Evaluating the Role of Capital Controls and Monetary Policy in Emerging Market Crises *

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Abstract

This paper explores the interactive role of optimal monetary policy and capital controls in dealing with 'sudden-stop' financial crises in emerging market economies. The model features collateral constraints embedding pecuniary externalities, as well as nominal rigidities in prices and wages. We explore the role of policy commitment and macro-prudential motives in the design of optimal monetary and capital market responses to crises, under alternative exchange rate regimes. We find that policy commitment is very important under flexible exchange rates, but commitment (to the path of capital taxes) is only of minor benefit under an exchange rate peg. As regards macro-prudential policy, we find the exact opposite. Under floating exchange rates, the optimal policy has almost no macro-prudential elements. On the other hand, when authorities are constrained by an exchange rate peg, macro-prudential policy is used aggressively as part of an optimal policy framework. An important additional finding is that the direction of capital controls is different under a fixed relative to a flexible exchange rate. With flexible exchange rates, policy makers impose inflow taxes immediately at the onset of a crisis. Under pegged exchange rates, they will impose capital inflow subsidies.

Keywords: Sudden stops, Pecuniary externality, Monetary policy, Capital controls, Commitment versus Discretion

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1 Introduction

Despite the growth rate successes of many emerging market economies, policy makers in these counties face continual difficulties in dealing with volatile capital flows and spillovers from shocks of all kinds coming from the US and other advanced economies. Now ten years since the global financial crisis, it is well recognized that the simple recipe of inflation targeting with floating exchange rates is not a sufficient policy framework for countries that are vulnerable to rapid capital flow reversals and large gyrations in real exchange rates, terms of trade, and external risk premiums. In fact over this period, many emerging economies have installed capital market intervention measures to supplement conventional monetary policy in an attempt to protect currency values and put a brake on capital inflows or outflows (see for instance, Fernandez et al., 2016).

There is a considerable recent academic literature on the experience of emerging market countries facing 'sudden stops' in capital flows (see the literature survey below). Many of these papers provide theoretical rationales for ex-ante or ex-post capital controls. The main theoretical case for these controls rests on the presence of financial frictions of one kind or another. In the presence of financial frictions, there generally arises market failures in the form of pecuniary externalities which may be corrected by direct intervention in capital markets.[1]

At the same time, in the presence of nominal rigidities in labor and goods markets, the response of emerging market economies to external shocks may give rise to large fluctuations in output and employment, generating output gaps that necessitate countervailing monetary policy responses. While the questions regarding optimal monetary policy in New Keynesian open economy models with wage and price rigidity have been extensively explored in the literature, the combination of financial frictions with nominal rigidities opens up new complications regarding the trade-off between closing traditional output gaps and targeting pecuniary externalities arising from price sensitive collateral constraints.

This paper explores the interactive role of optimal monetary policy and capital controls in dealing with 'sudden-stop' financial crises in emerging market economies. We follow in the line of a number of influential recent papers which analyze sudden stops in DSGE frameworks (Bianchi, 2011, Bianchi and Mendoza, forthcoming, Schmitt-Grohe and Uribe, 2016). Typically these papers characterize sudden stops as rare events displaying complex non-linear dynamics in stochastic environments. A sudden stop occurs when a

[1] See Bianchi (2011), Jeanne and Korinek (2010, 2013), Bianchi and Mendoza (forthcoming), Schmitt-Grohe and Uribe (2016) and among others.

financial constraint becomes binding at high levels of debt and states of low productivity or heightened stress in international capital markets. One feature of these models, however, is the difficulty in solving multi-state non-linear stochastic environments using global stochastic solution methods. Devereux, Young and Yu (2015) introduce sticky prices into a model of sudden stops with an optimal choice of monetary policy and capital controls. But constraints on the solution methods prevented them from adding more realistic sources of nominal rigidity (i.e. both wages and prices), and exploring the role of the exchange rate regime in responding to sudden stops.

A related conceptual hurdle is the problem of policy commitment. Most of the recent literature has abstracted from an investigation of optimal policy under commitment. Typically optimal policy under commitment involves keeping track of histories and 'promise keeping', and even in simple stochastic models, it is often prohibitively costly to keep track of the large state space generated by these computations.

A final important question which the literature has not fully confronted is the role of macro-prudential policy in crisis prone economies. By macro-prudential, we mean policies that take account of the current state of the world and the way in which it maps into future crisis probabilities. If policy makers act in a macro-prudential fashion, they may desire to use capital market interventions or offsetting monetary policy to avoid the occurrence of future crises, or to reduce the impact of future crises. Again, the full exploration of optimal macro prudential policies has typically been constrained by available solution techniques.

