can also be a welfare-enhancing tool as a means of terms of trade manipulation. For a recent example, see Costinot, Lorenzoni, and Werning (2011).

money and bond holdings affects real allocations.[7] Such a model is necessary for assessment of the implications of the sterilization decision of the monetary authority. In the wake of a foreign interest rate shock, increases in the costs of sterilization further constrain the central bank's ability to stabilize domestic price inflation. In particular, the decision to reduce the pace of sterilization combined with the consolidated government budget constraint implies that a country must tolerate additional inflation, as in the closed capital account model of Chang, Liu, and Spiegel (2012). While capital inflow surges in real models also result in price level increases, a monetary model is therefore necessary to evaluate the role that the sterilization decision, the primary policy instrument available to central banks of small open economies, plays in generating price instability. These results differ from non-monetary open-economy models [e.g. Hevia and Nicolini (2013)] that retain the "divine coincidence" result that price stabilization alone remains optimal in open-economy models with price rigidities.

In addition, to our knowledge our paper is the first that distinguishes between the effectiveness of optimal state-contingent capital account restrictions, and simple restrictions of the type that are observed empirically.

III. Benchmark model

We consider a small open economy with sticky prices and imperfect substitution between domestic and foreign assets. Residents in the country take the world interest rate, world prices, and export demand as given. Since domestic and foreign bonds are imperfect substitutes, the standard uncovered interest rate parity (UIP) condition fails to hold. The domestic interest rate will generally differ from the world interest rate, with the interest-rate spread depending upon the portfolio shares. This feature of the model allows the central bank to conduct independent monetary policy under flexible exchange rates. We assume that the central bank follows a flexible inflation targeting policy in the spirit of Svensson (2000).

The country is populated by a continuum of infinitely lived households. The representative household consumes a final good, holds real money balances, and supplies labor hours to firms. The final good is a composite of differentiated products, each of which is produced using labor and intermediate inputs. Intermediate goods are

[7]Unsal (2013) considers a "monetary authority" that follows a standard interest rate rule in a real economy, while Korinek (2013) examines "reserve accumulation," in the sense that a central planner purchases and holds foreign assets on behalf of domestic agents. Monacelli (2013) characterizes optimal monetary policy in an open economy as the constrained-efficient Ramsey allocation under preset prices, but does not consider capital account policies.

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 retail goods are monopolistically competitive. Each firm takes all prices but its own as given and sets a price for its differentiated product. Adjustments in prices are subject to a quadratic cost, as in Rotemberg (1982).

III.1. **The households.** The representative household has preferences represented by the utility function

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

where E is an expectation operator, C_t denotes consumption of final goods, M_t denotes nominal money balances, L_t denotes labor hours, and P_t denotes the price level. The parameter $\beta \in (0,1)$ is a subjective discount factor; the non-negative terms Φ_m and Φ_l are utility weights on real money balances and labor, respectively; and the parameter $\eta > 0$ is a curvature parameter that represents the disutility of labor.

The household faces the sequence of budget constraints

$$\begin{aligned} C_t + \frac{M_t}{P_t} + \frac{B_{ht} + e_t B_{ht}^*}{P_t} \left[1 + \frac{\Omega_b}{2} \left(\frac{B_{ht}}{B_{ht} + e_t B_{ht}^*} - \bar{\psi} \right)^2 \right] \\ \leq w_t L_t + \frac{M_{t-1}}{P_t} + \frac{R_{t-1} B_{h,t-1} + e_t R_{t-1}^* B_{h,t-1}^*}{P_t} + d_t, \end{aligned} \tag{2}$$

where B_{ht} denotes the household's holdings of a domestic nominal bond; B_{ht}^* denotes the holdings of a foreign-currency bond; e_t denotes the nominal exchange rate; R_t and R_t^* denote the nominal interest rates on domestic and foreign bonds, respectively; w_t denotes the real wage rate; and d_t is the real profit income from the household's ownership shares of firms. The parameter Ω_b represents the size of the portfolio adjustment costs. The term $\bar{\psi}$ denotes the steady state share of private domestic bonds in total bond holdings.

The household chooses C_t, M_t, L_t, B_{ht}, and B_{ht}^* to maximize the utility function (1) subject to the budget constraints (2).

Denote by Λ_t the Lagrangian multiplier for the budget constraint (2) and by $m_t \equiv \frac{M_t}{P_t}$ the quantity of real money balances. The optimal money demand equation is given by

$$\frac{\Phi_m}{\Lambda_t m_t} = \frac{R_t - 1}{R_t}. \tag{3}$$

The optimal labor supply decision equates the real wage rate to the marginal rate of substitution between leisure and consumption. In particular, it is described by the first-order condition

$$w_t = \frac{\Phi_l L_t^{\eta}}{\Lambda_t}. \tag{4}$$

Denote by $\psi_t = \frac{B_{ht}}{B_{ht}+e_t B_{ht}^*}$ the portfolio share of domestic bond in total bond holdings. We show in the Appendix that optimal choices of B_{ht} and B_{ht}^* imply that

$$\Omega_b(\psi_t - \bar{\psi})(1+\psi_t) = \mathrm{E}_t \frac{\beta\Lambda_{t+1}}{\Lambda_t}\frac{1}{\pi_{t+1}}\left[R_t - R_t^* \frac{e_{t+1}}{e_t}\right], \tag{5}$$

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., $\Omega_b = 0$), this equation reduces to the standard UIP condition.

With the portfolio adjustment costs, however, domestic and foreign bonds are no longer perfect substitutes and the deviation from UIP reflects the portfolio share of domestic bonds, ψ_t. 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 exchange rate adjusted nominal interest rate increases), the household's optimal share of domestic bond holdings increases.

III.2. **The firms.** There is a continuum of firms, each producing a differentiated product $Y_t(j)$ using the constant returns technology

$$Y_t(j) = \Gamma_t(j)^{\phi}(Z_t L_t(j))^{1-\phi}, \tag{6}$$

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

$$\ln\lambda_{zt} = (1-\rho_z)\ln\bar{\lambda}_z + \rho_z \ln\lambda_{z,t-1} + \sigma_z\varepsilon_{zt}, \tag{7}$$

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. We show in the appendix that cost-minimizing implies

$$v_t = \tilde{\phi}\tilde{\alpha}^{\phi} q_t^{\phi(1-\alpha)} \left(\frac{w_t}{Z_t}\right)^{1-\phi}. \tag{8}$$

where $\tilde{X}$ $(X = \phi, \alpha)$ are constants satisfying $\tilde{X} \equiv X^{-X}(1-X)^{X-1}$, α represents the expenditure share of domestic intermediate goods, q_t is the real exchange rate, and w_t represents the real wage. Given that inputs are perfectly mobile, the wage rate and the relative price of intermediate goods are identical for each firm, as is the real marginal cost.

