Exchange Rate Adjustment in Financial Crises*

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1 Introduction

In the 1990's many economists criticized emerging market countries for their unwillingness to allow exchange rates to adjust. The 'fear of floating' was seen as severe distortion in the international monetary system, and a hindrance to good macroeconomic policy for these countries. In the worst case, a persistent defence of an exchange rate peg could lead to over -borrowing and precipitate currency and financial crises, as witnessed in Asia in 1997/98. According to Obstfeld and Rogoff, 1995, exchange rate flexibility should be a key part of the macroeconomic adjustment process for open economies with liberalized capital accounts. In recent years, many emerging economies have in fact moved much more towards flexible exchange rate regimes. But the experience with volatile exchange rates has been decidedly mixed. As has long been acknowledged, even in advanced economies, exchange rates tend to overshoot, and wide movements in real exchange rates may in fact exacerbate rather than alleviate the impact of external macroeconomic shocks.

For emerging economies, the lesson is the same, only more-so. In many instances, highly volatile

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capital flows have led to huge swings in real exchange rates, as recently witnessed in Brazil and Russia. It is questionable whether exchange rate adjustment can be a very useful feature of macro policy in these countries. As argued in Rey (2013, 2015), flexible exchange rates may play little role in facilitating an independent monetary policy when capital flows are driven by large external shocks. In particular, emerging economies are excessively vulnerable to the 'global financial cycle' , which can cause unstable inflows and outflows of capital and associated boom and contraction in exchange rates, asset prices, credit and real economic activity.

These observations call for a rethinking of the role of the exchange rate and monetary policy in crisis-prone emerging countries. What survives of the validity of the traditional Mundell-Fleming trilemma? Is it possible to have any monetary policy autonomy in emerging economies, even with flexible exchange rates?. Given the history of financial crises in emerging market economies, and excessive vulnerability to global capital flows, is it realistic to expect exchange rate movements to play a large role in macroeconomic adjustment? Additional policy tools, such as capital controls, have been endorsed by international organizations and deployed by many countries in various circumstances. On the other hand, a large number of emerging and developing countries still stuck to a currency peg during and after the global financial crisis (Reinhart and Rogoff, 2004; Rose, 2014).

There is a substantial literature on capital market crises in emerging market countries (see below for a review). A key feature of emerging markets that differentiate them from advanced economies is the prevalence of 'sudden stops' in capital market access. These sudden reversals of capital flows have been associated with large financial and economic crises. The existing literature on sudden stops stresses the non-linear dynamics associated with crises, but has not integrated the modelling with the investigation of monetary policy or the exchange rate regime. But recent experience has made this a first order question. If emerging economies sudden stop episodes are driven solely by structural financial accelerator dynamics and independent of monetary policy stance, and moreover, are essentially impervious to alternative monetary policy rules, then the consequences for open capital markets are much more serious, since it implies that the only effective tools for insulating an economy from external funding shocks are controls on capital flows. But if the exchange rate regime can play an important role in responding to capital flow shocks, then the policy implications may be very different.

This paper explores the benefits of nominal exchange rate adjustment in a small economy which is vulnerable to 'sudden stop' financial crises associated with occasionally binding borrowing constraints. We contrast a policy of an exchange rate peg with a flexible inflation targeting monetary rule, a Ramsey optimal monetary policy, and a policy that makes use of both optimal monetary policy and prudential capital controls. The analysis is carried out in a stochastic environment using a global solution technique, assuming that the economy is vulnerable to domestic and external shocks, as well as unpredictable reversals in international capital flows. Our aim is to revisit the debate on the open economy 'Trilemma', asking to what extent nominal exchange rate adjustment can assist in dealing with sudden stop crises in emerging market economies.

The key technical novelty of the paper is to combine global solution methods for a small economy that is subject to occasionally binding borrowing constraints, with a sticky price New Keynesian model. This allows us to look at the effect of alternative monetary policy rules on the incidence and severity of financial crises. The main appeal of the modelling strategy is the fact that the analysis is carried out within a full global stochastic environment. In addition, we can use the model to derive the characteristics of an optimal monetary policy within this environment. We characterize the optimal monetary policy in both 'normal times' when the economy is far away from a binding borrowing constraint, and in 'crisis times', when the borrowing constraint tightly binds. We then compare theses optimal monetary policy rules to an environment where the monetary authority maintains an exchange rate peg. We can ask how costly is this peg in terms of macroeconomic management, both in normal times, and crisis times. We can further ask how the frequency of crises is affected by the exchange rate regime and the monetary policy rule. Finally, we can explore the role for macro-prudential capital flow taxes. Given the presence of financial frictions that depend on the cyclical value of collateral, macroprudential capital taxes may be a desirable addition to monetary policy. But our main focus here is the differential role of macroprudential policies across different exchange rate regimes.

Our results can be summarized briefly; in 'normal times', when the economy operates away from a binding borrowing constraint, the difference between an exchange rate peg and an optimal monetary policy (or a flexible inflation target) is quite small, both in terms of macroeconomic indicators and welfare. But in crises, nominal exchange rate adjustment can play a large and beneficial role, substantially reducing the negative impact of capital flow reversals as well as greatly improving conditional welfare. Under an exchange rate peg, a crisis forces a sharp deflation in order to facilitate a real exchange depreciation, and the fall in all measures of economic activity is significantly deeper than that seen under an optimal monetary rule or an inflation targeting rule.

How is the frequency of crises affected by the monetary regime? Alternative monetary regimes impact not just macroeconomic volatility, but also on average levels of external debt, asset prices and the real exchange rate. This leads to the prediction that the incidence of crises differs systematically across different regimes. We find the in the baseline model, crises should be *less* frequent under a pegged regime. This is because, given the greater consequences of a crisis under a peg, domestic agents will engage in more precautionary saving, leading to a lower mean level of net external debt, and consequently, a smaller probability of experiencing a binding external borrowing constraint. Of course this analysis implicitly assumes that an exchange rate peg is a full commitment policy. If agents suspect that the monetary authority would abandon the peg during a crisis, then the impact on precautionary saving and external debt would be much less.

We go on to look at the possibility of direct controls on capital flows which may supplement monetary policy. The existing literature has argued for the use of capital controls to reduce the risk of sudden stops as a result of overborrowing (Bianchi and Mendoza (2010)). By contrast, Farhi and Werning (2012) argue for the use of capital controls to supplement monetary policy when the monetary authority is committed to an exchange rate peg. Our analysis combines both these motives within the model of financial frictions and nominal rigidities. We ask whether capital controls may be desirable, in welfare terms, and how this differs across exchange rate regimes. We find a stark difference across the two exchange rate regimes. Under a flexible exchange rate regime (when authorities follow an inflation targeting policy, or an optimal monetary policy), there is no welfare case for a tax on foreign borrowing. In fact, following the results of Devereux, Young and Yu (2015), a small capital inflow subsidy, levied outside of crisis times, can enhance welfare by raising asset prices and borrowing capacity. On the other hand, under a pegged exchange rate regime, we find that a tax on foreign borrowing may be desirable. This tax can significantly reduce the probability of crises, and through reducing the average level of external debt, reduces the severity of crises when they do occur.

While the paper is mainly a theoretical analysis, the results suggest that the recent pessimism about the usefulness of exchange rate flexibility for emerging economies may be overdone. While it is clear that the policy issues raised by volatile capital flows and sudden stops present a very different and more serious set of problems for emerging economies than those faced by policy making in advanced economies, it is still the case that monetary policy can play a substantial role in responding to capital market crises. Moreover, efficient exchange rate adjustment plays a crucial role during a crisis.

1.1 Related literature

This work is related to several strands of recent literature.

1.1.1 Macroprudential capital controls in a small open economy

Bianchi (2011) studies an endowment economy with tradable and nontradable sectors. Private agents don't internalize the effects of their borrowing on asset prices in crisis, which leads to an overborrowing ex-ante. Bianchi and Mendoza (2010) develop state-contingent capital inflow taxes to prevent overborrowing. This state-contingent taxation can be understood as Pigouvian taxation (Jeanne and Korinek, 2010). Schmitt-Grohe and Uribe (2012) inspect a model with downward wage rigidity to explain the large and protracted slump in the Eurozone. On the other hand, when there exist ex post adjustments of production between tradable and nontradable sectors, private agents may engage in underborrowing (Benigno, Chen, Otrok, Rebucci and Young, 2013). Korinek (2011) and Lorenzoni (2015) provide comprehensive reviews on borrowing and macroprudential policies during financial crises. As regards the description of optimal policy, Bianchi and Mendoza (2013) explores a time-consistent macroprudential policy. Devereux, Young and Yu (2015) focus on time-consistent monetary and capital control policies in an inflation targeting regime. Capital controls in their case are welfare-reducing, because of a key time-consistency involved in the valuation of collateral.

Other references: Summary by Engel (2015 NBER 20951). Ostry, Ghosh, Chamon, Qureshi (JIE 2012) managing capital flows.

1.1.2 Exchange rate stabilization

Other references: survey on exchange rate stabilization: Corsetti, Dedola and Leduc (2010 Handbook chapter); Engel (2014, ARE); Obstfeld and Rogoff (2002, QJE). Devereux and Engel (2003 restud, pcp vs. lcp). Benigno and Benigno (2003 JME).