This paper circumvents some of the difficulties in exploring optimal monetary and capital control policies in emerging economy crises, exploring the importance of alternative degrees of nominal rigidities, alternative exchange rate systems, and the role of both policy commitment and macro-prudential policy. Our approach follows the recent literature on the zero lower bound in monetary economies by taking a simpler route to the characterization of optimal policy, but still working within a fully specified DSGE model of an open economy with nominal and financial frictions.[2]

The approach we take in the paper is to solve a non-linear perfect foresight model of a small open economy which is hit by a 'sudden stop' in it access to international capital markets, leading to a fall in capital inflows and a collapse in domestic economic activity. We solve the model under various forms of price and/or wage rigidities, and under both fixed and flexible exchange rate regimes. Our menu of policy levers allows both for monetary policy and controls on capital flows. We fully characterize optimal

[2]The literature on the zero bound (for instance, Christiano, Eichenbaum and Rebelo, 2011) typically assumes that a shock drives the policy interest rate to its lower bound for some finite time, following which the economy returns to its steady state, after which there are no further shocks.

monetary and capital control policy with and without policy commitment. Finally, we can explore the role of macro-prudential policy by investigating the benefits monetary policy and/or capital controls as precautionary measures taken in advance of crises.

Not surprisingly, policy choices will differ significantly depending on the exchange rate regime. Under floating exchange rates policy makers can avail of a mix of both monetary policy and capital flow taxes, while with a pre-set constraint of an exchange rate peg, capital controls represent the only available policy tool. Given these distinctions however, we ask how important is policy commitment, and what role exists for macro-prudential policy.

Our main results can be summarized quite succinctly. We find that policy commitment is very important under flexible exchange rates, but commitment (to the path of capital taxes) is only of minor benefit when the authorities are constrained by a pegged exchange rate. As regards macro-prudential policy, we find the exact opposite. The ability to act in advance of a crisis is of little benefit under floating exchange rates, and the optimal policy has almost no macro-prudential elements. On the other hand, when authorities are constrained by an exchange rate peg, macro-prudential policy is used aggressively as part of an optimal policy framework, and has a significant positive effect on the response of the economy to a crisis.

Another important question concerns the drivers of optimal policy in this environment. As discussed above, we set out a model in which there are two major sources of inefficiency - financial constraints generating pecuniary externalities, and sticky prices and wages, generating output and employment gaps. Which objectives are most important for the design of optimal policy? Here we also find a substantial distinction between fixed and flexible exchange rate regimes. Under the flexible exchange rate regime, both monetary and capital control policy are designed principally to correct pecuniary externalities, and this applies more-so when policy commitment is enforceable. Under commitment, optimal capital controls alternate between taxes on inflows during crises to subsidies towards inflows after crises, and this is designed to ease the tightness of financial constraints during crises. But under the pegged exchange rate regime, since the macro effects of crises are much more severe without nominal exchange rate adjustment, capital controls are principally designed to stimulate aggregate demand and cushion the economy from the negative macroeconomic effects of the sudden stop. By implication, the pecuniary externalities inherent in financial constraints are less important drivers of optimal policy in pegged exchange rate regimes.

The exchange rate regime is therefore of critical importance of understanding the characteristics of optimal capital market interventions in response to sudden stops. In fact, our results also show that the direction of capital controls is different under a fixed relative to a flexible exchange rate. With flexible exchange rates, policy makers impose inflow taxes immediately at the onset of a crisis. Under pegged exchange rates by contrast, they will impose capital inflow subsidies.

Another important factor is the nature of the financial constraint. In our paper, as in the classic paper by Kiyotaki and Moore (1997), we use an assumption that collateral is valued at future asset prices. Devereux, Young and Yu (2015) provide a micro-foundation for this type of constraint. An alternative assumption is that it is contemporaneous asset prices that constrain collateral (as in Bianchi and Mendoza, forthcoming, for instance). In a later section of the paper we explore how the results differ when this type of constraint is used. We find that there is a greater role for macro-prudential policy when collateral is valued at current asset prices.[3]

Our paper is related to two strands of the literature. First, this paper contributes to the literature on capital controls and macro-prudential policies on remedying pecuniary externalities. During a financial crisis, binding credit constraints lead to fire sales of assets and consequently repress the value of collateral. Nevertheless, competitive private agents do not take the negative effect of their fire-sales on asset prices into account. As a result, the economy ends up with an inefficient allocation from the social planner's perspective (Bianchi, 2011, Benigno et al., 2014, Korinek and Simsek, 2013). Various policies could be deployed to fix these externalities in such scenarios, including macro-prudential capital controls (Jeanne and Korinek, 2010, Bianchi and Mendoza, forthcoming, Schmitt-Grohe and Uribe, 2016, Farhi and Werning, 2016), and ex post policies (Jeanne and Korinek, 2013, Benigno et al., 2013, Bianchi, 2016, Farhi and Werning, 2016). Our paper focuses instead on capital controls under commitment across exchange rate regimes. On the one hand, we find that capital controls are substantially different in environments with versus without commitment in order to fix pecuniary externalities in a floating exchange rate regime, while these policies are secondary under a pegged exchange rate regime. On the other hand, macro-prudential policies play a minor role under flexible exchange rates, while they are essential in a pegged exchange rate regime.

