Capital Controls as an Instrument of Monetary Policy*

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First Draft: February 2014

This Draft: February 2015

Abstract

Large swings in capital flows into and out of emerging markets can potentially lead to excessive volatility in asset prices and credit supply. In order to lessen the impact of capital flows on financial instability, a number of researchers and policy makers have recently proposed the use of capital controls. This paper considers the benefit of adding capital controls as a potential instrument of monetary policy in a small open economy. In a DSGE framework, we find that when domestic agents are subject to collateral constraints and the value of collateral is subject to fluctuations driven by foreign capital inflows and outflows, the adoption of temporary capital controls can lead to a significant welfare improvement. The benefits of capital controls are present even when monetary policy is determined optimally, implying that there may be a role for capital controls to exist side-by-side with conventional monetary tools as an instrument of monetary policy.

JEL Classification: F32; F41; E52; E32

Keywords: capital controls; credit constraints; small open economy

*We would like to thank participants at the 10th Dynare conference for many helpful comments and suggestions. We would also like to thank Mick Devereux, Fabio Ghironi, Kevin Huang, Gianni Lombardo, and Albert Queralto. The views presented here are those of the authors and do not necessarily represent the views of the Federal Reserve Banks of Dallas or the Federal Reserve System.

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1 Introduction

Repeated cycles of capital flows into and out of emerging markets is a fixture of the financially integrated global economy. Surges in capital inflows have led to talk of "currency wars" and the danger of overheating in many emerging markets. Likewise, a sudden reversal of capital flows has been blamed for the recent financial and macroeconomic instability in many emerging markets.

Rey (2013) and Forbes and Warnock (2012) show that capital flows into and out of emerging markets are largely driven by global factors. They both show that a measure of global risk is one of the main determinants of international capital flows. Meanwhile, country-specific characteristics are largely irrelevant for driving capital flows into and out of a particular emerging market economy. Reinhart and Reinhart (2008) argue that surges in capital inflows into emerging markets are associated with a higher likelihood of banking, inflation and currency crises, and contribute to economic and financial instability. Kaminsky, Reinhart, and Végh (2005) show that capital inflows are a primary reason for the procyclicality of fiscal and monetary policy observed in many emerging markets. Rey (2013) argues that since these foreign capital flows can lead to asset price bubbles, excess credit creation, and financial instability, capital controls or some tool of active capital account management is necessary in many countries. She argues that this cycle of capital inflows and outflows means that the classic "trilemma" of international finance is actually more of a "dilemma", and that "independent monetary policies are possible if and only if the capital account is managed."[1]

In a recent paper, staff at the International Monetary Fund (2012) argue that in certain circumstances, active capital controls might be a useful policy instrument to manage the macroeconomic and financial risks associated with large swings in capital inflows and outflows. Jeanne, Subramanian, and Williamson (2012) argue that capital controls “properly

[1] Klein and Shambaugh (2013) dispute this result and instead argue that a country with an open capital account can still gain considerable monetary autonomy by simply allowing its exchange rate to float.

designed ... might even be a regular instrument of economic policy." (p. 95)

In a DSGE model, this paper will directly address this issue raised in these recent papers. Under what circumstances can capital controls be a useful instrument of monetary policy *in addition to* conventional monetary tools like the nominal risk-free interest rate? This paper will consider the optimal design of capital controls in a model with both sticky prices and collateral constraints. The sticky prices provide a role for conventional monetary policy in macroeconomic stabilization, while collateral constraints provide a means through which cycles of capital flows into and out of the small open economy cause financial instability. Crucially, the amount that individuals can borrow depends on the value of existing collateral at the current market price. A surge in capital inflows following a foreign shock can push up asset prices and loosen the collateral constraint in the small open economy, leading to excess credit-creation.

The externality created by the presence of the asset price in the collateral constraint leads to a role for policy to counter these surges in capital inflows and outflows. We show how this externality leads to a boom-bust cycle in the provision of credit. The response of investment following a surge in capital inflows in a model with a binding collateral constraint can differ strongly from the response in the model with no credit frictions. Optimal taxes on capital inflows and outflows significantly reduce the disparity between allocations in the economy with credit frictions and those in the efficient model. This is true both in a model with flexible prices and in a model with sticky prices, where there is also a role for conventional monetary policy. Thus, even when conventional monetary policy in a small open economy is chosen optimally, capital controls can be used as an additional tool for macroeconomic stabilization.[2]

[2] This paper will address in a theoretical framework under what conditions it might be appropriate to use capital controls as an instrument of policy. The potential effectiveness of these capital controls is a separate, empirical, question. Klein (2012) argues that temporary "episodic" capital controls have little effect on many macroeconomic variables. Cordero and Montecino (2010) argue that capital controls can be a useful tool of monetary policy and can help countries keep inflation under control and also maintain a stable and competitive real exchange rate. Ostry, Ghosh, Chamon, and Qureshi (2012) show that while capital controls tend to be of limited use in controlling the aggregate volume of capital flows, inflow controls can be a useful instrument of policy to reduce the financial stability risks associated with surges in capital inflows. Forbes,

However, this result only holds when borrowers in the small open economy face a collateral constraint. When there is no collateral constraint and price frictions are the only source of distortions in the model, the allocation under optimal conventional monetary policy with an open capital account is identical to the allocation when both conventional monetary policy and capital controls are chosen optimally (and thus optimally chosen capital controls are zero). Without a friction in the supply of credit that leads to a financial stability objective to monetary policy, as long as conventional monetary policy is chosen optimally, optimal capital account policy is to maintain an open capital account.

The use of capital controls as an instrument of monetary policy when combined with a fixed exchange rate has been part of the international macro literature since Mundell (1963) and Fleming (1962). A number of recent papers have addressed this issue of the optimal design of capital controls. The literature usually follows one of two strands. Schmitt-Grohe and Uribe (2012b) and Schmitt-Grohe and Uribe (2012a) discuss the optimal use of capital controls in an economy that is the member of a currency union and suffers from downward nominal wage rigidity. They show that capital controls can be a viable instrument of policy to overcome the involuntary unemployment caused by wage rigidity. Here they make use of the constraints imposed by the "trilemma"; in a currency union the country lacks a monetary instrument for stabilization, but capital controls can allow the country to still manipulate the price level and thus the real exchange rate while keeping the nominal exchange rate fixed. Farhi and Werning (2012) reach a similar conclusion, that a counter-cyclical capital controls policy can play a role in macroeconomic stabilization in a small open economy with a fixed exchange rate. Costinot, Lorenzoni, and Werning (2011) and de Paoli and Lipinska (2013), and Farhi and Werning (2014) discuss the optimal use of capital controls for terms-of-trade

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Fratzscher, and Straub (2015) show that capital controls can significantly reduce some measures of financial fragility.

Baba and Kokenyne (2011) and Magud, Reinhart, and Rogoff (2011) both find that while in practice capital controls do little to affect the volume of capital flows or other key macroeconomic variables, they do tend to "provide room" for monetary policy and tend to make monetary policy more independent in many emerging markets. Fernández, Rebucci, and Uribe (2013) discuss how theory suggests that policy makers should use capital controls countercyclically as a tool of macroprudential policy, but empirically they find that capital controls tend to be acyclical.

manipulation.

While these papers consider the role of capital controls as an instrument of monetary policy, they do not address the role of capital controls in fostering financial stability. Korinek (2010), Jeanne and Korinek (2010), Bianchi and Mendoza (2013), Bianchi (2011), Benigno, Chen, Otrok, Rebucci, and Young (2013), Korinek (2013), and Brunnermeier and Sannikov (2015) all discuss how the fact that collateral constraints depend on asset prices, which are subject to fluctuations from capital inflows, leads to over-borrowing and financial vulnerability in an open economy. Specifically the over-borrowing is caused by a pecuniary externality, where agents don't internalize the effect that their collective actions are having on asset prices, and thus collateral constraints. They discuss how counter-cyclical taxes on capital inflows and other macroprudential measures can be used to offset this externality and reduce financial vulnerabilities. Engel (2015) surveys the recent literature on capital controls and macroprudential policy in a world of volatile international capital flows and discusses how capital controls can be used as a macroprudential regulation to correct for certain financial distortions.

This paper seeks to combine the insights from these two strands of the literature discussing optimal capital controls. The first discusses the use of capital controls as a potential instrument of monetary policy in a model with sticky prices and thus a role for conventional monetary policy. These papers usually focus on a country that has adopted a fixed nominal exchange rate, and thus this strand of the literature focus on the ability of capital controls to act as an instrument of monetary policy within the confines of the trilemma of international finance. The second strand of the literature discusses the use of capital controls as a potential instrument of macroeconomic policy in models with collateral constraints or other financial frictions, and thus these papers focus on the financial stability motive for capital controls. By combining the insights from these two strands of the literature, this paper will consider the optimal design of capital controls as an instrument of monetary policy in a model with both sticky prices and collateral constraints.

In a sticky price DSGE model, we calculate Ramsey optimal policy under two scenarios, one where the policy maker can choose Ramsey optimal monetary policy but the capital account remains open, and one where the policy maker can choose both Ramsey optimal monetary policy and Ramsey optimal capital controls policy. With both impulse responses and consumption equivalent welfare cost measures we show that the option to choose Ramsey optimal capital controls leads to a significant welfare improvement when there are distortions in the model arising from credit frictions. In a version of the model without these credit distortions, there is no benefit to capital controls policy.

This paper will proceed as follows. The theoretical model used to derive these optimal policy results is described in section 2. The model is a two-country sticky price DSGE model, where one country is small relative to the rest of the world. In the model, borrowers face collateral constraints where the amount they can borrow depends on the value of existing collateral at the current market price. We show that in this framework the value of collateral, and thus the amount of borrowing in the small open economy, is subject to fluctuations based on surges of capital inflows and outflows from the rest of the world. The calibration of the model is discussed in section 3. The results from the model are presented in section 4. Here we will examine responses in the home country to a sharp drop in capital inflows from the rest of the world. We will examine these both under the cases of flexible prices (and thus no role for conventional monetary policy) and sticky prices. Finally section 5 concludes with some directions for further research.

2 The model

In this infinite-horizon model there are two countries, home and foreign. As in the New Open Economy Macro literature in Obstfeld and Rogoff (1995), the home country is size n and the foreign country is size $1-n$. As $n \to 0$, the model becomes one with a small open economy and the rest of the world. Foreign variables are written with an asterisk $(*)$

and home variables are not. In the following description of the model, foreign equations are omitted for brevity.

Time is discrete and indexed by t = 1, 2, ... The sources of aggregate uncertainty are given by shocks to the time discount factor and shocks to the collateral constraint; all information is publicly available.