1.1.3 Monetary policy and effects of capital controls on monetary policy

On the empirical side, Rey (2013) and Passari and Rey (2015) show that volatile capital flows can lead to substantial economic dislocation, even under a flexible exchange rate regime, while Georgiadis and Mehl (2015) still support the view of the traditional 'trilemma' case in favour of floating exchange rates. On the theoretical side, Farhi and Werning (2012) and Farhi and Werning (2013) explore optimal capital controls and monetary policy in a Gali-Monacelli type of small open economy model (Gali and Monacelli, 2005) and illustrate that capital controls can help regain monetary autonomy in a fixed exchange rate regime and work as terms of trade manipulation in a flexible exchange rate regime. Based on the experience of the Eurozone, Schmitt-Grohe and Uribe (2013) show that various types of taxes can be used to reduce the severity of financial crisis if nominal exchange rate can't be adjusted. Fornaro (2013b) extends Bianchi's model (Bianchi, 2011) to a Gali-Monacelli type of small open economies and shows that debt deleveraging may generate a world-wide recession in a monetary union. In a similar vein, Fornaro (2013a) investigates the tradeoff between price and financial stability in a small open economy with sticky wages and credit constraints. Faia and Iliopulos (2011) investigates optimal monetary policy to stabilize exchange rates and domestic inflation. In a sudden stop environment, Devereux, Young and Yu (2015) present that monetary policy should target domestic inflation in normal times but deviate from the target dramatically in sudden stop scenarios in order to stimulate domestic aggregate demand.

Other references: Liu and Speigel (2015 IMF-ER): capital controls and monetary policy in a soe, local approximation, imperfect asset substitutability. Korinek and Simsek (2016 AER) liquidity trade and capital controls. Pablo Ottonello(2015, U. of Michigan) monetary policy and capital control under the pegged.

Klein and Shambaugh (2014)-empirical analysis on monetary policy autonomy.

1.1.4 Currency manipulation and currency wars

Monetary authorities can manipulate their currency towards domestic benefits. Capital controls and foreign exchange interventions can be used as intertemporal terms of trade manipulation (Costinot, Lorenzoni and Werning, 2014). The choice of an exchange rate regime may reflect the intention of currency manipulation (Hassan, Mertens and Zhang, 2015). Market frictions and incompleteness of policy tools are also the roots of currency manipulation and even currency wars (Korinek, 2015).

2 The model

We consider a small economy. The baseline model structure is similar to Devereux, Young and Yu (2015), which is built upon Cespedes, Chang and Velasco (2004) and Mendoza (2010). In this small economy, there exist infinitely lived firm-households with a unit measure, who owns all domestic firms. International financial markets are incomplete. Households only trade across borders in foreign currency denominated non-state contingent bonds. There are two types of domestic producers: competitive wholesale goods producers and monopolistically competitive final goods producers. Wholesale producers combine imported intermediate inputs, domestic labor and physical capital in competitive factor markets,

$$M_t = A_t (Y_{F,t})^{\alpha_F} L_t^{\alpha_L} K_t^{\alpha_K}, \tag{1}$$

with $\alpha_F + \alpha_L + \alpha_K \leq 1$. M_t denotes the wholesale good production, A_t country-specific exogenous technological shock, $Y_{F,t}$ imported intermediate inputs, L_t labor demand and K_t physical capital. Imported intermediate inputs are aggregated with a constant elasticity of substitution technology given by,

$$Y_{F,t} = \left(\int_0^1 (Y_{F,t}(i))^{\frac{\theta-1}{\theta}} \, di \right)^{\frac{\theta}{\theta-1}}, \tag{2}$$

where θ stands for the elasticity of substitution between imported varieties. In this small open economy, prices in the rest of world are exogenously given. For simplicity but without loss of generality, we assume prices of all intermediate varieties are identical so that $P^*_{F,t} = P^*_{F,t}(i)$ in the rest of world. Foreign demand for domestic consumption composites, X_t, is given by

$$X_t = \left(\frac{P_t}{\mathcal{E}_t P^*_t} \right)^{-\rho} \zeta^*_t, \tag{3}$$

ζ^*_t stands for foreign demand. $\rho > 1$ is the elasticity of substitution between imports and locally produced goods in the foreign consumption basket. Note that the share of expenditures in the foreign country (the rest of world) on imports from the domestic country is too small to be taken into account. We normalize the consumer price index in the foreign country to unity $P^*_t = P^*_{F,t}(i) = 1$.

2.1 Firm-households

A representative infinitely lived firm-household has a form of preference given by

$$E_0 \sum_{t=0}^{+\infty} \beta^t U(c_t, l_t), \tag{4}$$

where E_0 represents the expectation conditional on information up to date 0. We assume that the subjective discount factor is constrained by $\beta R^*_{t+1} < 1$. This ensures that in a deterministic steady state, the small economy is a net debtor. Current utility function takes a GHH (Greenwood, Hercowitz and Huffman, 1988) form

$$U(c_t, l_t) = \frac{\left(c_t - \chi \frac{l_t^{1+\nu}}{1+\nu}\right)^{1-\gamma} - 1}{1-\gamma}. \tag{5}$$

Similar to Mendoza (2010), households borrow from abroad to finance imported intermediate inputs and consumption. Assume that borrowing is denominated in foreign currency and that total borrowing from abroad requires physical capital k_{t+1} as collateral, due to agency costs associated with imperfect contract enforcement

$$\vartheta(1+\tau_{N,t})Y_{F,t} - B^*_{t+1} \leq \kappa_t E_t \left\{ \frac{Q_{t+1}k_{t+1}}{\mathcal{E}_{t+1}} \right\}, \tag{6}$$

B^*_{t+1} stands for domestic savings in dollar at the end of period t, $\tau_{N,t}$ is a import tax, ϑ measures the fraction of imported inputs $(1+\tau_{N,t})Y_{F,t}$ which is financed in advance, and Q_{t+1} is the nominal capital price. Parameter κ_t capture the maximal loan-to-value ratio according to Kiyotaki and Moore (1997).

Households own all domestic firms equally and they make identical decisions in a symmetric equilibrium. A representative firm-household faces the following budget constraint

$$P_t c_t + Q_t k_{t+1} + \frac{B_{t+1}}{R_{t+1}} + \frac{(1-\tau_{c,t})B^*_{t+1}\mathcal{E}_t}{R^*_{t+1}} \leq W_t l_t + k_t(R_{K,t} + Q_t) + B_t + B^*_t \mathcal{E}_t + T_t$$

$$+ [P_{M,t}M(Y_{F,t}, L_t, K_t) - (1+\tau_{N,t})Y_{F,t}\mathcal{E}_t - W_t L_t - R_{K,t}K_t] + D_t. \tag{7}$$

The left-hand side of the constraint above displays domestic consumption expenditure $P_t c_t$, capital purchase $Q_t k_{t+1}$, domestic savings B_{t+1}/R_{t+1} and savings in foreign currency $B^*_{t+1}\mathcal{E}_t/R^*_{t+1}$. $\tau_{c,t}$ denotes capital controls imposed by domestic authorities. The right-hand side consists of labor income $W_t l_t$, the gross return on capital $k_t(R_{K,t} + Q_t)$, the gross return on domestic savings B_t and savings abroad $B^*_t\mathcal{E}_t$, lump-sum transfers from government T_t, profits from whole sale good producers $P_{M,t}M_t - (1+\tau_{N,t})Y_{F,t}\mathcal{E}_t - W_t L_t - R_{K,t}K_t$ and profits from the rest of domestic economy

D_t. The wholesale good production M_t is given by equation (1). As in (Bianchi and Mendoza, 2013), we assume that working capital incurs no interest rate payments.

Let $\mu_t e_t$ be the Lagrange multiplier for the borrowing constraint (6). A lower case price variable denotes the real price, i.e., $q_t = Q_t/P_t$, $w_t = W_t/P_t$. The consumer price index inflation rate is defined as $\pi_t = P_t/P_{t-1}$ and real exchange rate is $e_t = \mathcal{E}_t P_t^*/P_t$. Higher e_t implies a real exchange rate depreciation.

The optimal labor supply decision satisfies

$$w_t = \chi l_t^{\nu}. \tag{8}$$

The optimality conditions for the household's choice of capital, domestic denominated bonds, and foreign currency denominated bonds, respectively, are expressed as

$$q_t = \mu_t \kappa_t E_t \left\{ \frac{q_{t+1} e_t}{e_{t+1}} \right\} + E_t \left\{ \beta \frac{U_c(t+1)}{U_c(t)} (r_{K,t+1} + q_{t+1}) \right\}, \tag{9}$$

$$1 = E_t \left\{ \beta \frac{U_c(t+1)}{U_c(t)} \frac{R_{t+1}}{\pi_{t+1}} \right\}, \tag{10}$$

$$1 - \tau_{c,t} = \mu_t R_{t+1}^* + E_t \left\{ \beta \frac{U_c(t+1)}{U_c(t)} \frac{e_{t+1}}{e_t} R_{t+1}^* \right\}, \tag{11}$$

where $U_c(t)$ stands for marginal utility of consumption. We note that in the case of a binding constraint (6) the benefit to the household from holding an additional unity of capital or an additional foreign currency bond is enhanced as in (9) and (11).

The household firms choice of imported inputs, labor and capital are expressed as

$$p_{M,t} \frac{\alpha_F M_t}{Y_{F,t}} = e_t \left(1 + \vartheta \mu_t\right) \left(1 + \tau_{N,t}\right), \tag{12}$$

$$p_{M,t} \frac{\alpha_L M_t}{L_t} = w_t \tag{13}$$

$$p_{M,t} \frac{\alpha_K M_t}{K_t} = r_{K,t}. \tag{14}$$

where w_t denotes the cost of labor.