The basic modelling framework in this paper is based mostly on an earlier paper, Devereux, Young and Yu, 2015, but the methodology, analysis, and the results are substantially different. In methodology, we employ a different solution approach, as described above, which allows us to explore a much wider set of policy related questions involving multiple state variables (coming from the exchange rate peg, and

[3] See Schmitt-Grohe and Uribe (2017) for a discussion of the implications of various types of financial constraints.

sticky wages as well as prices). This means that we can undertake a much larger set of policy comparisons, involving both commitment and discretion (our earlier paper solved only the discretionary policy outcome, under floating exchange rates, with sticky prices alone), allowing for macro-prudential policy, and allowing for an analysis of the workings of capital controls under an exchange rate peg. In terms of analysis, this paper also explores the consequences of alternative types of collateral constraints, as described above. Finally, the results of this paper differ substantially from our earlier paper. Notably we find, as described above, a sharp difference between the value of commitment across different exchange rate regimes, and an equally sharp difference in the value of macro-prudential policy. Neither questions were explored at all in our earlier paper. We also find, as noted, that not just the importance of capital controls differs across exchange rate regimes, but also the direction of response is different in the different regimes. As an additional point, the distinction between the two drivers of optimal policy - the presence of nominal rigidities and the presence of pecuniary externalities - was not apparent in our earlier paper. Given that only prices, but not wages, were sticky in the earlier model, the presence of nominal rigidities played a negligible role in optimal policy responses to a crisis. [4]

Our paper is also related to the studies of monetary policy in affecting the nature of financial crises. In a recent debate, Rey (2015) and Passari and Rey (2015) show empirical evidence that the global financial cycle constrains monetary policy even under a flexible exchange rate regime when there is free capital mobility, and capital flow management is desirable to maintain monetary autonomy. Farhi and Werning (2012, 2014) explore optimal capital controls and monetary policy in a world economy with many small open economies and consider risk premium shocks. They find that capital controls are used to restore monetary autonomy in a fixed exchange rate regime and work as terms of trade manipulation in a flexible exchange rate regime. Beyond capital controls, exchange rate policies are also helpful in reducing the severity of a financial crisis (Schmitt-Grohe and Uribe, 2016, Ottonello, 2015, Fornaro, 2015, Devereux, Young and Yu, 2015, Devereux and Yu, 2017). Another important paper related to ours is Liu and Spiegel (2015) (see also Chang, Liu and Spiegel, 2015). They show that that capital controls can serve as welfare-enhancing tools when optimally combined with monetary policy when policy commitment is available. Our paper focuses on the comparison of optimal capital controls with and without commitment, and across exchange rate regimes, as well as allowing for macro-prudential capital controls.

[4] In addition, the earlier paper did not analyze the response to sudden stops under an alternative form of the collateral constraint, as is done here.

This paper is organized as follows. Section 2 presents the baseline model with sticky prices and wages. Section 3 calibrates the model and section 4 quantitatively conducts the positive and normative analysis of the baseline model. Section 5 presents optimal monetary policy and capital flow taxes under an alternative valuation of collateral. The last section concludes.

2 The Model

The baseline model is similar to Devereux, Young and Yu (2015) and Devereux and Yu (2017), which is a monetary version of a small open economy in line with Mendoza (2010) and Cespedes, Chang and Velasco (2004). There are infinitely-lived firm-households with unit measure in the economy. Competitive domestic firms import intermediate inputs and hire domestic labor and physical capital to produce wholesale goods. These wholesale goods are differentiated into various varieties in a consumption composite by domestic monopolistically competitive final goods producers. These composites are either consumed by domestic households or exported to the rest of the world. Domestic households trade only foreign currency denominated, non-state contingent bonds with foreigners. Variables in the rest of the world are exogenously given.

The wholesale good production has a form of Cobb-Douglas

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

with $\alpha_F + \alpha_L + \alpha_K \leq 1$. M_t is the production, A_t an aggregate exogenous technological shock, $Y_{F,t}$ imported intermediate inputs, L_t labor demand and K_t denotes physical capital.