Each country is populated by a representative household, entrepreneur, and firm, each of measure 1. Households supply labor to domestic firms and consume. They are net savers. Entrepreneurs borrow from domestic households to finance capital accumulation, and they rent this capital to firms. A financial friction limits, however, their ability to raise funds. Entrepreneurs are subject to a collateral constraint and cannot borrow more than a given fraction of the value of their capital stock. This credit constraint can be seen as emerging endogenously due to limited enforcement: if entrepreneurs renege on their debt contracts, the creditors can seize their assets and recover only part of the liquidation value of the physical capital. Firms hire labor, rent capital, and produce an output. The output from domestic firms is combined with the output from foreign firms to produce a final good that is used for consumption and investment. Firms are engaged in monopolistic competition and set prices according to a Calvo (1983) style price setting framework. Monetary policy is set according to the solution to a Ramsey problem to maximize total welfare in the economy. The conventional monetary policy instrument in this cash-less economy is the risk-free nominal rate of interest. The central bank in the small open economy also has the potential to impose temporary, episodic taxes or subsidies on capital inflows and outflows in order to deter or encourage capital flows.

In this section we will present the model and some of they key equilibrium conditions, the full set of first-order conditions and market clearing conditions is presented in the appendix.

2.1 Households

Households supply labor to domestic firms, and lend their savings to domestic entrepreneurs. They consume from their labor income and interest on savings. They are risk-averse and derive utility from consumption and disutility from labor effort.

The representative household chooses consumption, C_t , labor effort, H_t, and home and foreign currency bond holdings, B_{t+1} and B_{t+1}^f, to maximize expected lifetime utility given by:

$$E_0 \sum_{t=0}^{\infty} \beta^t A_t \left[\ln(C_t) - \psi (H_t)^{\frac{1+\sigma_H}{\sigma_H}} \right] \tag{1}$$

subject to their budget constraint:

$$\begin{aligned} & P_t C_t + B_{t+1} + S_t B_{t+1}^f \\ = \quad & W_t H_t + \Xi_t + (1+i_t) B_t + \left(1 - \chi^b S_t B_t^f - \tau_t\right)(1+i_t^*) S_t B_t^f \end{aligned}$$

where Ξ_t is profit from domestic firms, returned lump-sum to the household, S_t is the nominal exchange rate in units of the home currency per units of the foreign currency, and W_t is the wage rate. $\chi^b S_t B_t^f + \tau_t$ represents a tax on holding foreign bonds. The first component, $\chi^b S_t B_t^f$, is simply used to ensure stationarity of the linear approximation of the model as in Schmitt-Grohe and Uribe (2003) and has little effect on the dynamics of the model.[3] The component τ_t is a policy variable. It has a steady state value of zero and in some model specifications we will consider later, this tax is a policy instrument, and is akin to controls on capital outflows, as in Farhi and Werning (2012).

[3] In the steady state, foreign bond holding is zero, following a positive shock, the home country may run a current account surplus and thus accumulate a stock of foreign bonds, without this quadratic tax rate, there is nothing to say that they would return to the original steady state where the home country holds no foreign bonds, this tax rate means that when the home country holds a large stock of foreign bonds, $S_t B_t^f > 0$, the after tax return on those bonds is lower, meaning that the home country will gradually hold fewer foreign bonds until the stock of foreign bonds returns to the stationary steady state.

The intertemporal preference shock to home country household utility, A_t, follows the stochastic process:

$$A_t = A_{t-1} e^{\lambda_t}$$

where $\lambda_{t+1} = (1-\rho_\lambda)\bar{\lambda} + \rho_\lambda \lambda_t + \varepsilon_t^\lambda$, and $\bar{\lambda} > 0$ is a constant to ensure that in the steady state, households are net savers and entrepreneurs are net borrowers.

The analogous budget constraint for the foreign household is:

$$\begin{aligned} & P_t^* C_t^* + B_{t+1}^* + \frac{B_{t+1}^{f*}}{S_t} \\ = \quad & W_t^* H_t^* + (1+i_t^*) B_t^* + \left(1 - \chi^b \frac{B_t^{f*}}{S_t} - \tau_t^*\right)(1+i_t) \frac{B_t^{f*}}{S_t} \end{aligned}$$

The first order condition of the household's problem with respect to domestic bond holdings yields the familiar Fisher equation that links the nominal interest rate, i_{t+1}, to the real interest rate, r_{t+1}, and the expected inflation rate, $E_t(\pi_{t+1})$

$$i_{t+1} = r_{t+1} + E_t(\pi_{t+1})$$

The real interest rate is given by:

$$r_{t+1} = \frac{\Lambda_t}{\beta E_t\left(e^{\lambda_{t+1}} \Lambda_{t+1}\right)} - 1,$$

where Λ_t is the equilibrium marginal utility of household consumption.

No arbitrage conditions between home and foreign bonds give rise to the uncovered interest parity conditions (in levels):

$$\frac{S_t}{S_{t+1}} = \frac{\left(1+i^*_{t+1}\right)\left(1-\chi^b S_{t+1} B^f_{t+1} - \tau_{t+1}\right)}{1+i_{t+1}}$$

$$\frac{S_t}{S_{t+1}} = \frac{\left(1+i^*_{t+1}\right)}{\left(1+i_{t+1}\right)\left(1-\chi^b \frac{B^{f*}_{t+1}}{S_{t+1}} - \tau^*_{t+1}\right)}$$

From these two interest parity conditions, we can see that in this model the tax on the foreign bond holdings of home country residents, τ_t, must approximately equal the negative of the tax on home country bond holdings of foreign residents, τ^*_t. As in Farhi and Werning (2012), these tax rates, τ_t and τ^*_t, function as capital controls. They have a steady-state value of zero, but in what follows, we will consider the cases where control of these tax rates is given to policy makers and these capital controls can be a potential instrument of macroeconomic policy. From the home country perspective, τ_t is a tax on capital outflows and τ^*_t is a tax on capital inflows.

2.2 Entrepreneurs

In each country there is a representative entrepreneur. Entrepreneurs supply labor to domestic firms. They own capital and rent this capital to firms. They finance this stock of capital partially with their own equity and partially by borrowing from households. They are risk-averse and derive utility from consumption and disutility from labor effort.

The representative entrepreneur chooses their consumption, C^e_t, labor effort, H^e_t, investment, I_t, capital stock, K_{t+1}, and domestic currency bond holdings, b_{t+1}, to maximize expected lifetime utility given by:

$$E_0 \sum_{t=0}^{\infty} \beta^t \left[\ln\left(C^e_t\right) - \psi \left(H^e_t\right)^{\frac{1+\sigma_H}{\sigma_H}}\right] \tag{2}$$

subject to their budget constraint:

$$P_t C_t^e + P_t I_t + b_{t+1} = W_t H_t^e + R_t K_t + (1 + i_t)\, b_t$$

where H_t^e is the entrepreneur's labor effort, K_t is the stock of home country capital held by the representative home country entrepreneur, R_t is the rental rate on capital in the home country, and b_t is the stock of bonds held by the entrepreneur.[4]

Capital accumulation is subject to a constant depreciation rate δ and investment adjustment costs captured by the function $F(I_t, I_{t-1})$. The stock of capital evolves according to the following capital accumulation equations:

$$K_{t+1} = (1 - \delta)\, K_t + F(I_t, I_{t-1})\, I_t$$

where $F(I_t, I_{t-1}) = 1 - \frac{\kappa}{2}\left(\frac{I_t}{I_{t-1}} - 1\right)^2$. A similar law of motion applies to the capital stock in the foreign county, K_t^*.

This investment adjustment cost ensures that there is not a one-to-one transformation from consumption/investment goods and existing capital. This ensures that the price of existing capital relative to the price of the consumption/investment good is a function of past a future investment and the investment adjustment friction, κ. In a competitive market where existing capital can traded among entrepreneurs, the equilibrium relative price of existing capital, P_t^K, is given by:

$$1 = \left(1 - \kappa\left(\frac{I_t}{I_{t-1}} - 1\right)\frac{I_t}{I_{t-1}}\right) P_t^K + \kappa\left(\frac{I_{t+1}}{I_t} - 1\right)\left(\frac{I_{t+1}}{I_t}\right)^2 \frac{P_{t+1}^K}{1 + i_t}$$

Due to limited enforcement, entrepreneurs face a collateral constraint, they cannot borrow more than θ_t of the expected value of their capital stock:

[4] Bonds issued in the home currency can be held by three agents, home country households, home country entrepreneurs, and foreign households. The market clearing condition for the market for bonds denominated in the home country currency is:
$nB_t + nb_t + (1 - n)\, B_t^{f*} = 0$. The similar market clearing condition for bonds denominated in the foreign currency is: $(1 - n)\, B_t^* + (1 - n)\, b_t^* + nB_t^f = 0$.

$$-\left(1+i_t\right) b_{t+1} \leq \theta_t E_t\left[P_{t+1}^K\right] K_{t+1} \tag{3}$$

where the loan-to-value ratio, θ_t, can itself be stochastic and thus a source of credit driven business cycle fluctuations.

2.3 Final Goods Production

In each county, final output, which is used for consumption and investment, is produced in a perfectly competitive final goods sector that simply aggregates home and foreign goods in a CES production function:

$$C_t + C_t^e + I_t = y_t = \left[(\omega)^{\frac{1}{\rho}}\left[\left(\int_0^n y_t^d\left(i\right)^{\frac{\sigma-1}{\sigma}} di\right)^{\frac{\sigma}{\sigma-1}}\right]^{\frac{\rho-1}{\rho}} + \left(\omega^f\right)^{\frac{1}{\rho}}\left[\left(\int_n^1 y_t^m\left(i\right)^{\frac{\sigma-1}{\sigma}} di\right)^{\frac{\sigma}{\sigma-1}}\right]^{\frac{\rho-1}{\rho}}\right]^{\frac{\rho}{\rho-1}} \tag{4}$$

where $y_t^d\left(i\right)$ is the quantity of goods sold to the home market by home country firm i and $y_t^m\left(i\right)$ is the quantity imported into the home market and sold by foreign country firm i. ρ is the elasticity of substitution between home and foreign goods, and σ is the elasticity of substitution between goods from different firms within the same country.

From the aggregator function in (4), and its foreign counterpart (not listed), the demand for the output from home country firm $i \in [0\ n]$ in both the home and foreign markets is given by:

$$\begin{aligned} y_t^d\left(i\right) &= \omega\left(n\right)^{\frac{1-\rho}{1-\sigma}-1}\left(\frac{P_t\left(i\right)}{P_t^d}\right)^{-\sigma}\left(\frac{P_t^d}{P_t}\right)^{-\rho} y_t \\ y_t^{m*}\left(i\right) &= \omega^{f*}\left(n\right)^{\frac{1-\rho}{1-\sigma}-1}\left(\frac{S_t P_t\left(i\right)}{P_t^{m*}}\right)^{-\sigma}\left(\frac{P_t^{m*}}{P_t^*}\right)^{-\rho} y_t^* \end{aligned} \tag{5}$$

where $P_t\left(i\right)$ is the price set by firm $i \in [0\ n]$. The Law of One Price holds for the good from firm i, so if the good has a price $P_t(i)$ in the home market, then its price in the foreign market is $S_t P_t(i)$, where S_t is the nominal exchange rate in units of the foreign currency per units of the domestic currency. Thus the various price indices are given by:

$$\begin{aligned}
P_t^d &= \left(\frac{1}{n}\int_0^n (P_t(i))^{1-\sigma} di\right)^{\frac{1}{1-\sigma}} \\
P_t^m &= \left(\frac{1}{1-n}\int_n^1 \left(\frac{P_t^*(i)}{S_t}\right)^{1-\sigma} di\right)^{\frac{1}{1-\sigma}} \\
P_t &= \left[\omega(n)^{\frac{1-\rho}{1-\sigma}}\left(P_t^d\right)^{1-\rho} + \omega^f(1-n)^{\frac{1-\rho}{1-\sigma}}\left(P_t^m\right)^{1-\rho}\right]^{\frac{1}{1-\rho}}
\end{aligned}$$

Home country firm $i \in [0\ n]$ produces traded goods for the home and foreign markets with the following production technology:

$$y_t^d(i) + y_t^{m*}(i) = h_t(i)^{1-\alpha} k_t(i)^{\alpha} - \phi \tag{6}$$

where $h_t(i)$ and $k_t(i)$ are the labor and capital employed by the firm in period t .