The complementary slackness condition related by (6) is written as

$$\mu_t \left[\kappa_t E_t \left(\frac{q_{t+1} k_{t+1}}{e_{t+1}} \right) + b^*_{t+1} - \vartheta Y_{F,t}(1 + \tau_{N,t}) \right] = 0, \tag{15}$$

where we have replaced nominal bond B^*_{t+1} with real bonds $b^*_{t+1} = B^*_{t+1}/P^*_t$.

2.2 Final good producers

There is a continuum of monopolistically competitive final good producers with measure one, each of which differentiates wholesale goods into a variety of final goods. Each variety is an imperfect substitute for other varieties, implying that final good producers have monopoly power over their varieties. All consumption varieties are aggregated into the consumption composite, which has a constant elasticity of substitution (Dixit and Stiglitz, 1977) form of

$$Y_t = \left(\int_0^1 (Y_t(i))^{\frac{\theta-1}{\theta}} di \right)^{\frac{\theta}{\theta-1}},$$

where Y_t is total demand for consumption composites, and $Y_t(i)$ is demand for variety i in period t. $\theta > 1$ represents the elasticity of substitution between varieties. Let $P_t(i)$ be the nominal price of variety $Y_t(i)$. Cost minimization implies

$$P_t = \left(\int_0^1 (P_t(i))^{1-\theta} di \right)^{\frac{1}{1-\theta}},$$

and the demand for variety $Y_t(i)$

$$Y_t(i) = \left(\frac{P_t(i)}{P_t} \right)^{-\theta} Y_t. \tag{16}$$

Each variety producer makes use of a linear technology

$$Y_t(i) = M_t(i). \tag{17}$$

Firms set prices in domestic currency (producer currency pricing) and can reset their prices each period, but suffer a quadratic price adjustment cost (see Rotemberg, 1982). Profits per period gained by firm i equal total revenues net of wholesale prices and of price adjustment costs

$$D_{H,t}(i) \equiv (1+\tau_H) P_t(i) Y_t(i) - P_{M,t} Y_t(i) - \phi\left(\frac{P_t(i)}{P_{t-1}(i)}\right) Y_t P_t,$$

with asymmetric price adjustment cost $\phi\left(\frac{P_t(i)}{P_{t-1}(i)}\right)$ following Varian (1975) and Kim and Ruge-Murcia (2009)

$$\phi\left(\frac{P_t(i)}{P_{t-1}(i)}\right) \equiv \phi_P \frac{\exp\left(\gamma\left(\frac{P_t(i)}{P_{t-1}(i)} - \pi\right)\right) - \gamma\left(\frac{P_t(i)}{P_{t-1}(i)} - \pi\right) - 1}{\gamma^2}$$

where π is the inflation target and τ_H denotes a subsidy rate by the government in order to undo the monopoly power of price setting. In the cost function $\phi(\cdot)$, ϕ_P characterizes the Rotemberg price adjustment cost and γ captures the asymmetry of the price adjustment cost. When $\gamma < 0$, the price adjustment displays a pattern of downward rigidity.

Firm i faces the following problem

$$\max_{\{P_t(i), Y_t(i)\}} E_h\left(\sum_{t=h}^{+\infty} \Lambda_{h,t} \frac{P_h}{P_t} D_{H,t}(i)\right),$$

subject to demand for variety i (16) and production technology (17). The stochastic discount factor is given by $\Lambda_{h,t} = \beta^{t-h} U_c(t)/U_c(h)$ with $h \leq t$.

As usual, we consider a symmetric equilibrium, where all firms choose the same price, $P_t(i) = P_t$. Consequently, the supply of each variety should be identical $Y_t(i) = Y_t$. The optimality condition for price-setting can be simplified as

$$\begin{aligned} & Y_t\left[(1+\tau_H) - \theta\left(1+\tau_H - p_{M,t}\right)\right] - \phi_P Y_t \pi_t \frac{\exp\left(\gamma(\pi_t - \pi)\right) - 1}{\gamma} + \\ & E_t\left[\Lambda_{t,t+1} \phi_P \pi_{t+1} Y_{t+1} \frac{\exp\left(\gamma(\pi_{t+1} - \pi)\right) - 1}{\gamma}\right] = 0. \end{aligned} \tag{18}$$

Real profits from intermediate producers are

$$\begin{aligned} d_{H,t} \equiv \frac{D_{H,t}}{P_t} &= (1+\tau_H)Y_t - p_{M,t}Y_t - \phi(\pi_t)Y_t \\ &= Y_t\left[(1+\tau_H) - p_{M,t} - \phi(\pi_t)\right]. \end{aligned} \tag{19}$$

with

$$\phi(\pi_t) = \phi_P \frac{\exp\left(\gamma\left(\pi_t - \pi\right)\right) - \gamma\left(\pi_t - \pi\right) - 1}{\gamma^2}$$

Without nominal rigidities $\phi_P = 0$ and with appropriate subsidy $\tau_H = 1/(\theta - 1) > 0$, production markets are frictionless, so that $p_{M,t} = 1$.

Markets clear at the end of each period, including the labor market and consumption $l_t = L_t$, $c_t = C_t$. In the model we assume that domestic bonds can only be held by domestic agents $b_{t+1} = 0$ and in the aggregate, the capital stock is fixed, so that $K_{t+1} = k_{t+1} = 1$. Profits from final good producers yield $d_t = d_{H,t}$. The wholesale goods market clearing condition reads

$$\int_0^1 Y_t(i)di = \int_0^1 M_t(i)di = M_t. \tag{20}$$

Consumption composites are either consumed by domestic households or exported to the rest of world

$$Y_t\left[1 - \phi(\pi_t)\right] = C_t + X_t. \tag{21}$$

2.3 Government policy

The government makes lump-sum transfers to domestic households

$$T_t = -\tau_H Y_t P_t - \frac{\tau_{c,t} b^*_{t+1} e_t}{R^*_{t+1}} P_t - \tau_{N,t} Y_{F,t} e_t P_t. \tag{22}$$

Assume also that the government sets a production subsidy τ_H to offset the monopoly power of price setting. The central bank implements monetary policy with either a fixed exchange rate or flexible exchange rate regime. In the regime of flexible exchange rates, monetary policy follows an inflation targeting policy, although we will also derive an optimal, welfare maximizing monetary policy under flexible exchange rates. The monetary rule can be defined by [1]

$$R_{t+1} = R\left(\frac{\pi_t}{\pi}\right)^{\alpha_\pi}\left(\frac{Y_t}{Y}\right)^{\alpha_Y}\left(\frac{e_t}{e}\right)^{\alpha_e}. \tag{23}$$

A variable without a superscript denotes the value at the deterministic steady state. The response coefficients $\alpha_\pi > 0$ and $\alpha_Y > 0$ are interpreted in the usual manner. In the fixed exchange rate regime, domestic inflation is determined by foreign inflation and the change in the real exchange rate,

$$\pi_t = \frac{e_{t-1}}{e_t}\pi_t^* = \frac{e_{t-1}}{e_t}. \tag{24}$$

Combining firm-households' budget constraints (7) with the relevant market clearing conditions and taxation policy (22), yields the country level resource constraint

$$C_t + \left(\frac{b_{t+1}^*}{R_{t+1}^*} - b_t^*\right)e_t = Y_t\left(1 - \frac{\phi_P}{2}(\pi_t - \pi)^2\right) - e_t Y_{F,t} - (K_{t+1} - K_t)q_t. \tag{25}$$

Equivalently, (25) implies that trade surpluses are used to finance external debt

$$X_t - e_t Y_{F,t} = \left(\frac{b_{t+1}^*}{R_{t+1}^*} - b_t^*\right)e_t. \tag{26}$$

The current account may be expressed as

$$ca_t = X_t - e_t Y_{F,t} + \frac{e_t b_t^*}{R_t^*}(R_t^* - 1), \tag{27}$$

2.4 A recursive competitive equilibrium

A recursive competitive equilibrium consists of a sequence of allocations $\{L_t,\, C_t,\, Y_{F,t},\, Y_t,\, K_{t+1},\, b_{t+1}^*\}$, and a sequence of prices $\{w_t,\, q_t,\, \pi_t,\, \mu_t,\, r_{K,t},\, e_t,\, p_{M,t}\}$, for $t = \cdots, 0, 1, 2, \cdots$, given produc-

[1] Note that the change in the nominal exchange rate is a function of the change in the real exchange rates and inflation, $\mathcal{E}_t/\mathcal{E}_{t-1} = \pi_t e_t/e_{t-1}$. Therefore, stabilizing nominal exchange rates and inflation is equivalent to stabilizing both inflation and the real exchange rate.

tion subsidy τ_H, import tax $\tau_{N,t}$, capital inflow tax $\tau_{c,t}$ and monetary policy R_{t+1}, such that (a) allocations solve households' and firms' problems given prices and public policies and (b) prices clear corresponding markets.