Firms face competitive input markets and a monopolistically competitive product market. We assume that final consumption goods are a Dixit-Stiglitz aggregator of differentiated products produced by all firms, with the aggregation technology

$$Y_t = \left[\int_0^1 Y_t(j)^{\frac{\epsilon-1}{\epsilon}} dj\right]^{\frac{\epsilon}{\epsilon-1}}, \tag{9}$$

where $\epsilon > 1$ denotes the elasticity of substitution between differentiated products. The optimizing aggregation decisions imply the demand schedule

$$Y_t^d(j) = \left[\frac{P_t(j)}{P_t}\right]^{-\epsilon} Y_t, \tag{10}$$

where the price level P_t is related to the individual prices $P_t(j)$ by $P_t = \left[\int_0^1 P_t(j)^{1-\epsilon} dj\right]^{\frac{1}{1-\epsilon}}$.

Firm j takes the input prices q_{mt} and w_t, the price level P_t, and the demand schedule (10) as given, and sets a price $P_t(j)$ for its own differentiated product to maximize expected discounted dividend flows. Following Rotemberg (1982), firms are assumed to 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.[8]

Firm j solves the problem

$$\text{Max}_{P_t(j)} \quad E_t \sum_{k=0}^{\infty} \frac{\beta^k \Lambda_{t+k}}{\Lambda_t} \left[\left(\frac{P_{t+k}(j)}{P_{t+k}} - v_{t+k}\right) Y_{t+k}^d(j) - \frac{\Omega}{2}\left(\frac{P_{t+k}(j)}{\pi P_{t+k-1}(j)} - 1\right)^2 C_{t+k}\right], \tag{11}$$

where $Y_t^d(j)$ is given by equation (10).

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

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

$$v_t = \frac{\epsilon - 1}{\epsilon} + \frac{\Omega_p}{\epsilon}\frac{C_t}{Y_t}\left[\left(\frac{\pi_t}{\pi} - 1\right)\frac{\pi_t}{\pi} - \beta \mathrm{E}_t\left(\frac{\pi_{t+1}}{\pi} - 1\right)\frac{\pi_{t+1}}{\pi}\right]. \tag{12}$$

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.3. **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

$$ca_t = X_t - q_t\Gamma_{ft} + \frac{e_t(R^*_{t-1} - 1)B^*_{t-1}}{P_t} - \frac{(R_{t-1}(1-\tau_{t-1}) - 1)B_{f,t-1}}{P_t}, \tag{13}$$

where X_t represents the quantity of exports, B^*_{t-1} denotes the total holdings (private and public) of foreign-currency bonds at the beginning of period t, and $B_{f,t-1}$ denotes the foreign investor's holdings of the domestic bond.

We assume that the foreign investor's demand for the domestic bond is a downward-sloping function that takes the form

$$\frac{B_{ft}}{Z^p_t P_t} = f\left(\mathrm{E}_t(1-\tau_t)R_t\frac{e_t}{e_{t+1}} - R^*_t\right), \tag{14}$$

where $f'(\cdot) > 0$ so that, all else equal, an increase in interest-rate differential (adjusted for taxes and expected exchange rate appreciation) would raise the foreign demand for domestic bonds. This relation implies imperfect substitution between domestic and foreign assets from the perspective of the foreign investor. Further, we assume that $f(-\tau R^*) = 0$, so that, in the steady state, net foreign capital inflow is zero.

Note that the foreign investor pays a tax τ_t on the interest earnings of domestic bonds, whereas domestic residents do not need to pay such taxes. We interpret the tax rate as an instrument for implementing capital account policies.

The foreign interest rate R^*_t is exogenous and follows the stationary stochastic process

$$\ln R^*_t = (1-\rho_r)\ln R^* + \rho_r \ln R^*_{t-1} + \sigma_r\varepsilon_{rt}, \tag{15}$$

where R^* is the steady state foreign interest rate, $\rho_r \in (0,1)$ 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

$$X_t = \left(\frac{P_t}{e_t P_t^*}\right)^{-\theta} \tilde{X}_t^* Z_t^p = q_t^\theta \tilde{X}_t^* Z_t^p, \tag{16}$$

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

$$\ln \tilde{X}_t^* = (1-\rho_x)\ln \tilde{X}^* + \rho_x \ln \tilde{X}_{t-1}^* + \sigma_x \varepsilon_{xt}, \tag{17}$$

where $\tilde{X}^*$ is the steady state value of foreign aggregate demand, $\rho_x \in (0,1)$ 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.

In each period, the country's faces a net foreign capital inflow if it runs a current account surplus. The law of motion of the total foreign bond holdings is given by

$$ca_t = e_t \frac{B_t^* - B_{t-1}^*}{P_t} - \frac{B_{ft} - B_{f,t-1}}{P_t}. \tag{18}$$

III.4. **The government.** The government faces the flow-of-funds constraints

$$e_t(B_{gt}^* - R_{t-1}^* B_{g,t-1}^*) \leq B_t - R_{t-1}B_{t-1} + M_t^s - M_{t-1}^s + \tau_t R_t B_{ft}, \tag{19}$$

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, seigniorage revenue, and tax revenue from foreign investor's holdings of domestic bonds.

We assume that the central bank follows a flexible inflation targeting policy with commitment in the spirit of Svensson (2000).[9] We consider a loss function that includes, in addition to the standard goals of inflation and output stability, a desire to smooth fluctuations in foreign capital inflows and in the real exchange rate. The term involving capital flows in the loss function is a reduced form representation that captures the potential losses stemming from fluctuations in the household's portfolio share. As we show below, the desire to stabilize foreign capital inflows gives rise to a

[9]We follow the literature by focusing on optimal policy with commitment. An alternative approach would be to study optimal discretionary policy, which can be quite different from the commitment case in a forward-looking model like ours. The issue of discretionary optimal policy under alternative capital account and monetary policy regimes is sufficiently important by itself for future research.

monetary policy tradeoff between inflation stabilization and sterilization. For example, following a surge in capital inflows, the central bank can choose to mitigate the inflationary impact by sterilizing these inflows through selling domestic bonds.

III.5. **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 $\{C_t, Y_t, \Gamma_t, \Gamma_{ht}, \Gamma_{ft}, X_t, L_t, M_t, M_t^s, B_t, B_{ht}, B_{ft}, B_{ht}^*, B_{gt}^*, B_t^*\}$, as well as the prices $P_t(j)$ and quantities $\{Y_t(j), L_t(j), \Gamma_t(j)\}$ for each firm $j \in [0,1]$, such that (i) taking all prices but its own as given, the price and allocations for each firm solves its profit maximizing problem, (ii) taking all prices as given, the allocations for the households solve the utility maximizing problem, and (iii) markets for the final goods, intermediate goods, labor, money balances, and bond holdings all clear.