From the firm's cost minimization problem, the demand from firm i for labor and capital is given by:

$$\begin{aligned}
h_t(i) &= (1-\alpha)\frac{MC_t}{W_t}\left(y_t^d(i) + y_t^{m*}(i) + \phi\right) \\
k_t(i) &= \alpha\frac{MC_t}{R_t}\left(y_t^d(i) + y_t^{m*}(i) + \phi\right)
\end{aligned} \tag{7}$$

where $MC_t = \left(\frac{W_t}{1-\alpha}\right)^{1-\alpha}\left(\frac{R_t}{\alpha}\right)^{\alpha}$. Due to sticky output prices, the firm may earn a non-zero profit in certain periods. This profit, $\Xi_t(i) = P_t^z(i)\left(y_t^d(i) + y_t^{m*}(i)\right) - W_t h_t(i) - R_t k_t(i)$ is returned lump-sum to the households.

Market clearing in the labor and capital markets requires that the total demand for labor by firms is equal to the supply of labor from households and entrepreneurs:

$$\int_0^n h_t(i)\,di = H_t + H_t^e$$

and the quantity of physical capital employed by firms in period t is equal to the economy's stock of physical capital at the beginning of the period:

$$\int_0^n k_t(i)\,di = K_t$$

Price setting Firms set prices according to a Calvo style price setting framework. In period t, the firm will be able to change its price in the domestic market with probability $1-\xi_p$. If the firm cannot change prices then they are reset automatically according to $P_t(i) = \pi_{t-1} P_{t-1}(i)$, where $\pi_{t-1} = \frac{P_{t-1}}{P_{t-2}}$.

Thus if allowed to change their price in period t, the firm will set a price to maximize:

$$\max_{P_t^y(i)} E_t \sum_{\tau=0}^{\infty} \beta^\tau \left(\xi_p\right)^\tau \Lambda_{t+\tau} \left\{ \Pi_{t,t+\tau} P_t(i) \left(y_t^d(i) + y_t^{m*}(i)\right) - MC_{t+\tau}\left(y_t^d(i) + y_t^{m*}(i)\right)\right\}$$

where Λ_t is the marginal utility of household consumption in period t and $\Pi_{t,t+\tau} = \pi_{t+\tau-1}\Pi_{t,t+\tau-1}$ for $\tau > 0$. The firm that is able to change its price in period t will set its price to:

$$P_t(i) = \frac{\sigma}{\sigma-1} \frac{E_t \sum_{\tau=0}^{\infty} \beta^\tau \left(\xi_p\right)^\tau \Lambda_{t+\tau} MC_{t+\tau} \left(\omega \left(\frac{\Pi_{t,t+\tau}}{P_{t+\tau}^d}\right)^{-\sigma} \left(\frac{P_{t+\tau}^d}{P_{t+\tau}}\right)^{-\rho} y_{t+\tau} + \omega^{f*} \left(\frac{S_{t+\tau}}{P_{t+\tau}^{m*}}\right)^{-\sigma} \left(\frac{P_{t+\tau}^{m*}}{P_{t+\tau}^{*}}\right)^{-\rho} y_{t+\tau}^{*}\right)}{E_t \sum_{\tau=0}^{\infty} \beta^\tau \left(\xi_p\right)^\tau \Lambda_{t+\tau} \Pi_{t,t+\tau} \left(\omega \left(\frac{\Pi_{t,t+\tau}}{P_{t+\tau}^d}\right)^{-\sigma} \left(\frac{P_{t+\tau}^d}{P_{t+\tau}}\right)^{-\rho} y_{t+\tau} + \omega^{f*} \left(\frac{S_{t+\tau}}{P_{t+\tau}^{m*}}\right)^{-\sigma} \left(\frac{P_{t+\tau}^{m*}}{P_{t+\tau}^{*}}\right)^{-\rho} y_{t+\tau}^{*}\right)}$$

If prices are flexible, i.e. $\xi_p = 0$, then this expression collapses to:

$$P_t(i) = \frac{\sigma}{\sigma-1} MC_t$$

which implies that the firm will change a constant mark-up over its marginal cost.

Write the price set by the firm that can reset prices in period t as $\tilde{P}_t(i)$ to denote that it is an optimal price. Firms that can reset prices in period t will all reset to the same level, so $\tilde{P}_t(i) = \tilde{P}_t$. Substitute this optimal price into the price index $P_t^d = \left(\frac{1}{n}\int_0^n (P_t(i))^{1-\sigma} di\right)^{\frac{1}{1-\sigma}}$. Since a firm has a probability of $1-\xi_p$ of being able to change their price, then by the law of large numbers in any period $1-\xi_p$ percent of firms will reoptimize prices, and the prices of ξ_p percent of firms will be automatically reset using the previous periods inflation rate. Thus the price index for domestic traded goods, P_t^d, can be written as:

$$P_t^d = \left(\xi_p \left(\pi_{t-1} P_{t-1}^d\right)^{1-\sigma} + \left(1-\xi_p\right)\left(\tilde{P}_t\right)^{1-\sigma}\right)^{\frac{1}{1-\sigma}}$$

2.4 Monetary Policy

There is a role for monetary policy in the version of the model with sticky prices. Monetary policy in the home economy is characterized as the solution to a Ramsey problem where the policy maker maximizes the second-order approximation of the sum of the home country household and entrepreneur welfare functions in (1) and (2) subject to the first-order conditions and resource constraints for the household, entrepreneur and firm.

Similarly, monetary policy in the foreign economy is the solution to a Ramsey problem where the policy maker maximizes the second-order approximation of the sum of the foreign country household and entrepreneur welfare functions.

3 Calibration and Solution

The model's parameters and their values are reported in table 1. The first eight parameters in the table, the discount factor, capital's share of value added, the capital depreciation rate, the small constant tax on foreign bond holdings that is used to ensure stationarity, the investment adjustment cost parameter, the probability that a firm cannot change prices in a given period, and the elasticities of substitution between goods from different firms, and between home and foreign traded goods, are all set to values commonly used in the literature. The relative country size parameter, n, is set very small to ensure that the home economy is a small open economy and does not have a significant effect on events in the rest of the world. The weights on domestic and foreign goods in the traded goods aggregator function, ω and ω^f, are set such that there is no steady-state home bias in the preference for traded goods.[5] Since the home country is a small open economy, the equivalent parameters for the rest of the world are $\omega^* \approx 1$ and $\omega^{f*} \approx 0$.

The steady state value of the discount factor shock, $\bar{\lambda}$, implies that the first-order excess return is about 3.6% per year.[6]

The parameter $\bar{\theta}$ measures the entrepreneur's steady state loan to value ratio. We use a value of 0.75, which is the value used by Liu, Wang, and Zha (2013). Iacoviello (2005) estimates this parameter and shows that it lies between 0.55 (for households) and 0.89 (for firms).

3.1 Shock process and solution procedure

The model is solved with a first-order approximation around the steady state where the collateral constraint (3) is binding, as in Iacoviello (2005), Jermann and Quadrini (2012), and Liu, Wang, and Zha (2013).

We will just consider the effect of shocks originating in the rest of the world on the small open home economy. We will consider the optimal policy response to two foreign shocks that would lead to a surge in capital inflows into or out of the small open economy: a shock to the foreign real interest rate and a shock to the multiplier on the foreign borrowing constraint.

[5] From the demand functions for domestic and imported traded goods in (5), the steady state import share is: $m = \frac{\int_n^1 P_t^m(i) y_t^m(i)}{\int_0^n P_t^d(i) y_t^d(i) + \int_n^1 P_t^m(i) y_t^m(i)} = \frac{\omega^f (1-n)^{\frac{1-\rho}{1-\sigma}}}{\omega (n)^{\frac{1-\rho}{1-\sigma}} + \omega^f (1-n)^{\frac{1-\rho}{1-\sigma}}}$

[6] The steady state risk-free interest rate, $r_t = \frac{1}{\beta(1+\bar{\lambda})} - 1$, which reflects the household's discount rate, $\beta\left(1+\bar{\lambda}\right)$. The steady state return on investment, $R_t - \delta = \frac{1}{\beta} - 1$, which reflects the entrepreneur's discount rate β. The per annum steady state first-order excess return is then given by $\left(1 + R_t - \delta - r_t\right)^4 - 1 \approx 4\beta\bar{\lambda}$

The first shock is a shock to the foreign real interest rate. This shock to the foreign real interest rate is simply engineered by a stochastic shock to the foreign household's discount factor, $\beta e^{\lambda^*_{t+1}}$. A negative shock to λ^*_{t+1} would make foreign household's less patient, they would save less, and the foreign real interest rate would increase. Of course, the foreign real interest rate is exogenous from the perspective of the small open economy, so for the first shock driving the model, assume that the foreign real interest rate increases by 1% and that this shock has a half-life of one quarter.

$$r^*_t = 0.5 r^*_{t-1} + \varepsilon^*_t$$

and $\varepsilon^*_1 = 1$ and $\varepsilon^*_\tau = 0$ for $\tau > 1$.

The second shock we will consider is a shock to the multiplier on the foreign borrowing constraint. This shock to the multiplier on the foreign borrowing constraint is engineered by a stochastic shock to the foreign loan-to-value ratio, θ^*_t. A positive shock to θ^*_t loosens the foreign borrowing constraint, and thus leads to a fall in the multiplier on the foreign borrowing constraint. The foreign borrowing constraint is exogenous from the perspective of the small open economy, so for the second shock driving the model, assume that the foreign multiplier falls by 1% and that this shock has a half-life of one quarter.

$$\mu^*_t = 0.5 \mu^*_{t-1} + \epsilon^*_t$$

and $\epsilon^*_1 = -1$ and $\epsilon^*_\tau = 0$ for $\tau > 1$.

Since each shock is considered separately and the model is solved with a first-order approximation, for the most part the variance of the shocks are immaterial for both simulations and the calculation of optimal policy. The one caveat is that this model is solved with a first-order approximation in the neighborhood of the steady state where the collateral constraint is binding. If a shock that loosens this constraint is "too big" it could result in an equilibrium where the constraint does not bind, and thus our approximation around the binding constraint is inaccurate. The need for the collateral constraint to always bind provides an upper bound on the size of the shocks. In the impulse response diagrams in the next section we will plot the response of the multiplier on the collateral constraint and show that it remains positive under every shock.