3 Calibration

The model parameters are quite standard in the literature and mainly taken from Devereux, Young and Yu (2015). The model period is defined as one quarter. The subjective discount factor is set to 0.975 to generate a 10% real interest rate per annum in emerging markets. The relative risk aversion is 2, and the inverse of the Frisch labor supply elasticity is one. The parameter governing the disutility of labor supply is set as 0.4 to generate a one unit supply of labor at the steady state. We set the input share in the wholesale good production at $\alpha_F = 0.16$, the share of labor, $\alpha_L = 0.57$ and $\alpha_K = 0.03$ to match the import-GDP ratio, labor income-GDP ratio and the external debt-GDP in emerging economies. The nominal price adjustment cost and downward nominal price rigidity are set as $\phi_P = 76$ and $\gamma = -50$. We make use of a moderate working capital share $\vartheta = 0.5$ as in Devereux, Young and Yu (2015). Combined with imported input share in the production $\alpha_F = 0.16$, the model generates a working-capital GDP of 10%. The elasticity of substitution among imported varieties and the elasticity of substitution in the foreign country are set the same $\theta = \rho = 10$, implying a 10% price markup within the country and across borders. The scale parameter in foreign demand is chosen to be $\zeta = 0.117$ which ensures that the real exchange rate equals one in the steady state.

The model is simulated with three stochastic shocks. We consider a domestic productivity shock, a foreign interest rate shock, and 'deleveraging' shock. The quarterly international rate interest rate is set to be 1.5% with persistence $\rho_R = 0.6$ and a standard deviation $\sigma_R = 0.00623$. The domestic productivity shock is normalized to be one with persistence $\rho_A = 0.95$ and standard deviation $\sigma_R = 0.008$. The leverage parameter takes two values, high $\kappa_L = 0.35$ and low $\kappa_H = 0.45$, with transition probability from high leverage to high leverage $p_{H,H} = 0.975$ and from low leverage to low leverage $p_{L,L} = 0.775$ (Bianchi and Mendoza, 2013). The unconditional probability of lower leverage becomes 10%. A jump of leverage from κ_H to κ_L is associated with a tighter collateral constraint.[2]

There are several policy instruments in the model. We fix $\tau_H = \frac{1}{\theta-1}$ and $\tau_{N,t} = \frac{1}{\rho-1}$ to eliminate monopolistic market power in the firm's price setting in the steady state.

Table 1: Parameter values

Parameter		Values
Preference		
β	Subjective discount factor	0.975
σ	Relative risk aversion	2
ν	Inverse of Frisch labor supply elasticity	1
χ	Parameter in labor supply	0.4
Production		
α_F	Intermediate input share in production	0.16
α_L	Labor share in production	0.57
α_K	Capital share in production	0.03
ϕ_P	Price adjustment cost	76
γ	Asymmetric price adjustment cost	-50
ϑ	Share of working capital	0.5
θ	Elasticity of substitution among imported varieties	10
ρ	Elasticity of substitution in the foreign countries	10
ζ	Steady state of foreign demand	0.117
R^*	Steady state of world interest rate	1.015
A	Steady state of TFP shock	1
ρ_A	Persistence of TFP shocks	0.95
σ_A	Standard deviation of TFP shocks	0.008
ρ_R	Persistence of foreign interest rate shocks	0.6
σ_R	Standard deviation of foreign interest rate shocks	0.00623
$p_{H,H}$	Transitional probability of high leverage to high leverage	0.975
$p_{L,L}$	Transitional probability of low leverage to low leverage	0.775
Policy variables		
α_π, α_Y, α_e	Coefficients in the Taylor rule	
τ_H	Subsidy to final goods producers	$\frac{1}{\theta-1}$
$\tau_{N,t}$	Import tax rate	$\frac{1}{\rho-1}$

[2]Increasing κ_H doesn't change the results since the borrowing constraint almost never binds when $\kappa_H = 0.45$.

4 Results without capital controls

Note that the collateral constraint (6) may or may not bind, and it is determined by the inherited debt level and the exogenous shocks. The dynamics of the model exhibit a highly nonlinear pattern. We solve the model using a global solution method, which enables us to analyze both 'normal time' business cycles and recessions. More solution details can be found in Devereux and Yu (2014) and Devereux, Young and Yu (2015).

When a country that has accumulated a large external debt is hit by a severe adverse shock, particularly a deleveraging shock, it faces a tighter borrowing constraint. This adverse credit condition makes the country reduce its external borrowing substantially. Limited debt rollover in turn depresses consumption and the value of collateral (the real price of capital), which results in a vicious circle of curtailed international borrowing and deteriorating domestic fundamental and financial variables. Note that external borrowing is denominated in foreign currency. The Central Bank cannot reduce its value by creating domestic inflation. Nevertheless, because prices are sticky, the monetary authority can manage domestic aggregate demand by creating domestic inflation, and enhance foreign demand through intervention in the foreign exchange rate market.

Tables 2, 3 and 4 compare the simulation results under three alternative regimes, corresponding to a policy of strict inflation targeting, an optimal monetary policy (see below for a description), and a pegged exchange rate regime. In each case we report the mean and standard deviation of the main endogenous variables in the model. We do this for the full sample, and then for the separate subsamples pertaining to the cases where the collateral constraint is non-binding (or what we call 'normal times') and for the case where the collateral constraint binds ('crisis times').

In a crisis, the binding collateral constraint forces a deleveraging, leading to a fall in consumption, output and a fall in the price of capital, which leads to a further tightening of the collateral constraint in the manner of the debt-deflation process described by Mendoza (2010). This is exacerbated by the rise in the cost of imported inputs, since the effective cost of borrowing in order to finance working capital is pushed up, according to (12). This in turn further reduces the marginal product of labor and leads to a decline in employment and output.

The critical issue for our analysis is the possibility for the real exchange rate to depreciate, acting as a shock absorber in response to the fall in aggregate demand. Tables 2 and 4 show that there is a substantial difference between fixed and flexible exchange rates in the response of the economy to a crisis.

We first compare the response to a crisis by comparing mean outcomes. Under the inflation targeting regime, a crisis leads to a 5 percent fall in net external debt. Output, employment and imported intermediate inputs all fall, and the price of collateral capital falls by 8 percent on average. The sharp rise in the cost of borrowing leads to a jump in the domestic interest rate to 10 percent. But this is tempered by a real exchange rate depreciation. By contrast, under a pegged exchange rate, the scale of deleveraging is much greater - net foreign debt falls by 15 percent, the fall in output and employment is much larger, and the interest rate spikes to 16 percent.[3] At the same time, the real exchange rate is effectively unchanged in a crisis under a pegged exchange rate regime. Hence, the inability to generate a real depreciation through a nominal depreciation, in the presence of domestic price stickiness, leads to a substantially greater impact of a crisis scenario in the pegged exchange rate regime.

By contrast, in 'normal times', when the collateral constraint is slack, there is little difference between the inflation targeting regime and the pegged regime. In terms of means, consumption, output and employment are effectively identical across these regimes during normal times. But net external debt is lower under the peg. This occurs due to the process of precautionary saving that agents in a pegged exchange regime undertake, in order to avoid the consequences of a crisis. As a result, we find that the frequency of crises under the pegged regime is actually lower (6.8%, compared to 10.7%) than under the inflation targeting regime.

The comparison in terms of second moments tells a similar story. Consumption, output, and employment volatility during a crisis is dramatically higher under a pegged exchange rate regime than under the inflation targeting rule, while real exchange rate volatility is much lower. Interestingly, output volatility in normal times is lower under a peg than under strict inflation targeting.

[3] This is consistent with the empirical literature. See for instance Domac and Martinez Peria, 2003.

The reason comes from the productivity shock in the model. When the collateral constraint doesn't bind, price stability will replicate the flexible price equilibrium. In this case productivity shocks generate a procyclical real exchange rate (a rise in output supplied requires a real exchange rate deprecation to stimulate the rise in demand). Under the pegged exchange rate regime, this can't happen so easily, due to sticky prices and the nominal exchange rate peg, so the output response to a productivity shock is dampened. If the model were to be calibrated to a higher share for leverage shocks and/or foreign interest shocks, the model under the peg would generate higher output volatility than that under inflation targeting.

Now we turn to the optimal monetary regime under floating. Here we focus on a time-consistent monetary policy as in Devereux, Young and Yu (2015). When it actively chooses the domestic nominal interest to manage inflation and nominal exchange rate, the monetary authority can boost the domestic economy by creating inflation and further depreciating nominal exchange rate in crisis. Table 3 reports the model moments under the optimal monetary policy. Two points are worth emphasizing. First, inflation is zero in normal times whenever the borrowing constraint does not bind. This is an important point in that it implies that there is no role for 'macroprudential' monetary policy, raising interest rates in advance of potential future crises. Second, the central bank creates a little bit of inflation in a crisis, stimulating a depreciation in the nominal exchange rate to crowd in foreign demand. As a result, in the stationary equilibrium, net external debt is slightly lower. This leads to a slightly lower frequency of financial crises under an optimal monetary policy (10.7% vs. 11.1%).

In order to see more clearly what happens in a typical financial crisis, we now turn to the event analysis. We define an 'event' in the simulations as a situation where the collateral constraint is non-binding for 2 periods, and then becomes binding for at least one period following this. Then we average the responses of all macroeconomic variables across all such events. Figure 1 and 2 reports variables of interest during the evolution of a crisis. When a crisis occurs unexpectedly, the borrowing constraint becomes tighter leading to a sudden jump in the Lagrange multiplier μ. Imports, output, employment and consumption decline dramatically. But clearly, the response under a peg is substantially greater in most dimensions. The multiplier jumps much more under the peg. The fall in borrowing is much greater, and the impact on the real economy (the fall in output, imports, employment and consumption) is significantly greater. At the same time, while the real exchange rate depreciates in both regimes there is a much larger depreciation under the floating exchange rate regime. Because of the inverse relationship between inflation and real exchange rate, under the pegged exchange rate, the real exchange rate depreciation requires a substantial deflation on impact and then a dramatic inflation following the impact period. The Figures also illustrate that on average, a crisis under a pegged exchange rate regime is precipitated at a lower level of net external debt than under the floating regime. As we described above, on average the exchange rate peg leads to a lower mean level of external borrowing due to precautionary saving motives.