The market-clearing conditions are summarized below.

$$Y_t = C_t + \Gamma_{ht} + X_t + \frac{\Omega_p}{2}\left(\frac{\pi_t}{\pi} - 1\right)^2 C_t + \frac{1}{\psi_t}\frac{B_{ht}}{P_t}\frac{\Omega_b}{2}\left(\psi_t - \bar{\psi}\right)^2, \tag{20}$$

$$L_t = \int_0^1 L_t(j)dj, \tag{21}$$

$$\Gamma_t = \int_0^1 \Gamma_t(j)dj. \tag{22}$$

$$M_t = M_t^s, \tag{23}$$

$$B_t = B_{ht} + B_{ft}, \tag{24}$$

$$B_t^* = B_{ht}^* + B_{gt}^*, \tag{25}$$

where equation (20) is the final goods market-clearing condition, (21) is the labor market-clearing condition, (22) is the intermediate-goods market-clearing condition, (23) is the money market-clearing condition, and (25) is the foreign bond market clearing condition.

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

$$GDP_t = C_t + X_t - q_t\Gamma_{ft}. \tag{26}$$

IV. Optimal policy

There are two sources of inefficiency in the model—nominal rigidities and imperfect capital mobility. Imperfect capital mobility implies imperfect risk sharing, which renders the flexible-price equilibrium allocations inefficient even if the monopolistic markup distortions can be removed by steady-state production subsidies (Corsetti, Dedola, and Leduc, forthcoming). Thus, monetary policy faces a tradeoff between stabilizing inflation and the welfare-relevant output gap. In this environment, optimal monetary policy alone cannot restore the efficient allocation and additional policy instruments, such as capital account restrictions, can potentially improve outcomes.

In what follows, we focus on capital account restrictions as additional policy instruments. We consider two types of capital account restrictions—an optimal time-varying tax rate on capital inflows and a simple constant tax on capital inflows. Under each capital account policy, we compare the macroeconomic implications of the benchmark monetary policy regime with two alternative monetary policy regimes—one with a conservative central banker that places a greater weight on inflation and the other with an exchange-rate targeting regime under which the central bank places a positive weight on real exchange rate fluctuations in the loss function.

IV.1. **Policy objective and welfare measure.** The complexity of our model prevents us from deriving an explicit welfare objective from quadratic approximations of the representative household's value function. Instead, we assume that the central bank minimizes an ad hoc loss function that reflects its desire for macroeconomic stability and financial stability. However, we compute welfare losses for a given policy by taking a second-order approximation of the *unconditional expectations* of the representative household's value function. We evaluate both the stabilizing properties and welfare implications of each policy regime.

Under the benchmark monetary policy regime, we assume that the policymaker faces the loss function

$$\mathcal{L} = \sum_{t}^{\infty} L_t, \quad L_t = \lambda_\pi \hat{\pi}_t^2 + \lambda_y \hat{gdp}_t^2 + \lambda_b \hat{b}_{yt}^2 + \lambda_q \hat{q}_t^2, \tag{27}$$

where $\hat{\pi}_t$, $\hat{gdp}_t$, $\hat{b}_{yt}$, and $\hat{q}_t$ denote deviations of domestic inflation, real GDP, the ratio of domestic bond held by foreign investors to GDP, and the real exchange rate from their respective steady-state levels. The parameters λ_π, λ_y, λ_b, and λ_q are the weights assigned to these variables.

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)].In addition to stabilizing inflation and output fluctuations, we assume that the central bank also smooths fluctuations in capital inflows. This is captured by the quadratic term involving the ratio of foreign holdings of domestic bond to GDP in the loss function (27). One could interpret this last term in the loss function as a goal of achieving financial stability.

The Ramsey planner minimizes the quadratic loss function (27), subject to the log-linearized private sector's optimizing decisions.

Under each policy regime, we evaluate welfare by calculating the unconditional expectations of the representative household's value function. Taking a second-order approximation to the representative household's period utility function, we obtain

$$U_t = \hat{C}_t + \Phi_m \hat{m}_t - \Phi_l \left(L^\eta \hat{L}_t + \frac{\eta}{2} L^{\eta-1} \hat{L}_t^2 \right). \tag{28}$$

The unconditional expectation of the value function, which is the expected infinite discounted sum of the period utilities, is given by

$$(1-\beta)V = (1-\beta)\mathrm{E}\sum_{t=0}^{\infty} \beta^t U_t = -\Phi_l \frac{\eta}{2} L^{\eta-1} var(\hat{L}), \tag{29}$$

where $var(\hat{L})$ denotes the unconditional variance of labor hours and we have used the results that $\mathrm{E}\hat{X}_t = 0$ for all log-linearized variable X.

To express welfare in units of consumption, we divide the value function by the marginal utility of consumption evaluated at the steady state, and denote this welfare measure by W. We have

$$W = -\frac{1}{1-\beta} \tilde{C} \Phi_l \frac{\eta}{2} L^{\eta-1} var(\hat{L}). \tag{30}$$

Thus, to compute welfare under each policy, it is sufficient to compute the unconditional variance of employment in the model.

IV.2. **Parameter calibration.** We focus on a balanced-trade steady-state. The current account balances and the foreign bonds held in the country are both zero, implying that $X = q\Gamma_f$.

There are four sets of parameters to be calibrated. The first set of parameters are those in preferences and technologies. These include β, the subjective discount factor for the household; Φ_m, the scale parameter for the utility of money balances; Φ_l, the scale parameter for the disutility of working; η the inverse Frisch elasticity of labor supply; ϕ, the cost share of intermediate input; α, the share of domestic intermediate goods; θ, the demand elasticity for exported goods; and $\bar{\lambda}_z$, the mean growth rate of technology.

The second set of parameters are those characterizing nominal and real rigidities in the model. These parameters include ϵ, the demand elasticity for differentiated goods; Ω_p, the price adjustment cost parameter; $\bar{\psi}$, the average portfolio share of domestic bonds held by the private sector; Ω_b, the scale of the portfolio adjustment cost function; and $\theta_f \equiv f'(-\tau R^*)$, the steady-state elasticity of the foreign investor's demand for domestic bond (i.e., capital inflows) with respect to interest-rate differentials.

The third set of parameters are related to policies. These include λ_π, λ_y, and λ_b, the central bank's welfare weights for inflation, output, and privately held foreign bond relative to GDP. In addition, we need to set a value for τ, the average tax rate on capital inflows.