Foreign demand for domestic consumption composites, X_t, is given by

$$X_t = \left(\frac{P_t}{\mathcal{E}_t P_t^*} \right)^{-\rho} \zeta_t^*, \tag{2}$$

ζ_t^* stands for an exogenous foreign demand, $\mathcal{E}_t$ the nominal exchange rate, and P_t^* is the foreign price of foreign consumption composite. We normalize foreign prices to be unity. $\rho > 1$ is the elasticity of substitution between imports and locally produced goods in the foreign consumption basket.

2.1 Firm-households

A representative firm-household has a preference given by

$$E_0 \sum_{t=0}^{+\infty} \beta^t U(c_t, l_t), \tag{3}$$

where E_0 stands for mathematical expectations conditional on information up to date 0 and β is the subjective discount factor. The period utility function takes the GHH (Greenwood, Hercowitz and Huffman, 1988) form

$$U(c_t, l_t) = \frac{\left(c_t - \chi \frac{l_t^{1+\nu}}{1+\nu}\right)^{1-\sigma} - 1}{1-\sigma}. \tag{4}$$

Households can borrow from abroad to finance consumption and imported intermediate inputs. Borrowing must be undertaken in foreign currency. Borrowing from abroad requires capital k_{t+1} as collateral:

$$\vartheta Y_{F,t} P_{F,t}^*(1+\tau_N) - B_{t+1}^* \leq \kappa_t E_t \left\{ \frac{Q_{t+1} k_{t+1}}{\mathcal{E}_{t+1}} \right\}, \tag{5}$$

B_{t+1}^* stands for domestic purchases of foreign currency bonds in dollar terms at the end of period t. If the economy is a net intertemporal borrower, B_{t+1}^* is negative. The term τ_N captures the presence of a fiscal tax on intermediate imports as in Devereux, Young and Yu (2015) and Devereux and Yu (2017). This tax is set so as to reduce the demand for intermediate imports to the level where the country optimally exploits its monopoly power in its export good. Hence $Y_{F,t} P_{F,t}^*(1+\tau_N)$ represents the total expenditure on intermediate inputs in terms of the foreign good, and ϑ measures the fraction of imported inputs $Y_{F,t}$ which are financed in advance. We also normalize the foreign import price to be unit $P_{F,t}^* = 1$. Q_{t+1} denotes the nominal capital price in domestic currency units. The parameter κ_t captures the maximal loan-to-value ratio in the spirit of Kiyotaki and Moore (1997).[5]

We assume that firm-households supply different varieties of labor services but they can share their

[5]The external borrowing is fully collateralized by future value of assets, which can be motivated by margin requirements in financial contracts as in Brumm, Grill, Kubler and Schmedders (2015). This type of credit constraint is widely used by the literature, for instance, Iacoviello (2005), Liu, Wang and Zha (2013) and Liu, Miao and Zha (2016). Devereux, Young and Yu (2015) give a micro-founded rationale for this collateral constraint. One point to note is that the collateral constraint mixes two types of borrowing - that done by firms to finance intermediate inputs, and that by households for inter-temporal consumption smoothing. This interaction between inter-temporal debt and production-related borrowing is important for capturing the real impact of sudden stops, as explained in Mendoza (2010), since it means that capital flow reversals raise the cost of production for the firm. It is consistent with the treatment of firm-households as a single entity in decision making, as in Mendoza (2010).

income risk perfectly and they own firms equally. Consequently they make identical consumption and borrowing decisions. We write the decisions for the wholesale good producer explicitly. The representative firm-household faces the following budget constraint

$$P_t c_t + Q_t k_{t+1} + \frac{B_{t+1}}{R_{t+1}} + \sum_{s_{t+1}} Q^b_{s_{t+1}} B_{j,s_{t+1}} + \frac{B^*_{t+1}\mathcal{E}_t}{R^*_{t+1}}(1-\tau_{c,t}) \leq W^h_t l_t(j) + k_t(R_{K,t}+Q_t) +$$

$$B_t + B_{j,s_t} + B^*_t \mathcal{E}_t + T_t + \left[P_{M,t} M(Y_{F,t}, L_t, K_t) - (1+\tau_N) Y_{F,t} P^*_{F,t} \mathcal{E}_t - W_t L_t - R_{K,t} K_t\right] + D_t. \quad (6)$$