4 Optimal Capital Controls Policy

In discussing optimal capital controls policy, we will present the results in two steps. First, we will consider optimal capital controls policy in a model with flexible prices. We will then consider capital controls policy in a sticky price model, and thus in a model where there is already a role for conventional monetary policy. We will ask if when conventional monetary policy instruments are chosen optimally, is there a role for capital controls as an additional instrument of monetary policy.

4.1 Flexible Prices

Figure 1 presents the responses of GDP, investment, the current account, the multiplier on the entrepreneurs collateral constraint, the real exchange rate, and taxes on capital outflows in the small open economy following a foreign real interest rate shock. As can be seen in the top row of this figure, this foreign shock leads to a rise in the foreign real interest rate and a fall in foreign GDP.

Impulse responses from three simulations of the model are presented in the figure. In all three simulations there is no price stickiness and the collateral constraint is the only source of frictions in the model. The dotted line assumes that there are no collateral constraints in the home economy, so from the perspective of the home country policy maker, this simulation represents the efficient allocation. The solid line assumes that there are collateral constraints in both the home and foreign economies, but in this simulation there are no barriers to the free flow of capital between countries. The dashed line assumes that there are collateral constraints in both the home and foreign economies, but home country policy makers have the option of imposing temporary taxes or subsidies on either the returns home residents receive on foreign bonds (controls on capital outflows) or the return that foreign residents receive on home country bonds (controls on capital inflows). In this model with flexible prices, capital controls are the only option available to the policy maker.

Except for the responses of interest rates and the current account, these responses are expressed as percent deviations from the steady state. The responses of interest rates and the current account are presented as percentage point deviations from the steady state. As can be seen in the figure, this shock to the foreign real interest leads to a sharp decline in capital inflows into the home economy, as represented by the 1% rise in the home current account, a 1% decrease in home investment, and the 0.5% depreciation in the real exchange rate in the efficient allocation. This fall in capital inflows and decrease in investment leads to a decrease in the price of existing capital. In the version of the model where entrepreneurs face binding collateral constraints, an decrease in the price of existing capital tightens this constraint, forcing entrepreneurs to cut borrowing and investment. The figure shows that the foreign shock leads to a nearly 6% rise in the multiplier on the borrowing constraint. This then forces entrepreneurs to cut borrowing and investment and the same foreign shock that led to a 1% decrease in investment in the efficient allocation now leads to a 2.5% decrease in investment and a nearly 3% surge in current account.

Thus a fall in capital inflows, combined with a binding collateral constraint and a procyclical price of capital can lead to a credit and investment bust in the small open economy far in excess of what would occur in the efficient allocation without a collateral constraint. The figure shows that when the home country policy maker is allowed to impose temporary taxes or subsidies on capital inflows and outflows, optimally chosen capital controls can curtail many of the "bust" effects following this foreign shock. The figure shows that the policy maker will impose a temporary tax on the returns from holding foreign bonds (and thus tax capital outflows). Since in this model taxes on capital inflows must be the mirror image of taxes on capital outflows, the policy maker will impose a temporary 1.5% subsidy on foreign holdings of home country bonds. And thus in the face of a sharp fall in capital inflows from abroad, the optimal policy is to impose temporary controls on capital outflows and implement policies to encourage capital inflows. The figure shows that under optimal capital controls, current account only rise by 1% following the foreign shock, and this inflow of foreign capital only leads to 0.5% depreciation in the real exchange rate and a 1% tightening of the borrowing constraint. As a result, investment increases by only 1 to 1.5% following the foreign shock. Under optimal capital controls policy, the responses of GDP, investment, and current account are very similar to their responses in the efficient allocation.

Figure 2 presents the responses of these same variables following a shock to the foreign loan-to-value ratio. This shock leads to a sudden decrease in the collateral that foreign entrepreneurs need to put up in order to borrow from foreign households, and thus this foreign credit supply shock leads to a rise in foreign investment demand, GDP, and the real interest rate.

As shown in the figure, this foreign credit supply shock leads to a sharp fall in capital inflows into the small open home economy. Just as before with the shock to the foreign real interest rate, this shock leads to a rise in home current account and an decrease in home investment under the frictionless, efficient allocation where home country entrepreneurs do not face a borrowing constraint. However, when home country entrepreneurs face a constraint, these responses are magnified. Just as before, the sharp drop in foreign capital inflows leads to a fall in the price of entrepreneurs' existing capital, which leads to a tightening of the borrowing constraint and a temporary credit bust in the home economy. The figure shows that under an optimally chosen capital controls policy, policy makers will impose temporary controls on capital outflows and are thus able to nearly match the responses under the efficient allocation.

4.2 Sticky Prices

Sticky output prices allow conventional monetary policy (changing the nominal risk-free rate) to act as an additional instrument available to the policy maker as well as add an additional friction to the model. The responses in the small open home economy to a shock that causes a rise in the foreign real interest rate are presented in figure 3. The figure presents the responses under three versions of the model. The dotted line in the figure again represents the efficient allocation where there are no price frictions or collateral constraints (and thus is identical to the dotted line in figure 1). The solid line in the figure represents the version of the model where there are price frictions and collateral constraints, conventional monetary policy is chosen optimally, but capital markets remain open. The dashed line in the figure represents the version of the model where policy makers can choose both optimal conventional monetary policy and the optimal set of controls on capital inflows and outflows.

As can be seen in the figure, the fall in capital inflows causes an depreciation in the home country real exchange rate. Under optimal monetary policy, policy makers sharply increase the nominal interest rate in order to encourage capital inflows, but the exchange rate depreciation still leads to a dramatic rise in home country inflation and GDP. As seen in the model without price frictions, the fall in capital inflows leads to a fall in investment in the home country. In the version of the model where entrepreneurs face collateral constraints, the fall in capital inflows leads to an decrease in the price of existing capital, which leads to a tightening of the borrowing constraint and a fall in credit and investment in excess of what would occur in the efficient allocation.

However, it is interesting to compare the responses in the model without price frictions in figure 1 to those in the model with price frictions, and thus a role for conventional monetary policy, in figure 3. In the model without price frictions, without the use of capital controls, policy makers could do nothing in the face of a drop in foreign capital inflows. The foreign shock led to a 6% rise in the multiplier on the home country entrepreneur borrowing constraint and a 2.5% decrease in investment (compared to a 1% decrease under the efficient allocation). When price frictions give a policy makers the conventional monetary policy instrument, policy makers can encourage capital inflows by raising the nominal interest rate. As seen in figure 3, now the foreign shock only leads to a 3% rise in the multiplier on the home entrepreneur's borrowing constraint and a 1.5% decrease in investment. This shows that there is a role for conventional monetary policy in curtailing some of the adverse effects of a surge in foreign capital inflows. However, the figure shows that when capital controls are also available as a policy instrument, just as before the policy maker will impose a temporary tax on capital outflows and temporary subsidies on capital inflows. This will curtail some of the drop in capital inflows, leading to a smaller exchange rate depreciation, a smaller rise in inflation, a smaller increase in the multiplier on the borrowing constraint and a smaller drop in investment. Thus the figure shows that conventional monetary policy can react by raising the nominal interest rate in order to partially curtail any drop in foreign capital inflows, but even when conventional monetary policy is chosen optimally, there is still a role for capital controls as an additional instrument of monetary policy to help counteract the credit bust caused by a sudden drop in capital inflows from abroad.

However, figure 4 shows that the usefulness of capital controls as an additional instrument of monetary policy is entirely due to the fact that entrepreneurs face a borrowing constraint and thus the fall in capital inflows can lead to a tightening of the borrowing constraint and a boom in credit and investment. Figure 4 presents the responses to the same foreign shock, but sticky output prices are the only source of friction in the model. The figure shows that without frictions caused by borrowing constraints, there is almost no difference between optimal conventional monetary policy (solid line) and the combination of optimal conventional monetary policy and optimal capital controls policy (dashed line). The figure shows that even when the policy maker has the option to use capital controls as a policy instrument, capital markets will remain open.

This same exercise, but in response to a foreign credit supply shock that leads to a drop in foreign capital inflows is presented in figure 5. The earlier results continue to hold; even when conventional monetary policy is chosen optimally, there is still a role for capital controls as an additional instrument of monetary policy to help counteract the credit bust caused by a sudden fall in capital inflows from abroad.

4.2.1 Fixed Exchange Rate

While it may not constitute optimal conventional monetary policy, it is still interesting to note the responses in the home country to a foreign shock when the home country maintains a fixed nominal exchange rate. The trilemma of international finance states that a country cannot at the same time maintain a fixed nominal exchange rate, an independent monetary policy, and an open capital account. Without capital controls, conventional monetary policy must be dedicated to maintaining the fixed exchange rate and policy makers don't have an independent monetary instrument.

This scenario is presented in figure 6. The figure plots the responses in the home economy to the foreign real interest rate shock that leads to a fall in foreign capital inflows. The solid line presents the responses when the home country has a fixed exchange rate and an open capital account (there is no independent monetary instrument), the dashed line presents the responses when the home country has an open capital account and monetary policy is chosen optimally (the currency is freely floating, this corresponds to the results presented with the solid line in figure 3), and the dotted line presents the responses when the home country maintains a fixed nominal exchange rate but capital controls still allow it to set monetary policy optimally.

The figure shows that when the exchange rate is fixed but the capital account is open, the home country must match the sharp increase in the foreign nominal interest rate and this leads to an overly restrictive monetary policy, an 8% fall in GDP, a dramatic tightening of the borrowing constraint, and a 15% decrease in investment. Thus when the capital account is open, a fixed exchange rate is clearly suboptimal. If instead the policy maker is able to impose capital controls, in response to the foreign shock the policy maker will impose temporary capital controls to curtail capital outflows and encourage capital inflows. Thus the country can still use an independent monetary policy and there is no need to match the sharp increase in the foreign nominal interest rate. The home country can maintain a fixed nominal exchange rate without the same decrease in GDP, investment, and inflation due to an overly restrictive monetary policy.

This same exercise, but in response to a foreign credit supply shock is presented in figure 7. Again, when the home country tried to maintain a fixed nominal exchange rate and an open capital account, the loss of an independent monetary policy leads to an outcome that is clearly suboptimal, but the use of temporary capital controls allows the country to maintain a fixed nominal exchange rate without sacrificing macroeconomic stability.

4.3 Welfare costs

The welfare costs of distortions caused by price or credit frictions in the model is presented in table 2. This table presents the welfare cost, as a percentage of steady state consumption, of various distortions in each of the scenarios covered in the impulse response analysis.