The fourth set of parameters are those in the shock processes. We focus on two external shocks: a shock to the foreign interest rate R_t^* described in equation (15) and a shock to export demand X_t^* in equation 17.[10]

We follow the literature where we can to calibrate the parameters. For the preference parameters, we set $\beta = 0.998$. This value of the subjective discount factor, together with our calibrate technology growth rate of $\bar{\lambda}_z = 1.01$, implies an average annualized real interest rate of about 4.8 percent. Based on the money demand regression by Chari, Kehoe, and McGrattan (2000), we set $\Phi_m = 0.06$. We set $\eta = 2$, so that the Frisch elasticity of labor supply is 0.5, which is consistent with empirical studies Keane and Rogerson (2011). 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 $\phi = 0.5$ and the mean technology growth rate to $\bar{\lambda}_z = 1.01$. For the parameters describing the external links, we set the elasticity of substitution between domestic and foreign goods to $\theta = 1.5$, which is in line with (Feenstra, Obstfeld, and Russ, 2012). We set the steady-state portfolio share of domestic bonds to $\bar{\psi} = 0.9$, following the study by Coeurdacier and Rey (2011). Given this value of $\bar{\psi}$, the estimation results from a generalized UIP model by Chang, Liu, and Spiegel (2012) then implies that the portfolio adjustment cost parameter is $\Omega_b = 0.117$. The value of α is set to 0.756, which implies a steady-state imports to GDP ratio of 20 percent.

We calibrate the value of ϵ so that the model implies a steady-state markup of 11 percent (i.e., $\epsilon = 10$), 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

[10]We have also examined a case with a productivity shock. The reported results are robust to the inclusion of this shock.

and Steinsson, 2008).[11] We normalize the local elasticity of capital inflows with respect to interest-rate differentials to $\theta_f = 1$.

For the policy parameters, we normalize $\lambda_y = 1$ and set $\lambda_\pi = 1$ as a baseline value. We set $\lambda_b = 0.1$. We set the average tax rate on capital inflows to $\tau = 0.3$ as a benchmark. We consider greater values of λ_π to assess the consequences of policy regimes that are more hawkish against inflation. We also consider an exchange-rate targeting regime that has the real exchange rate fluctuations as an additional component of the central bank's loss function, with a weight of $\lambda_q = 0.1$.

For parameters in the shock processes, 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 $\sigma_r = 0.01$.

As we lack guidance to calibrate the export demand shock process, we arbitrarily set the persistence of that shock to $\rho_x = 0.95$ (which reflects the persistence in the U.S. productivity shocks as found in the standard real business cycle models) and the standard deviation of the export demand shock to $\sigma_x = 0.01$. The qualitative results are the same when we vary these parameter values within a reasonable range.

IV.3. **Optimal time-varying capital account restrictions.** We first consider the case in which the government can optimally choose a time path for the tax rate on capital inflows (i.e., τ_t). Since imperfect capital mobility implies inefficient flexible-price allocations, optimal monetary policy alone cannot achieve the first-best allocation. We therefore evaluate the effectiveness of time-varying capital account restrictions for insulating the small open economy from external shocks, such as the declines in foreign interest rates or export demand that we observed during the financial crisis.

To answer this question, we solve the Ramsey optimal policy problem that minimizes the loss function (27) subject to the private sector's optimizing decisions. The

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[11]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.

Ramsey planner chooses all endogenous variables, including τ_t, the time-varying tax rate on foreign capital inflows. We consider three alternative monetary policy regimes: the benchmark monetary policy with our calibrated parameters in the loss function, a hawkish monetary policy with a higher weight on inflation (in particular, with $\lambda_\pi = 3$ instead of 1), and an exchange-rate targeting policy with the real exchange rate stability as an additional term in the loss function with a weight of $\lambda_q = 0.1$.

Figure 1 shows that the optimal tax rate on capital inflows responds to external shocks. In response to a negative foreign interest rate shock, the tax rate on capital inflows increases persistently (the top panel of the figure). The responses of the optimal tax rate do not depend on the monetary policy regime (the three lines in the figure are on top of each other). The higher tax rate discourages capital inflows and therefore helps mitigate the impact of the shock on domestic variables. Indeed, under optimal capital account restrictions, domestic variables (such as inflation, real GDP, current account, and employment) do not respond much to the foreign interest rate shock, and we do not display the impulse responses to this shock to conserve space.[12]

Optimal time-varying capital account restrictions are less effective for insulating the domestic economy from export demand shocks. As a result, this leaves room for other instruments, such as real exchange rate stabilization, to generate additional welfare gains, as we show below.

As shown in the bottom panel of Figure 1, optimal policy calls for a much smaller response of the tax rate to an export demand shock than to a foreign interest rate shock. Under the benchmark monetary policy, the optimal tax rate on capital inflows falls slightly when export demand falls. This is because monetary policy accommodates the negative demand shock by lowering the domestic interest rate. Since the foreign interest rate is exogenous, the decline in the domestic interest rate makes the domestic bond less attractive. The planner optimally lowers the tax rate on foreign investors' holdings of domestic bonds to prevent capital outflow. Under the benchmark monetary policy, the optimal capital account restrictions imply that the foreign demand for the domestic bond stays constant.

Figure 2 shows the impulse responses under optimal capital controls of macroeconomic variables following an exogenous decline in export demand, which captures the large recessions experienced by advanced economies during the crisis. We plot the responses under three different monetary policy regimes: the benchmark policy

[12]The magnitude of the impulse responses of macroeconomic variables are in the order of 10^{-12}.

with calibrated weights in the loss function, a hawkish policy with a higher weight on inflation, and an exchange rate targeting policy.

All else equal, a decline in the domestic nominal interest rate (relative to the foreign interest rate) should lead to a current depreciation and an expected appreciation of the domestic currency (this is an implication from the standard UIP condition). However, Figure 2 shows that the real exchange rate appreciates following the negative export demand shock.

This result appears puzzling, but it is a natural implication of sterilized intervention under imperfect asset substitutability. With imperfect substitutability, the standard UIP condition no longer holds. It is replaced by the modified UIP condition (5). Log-linearizing the modified UIP condition around the steady state, we obtain

$$\hat{R}_t - \hat{R}_t^* = \mathrm{E}_t \gamma_{e,t+1} + \Omega_b \bar{\psi}(1+\bar{\psi})\hat{\psi}_t, \tag{31}$$

where a hatted variable denotes the log-deviations from the steady state, the term $\gamma_{e,t+1}$ denotes the log-growth rate of the nominal exchange rate from period t to $t+1$, and the term $\hat{\psi}_t$ denotes the log-deviations of the portfolio share of privately held domestic bond from its steady-state share $\bar{\psi}$. Absent portfolio adjustment costs (i.e., given $\Omega_b = 0$), this relation reduces to the standard UIP condition, which would imply that a decline in the relative interest rate is associated with an expected appreciation of the domestic currency (i.e., a decline in $\mathrm{E}_t \gamma_{e,t+1}$).