The left-hand side of the equation displays consumption expenditures $P_t c_t$, purchases of capital $Q_t k_{t+1}$, bond purchases denominated in domestic currency B_{t+1}/R_{t+1}, (R_{t+1} is the domestic nominal interest rate) and in dollars $B^*_{t+1}\mathcal{E}_t/R^*_{t+1}$. Domestic households trade state-contingent bonds among themselves with bond price $Q^b_{s_{t+1}}$ and bond holding $B_{j,s_{t+1}}$. As in the literature (Bianchi and Mendoza, forthcoming; Farhi and Werning, 2012, 2014), government subsidizes foreign bond purchases at the rate of $\tau_{c,t}$. Hence $\tau_{c,t} > 0$ is equivalent to a tax on foreign borrowing. The right-hand side shows income sources, including labor income $W^h_t l_t(j)$ (W^h_t is the nominal wage for wholesale labor service and labor supply $l_t(j)$), gross return on capital $k_t(R_{K,t} + Q_t)$, ($R_{K,t}$ is the marginal product of capital) gross return on domestic bond holdings B_t, income from foreign bonds, $B^*_t \mathcal{E}_t$, lump-sum transfers from government T_t, profits from wholesale good producers $P_{M,t} M_t - (1 + \tau_N) Y_{F,t} \mathcal{E}_t - W_t L_t - R_{K,t} K_t$ and profits from other firms D_t.

Let $\mu_t e_t$ be the Lagrange multiplier associated with the collateral constraint (5). A lower case price variable denotes the real price, i.e., $q_t = Q_t/P_t$. The CPI inflation is defined as $\pi_t = P_t/P_{t-1}$ and the real exchange rate (also the terms of trade) is $e_t = \mathcal{E}_t P^*_t/P_t$. Lower e_t implies appreciation of the real exchange rate. The household optimality condition for wholesale labor supply reads

$$w^h_t = \chi l_t(j)^\nu. \quad (7)$$

The optimality conditions for capital, domestic and foreign currency bonds yield

$$q_t = \mu_t \kappa_t E_t \left\{ \frac{q_{t+1} e_t}{e_{t+1}} \right\} + E_t \left\{ \beta \frac{U_c(t+1)}{U_c(t)} (r_{K,t+1} + q_{t+1}) \right\}, \quad (8)$$

$$1 = E_t \left\{ \beta \frac{U_c(t+1)}{U_c(t)} \frac{R_{t+1}}{\pi_{t+1}} \right\}, \quad (9)$$

$$1-\tau_{c,t}=\mu_t R^*_{t+1}+E_t\left\{\beta\frac{U_c(t+1)}{U_c(t)}\frac{e_{t+1}}{e_t}R^*_{t+1}\right\}, \tag{10}$$

where $U_c(t)$ denotes the marginal utility of consumption. Condition (8) says that in choosing to acquire an additional unit of capital, the household trades off the cost of the capital against the expected benefit in terms of the returns and capital gains next period, adjusted by the stochastic discount factor, and in addition, there is a current benefit in terms of a looser borrowing constraint when $\mu_t > 0$, which depends on the expected next period price of capital. Condition (10) indicates that the cost of purchasing a foreign currency bond $(1-\tau_{c,t})/R^*_{t+1}$ must be weighed against the expected benefit next period in terms of the discounted return, plus the additional benefit which comes from a looser borrowing constraint when $\mu_t > 0$.

The optimal demand for intermediate inputs, labor, and capital for the wholesale firm-household yields,

$$p_{M,t}\frac{\alpha_F M_t}{Y_{F,t}}=(1+\tau_N)e_t\left(1+\vartheta\mu_t\right), \tag{11}$$

$$p_{M,t}\frac{\alpha_L M_t}{L_t}=w_t, \tag{12}$$

$$p_{M,t}\frac{\alpha_K M_t}{K_t}=r_{K,t}. \tag{13}$$

Note that (11) implies that the cost to the household-firm of importing intermediate inputs is increasing in the real exchange rate and also increasing in the multiplier on the collateral constraint μ_t. Since intermediate inputs must be partially financed by borrowing, a tightening of the collateral constraint increases the real cost of importing for the firm.

Finally, the complementary slackness condition reads

$$e_t\mu_t\left[\kappa_t E_t\left(\frac{q_{t+1}k_{t+1}}{e_{t+1}}\right)+b^*_{t+1}-\vartheta(1+\tau_N)Y_{F,t}\right]=0, \tag{14}$$