Finally, it is interesting to note that, while an optimal monetary policy differs from the strict inflation targeting regime during a crisis, in practice, there is little difference between the two policies, even in a crisis. The monetary authority does allow for a jump in inflation during a crisis, under an optimal monetary policy. But this is much smaller than the response of inflation in the peg, and has little effect on the other response of the real economy, compared to that under the strict inflation targeting regime.

5 Results with capital controls

In the baseline model, we have two types of frictions: nominal rigidities and pecuniary externalities. In the floating regime, Devereux, Young and Yu (2015) have shown that the optimal time-consistent capital control is to tax capital inflows only in a crisis, since without policy commitment, policy makers have an incentive to increase the economy's current borrowing capacity by taxing capital inflows, and thereby reducing future debt repayments so as to push up the future capital price. Nevertheless, the higher capital inflow tax in the stationary equilibrium substantially reduces households' borrowing capacity and leads to lower welfare ex ante. Here, we take a different perspective, avoiding the time consistency problem that is highlighted in Devereux, Young and

Table 2: Model moments under the strict inflation targeting regime

	Mean	Std.(%)	Corr(.,GDP)
Probability of crisis	11.1		
Panel A: the whole sample			
Effective consumption	0.3883	1.14	0.81
Output	0.6877	1.80	1.00
Bond	-0.3185	1.31	0.23
Real exchange rate	0.9871	0.69	0.53
Price markup	1.0000	0.00	0.00
Inflation	1.0000	0.00	0.00
Labor	0.9898	1.30	1.00
Capital price	0.9364	3.43	0.84
Domestic interest rate	1.0254	5.76	-0.32
External finance premium	0.0074	3.91	-0.30
Panel B: the subsample with binding constraints			
Effective consumption	0.3677	2.10	0.78
Output	0.6645	1.82	1.00
Bond	-0.3064	2.83	-0.03
Real exchange rate	0.9904	1.14	-0.22
Price markup	1.0000	0.00	0.00
Inflation	1.0000	0.00	0.00
Labor	0.9730	1.33	1.00
Capital price	0.8738	5.70	0.81
Domestic interest rate	1.1042	15.29	-0.57
External finance premium	0.0665	10.08	-0.53
Panel C: the subsample without binding constraints			
Effective consumption	0.3908	0.78	0.94
Output	0.6906	1.80	1.00
Bond	-0.3200	1.23	0.48
Real exchange rate	0.9867	0.59	0.90
Price markup	1.0000	0.00	0.00
Inflation	1.0000	0.00	0.00
Labor	0.9918	1.29	1.00
Capital price	0.9442	2.54	0.94
Domestic interest rate	1.0156	0.52	-0.36

Notes: The moments are generated by a simulation of 210,000 periods with dropping the first 10,000 periods. A crisis scenario is defined as a binding collateral constraint.

Table 3: Model moments under optimal monetary policy

	Mean	Std.(%)	Corr(.,GDP)
Probability of crisis	10.7		
Panel A: the whole sample			
Effective consumption	0.3883	1.14	0.80
Output	0.6877	1.79	1.00
Bond	-0.3183	1.31	0.24
Real exchange rate	0.9871	0.70	0.53
Price markup	1.0001	0.08	-0.28
Inflation	1.0000	0.01	-0.27
Labor	0.9899	1.28	1.00
Capital price	0.9364	3.42	0.84
Domestic interest rate	1.0254	5.77	-0.30
External finance premium	0.0074	3.92	-0.28
Panel B: the subsample with binding constraints			
Effective consumption	0.3676	2.14	0.75
Output	0.6652	1.79	1.00
Bond	-0.3047	2.80	-0.02
Real exchange rate	0.9908	1.18	-0.18
Price markup	1.0014	0.21	-0.51
Inflation	1.0002	0.03	-0.52
Labor	0.9742	1.26	1.00
Capital price	0.8734	5.79	0.78
Domestic interest rate	1.1072	15.56	-0.54
External finance premium	0.0690	10.23	-0.50
Panel C: the subsample without binding constraints			
Effective consumption	0.3908	0.78	0.94
Output	0.6904	1.79	1.00
Bond	-0.3200	1.23	0.48
Real exchange rate	0.9867	0.59	0.90
Price markup	1.0000	0.00	0.67
Inflation	1.0000	0.00	0.67
Labor	0.9917	1.29	1.00
Capital price	0.9440	2.53	0.93
Domestic interest rate	1.0156	0.52	-0.37

Notes: The moments are generated by a simulation of 210,000 periods with dropping the first 10,000 periods. A crisis scenario is defined as a binding collateral constraint.

Table 4: Model moments under the pegged regime

	Mean	Std.(%)	Corr(.,GDP)
Probability of crisis	6.8		
Panel A: the whole sample			
Effective consumption	0.3879	1.02	0.97
Output	0.6877	1.65	1.00
Bond	-0.3163	0.80	-0.05
Real exchange rate	0.9874	0.30	-0.01
Price markup	1.0005	2.41	0.56
Inflation	1.0000	0.30	0.41
Labor	0.9900	2.10	0.88
Capital price	0.9338	3.05	0.97
Domestic interest rate	1.0252	5.89	-0.82
External finance premium	0.0073	3.58	-0.82
Panel B: the subsample with binding constraints			
Effective consumption	0.3634	2.77	0.99
Output	0.6492	4.49	1.00
Bond	-0.2770	0.61	0.24
Real exchange rate	0.9886	0.52	-0.47
Price markup	0.9676	6.07	0.91
Inflation	0.9993	0.60	0.81
Labor	0.9460	6.09	0.98
Capital price	0.8602	7.72	0.99
Domestic interest rate	1.1654	18.68	-0.96
External finance premium	0.1070	10.60	-0.97
Panel C: the subsample without binding constraints			
Effective consumption	0.3896	0.57	0.92
Output	0.6905	0.97	1.00
Bond	-0.3191	0.74	0.65
Real exchange rate	0.9873	0.28	0.71
Price markup	1.0029	1.59	-0.16
Inflation	1.0001	0.26	0.07
Labor	0.9932	0.96	0.59
Capital price	0.9391	1.90	0.92
Domestic interest rate	1.0150	0.52	-0.30

Notes: The moments are generated by a simulation of 210,000 periods with dropping the first 10,000 periods. A crisis scenario is defined as a binding collateral constraint.

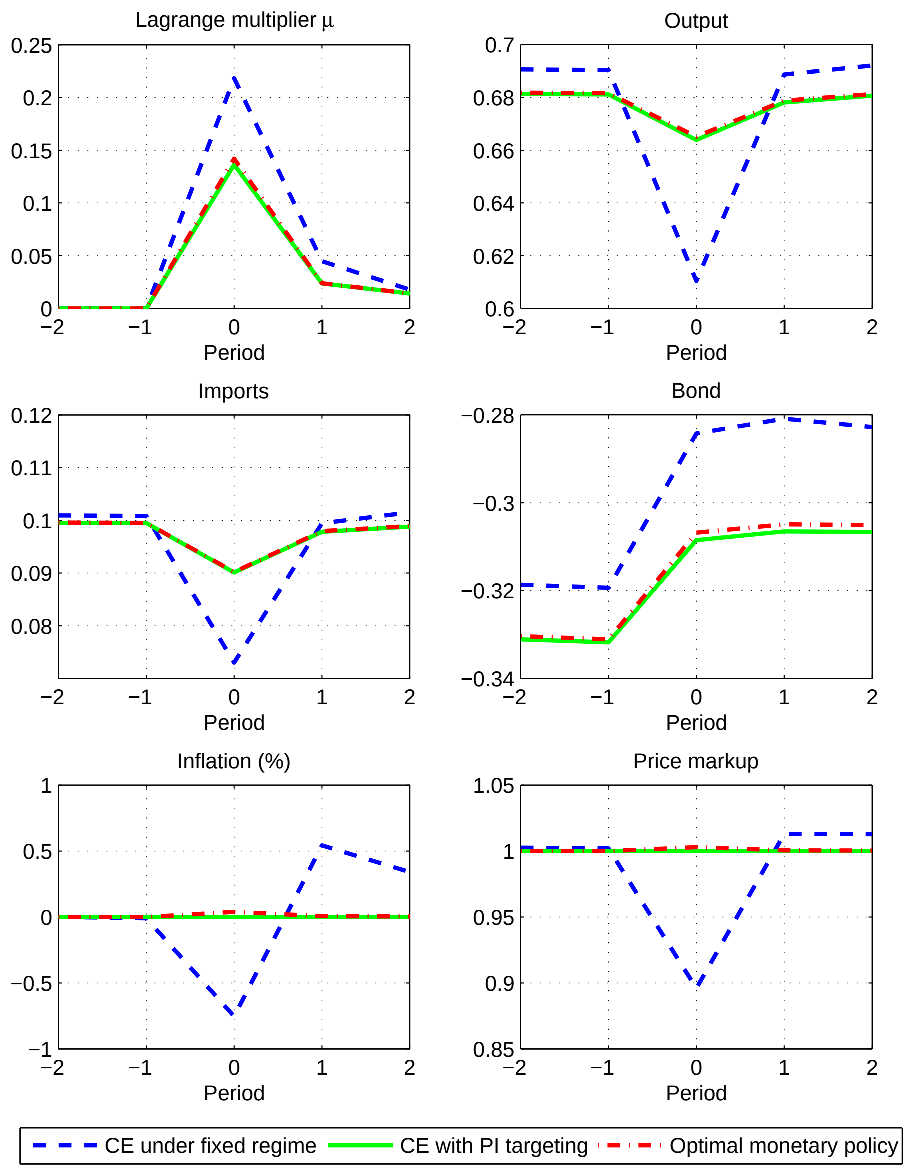

Figure 1: Event analysis for the competitive equilibrium under the strict price inflation targeting regime, optimal monetary policy under the floating and a pegged exchange rate regime. A typical five-period event window is chosen as: (a) no binding collateral constraints in the first two periods $t = -2, -1$, (b) binding constraint at period $t = 0$ and (c) no restrictions in the last two periods $t = 1, 2$. The events in the figure are an average of all event series in a simulation of $200,000$ periods.