However, with imperfect asset substitutability, movements in the portfolio share can accommodate our surprising outcome. In our case, the central bank eases by purchasing domestic debt from domestic citizens (recall that foreign holdings remain virtually unchanged). Thus, the portfolio share of domestic debt ψ_t falls. The reduction in holdings of domestic bonds leads to a reduction in the demand for foreign-currency bonds by the household because variations in the portfolio share incur a quadratic adjustment cost. As demand for foreign-currency bond falls, the exchange rate appreciates. Over time, the exchange rate returns to its long-run steady state. Thus, the appreciation in the impact period is followed by expected depreciation in subsequent periods (i.e., $\mathrm{E}_t \gamma_{e,t+1}$ rises). Note that domestic private agents are willing to hold domestic assets, despite their lower expected rates of return because of the lower share of those assets in their portfolios.

Notwithstanding the current account deficits and the real appreciation of the currency, optimal capital control policy is quite effective for insulating domestic inflation and real GDP from export demand shocks. However, the reduction in export demand implies a decline in employment, which leads to welfare losses.

Table 2 shows the welfare and macroeconomic volatilities under the optimal time-varying capital account policy and the simple capital account policy given both shocks.[13] The table shows that optimal capital account policy under the benchmark monetary policy regime is very effective for insulating the economy from external shocks (i.e., the foreign interest rate shock and the export demand shock). Consistent with the impulse responses, inflation and real GDP are completely stabilized, although the economy experiences small fluctuations in current account and employment. The welfare loss under this optimal policy is about one-third of one percent of steady-state consumption, which is broadly in line with the literature on the welfare cost of business cycles (Lucas, 2003). Table 2 also confirms that adopting a hawkish monetary policy regime does not change the welfare loss under optimal capital controls.

In contrast, adopting an exchange-rate targeting regime does improve welfare outcomes when the capital account policy is chosen optimally. We observe a decline in GDP, which mitigates the extent of current account depreciation and avoids the real exchange rate appreciation we observed in the benchmark case (Figure 2). We do see an uptick in inflation, stemming from monetary easing, but real exchange rates are kept close to their long run values through a temporary offsetting nominal exchange rate appreciation, followed by a period of depreciation. This depreciation in the nominal exchange rate reduces the foreign demand for domestic bonds despite the short run increase in the nominal interest rate.

Overall, optimal policy under the exchange-rate targeting regime does not completely offset fluctuations in inflation and output, but it does lead to smaller fluctuations in the current account and employment, as confirmed by Table 2. Thus, the exchange-rate targeting regime leads to smaller welfare losses than either the benchmark policy or the hawkish policy.

IV.4. **Simple capital account restrictions.** We have shown that time-varying capital account restrictions are effective for achieving macroeconomic stability in face of external shocks, and in particular, for shocks to foreign interest rates. In practice, however, we do not observe such time-varying (and state-contingent) tax policies in emerging market economies. A common practice is a constant tax rate on capital

[13]We follow the literature by assuming that these shocks are independent. However, in practice they may well be correlated.

inflows. We therefore also examine the macroeconomic implications and welfare consequences of a simple capital control policy with a constant τ (which is fixed at the steady-state level of 0.3 instead of being a choice variable for optimal policy).

To understand the stabilizing properties of simple capital control policies, we examine the impulse responses of macroeconomic variables to the two types of external shocks.

Figure 3 shows the impulse responses to an exogenous decline in the foreign interest rate under the simple capital control policy. Under the benchmark monetary policy, the decline in the foreign interest rate raises the demand for domestic bonds by the foreign investor, giving rise to capital inflows. Unlike the case with optimal capital control policy, the government cannot adjust the tax rate to curb such capital inflows. The capital inflows therefore lead to a real appreciation and a current account deficit. They also drive down the domestic nominal interest rate as the demand for domestic bonds rises. Despite the current account deficit, the decline in the nominal interest rate and thus the expansion in money supply raise domestic consumption and lead to a short-run increase in real GDP. The expansionary monetary policy also creates inflationary pressure, which, however, is more than offset by the decline in the real marginal cost because the relative price of imported intermediate goods declines as the currency appreciates (i.e., the country has a more favorable terms of trade).

Our "hawkish" central banker puts a higher weight on deviations of inflation in its loss function, either positive or negative. In this case, this results in a smaller initial decline in inflation than the decline observed under the benchmark case. This relative easing of monetary policy leads to a larger expansion in real GDP. However, the relatively larger increases in real activity imply that in equilibrium the domestic nominal interest rate declines by less than under the benchmark policy regime.

When the central bank targets the real exchange rate, the foreign interest rate shock leads to a much smaller real appreciation than under the benchmark policy or the hawkish policy. The smaller real appreciation implies a smaller current account deficit. Since the improvement in the terms of trade is relatively small, the decline in the cost of imported intermediate goods is more than offset by the inflationary pressure created by capital inflows. Thus, inflation rises along with real GDP. The optimal response of the nominal interest rate is accordingly smaller than that in the case with the benchmark or hawkish policy. Since the interest-rate spread is larger, the economy experiences more capital inflows than under the benchmark or hawkish policy.

Figure 4 show shows the impulse responses of macroeconomic variables under simple capital controls following an exogenous decline in export demand. Unlike the optimal capital account restriction case, the benchmark monetary policy combined with a simple capital account policy cannot completely stabilize fluctuations in inflation and real GDP following an export demand shock. The decline in export demand leads to a current account deficit and generates a modest recessionary effect. Optimal monetary policy responds by lowering the domestic nominal interest rate. Since the foreign interest rate is unchanged, the optimal leads to a reduction in the relative yield on domestic bonds. Investors—both domestic and foreign—respond by reducing their holdings of domestic bonds. Accordingly, the shock leads to a capital outflow. The government purchases the domestic currency bonds from the private sector and foreign investors by selling foreign currency reserves and by expanding the money supply.

Since the relative bond yield declines, the UIP condition implies that the domestic currency is expected to appreciate. The currency appreciation improves the terms of trade and thus reduces the relative cost of imported intermediate goods. However, the expansionary monetary policy more than offsets the cost reduction through improved terms of trade. In equilibrium, inflation rises slight on impact of the shock.

Similar to the case with optimal capital controls, the hawkish monetary policy does not change much of the impulse responses of macroeconomic variables to an export demand shock. The exchange-rate targeting policy, however, has significantly different macroeconomic implications, as shown by the dashed and dotted lines in Figure 4. Indeed, under the exchange-rate targeting regime, the macroeconomic responses to an export demand shock are not sensitive to the choice of capital account policies. The qualitative patterns of the impulse responses plotted in Figure 4 under the exchange-rate targeting regime with simple capital account restrictions are the same as those plotted in Figure 2 for the case with optimal capital control policies. The intuitions for these impulse responses are also similar to those provided in Section IV.3.