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

We assume that there is a labor union which differentiates homogeneous wholesale labor services into different varieties $l_t\left(j\right)$ and it is the monopoly supplier to the market, whose profits are returned back to households (Erceg, Henderson and Levin, 2000). These labor services are aggregated into a labor composite

$$l_t=\left(\int_0^1 l_t\left(j\right)^{\frac{\theta_W-1}{\theta_W}}dj\right)^{\frac{\theta_W}{\theta_W-1}},$$

where $\theta_W > 1$ is the elasticity of substitution between different types of labor. The wage rate for one unit of aggregate labor services is

$$W_t = \left(\int_0^1 W_t\left(j\right)^{1-\theta_W} dj \right)^{\frac{1}{1-\theta_W}},$$

and the demand for labor of type j is

$$l_t\left(j\right) = \left(\frac{W_t\left(j\right)}{W_t} \right)^{-\theta_W} l_t. \tag{15}$$

Individual nominal wage adjustment suffers resource cost, $\psi\left(j,t\right)$. We permit asymmetric wage adjustment cost following Varian (1975) and Kim and Ruge-Murcia (2009),

$$\psi\left(t\right) \equiv \psi\left(\Omega_t^{int}\right) = \frac{\phi_W}{\gamma_W^2}\left[\exp\left(\gamma_W\left(\Omega_t^{int}-1\right)\right) - \gamma_W\left(\Omega_t^{int}-1\right) - 1\right],$$

where

$$\Omega_t^{int} \equiv \frac{W_t}{\pi_t^{\varphi} W_{t-1}} = \frac{\pi_{W,t}}{\pi_t^{\varphi}},$$

with wage inflation $\pi_{W,t} = \frac{W_t}{W_{t-1}}$. φ captures indexation of nominal wages to inflation. Following Rotemberg price adjustment cost (see Rotemberg, 1982), ϕ_W captures the convexity of adjustment costs, and γ_W controls the asymmetry (specifically, $\gamma_W < 0$ implies it is costlier to reduce than increase nominal wages).

The wage setter's profit from charging labor variety j reads,

$$D_{W,t}(j) \equiv \left(1+\tau_W\right) W_t(j) l_t(j) - W_t^h l_t(j) - \psi\left(\Omega_t(j)^{int}\right) W_t l_t,$$

The problem faced by wage setter j is then defined as

$$\max_{\{W_t(j), l_t(j)\}} E_h \left(\sum_{t=h}^{+\infty} \Lambda_{h,t} \frac{P_h}{P_t} D_{W,t}(j) \right),$$

subject to demand for labor of type j equation (15). The stochastic discount factor is given by $\Lambda_{h,t} = \beta^{t-h} U_c(t)/U_c(h)$ with $h \leq t$.

We consider a symmetric equilibrium where nominal wages do not depend on j, $W_t = W_t(j)$ and

$l_t = l_t(j)$, leading to the wage Phillips curve (labor supply curve),

$$
\begin{aligned}
0 \;=\; & \theta_W \left(\frac{\chi l_t^{\nu}}{w_t} \right) - (\theta_W - 1)(1 + \tau_W) - \frac{\pi_{W,t}}{\pi_t^{\varphi}} \frac{\phi_W}{\gamma_W} \left[\exp\left(\gamma_W \left(\Omega_t^{int} - 1 \right) \right) - 1 \right] + \\
& \beta E_t \left[\frac{U_c(t+1)}{U_c(t)} \frac{\pi_{W,t+1}^2}{\pi_{t+1}^{1+\varphi}} \frac{l_{t+1}}{l_t} \frac{\phi_W}{\gamma_W} \left[\exp\left(\gamma_W \left(\Omega_{t+1}^{int} - 1 \right) \right) - 1 \right] \right]. \qquad (16)
\end{aligned}
$$

If wages are costlessly to adjust ($\phi_W = 0$) then the real wage equals the disutility of labor times a constant markup,

$$
w_t = \frac{\theta_W}{\theta_W - 1} \frac{1}{1 + \tau_W} \chi l_t^{\nu},
$$

we set $\tau_W = 1/(\theta_W - 1)$ to eliminate the monopoly distortion under flexible wages. In general, the evolution of the real wage is determined by the gap between wage inflation and price inflation,

$$
w_t = \frac{\pi_{W,t}}{\pi t} w_{t-1}. \qquad (17)
$$

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. Varieties are imperfect substitutes, and final good producers have monopoly power over their varieties. Consumption varieties are aggregated into a consumption composite via a CES aggregator with elasticity of substitution θ.

Let $P_t(i)$ be the price of variety $Y_t(i)$. Cost minimization implies the demand for variety $Y_t(i)$

$$
Y_t(i) = \left(\frac{P_t(i)}{P_t} \right)^{-\theta} Y_t. \qquad (18)
$$

The technology employed by a firm i is linear

$$
Y_t(i) = M_t(i). \qquad (19)
$$

Firms set prices in domestic currency (whether for domestic sales or export). They can reset their prices each period but suffer an asymmetric price adjustment cost. Profits per period gained by firm i

equals 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 $\phi\left(\frac{P_t(i)}{P_{t-1}(i)}\right)$

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

where π is the inflation target and τ_H denotes a subsidy rate by the government in order to undo the monopoly power of final good producers. In the price adjustment cost function $\phi(\cdot)$, ϕ_P characterizes the Rotemberg price adjustment cost and γ captures the asymmetry of price adjustment cost.