The first two columns of the table correspond to the version of the model with credit frictions, but no price frictions. Thus these two columns correspond to the scenarios presented in the impulse response diagrams in figures 1 and 2. In the model driven by foreign real interest rate shocks, without capital controls, distortions caused by credit frictions reduce household welfare by an amount equivalent to 0.24 percent of steady state consumption and these distortions reduce entrepreneur welfare by an amount equivalent to 0.74 percent of steady state consumption. With capital controls, these distortions caused by credit frictions only lead to a 0.07 percent and 0.26 percent fall in consumption equivalent household and entrepreneur welfare, respectively.

The next two columns in the table correspond to the version of the model where there are both price and credit frictions. In these columns the small open economy has a floating nominal exchange rate, so conventional monetary policy is determined optimally. These columns correspond to the scenarios presented in the impulse response diagrams in figures 3 and 5. In the model driven by foreign real interest rate shock, without capital controls, distortions caused by both price and credit frictions reduce household and entrepreneur steady state consumption equivalent welfare by 0.30 and 0.55 percent, respectively. When policy makers can use capital controls as an additional tool of optimal monetary policy, these consumption equivalent welfare costs fall to 0.07 and 0.27.

The fifth and sixth columns in the table correspond to the version of the model where there are price frictions but no credit frictions. Thus these columns correspond to the scenarios presented in the impulse response diagrams in figures 4 (since there are no credit frictions in the model, the foreign credit supply shock wouldn't make sense, so this version of the model can only be driven by foreign real interest rate shocks). The table shows that optimally chosen monetary policy nearly eliminates all distortions caused by sticky prices in the model, and the welfare costs of distortions due to price frictions are less than 0.01 percent of both household and entrepreneur steady state consumption. As was seen earlier in the impulse response diagrams, optimally chosen capital controls policy is nearly zero when there are no credit frictions in the model, and the table shows there is no change in consumption equivalent welfare when capital controls are included as an additional policy instrument.

Finally the last two columns in the table correspond to the version of the model with both price and credit frictions, but where instead of having a floating currency and choosing conventional monetary policy optimally, the small open economy has a fixed nominal exchange rate. These columns correspond to the scenarios presented in figures 6 and 7. When the model is driven by foreign real interest rate shocks, without capital controls, distortions caused by both price and credit frictions reduce household and entrepreneur steady state consumption equivalent welfare by 9 and 18 percent, respectively! In this model with both credit and price frictions, not allowing the currency to float and thus sacrificing a monetary policy instrument results in a huge welfare loss. The table shows that when capital controls are added as a potential policy instrument, policy makers in the small open economy regain monetary autonomy Now the welfare costs fall to 0.1 and 0.27 percent of consumption equivalent welfare. Of course, these welfare costs are still greater than when the central bank could also choose optimal conventional monetary policy, but they are much lower than the scenario where the central bank adopts a fixed nominal exchange rate with an open capital account, and thus sacrifices monetary independence.

5 Conclusion

Dramatic shifts in capital flows into and out of many emerging market economies over the past few years have led some researcher and policy makers to question whether an open capital market is always welfare maximizing. Specifically, surges in capital inflows and outflows can lead to excessive asset price volatility in many emerging markets. If due to limited enforcement, borrowers in these economies are subject to collateral constraints then these fluctuations in asset prices act like an exogenous "shock" on the borrower's collateral constraint. Thus when asset prices are subject to excessive fluctuations from capital inflows and outflows and borrowers face a collateral constraint that is tied to asset prices, there may be a role for policy to control these excessive capital inflows and outflows and reduce this volatility in the borrower's collateral constraint.

Traditionally, capital controls have been thought of as one leg of the Mundell-Fleming "trilemma of international finance". Capital controls were necessary for macroeconomic stabilization since they provided a degree of monetary independence for a country with a fixed exchange rate, but if the exchange rate was allowed to float, capital controls were unnecessary and stabilization could be achieved through monetary policy. However, recent experience has shown that surges in capital inflows and outflows can lead to financial instability even in countries with a floating exchange rate and an independent monetary policy. In a DSGE framework, this paper shows that the benefits of capital controls are present even when monetary policy is determined optimally. Due to the financial instability caused by fluctuations in capital inflows and outflows, there may be a role for capital controls to exist side-by-side with conventional monetary tools as an instrument of monetary policy.

A Technical Appendix - Not for Publication

A.1 Equilibrium conditions of the model

In the model there are two countries, home and foreign. The home country is size n and the foreign country is size $1-n$. As $n \to 0$, the model becomes one with a small open economy and the rest of the world. Other than country size, the two countries are identical. Foreign country variables are written with an asterisk (*). For brevity only the equations for the home country will be listed here.

Each country is populated by representative households, entrepreneurs, and firms. Households supply labor to domestic firms and consume. They are net savers. Entrepreneurs borrow from domestic households to finance a capital stock, and they rent this capital to firms. Due to limited enforcement, entrepreneurs are subject to a collateral constraint and cannot borrow more than a given fraction of the value of their capital stock. Firms hire labor, rent capital, and produce an output. The output from domestic firms is combined with the output from foreign firms to produce a final good that is used for consumption and investment. Firms are engaged in monopolistic competition and set prices according to a Calvo (1983) style price setting framework. Monetary policy is set according to the solution to a Ramsey problem to maximize total welfare in the economy. The conventional monetary policy instrument in this cash-less economy is the risk-free nominal rate of interest. The central bank in the small open economy also has the potential to impose temporary, episodic taxes or subsidies on capital inflows and outflows in order to deter or encourage capital flows.

A.1.1 Households

Households choose the combination of C_t, H_t, B_{t+1}, and B^f_{t+1} $\forall t$ to maximize:

$$\max E_0 \sum_{t=0}^{\infty} \beta^t A_t \left[\ln(C_t) - \psi (H_t)^{\frac{1+\sigma_H}{\sigma_H}} \right]$$

subject to their budget constraint:

$$
\begin{aligned}
& P_t C_t + B_{t+1} + S_t B_{t+1}^f & (8) \\
= \;& W_t H_t + \Xi_t + (1+i_t) B_t + (1-\tau_t)(1+i_t^*) S_t B_t^f \left(1 - \chi^b S_t B_t^f\right)
\end{aligned}
$$

The multiplier on the budget constraint is Λ_t (the marginal utililty of income). The household takes A_t, P_t, S_t, W_t, Ξ_t, i_t, τ_t, and i_t^* as given.

The first order conditions of the household's problem are given by:

$$
\begin{aligned}
\frac{1}{C_t} &= P_t \Lambda_t & (9) \\
\frac{1+\sigma_H}{\sigma_H} \psi (H_t)^{\frac{1}{\sigma_H}} &= W_t \Lambda_t \\
\Lambda_t A_t &= \beta \Lambda_{t+1} A_{t+1} (1+i_t) \\
\Lambda_t A_t S_t &= \beta \Lambda_{t+1} A_{t+1} (1-\tau_{t+1}) \left(1+i_{t+1}^*\right) S_{t+1} \left(1 - \chi^b S_{t+1} B_{t+1}^f\right)
\end{aligned}
$$

A.1.2 Entrepreneurs

Entrepreneurs choose the combination of C_t^e, H_t^e, b_{t+1}, I_t, K_{t+1} $\forall t$ to maximize:

$$
\max E_0 \sum_{t=0}^{\infty} \beta^t \left[\ln (C_t^e) - \psi (H_t^e)^{\frac{1+\sigma_H}{\sigma_H}} \right]
$$

subject to their budget constraint, the capital accumulation equation, and a borrowing constraint:

$$
\begin{aligned}
P_t C_t^e + P_t I_t + b_{t+1} &= W_t H_t^e + R_t K_t + (1+i_t) b_t & (10) \\
K_{t+1} &= (1-\delta) K_t + F(I_t, I_{t-1}) I_t \\
-(1+i_t) b_{t+1} &\leq \theta_t E_t \left[P_{t+1}^K\right] K_{t+1}
\end{aligned}
$$

where $F(I_t, I_{t-1}) = 1 - \frac{\kappa}{2}\left(\frac{I_t}{I_{t-1}} - 1\right)^2$. The multipliers for the budget constraint, the capital accumulation equation, and the borrowing constraint are given by Λ_t^e, υ_t, and μ_t, respectively.

The first order conditions of the entrepreneur's problem are given by:

$$\begin{aligned}
\frac{1}{C_t^e} &= P_t \Lambda_t^e \\
\frac{1+\sigma_H}{\sigma_H}\psi\left(H_t^e\right)^{\frac{1}{\sigma_H}} &= W_t \Lambda_t^e \\
\Lambda_t^e - (1+i_t)\mu_t &= \beta(1+i_t)E_t\left[\Lambda_{t+1}^e\right] \\
P_t \Lambda_t^e &= F(I_t, I_{t-1})\upsilon_t + F_1(I_t, I_{t-1}) I_t \upsilon_t + \beta E_t\left[F_2(I_{t+1}, I_t) I_{t+1}\upsilon_{t+1}\right] \\
\upsilon_t - \theta_t E_t\left[P_{t+1}^K\right]\mu_t &= \beta E_t\left[R_{t+1}\Lambda_{t+1}^e + (1-\delta)\upsilon_{t+1}\right]
\end{aligned} \tag{11}$$

A.1.3 Firms

Firms set prices according to a Calvo style price setting framework. In period t, the firm will be able to change its price in the domestic market with probability $1 - \xi_p$. If the firm cannot change prices then they are reset automatically according to $P_t(i) = \pi_{t-1}P_{t-1}(i)$, where $\pi_{t-1} = \frac{P_{t-1}}{P_{t-2}}$.

Every period the firm will choose the optimal combination of $h_t(i)$ and $k_t(i)$ to maximize:Thus if allowed to change their price in period t, the firm will set a price to maximize:

$$\max_{P_t^y(i)} E_t \sum_{\tau=0}^{\infty} \beta^\tau \left(\xi_p\right)^\tau \Lambda_{t+\tau}\left\{\Pi_{t,t+\tau}P_t(i)\left(y_{t+\tau}^d(i) + y_{t+\tau}^{m*}(i)\right) - W_{t+\tau}h_{t+\tau}(i) - R_{t+\tau}k_{t+\tau}(i)\right\} \tag{12}$$

subject to the demand for its output in both the domestic and foreign markets, and a production technology:

$$
\begin{aligned}
y_t^d(i) &= \omega(n)^{\frac{1-\rho}{1-\sigma}-1}\left(\frac{P_t(i)}{P_t^d}\right)^{-\sigma}\left(\frac{P_t^d}{P_t}\right)^{-\rho} y_t \\
y_t^{m*}(i) &= \omega^{f*}(n)^{\frac{1-\rho}{1-\sigma}-1}\left(\frac{S_t P_t(i)}{P_t^{m*}}\right)^{-\sigma}\left(\frac{P_t^{m*}}{P_t^*}\right)^{-\rho} y_t^* \\
y_t^d(i) + y_t^{m*}(i) &= h_t(i)^{1-\alpha} k_t(i)^{\alpha} - \phi
\end{aligned} \tag{13}
$$

The first-order conditions of the firm's problem with respect to capital and labor inputs are given by:

$$
\begin{aligned}
h_t(i) &= (1-\alpha)\frac{MC_t}{W_t}\left(y_t^d(i) + y_t^{m*}(i) + \phi\right) \\
k_t(i) &= \alpha\frac{MC_t}{R_t}\left(y_t^d(i) + y_t^{m*}(i) + \phi\right)
\end{aligned} \tag{14}
$$

where $MC_t = \left(\frac{W_t}{1-\alpha}\right)^{1-\alpha}\left(\frac{R_t}{\alpha}\right)^{\alpha}$.