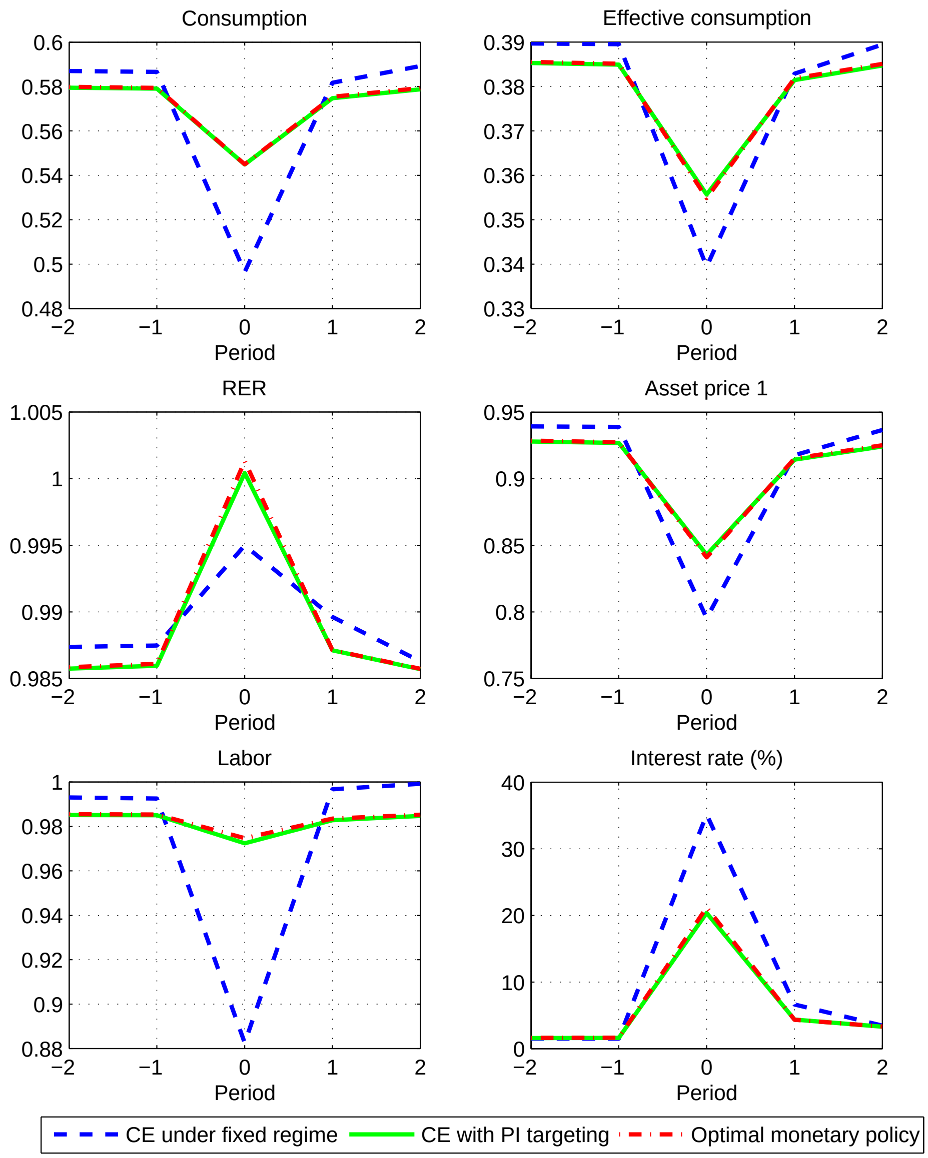

Figure 2: Event analysis for the competitive equilibrium under the strict price inflation targeting regime, optimal monetary policy under the floating and a pegged exchange rate regime. A typical five-period event window is chosen as: (a) no binding collateral constraints in the first two periods $t = -2, -1$, (b) binding constraint at period $t = 0$ and (c) no restrictions in the last two periods $t = 1, 2$. The events in the figure are an average of all event series in a simulation of $200,000$ periods.

Yu (2015). Rather, we focus on a situation where there is effective commitment, but rather than solving the full optimal dynamic capital tax problem with commitment, [4] we limit our analysis to a comparison of the positive an normative effects of a series of ad-hoc capital inflow taxes and subsidies.

Note first that when the borrowing capacity is exogenously given, so that there is no pecuniary externality associated with the effect of the capital price on the borrowing limit, there is no benefit of a capital inflow tax or subsidy under the floating regime. This is because the floating regime can replicate the full flexible price equilibrium and there is no further gain from driving a wedge between the domestic and world interest rate. But with a collateral constraint in the form of 6, the pecuniary externality will in general imply the need for an additional policy instrument, and in particular we can focus a capital tax as the instrument. Whether this would be in the form of a capital inflow tax or a capital subsidy is in fact ambiguous. In Devereux, Young and Yu (2015) it is shown that a capital inflow subsidy, when applied during a crisis, can raise expected utility for households in the small economy. [5] This is because the subsidy boosts the demand for capital, raising the capital price in times of crisis, and acts so as to relax the collateral constraints.

More generally, there will be a trade-off between the benefits of capital inflow taxes and capital inflow subsidies. Households are impatient, and would like to borrow more and front load their consumption once they have a chance. On the one hand, subsidizing capital inflows encourages households to borrow more. A rise in borrowing increase households' consumption and pushes up the capital price, which in turn further relaxes the borrowing constraint. In other words, there are *positive* externalities in the market for collateral capital. Policy makers take into account these positive externalities and will, ceteris paribus, encourage households and firms to borrow more. On the other hand, higher borrowing and leverage will raise the probability and severity of financial crisis as shown in panel A of figure 7. Whether welfare improves or not under capital controls, and whether the policy maker should tax or subsidize capital inflows depends on the tradeoff between positive externalities and higher cost of financial crisis.

[4] Given our stochastic global solution method, such a solution is beyond the scope of the current paper.

[5] This policy will in general be time inconsistent, in the absence of a commitment technology.

Under the floating regime, once monetary policy stabilizes domestic inflation, a moderate constant capital inflow subsidy will increase borrowing capacity and welfare for the reason we have discussed above. Panel B of figure 7 shows the relation between welfare change and the sign and size of capital inflow taxes.

By contrast, in the pegged exchange rate regime, a capital inflow subsidy produces a larger distortion when both prices and the nominal exchange rate are sticky. Under a pegged exchange rate, a capital inflow subsidy destabilizes the domestic economy. By increasing the level of net external assets, it leads to a higher external finance premium in a crisis, leading to higher nominal interest rates in states of the world where the domestic nominal interest rate is already raised, due to the binding collateral constraint (see figure 5). And perversely, in normal times the capital inflow subsidy produces lower interest rates, which leads to overborrowing (figure 5).

The price markup is a good indicator of the distortionary impact of a capital subsidy under a pegged exchange rate. Figure 6 displays that the capital inflow subsidy significantly pushes the price markup away from its undistorted level both in normal times and crises. Outside of a crisis, a capital inflow subsidy leads to a rise in the price markup under a pegged exchange rate, relative to that under a floating exchange rate regime (whether under inflation targeting or the optimal monetary rule). This is because, in the absence of nominal exchange rate flexibility, the capital inflow subsidy generates a real appreciation by on average leading to higher domestic inflation. By contrast, during a crisis, real depreciation is generated by a significant domestic deflation, as we've seen in the previous section. A capital inflow subsidy exacerbates this deflation, because it implies that the average crisis occurs under a larger level of net external debt. Hence, on balance, in a pegged exchange rate regime, a capital inflow subsidy generates higher nominal distortions and works against macroeconomic stability.

As a result of these factors, under a pegged exchange rate regime, the increased nominal distortion effects of subsidies dominates the enhancement of borrowing capacity that is prevalent under the floating regime. Welfare is lower with a capital inflow subsidy under the pegged exchange rate regime(see figure 7). On the other hand, a small capital inflow tax can make the domestic nominal interest rate move in the right direction to stabilize aggregate demand (figure 5 and 6). Hence, our conclusion is that there is a sharp dichotomy between the case for capital controls between fixed and flexible exchange rate regimes in an environment with occasionally binding collateral constraints. Under a flexible exchange rate, a small capital inflow subsidy is desirable. But under a pegged exchange rate regime, it is better to reduce the overall scale of borrowing through a capital inflow tax.