Firm i solves

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

subject to demand for variety i (18) and the production technology (19).

In a symmetric equilibrium, all firms choose the same price, $P_t(i) = P_t$, when resetting their prices. Consequently, the supply of each variety is identical: $Y_t(i) = Y_t$. The optimality condition for price-setting can be simplified as

$$\begin{aligned} & Y_t\left[(1+\tau_H) - \theta\left(1+\tau_H - p_{M,t}\right)\right] - \phi_P Y_t \pi_t \frac{\exp\left(\gamma(\pi_t - \pi)\right) - 1}{\gamma} + \\ & E_t\left[\Lambda_{t,t+1} \phi_P \pi_{t+1} Y_{t+1} \frac{\exp\left(\gamma(\pi_{t+1} - \pi)\right) - 1}{\gamma}\right] = 0. \end{aligned} \tag{20}$$

2.3 Market clearing conditions

The labor market clearing condition implies that $l_t = L_t$. Per capita consumption must equal total consumption, so that $c_t = C_t$. Since foreigners do not hold domestic currency denominated bonds, the domestic bond market equilibrium requires $b_{t+1} = 0$.

The capital stock is in fixed supply, so in equilibrium we have $K_{t+1} = k_{t+1} = 1$. The wholesale good market clearing condition reads

$$\int_0^1 Y_t(i) di = \int_0^1 M_t(i) di = M_t. \tag{21}$$

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

$$Y_t - \phi(\pi_t) Y_t - w_t L_t \psi\left(\Omega_t^{int}\right) = C_t + X_t + q_t (K_{t+1} - K_t). \tag{22}$$

Finally, profits from final good producers are $d_t = d_{H,t} + d_{W,t}$.

2.4 Government policy

To balance its budget, the government's lump-sum transfer is given by

$$T_t = -\left(\tau_H Y_t + \tau_W w_t L_t - \tau_N Y_{F,t} e_t + \frac{\tau_{c,t} b_{t+1}^* e_t}{R_{t+1}^*}\right) P_t \tag{23}$$

The government chooses the production subsidy τ_H, labor subsidy, τ_W, the tax on imports, τ_N, and capital control $\tau_{c,t}$. We will look at various alternatives for monetary policy. In our baseline case, where monetary policy is not chosen optimally, we assume an inflation targeting rule represented by a Taylor rule:

$$R_{t+1} = R\left(\frac{\pi_t}{\pi}\right)^{\alpha_\pi}\left(\frac{Y_t}{Y}\right)^{\alpha_Y}. \tag{24}$$

A variable without a superscript denotes the value of that variable at the deterministic steady state. In the fixed exchange rate regime, domestic inflation is determined by foreign inflation and the change in the real exchange rate,

$$\pi_t = \frac{e_{t-1}}{e_t}\pi_t^* = \frac{e_{t-1}}{e_t}. \tag{25}$$

Combining firm-households' budget constraints (6) with the relevant market clearing conditions and taxation policy (23), we see that trade surpluses lead to net foreign asset accumulation:

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

Definition 1. *A* ***competitive equilibrium*** *consists of a sequence of allocations* $\{C_t, k_{t+1}, b_{t+1}, b_{t+1}^*, L_t, Y_{F,t}, K_t, M_t, Y_t\}$ *, and a sequence of prices* $\{w_t, q_t, \mu_t, r_{K,t}, e_t, \pi_t, \pi_{W,t}, p_{M,t}\}$*, for* $t = 0, 1, 2, \cdots$*, given fiscal subsidies* τ_W*,* τ_H *and* τ_N*, monetary policy* R_{t+1} *and capital inflow tax* $\tau_{c,t}$ *chosen by the fiscal authority and monetary authority and given exogenous shocks* $\{A_t, \kappa_t, R_{t+1}^*\}$*, such that*

1. *The allocation C_t, k_{t+1}, b_{t+1} and b^*_{t+1} solves households' problem, given prices and policy $\tau_{c,t}$; the optimality conditions are equation (6), (8)-(10);*

2. *The allocation L_t, $Y_{F,t}$, K_t, and M_t solves wholesale producers' problem, given prices and policy τ_N; the optimality conditions are equation (1), (11)-(13);*