If they are allowed to change their price in period t then the firm will also choose the optimal $P_t(i)$ to maximize profit:

$$
P_t(i) = \frac{\sigma}{\sigma-1}\frac{E_t\sum_{\tau=0}^{\infty}\beta^{\tau}\left(\xi_p\right)^{\tau}\Lambda_{t+\tau}MC_{t+\tau}\left(\omega\left(\frac{\Pi_{t,t+\tau}}{P_{t+\tau}^d}\right)^{-\sigma}\left(\frac{P_{t+\tau}^d}{P_{t+\tau}}\right)^{-\rho}y_{t+\tau} + \omega^{f*}\left(\frac{S_{t+\tau}}{P_{t+\tau}^{m*}}\right)^{-\sigma}\left(\frac{P_{t+\tau}^{m*}}{P_{t+\tau}^*}\right)^{-\rho}y_{t+\tau}^*\right)}{E_t\sum_{\tau=0}^{\infty}\beta^{\tau}\left(\xi_p\right)^{\tau}\Lambda_{t+\tau}\Pi_{t,t+\tau}\left(\omega\left(\frac{\Pi_{t,t+\tau}}{P_{t+\tau}^d}\right)^{-\sigma}\left(\frac{P_{t+\tau}^d}{P_{t+\tau}}\right)^{-\rho}y_{t+\tau} + \omega^{f*}\left(\frac{S_{t+\tau}}{P_{t+\tau}^{m*}}\right)^{-\sigma}\left(\frac{P_{t+\tau}^{m*}}{P_{t+\tau}^*}\right)^{-\rho}y_{t+\tau}^*\right)} \tag{15}
$$

A.2 Market Clearing

Goods market clearing:

$$C_t + C_t^e + I_t = y_t = \left[(\omega)^{\frac{1}{\rho}} \left[\left(\int_0^n y_t^d (i)^{\frac{\sigma-1}{\sigma}} di \right)^{\frac{\sigma}{\sigma-1}} \right]^{\frac{\rho-1}{\rho}} + \left(\omega^f\right)^{\frac{1}{\rho}} \left[\left(\int_n^1 y_t^m (i)^{\frac{\sigma-1}{\sigma}} di \right)^{\frac{\sigma}{\sigma-1}} \right]^{\frac{\rho-1}{\rho}} \right]^{\frac{\rho}{\rho-1}} \tag{16}$$

Labor market clearing:

$$\int_0^n h_t (i)\, di = H_t + H_t^e \tag{17}$$

Capital market clearing:

$$\int_0^n k_t (i)\, di = K_t \tag{18}$$

Bond market clearing:

$$\begin{aligned} nB_t + nb_t + (1-n) B_t^{f*} &= 0 \\ (1-n) B_t^* + (1-n) b_t^* + nB_t^f &= 0 \end{aligned} \tag{19}$$

A.2.1 Monetary Policy

In the case where there are sticky prices, monetary policy will set the optimal path of i_t $\forall t$ in order to maximize the sum of the household and entrepreneur welfare subject to the first order conditions and the market clearing conditions listed above. This is true for both the home and foreign policy maker.

When the policy marker can also set capital controls, the policy maker will choose the optimal path of τ_t $\forall t$ to maximize the sum of household and entrepreneur welfare subject to the first order conditions and the market clearing conditions listed above. Since the model is a two country model and the home country is small relative to the foreign country, the foreign policy maker for all intents and purposes sees the foreign economy as a closed economy, so the foreign policy maker will not set taxes or subsidies on capital inflows from the small home economy.

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Table 1: Parameter Values

Symbol	Value	Description
β	0.98	discount factor
α	.36	capital share in production of value added
δ	0.025	capital depreciation rate
χ^b	0.001	small constant tax on foreign bond holdings
κ	2.48	investment adjustment cost parameter
ξ_p	0.75	probability that a firm cannot reset prices
ω	0.73	weight on domestic goods in the CES aggregator function
ω^f	0.50	weight on foreign goods in the CES aggregator function
σ	10	elasticity of substitution across varieties from different firms
ρ	1.5	elasticity of substitution between home and foreign goods
ϕ	0.3303	fixed cost to ensure firms earn zero profit in steady state
n	0.001	relative size of the home country
$\bar{\lambda}$	0.0089	steady state value of discount factor shock
$\bar{\theta}$	0.75	steady state value of borrowing limit

Table 2: Cost of distortions as a percentage of steady state consumption

Price Frictions:	No	No	Yes	Yes	Yes	Yes	Yes	Yes
Credit Frictions:	Yes	Yes	Yes	Yes	No	No	Yes	Yes
Fixed FX Rate:	N/A	N/A	No	No	No	No	Yes	Yes
Cap. Controls:	No	Yes	No	Yes	No	Yes	No	Yes
Foreign real interest rate shock:								
Household consumption:	0.24	0.07	0.30	0.07	$2.5x10^{-3}$	$2.0x10^{-3}$	9.18	0.10
Entrepreneur consumption:	0.74	0.26	0.55	0.27	$2.7x10^{-3}$	$2.1x10^{-3}$	17.63	0.27
Foreign credit supply shock:								
Household consumption:	0.53	0.07	0.59	0.06	N/A	N/A	8.03	0.09
Entrepreneur consumption:	0.54	0.17	0.38	0.17	N/A	N/A	16.55	0.18

Notes: In the simulations of the model that give rise to these welfare costs measures, we assume that the variance of the one shock driving the model is set such that the standard deviation of the foreign nominal interest rate is 1.17%, the standard deviation of the HP-detrended U.S. 3-month T-bill from 1981 to 2013.

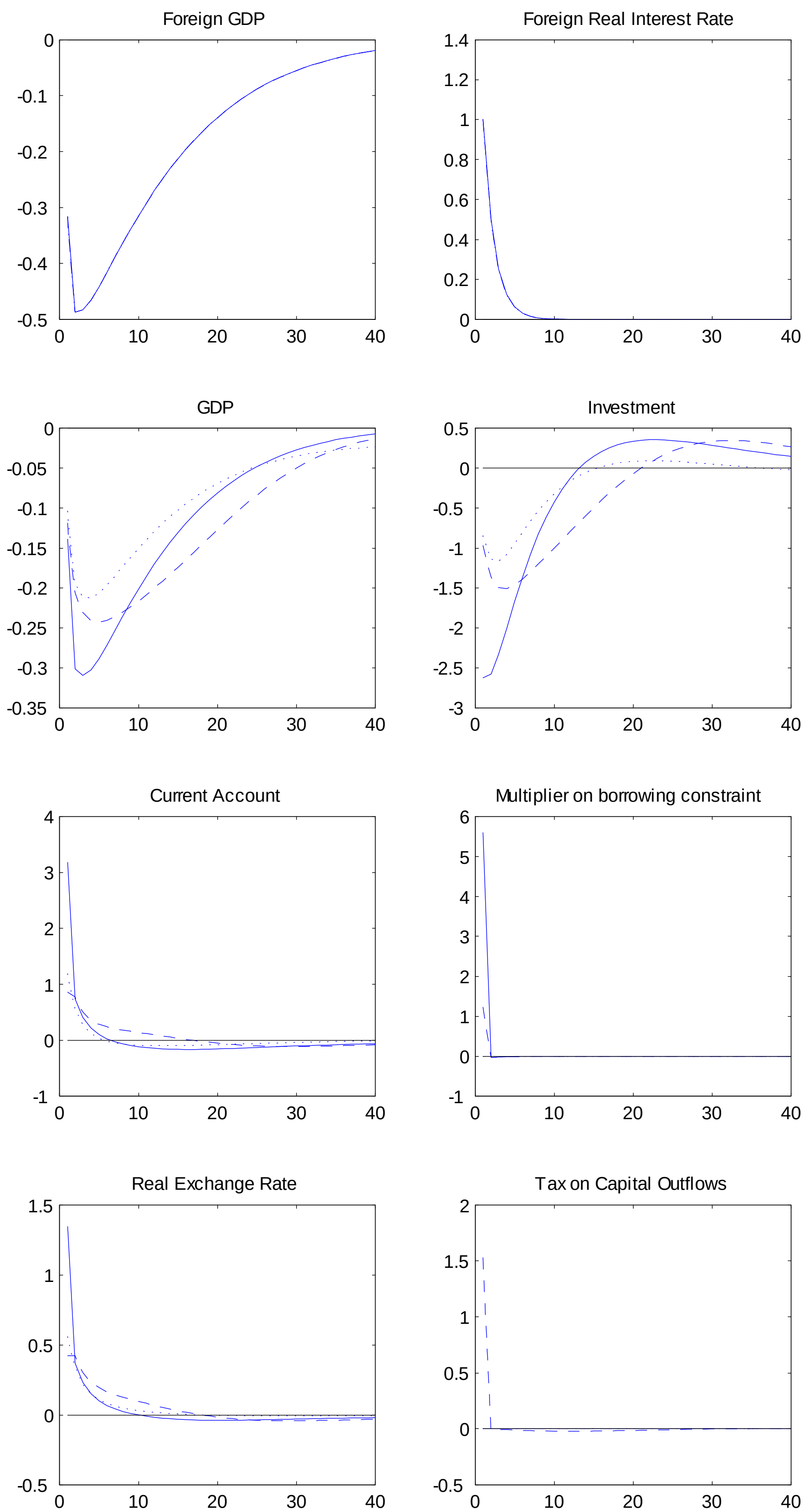

Figure 1: Impulse responses (expressed as percent deviations from the steady state) in the small open economy following a foreign real interest rate shock in the model with flexible prices. The dotted line represents the efficient allocation where there are no collateral constraints. The solid line represents the model with collateral constraints and open capital markets. The dashed line represents the model with collateral constraints and where capital controls are chosen optimally.