Note that we choose capital controls arbitrarily and optimal monetary policy should take into account the presence of these capital controls. Figure 6 shows that the monetary authority should create inflation in a crisis and deflation in normal times when it taxes capital inflows at the same time. This result is consistent with Farhi and Werning (2012) and Farhi and Werning (2013), who show that capital inflow tax can reduce inflation dynamics and the adjustment of relative prices.

Based on the analysis above, we conjecture that a capital inflow subsidy/tax either in crises or in normal times may have similar effects as a constant capital flow regulation. As a robustness check, we link the capital control with the tightness of the borrowing constraint (6). Results (not reported here) confirm that a capital inflow tax can improve welfare under the pegged regime, while capital inflow subsidy makes domestic agents better off under the floating regime. Monetary policy will work with capital control regulation jointly to stabilize the domestic economy.

6 Conclusion

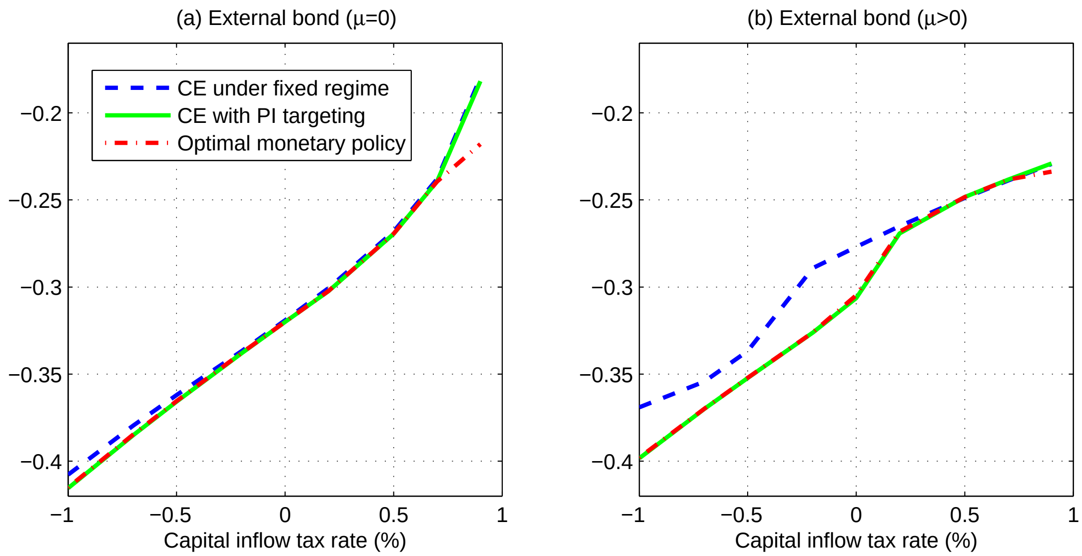

Figure 3: Average external bond for the competitive equilibrium under the strict price inflation targeting regime, optimal monetary policy under the floating and a pegged exchange rate regime. The initial conditional for welfare is $b_t = -0.35$, $e_{t-1} = 1$. Welfare gains and losses are lower for lower external borrowing.

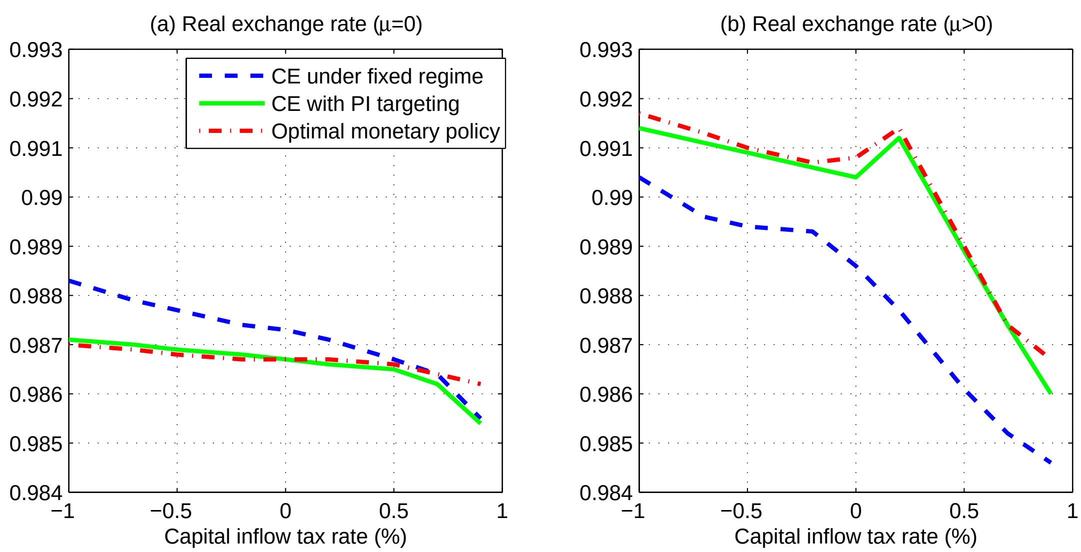

Figure 4: Average real exchange rates for the competitive equilibrium under the strict price inflation targeting regime, optimal monetary policy under the floating and a pegged exchange rate regime. The initial conditional for welfare is $b_t = -0.35$, $e_{t-1} = 1$. Welfare gains and losses are lower for lower external borrowing.

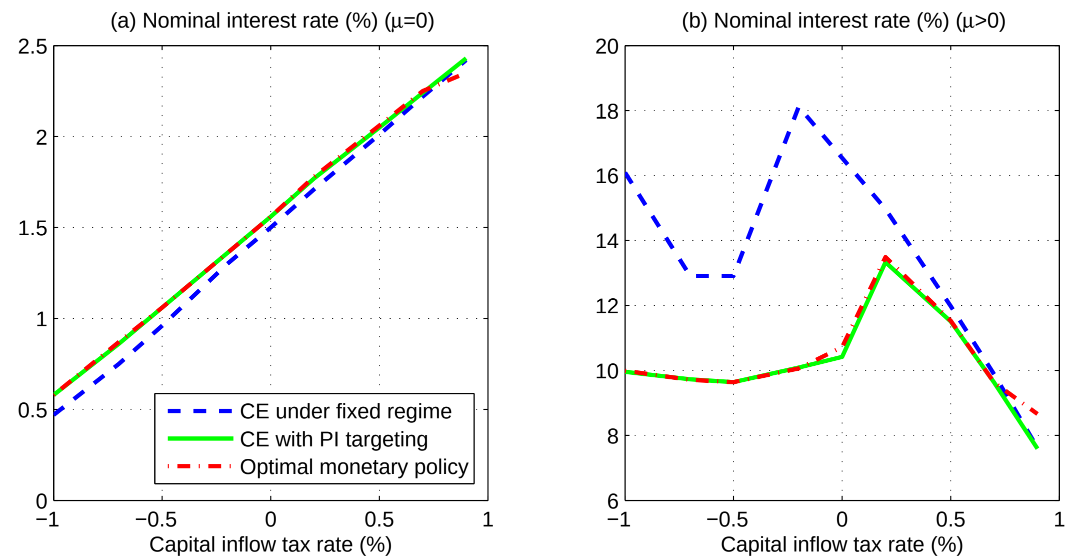

Figure 5: Average domestic nominal interest rates for the competitive equilibrium under the strict price inflation targeting regime, optimal monetary policy under the floating and a pegged exchange rate regime. The initial conditional for welfare is $b_t = -0.35$, $e_{t-1} = 1$. Welfare gains and losses are lower for lower external borrowing.

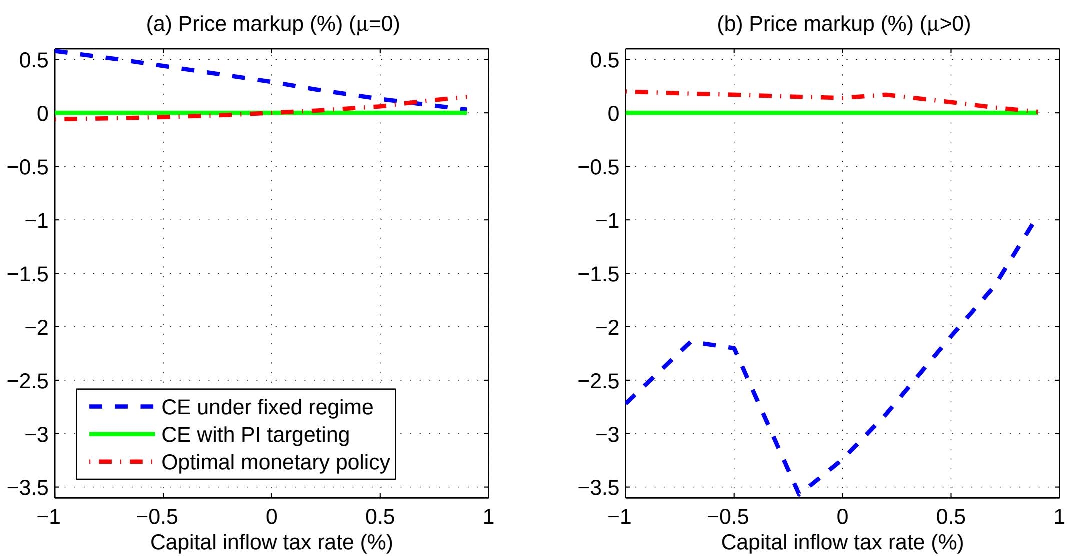

Figure 6: Average price markups $p_{M,t} - 1$ for the competitive equilibrium under the strict price inflation targeting regime, optimal monetary policy under the floating and a pegged exchange rate regime. The initial conditional for welfare is $b_t = -0.35$, $e_{t-1} = 1$. Welfare gains and losses are lower for lower external borrowing.