Table 2 again displays the welfare results for both shock under the simple capital account restriction. Under the simple capital account controls, adopting a hawkish regime better weathers the external shocks than does the benchmark regime, leading to a significant welfare improvement. Consistent with the impulse responses shown in Figures 3 and 4, the hawkish regime leads to slightly more volatile fluctuation in foreign capital inflows, but smaller volatility of inflation, current account, and employment. With more stable employment, the hawkish regime incurs lower welfare losses.

The table also reveals that the exchange-rate targeting regime again leads to even lower welfare losses than does the hawkish policy under simple capital controls, as suggested by the impulse response functions in Figures 3 and 4.

Comparing the welfare losses and the macroeconomic volatilities under simple capital controls with those under optimal capital controls shows that, although the two capital account policies with an exchange-rate targeting policy lead to very different macroeconomic fluctuations, they have very similar welfare results. Simple capital controls imply much larger volatilities in current account and capital inflows than optimal capital controls. However, simple capital controls do not prevent optimal exchange-rate targeting policies to smooth fluctuations in inflation, real GDP, and more importantly, employment. In this sense, exchange-rate targeting is a robust and effective policy regime that helps insulate domestic fluctuations from external shocks.

V. Conclusion

This paper compares the effectiveness of monetary policy and capital controls in smoothing external shocks by comparing welfare outcomes under both simple and optimal capital controls policies and under different monetary regimes. As our environment is one of imperfect risk sharing, there is a role for these policies to improve welfare in the face of external shocks. Moreover, as our analysis is conducted in a consistent model with comparable steady states, we can coherently compare welfare outcomes across these alternative regimes. To our knowledge, our paper is the first that examines these issues for small open economies in a full monetary model that allows for consideration of the full implications of central bank sterilization decisions. We find that sterilization policies can play an important role in smoothing external shocks in our model, and indeed, they appear to be an important policy component empirically as well.

We confirm that optimal capital control policies do a very good job of smoothing both foreign interest rate and export demand shocks. However, as such complicated policies are not observed in practice, we also examine the effectiveness of "simple" capital controls, in our case a constant tax on foreign borrowing. We find that the simple capital control policy leaves substantive scope for welfare improvement through monetary policy discipline. This is demonstrated through our finding that under simple controls, the loss function followed by the monetary authority matters. Under simple capital controls, welfare outcomes are substantively improved by moving from a central banker with standard weights to a "conservative" central banker who puts greater weight on controlling inflation volatility. However, the greatest improvement is seen under a central banker that also considers the real exchange rate in setting his monetary policy. Indeed, under the "exchange rate targeting" central banker, there is little further welfare enhancement in moving from the simple to optimal capital account policies.

In reality, capital controls that we observe empirically are somewhere between these two extremes, commonly being imposed during episodes of vulnerability, kept constant throughout those episodes, and then reduced or removed entirely as volatility recedes. However, such a policy would have a different steady state than those we consider above, precluding consistent comparison of welfare outcomes under these policies.

We leave consideration of such policies for future research. In addition, we plan in future research to add an explicit financial sector to consider the impact of foreign capital inflows on financial conditions in a small open economy.

VI. Appendix

VI.1. **Derivations of the generalized UIP condition** (5)**.** The first order condition for domestic nominal bond holdings is given by

$$1 + \frac{\Omega_b}{2}(\psi_t - \bar{\psi})^2 + \Omega_b(\psi_t - \bar{\psi}) = \mathrm{E}_t \frac{\Lambda_{t+1}}{\Lambda_t} \frac{R_t}{\pi_{t+1}}, \tag{32}$$

where, as we explain in the text, the term ψ_t denotes the share of domestic bond in the household's total bond holdings, Λ_t is the Lagrangian multiplier for the household's budget constraint, and π_{t+1} is the inflation rate from period t to $t+1$.

Similarly, the first order condition for foreign bond holdings is given by

$$1 + \frac{\Omega_b}{2}(\psi_t - \bar{\psi})^2 - \Omega_b(\psi_t - \bar{\psi})\psi_t = \mathrm{E}_t \frac{\Lambda_{t+1}}{\Lambda_t} \frac{e_{t+1}}{e_t} \frac{R_t^*}{\pi_{t+1}}. \tag{33}$$

Subtracting equation (33) from equation (32), we obtain

$$\Omega_b(\psi_t - \bar{\psi})(1 + \psi_t) = \mathrm{E}_t \frac{\beta \Lambda_{t+1}}{\Lambda_t} \frac{1}{\pi_{t+1}} \left[R_t - R_t^* \frac{e_{t+1}}{e_t} \right], \tag{34}$$

which corresponds to equation (5) in the text.

VI.2. **Derivation of real marginal cost equation** (8)**.** Denote by v_t the real marginal cost for firms. Cost-minimizing implies that

$$v_t = \tilde{\phi} q_{mt}^{\phi} \left(\frac{w_t}{Z_t} \right)^{1-\phi}, \tag{35}$$

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

$$\frac{w_t}{q_{mt}} = \frac{1-\phi}{\phi}\frac{\Gamma_t(j)}{L_t(j)}. \tag{36}$$

The intermediate input for production is a composite of domestically produced and imported goods

$$\Gamma_t = \Gamma_{ht}^{\alpha}\Gamma_{ft}^{1-\alpha}, \tag{37}$$

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

$$q_{mt} = \tilde{\alpha}\left(\frac{e_t P_t^*}{P_t}\right)^{1-\alpha} \equiv \tilde{\alpha} q_t^{1-\alpha}, \tag{38}$$

where P_t^* denotes the foreign price level and q_t denotes the real exchange rate. 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

$$q_t = \frac{1-\alpha}{\alpha}\frac{\Gamma_{ht}}{\Gamma_{ft}}. \tag{39}$$

Thus, the real marginal cost in equation (35) can be expressed as a function of the real exchange rate q_t and the real wage rate w_t:

$$v_t = \tilde{\phi}\tilde{\alpha}^{\phi} q_t^{\phi(1-\alpha)}\left(\frac{w_t}{Z_t}\right)^{1-\phi}. \tag{40}$$

where $\tilde{X}$ $(X = \phi, \alpha)$ are constants satisfying $\tilde{X} \equiv X^{-X}(1-X)^{X-1}$, α represents the expenditure share of domestic intermediate goods, q_t is the real exchange rate, and w_t represents the real wage.