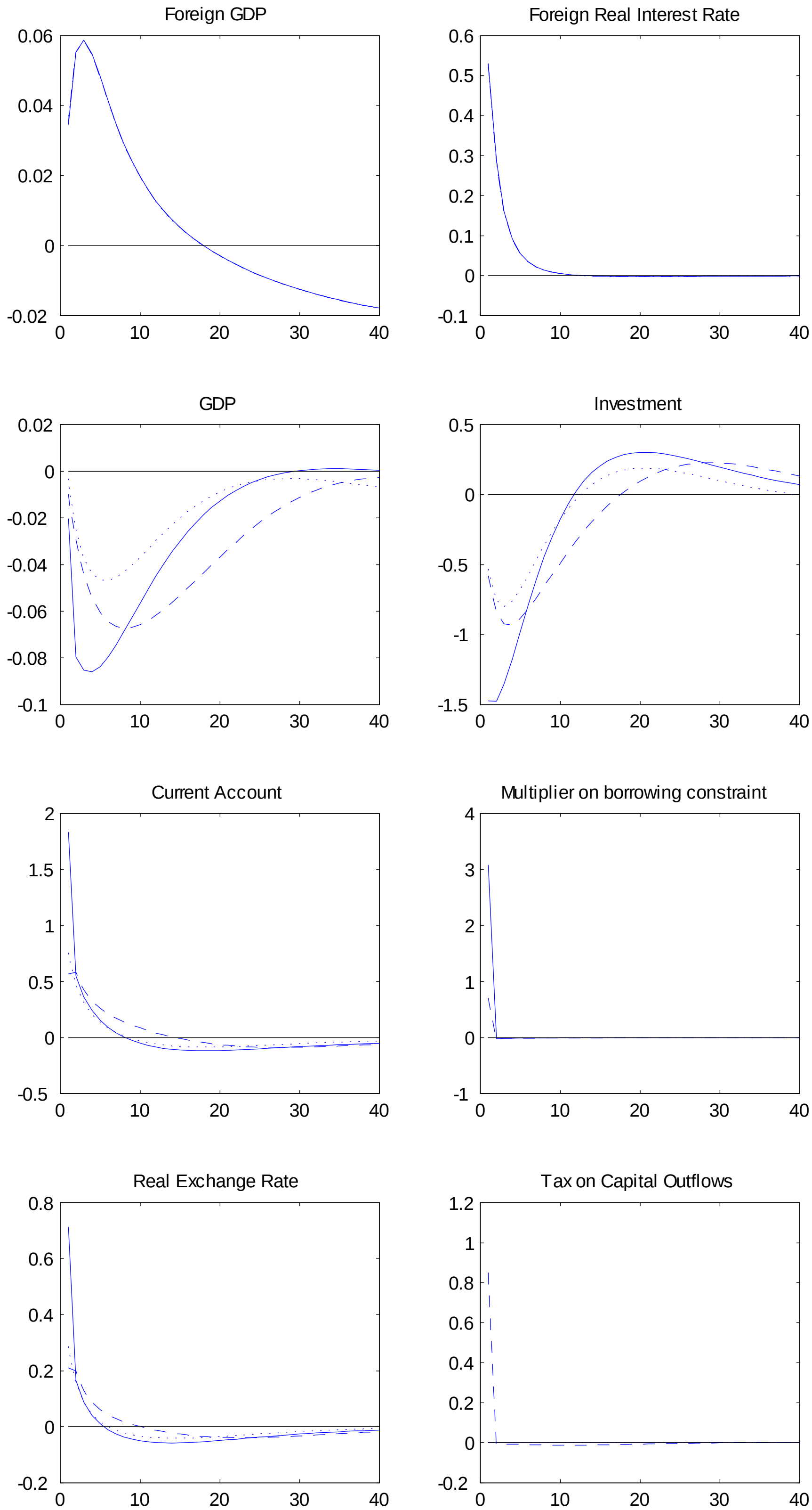

Figure 2: Impulse responses (expressed as percent deviations from the steady state) in the small open economy following a foreign credit supply shock in the model with flexible prices. The dotted line represents the efficient allocation where there are no collateral constraints. The solid line represents the model with collateral constraints and open capital markets. The dashed line represents the model with collateral constraints and where capital controls are chosen optimally.

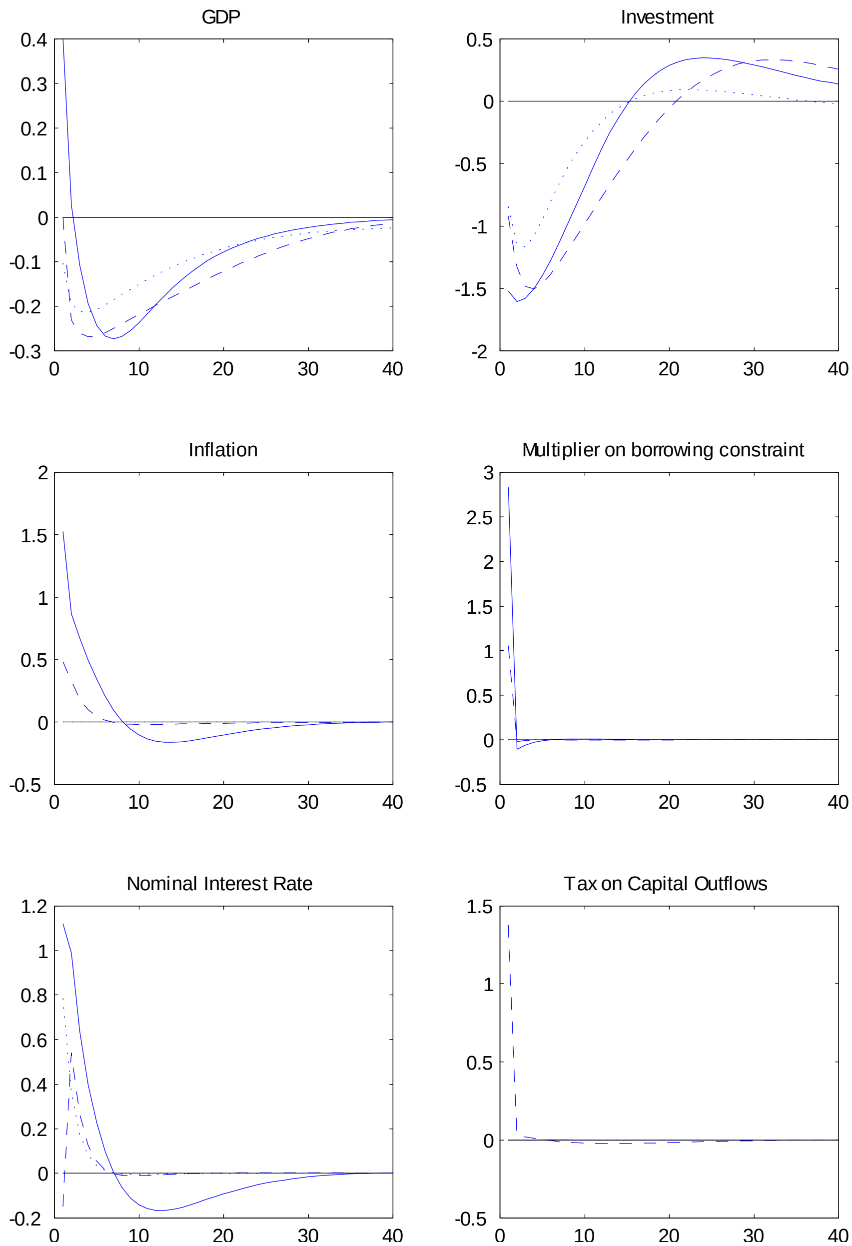

Figure 3: Impulse responses (expressed as percent deviations from the steady state) in the small open economy following a foreign real interest rate shock. The dotted line represents the efficient allocation where there are flexible prices and no collateral constraints. The solid line represents the model with sticky prices, collateral constraints and open capital markets. The dashed line represents the model with sticky prices, collateral constraints and where capital controls are chosen optimally.

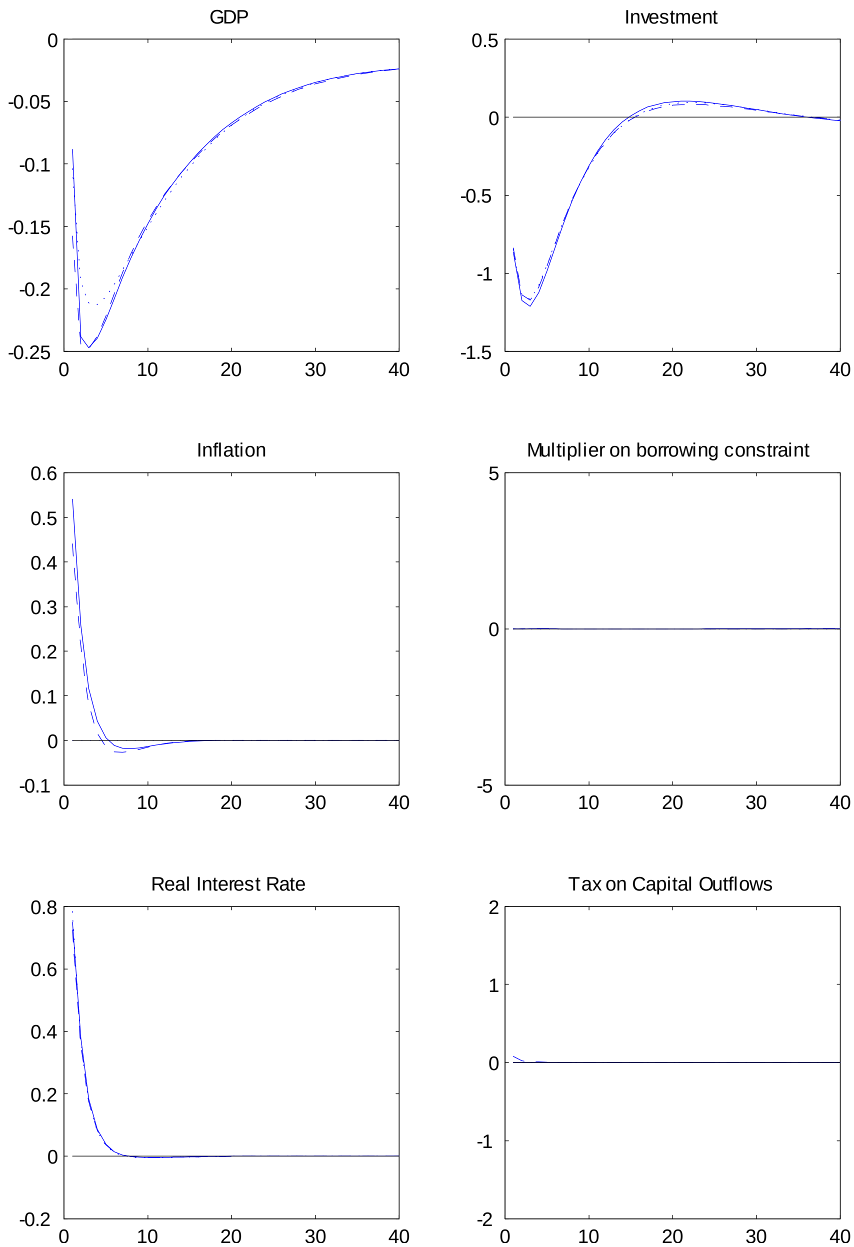

Figure 4: Impulse responses (expressed as percent deviations from the steady state) in the small open economy following a foreign real interest rate shock in the model with no credit frictions. The dotted line represents the efficient allocation where there are flexible prices. The solid line represents the model with sticky prices and open capital markets. The dashed line represents the model with sticky prices and optimally chosen capital controls.