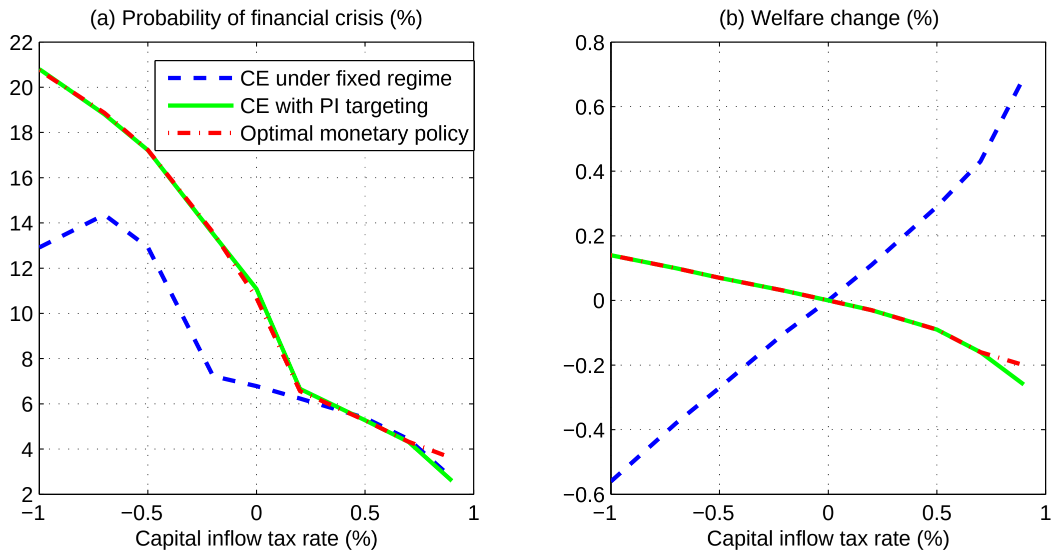

Figure 7: Conditional welfare gains (panel a) relative to no capital control and the unconditional probability of financial crisis (panel b) for the competitive equilibrium under the strict price inflation targeting regime, optimal monetary policy under the floating and a pegged exchange rate regime. The initial conditional for welfare is $b_t = -0.35$, $e_{t-1} = 1$. Welfare gains and losses are lower for lower external borrowing.

References

Benigno, Gianluca, Huigang Chen, Christopher Otrok, Alessandro Rebucci, and Eric R. Young (2013) 'Financial crises and macro-prudential policies.' *Journal of International Economics* 89(2), 453–470

Bianchi, Javier (2011) 'Overborrowing and Systemic Externalities in the Business Cycle.' *American Economic Review* 101(7), 3400–3426

Bianchi, Javier, and Enrique G. Mendoza (2010) 'Overborrowing, Financial Crises and 'Macro-prudential' Taxes.' NBER Working Papers 16091, National Bureau of Economic Research, Inc, June

_ (2013) 'Optimal Time-Consistent Macroprudential Policy.' NBER Working Papers 19704, National Bureau of Economic Research, Inc, December

Cespedes, Luis Felipe, Roberto Chang, and Andres Velasco (2004) 'Balance Sheets and Exchange Rate Policy.' *American Economic Review* 94(4), 1183–1193

Costinot, Arnaud, Guido Lorenzoni, and Ivan Werning (2014) 'A Theory of Capital Controls as Dynamic Terms-of-Trade Manipulation.' *Journal of Political Economy* 122(1), 77 – 128

Devereux, Michael B., and Changhua Yu (2014) 'International Financial Integration and Crisis Contagion.' NBER Working Papers 20526, National Bureau of Economic Research, Inc

Devereux, Michael B., Eric R. Young, and Changhua Yu (2015) 'A New Dilemma: Capital Controls and Monetary Policy in Sudden Stop Economies.' NBER Working Papers 21791, National Bureau of Economic Research, Inc, December

Dixit, Avinash K, and Joseph E Stiglitz (1977) 'Monopolistic competition and optimum product diversity.' *American Economic Review* 67(3), 297–308

Domac, Ilker, and Maria Soledad Martinez Peria (2003) 'Banking crises and exchange rate regimes: is there a link?' *Journal of International Economics* 61(1), 41–72

Faia, Ester, and Eleni Iliopulos (2011) 'Financial openness, financial frictions and optimal monetary policy.' *Journal of Economic Dynamics and Control* 35(11), 1976–1996

Farhi, Emmanuel, and Ivan Werning (2012) 'Dealing with the Trilemma: Optimal Capital Controls with Fixed Exchange Rates.' NBER Working Papers 18199, National Bureau of Economic Research, Inc, June

_ (2013) 'Dilemma not Trilemma? Capital Controls and Exchange Rates with Volatile Capital Flows.' Working Paper 133566, Harvard University OpenScholar, January

Fornaro, Luca (2013a) 'Financial crises and exchange rate policy.' Economics Working Papers, Department of Economics and Business, Universitat Pompeu Fabra, November

_ (2013b) 'International debt deleveraging.' Economics Working Papers 1401, Department of Economics and Business, Universitat Pompeu Fabra, November

Gali, Jordi, and Tommaso Monacelli (2005) 'Monetary policy and exchange rate volatility in a small open economy.' *The Review of Economic Studies* 72(3), 707–734

Georgiadis, Georgios, and Arnaud Mehl (2015) 'Trilemma, not dilemma: financial globalisation and Monetary policy effectiveness.' Globalization and Monetary Policy Institute Working Paper 222, Federal Reserve Bank of Dallas, January

Greenwood, Jeremy, Zvi Hercowitz, and Gregory W Huffman (1988) 'Investment, Capacity Utilization, and the Real Business Cycle.' *American Economic Review* 78(3), 402–17

Hassan, Tarek A., Thomas M. Mertens, and Tony Zhang (2015) 'Currency manipulation.' mimeo, University of Chicago

Jeanne, Olivier, and Anton Korinek (2010) 'Excessive Volatility in Capital Flows: A Pigouvian Taxation Approach.' *American Economic Review* 100(2), 403–07

Kim, Jinill, and Francisco J. Ruge-Murcia (2009) 'How much inflation is necessary to grease the wheels?' *Journal of Monetary Economics* 56(3), 365–377

Kiyotaki, Nobuhiro, and John Moore (1997) 'Credit cycles.' *Journal of Political Economy* 105(2), 211–48

Korinek, Anton (2011) 'The New Economics of Prudential Capital Controls: A Research Agenda.' IMF Economic Review, International Monetary Fund

_ (2015) 'Currency wars or efficient spillovers?' mimeo, Johns Hopkins University

Lorenzoni, Guido (2015) 'Chapter 12 - international financial crises.' In *Handbook of International Economics,* ed. Kenneth Rogoff Elhanan Helpman and Gita Gopinath, vol. 4 of *Handbook of International Economics* (Elsevier) pp. 689 – 740

Mendoza, Enrique G (2010) 'Sudden stops, financial crises, and leverage.' *The American Economic Review* 100(5), 1941–1966

Obstfeld, Maurice, and Kenneth Rogoff (1995) ‘The mirage of fixed exchange rates.’ *Journal of Economic Perspectives* 9(4), 73–95

Passari, Evgenia, and Hlne Rey (2015) ‘Financial Flows and the International Monetary System.’ *Economic Journal* 0(584), 675–698

Reinhart, Carmen M., and Kenneth S. Rogoff (2004) ‘The Modern History of Exchange Rate Arrangements: A Reinterpretation.’ *The Quarterly Journal of Economics* 119(1), 1–48

Rey, Helene (2013) ‘Dilemma not trilemma: the global cycle and monetary policy independence.’ *Proceedings - Economic Policy Symposium - Jackson Hole* pp. 1–2

_ (2015) ‘International Channels of Transmission of Monetary Policy and the Mundellian Trilemma.’ CEPR Discussion Papers 11027, C.E.P.R. Discussion Papers, December

Rose, Andrew K. (2014) ‘Surprising similarities: Recent monetary regimes of small economies.’ *Journal of International Money and Finance* 49(PA), 5–27

Rotemberg, Julio J (1982) ‘Monopolistic Price Adjustment and Aggregate Output.’ *Review of Economic Studies* 49(4), 517–31

Schmitt-Grohe, Stephanie, and Martn Uribe (2012) ‘Prudential Policy for Peggers.’ CEPR Discussion Papers 8961, C.E.P.R. Discussion Papers, May

_ (2013) ‘Downward nominal wage rigidity, currency pegs, and involuntary unemployment.’ Manuscript, Columbia University

Varian, Hal R (1975) ‘A bayesian approach to real estate assessment.’ *Studies in Bayesian econometrics and statistics in honor of Leonard J. Savage* pp. 195–208