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	2
	Technologies	
ϕ	Cost share of intermediate goods	0.50
$\bar{\lambda}_z$	Mean productivity growth rate	1.01
	Nominal and real rigidities	
ϵ	Elasticity of substitution between differentiated goods	10
Ω_p	Price adjustment cost	30
Ω_b	Portfolio adjustment cost parameter	0.117
	International trade	
α	Share of domestic intermediate goods	0.756
θ	Export demand elasticity	1.5
τ	Tax on foreign investor's holdings of domestic bond	0.3
θ_f	Elasticity of capital inflows	1
	Loss function	
λ_π	Weight on inflation	1
λ_y	Weight on GDP	1
λ_b	Weight on capital inflows	0.1
λ_q	Weight on real exchange rate	0.1

TABLE 2. Welfare and macroeconomic volatilities under alternative policy regimes

	Optimal capital controls			Simple capital controls		
	Benchmark	Hawkish	ER-targeting	Benchmark	Hawkish	ER-targeting
Welfare	-0.35	-0.35	-0.10	-3.21	-1.83	-0.11
σ_π	0	0	0.0006	0.0025	0.0012	0.0012
σ_y	0	0	0.0014	0.0047	0.0049	0.0022
σ_{ca}	0.0077	0.0077	0.0055	0.0163	0.0161	0.0224
σ_{b_f}	0	0	0.0014	0.0456	0.0464	0.0493
σ_l	0.0036	0.0036	0.0019	0.0109	0.0082	0.0020

Note: Welfare is measured by percentage losses in units of steady-state consumption (a number closer to zero means a lower welfare loss). The term σ_x *denotes the standard deviation of the variable* x*, where* x *denotes domestic inflation* (π)*, real GDP (y), current account balances (ca), capital inflows* (b_f)*, and employment (l). With each type of capital account policy, we consider three different monetary policy regimes. The benchmark regime ("Benchmark") has a loss function with the calibrated welfare weights. The hawkish regime is one with a greater weight on inflation than in the benchmark model* (λ_{pi} *is raise to 3 from 1). The exchange-rate targeting regime is otherwise identical to the benchmark regime, but the loss function contains the deviations of the real exchange rate from steady state as an additional variable, with a weight of* $\lambda_q = 0.1$.

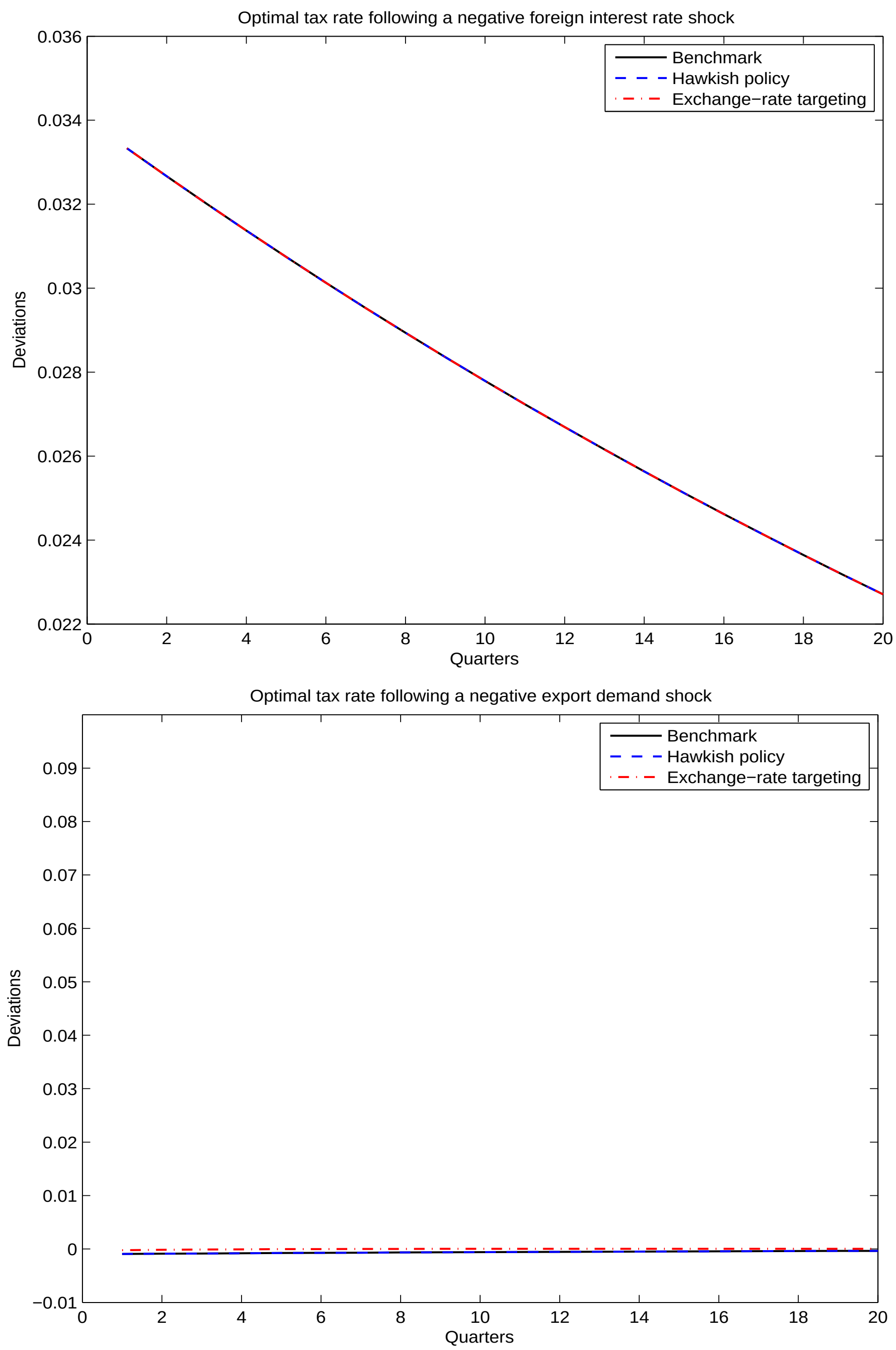

FIGURE 1. Impulse responses of optimal capital inflow taxes. The top panel shows the response of the optimal tax rate following a negative shock to the foreign interest rate. The bottom panel shows the response following a negative shock to export demand.