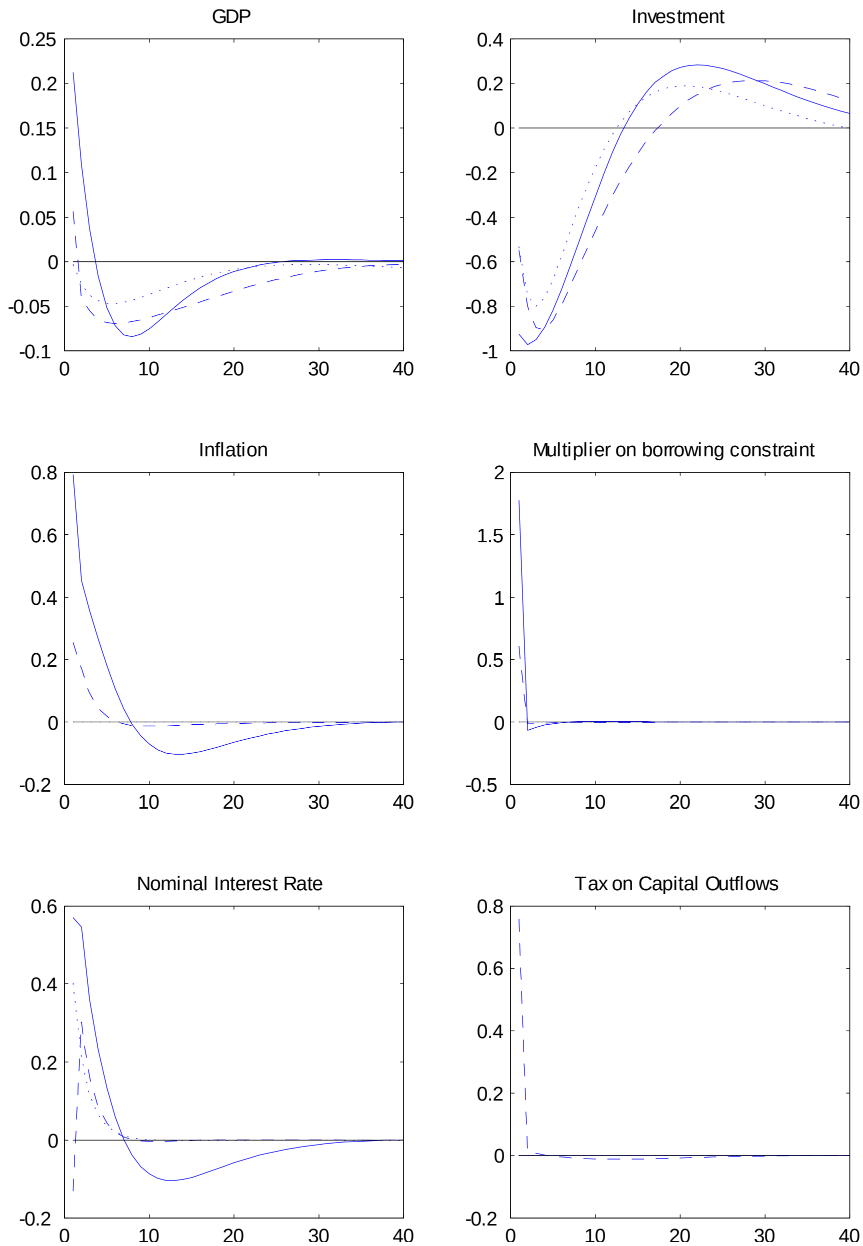

Figure 5: Impulse responses (expressed as percent deviations from the steady state) in the small open economy following a foreign credit supply shock. The dotted line represents the efficient allocation where there are flexible prices and no collateral constraints. The solid line represents the model with sticky prices, collateral constraints and open capital markets. The dashed line represents the model with sticky prices, collateral constraints and where capital controls are chosen optimally.

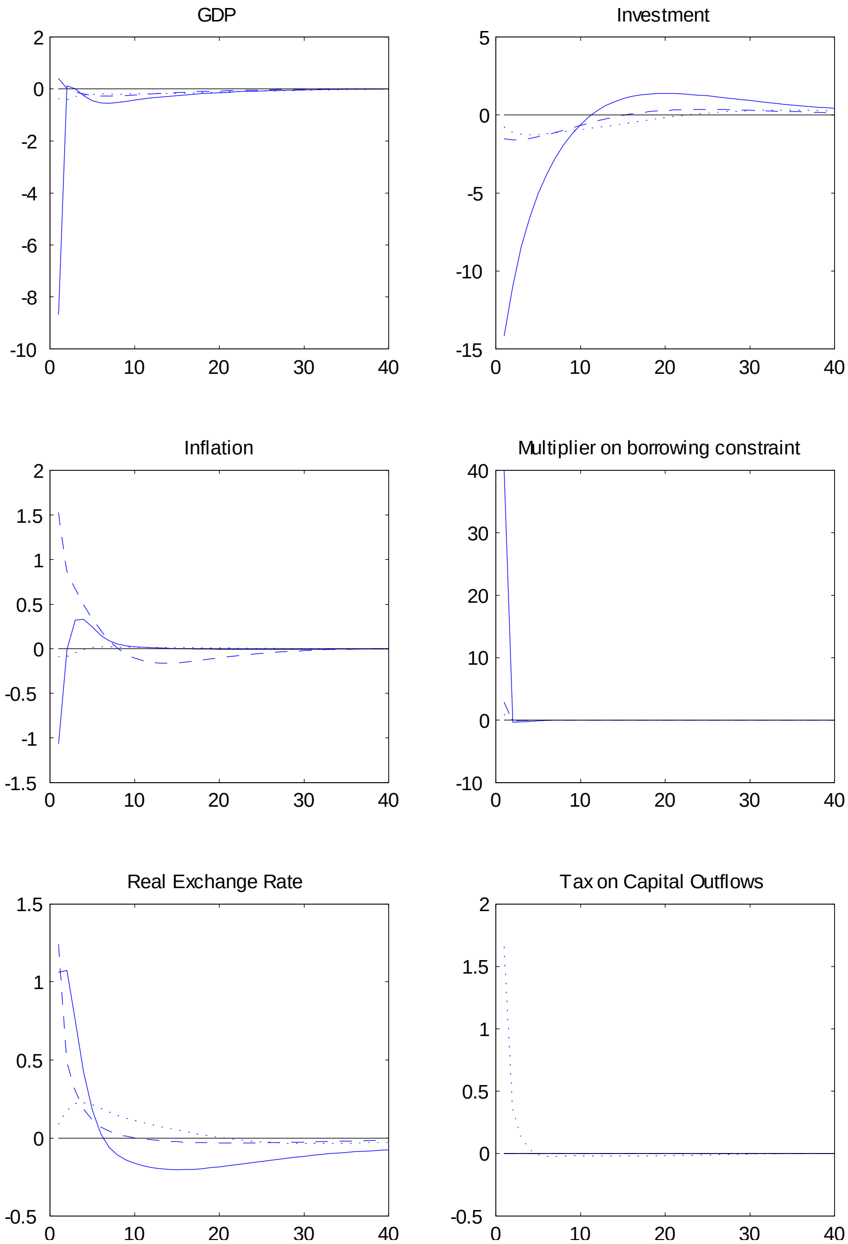

Figure 6: Impulse responses (expressed as percent deviations from the steady state) in the small open economy following a foreign real interest rate shock. The solid line represents the model with a fixed nominal exchange rate and an open capital account. The dashed line represents the model with an optimally chosen monetary policy and an open capital account. The dotted line represents the model with a fixed exchange rate and optimally chosen capital controls.

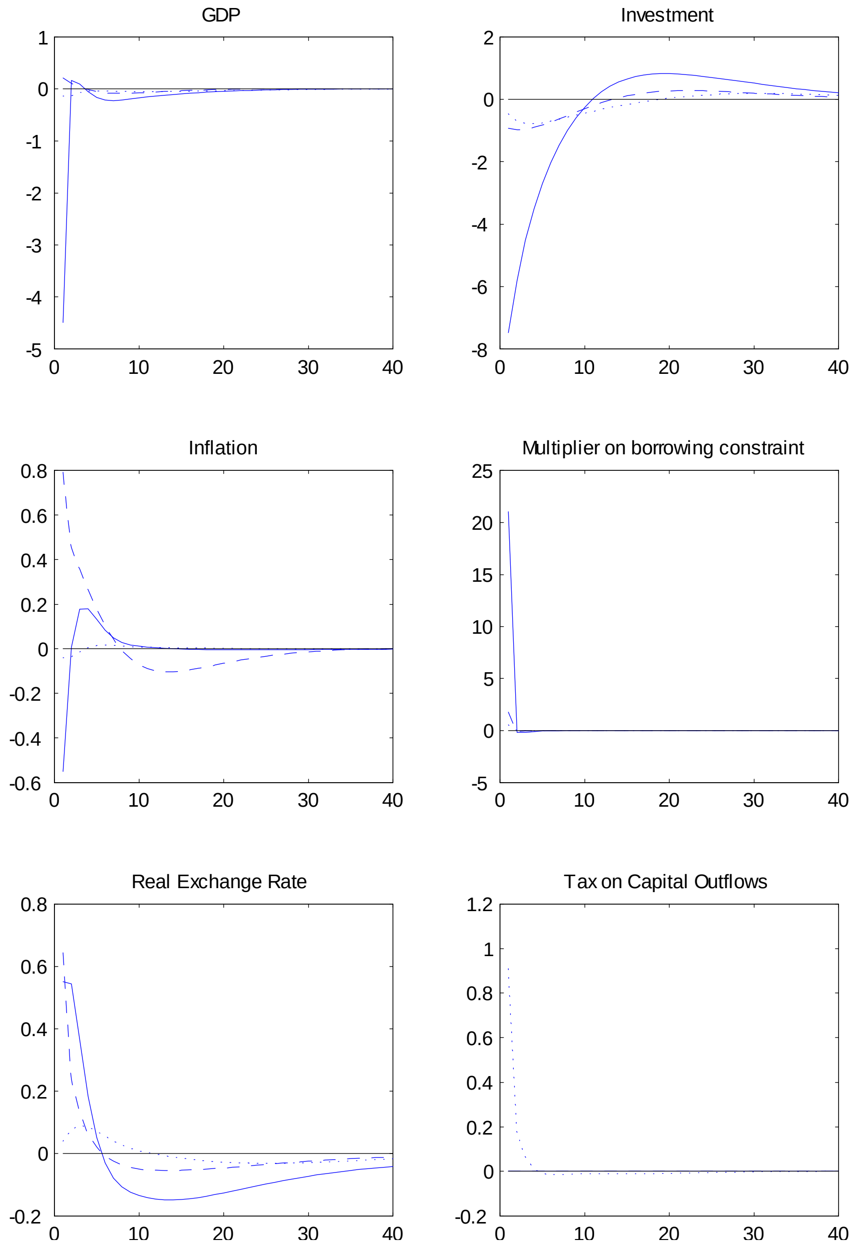

Figure 7: Impulse responses (expressed as percent deviations from the steady state) in the small open economy following a foreign credit supply shock. The solid line represents the model with a fixed nominal exchange rate and an open capital account. The dashed line represents the model with an optimally chosen monetary policy and an open capital account. The dotted line represents the model with a fixed exchange rate and optimally chosen capital controls.