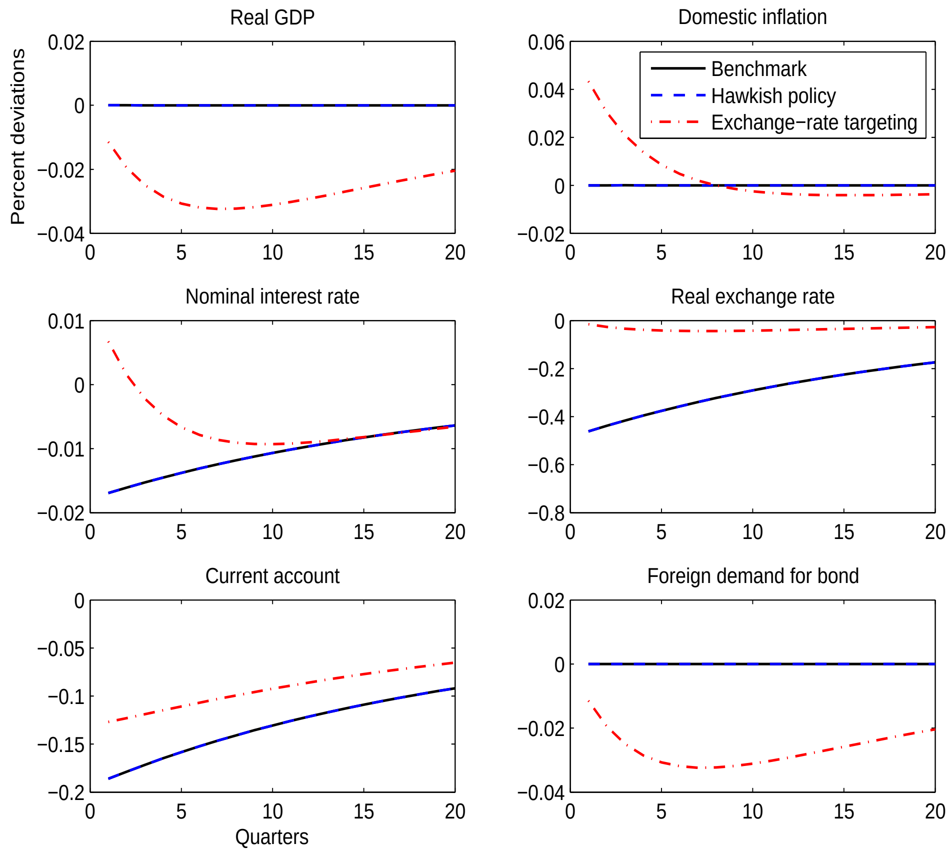

FIGURE 2. Impulse responses to a negative export demand shock under optimal capital controls and alternative monetary policy regimes.

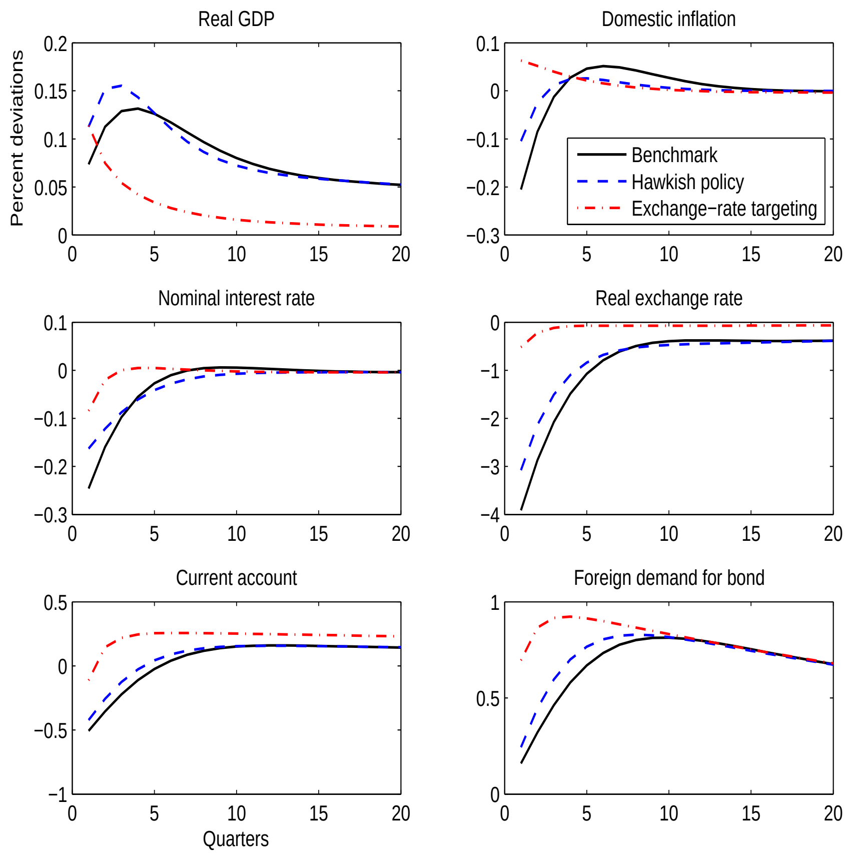

FIGURE 3. Impulse responses to a negative shock to the foreign interest rate under simple capital controls and alternative monetary policy regimes.

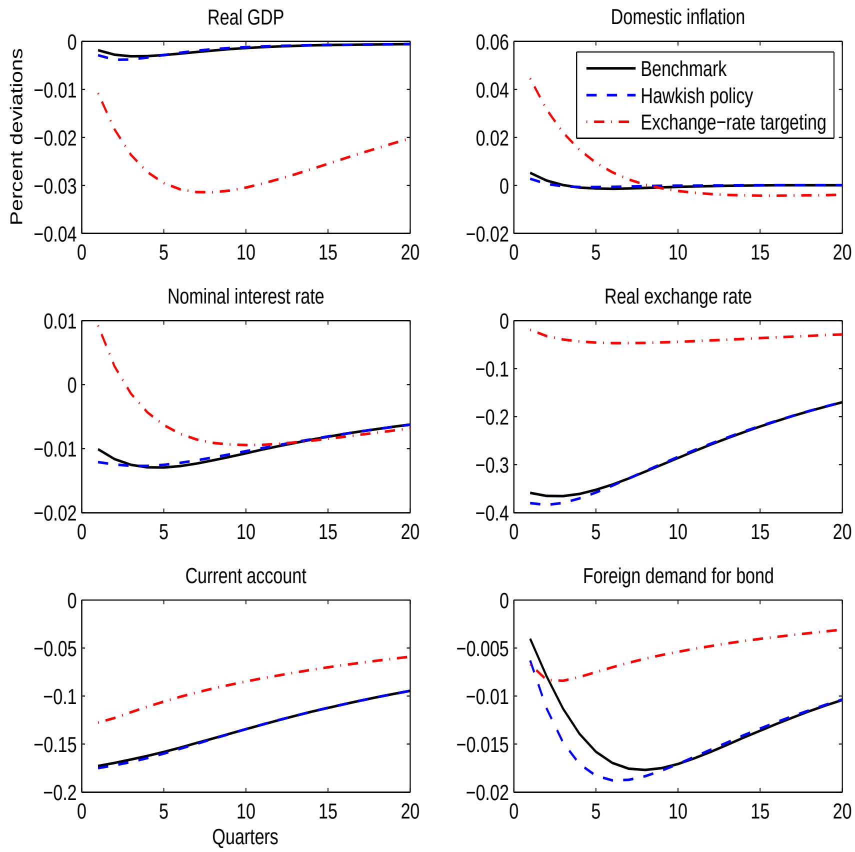

FIGURE 4. Impulse responses to a negative export demand shock under simple capital controls and alternative monetary policy regimes.

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