3. *The labor union optimally sets wage inflation $\pi_{W,t}$ and labor L_t in equation (16)-(17), given other prices and policy τ_W;*

4. *The final good producers optimally set price inflation π_t and final output Y_t, in equation (19)-(20), given other prices and policy τ_H;*

5. *Wages and prices w_t, q_t, $r_{K,t}$, $p_{M,t}$, e_t clear labor market, capital market, rental market, wholesale good market and final good market respectively. μ_t satisfies collateral constraint (14).*

3 Calibration

The model period is one year. We take parameters from Devereux, Young and Yu (2015), which are based on a group of emerging market economies. There are two groups of parameters. One group of parameters are calibrated using standard numbers from the existing literature, while the other group are taken from the data sample. Table 1 lists parameter values in our baseline model.

In the first group of parameters, we include the subjective discount factor, β, which we set equal to 0.95, such that the shadow price of the credit constraint in the steady state is very small. Relative risk aversion is set to $\sigma = 2$ and the inverse of the Frisch labor supply elasticity is $\nu = 1$. We set the trade elasticity of substitution $\rho = 5$, which is in line with recent macroeconomic and microeconomic estimates (Simonovska and Waugh, 2014; Imbs and Mejean, 2015).

The second group of parameters are estimated from macro data on emerging market economies in Devereux, Young and Yu (2015). Parameters in the production function are set to match the average import share of 17% of GDP, labor share of 65% of GDP, and the external debt-GDP ratio 55% in their data sample. We set $\alpha_F = 0.145$, $\alpha_L = 0.57$ and $\alpha_K = 0.14$. Parameter ϑ is set to 1.4, implying a share of working capital 20% of GDP (Mendoza, 2010). The equilibrium labor supply is normalized to be one, which implies that $\chi = 0.4$. In the baseline perfect foresight model, we mainly focus on the qualitative features of the model. So we set the leverage in normal time to be $\kappa = 0.25$ and consider a deleveraging shock $\kappa = 0.22$ in crisis (i.e., Mendoza, 2010).

For simplicity but without loss of generality, we set the inflation target rate in the model equal to zero. In the Rotemberg adjustment cost function we set $\phi_P = 76$, and assume a small downward price rigidity $\gamma = -100$ in the baseline model (for instance see Aruoba, Cuba-Borda and Schorfheide, 2013, Peltzman, 2000, Chen, Levy, Ray and Bergen, 2008). Following the new Keynesian literature (Christiano, Eichenbaum and Evans, 2005; Gali, 2015), we set the elasticity of varieties in the domestic consumption basket as $\theta = 10$, implying a price markup of 11%. We set $\phi_W = 32$, $\theta_W = 3.5$ as in Kim and Ruge-Murcia (2009), and focus on a small downward wage asymmetry $\gamma_W = -20$ for illustrative purposes. The wage indexation parameter is set as $\varphi = 0$, so we assume nominal wage rigidity. The real exchange rate is normalized to be one in a deterministic steady state when the collateral constraint binds, which requires $\zeta_t^* = 0.1037$.

4 Results

As discussed above, our principle objective in this paper is to illustrate the implications of policy commitment in responding to financial crises, under alternative exchange rate regimes. It is well recognized (see Devereux, Young and Yu, 2015 for further discussion) that with currently available solution methods, it is very difficult to obtain global stochastic solutions for the full model described above, with policy commitment, both wage and price rigidity, and a pegged exchange rate regime. Policy commitment involves taking account of 'promises' made by policy-makers in response to past conditions, and greatly increases the state space. Adding wage and price rigidity and the possibility of a pegged exchange rate also adds additional state variables, and greatly complicates the possibility of obtaining accurate solutions for equilibrium laws of motion. In light of these constraints, we pursue a simpler strategy. We solve a (non-linear) perfect foresight version of the model, assuming the occurrence of shocks which precipitate a financial crisis, and investigate the characteristics of optimal policy with and without commitment, under alternative forms of price rigidity, and under alternative exchange rate regimes. Following this, we examine the possibility of a type of macro-prudential policy, using the same taxonomy of constraints.

Table 1: Parameter values

Parameter		Values
Preference		
β	Subjective discount factor	0.95
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	0.145
α_L	Labor share in production	0.57
α_K	Capital share in production	0.14
ϑ	Share of working capital	1.4
ϕ_P	Price adjustment cost	76
γ	Asymmetry of price adjustment cost	-100
θ	Elasticity of substitution among varieties	10
ρ	Trade elasticity of substitution	5
ϕ_W	Wage adjustment cost	32
γ_W	Asymmetry of wage adjustment cost	-20
θ_W	Elasticity of substitution among labor services	3.5
φ	Wage indexation parameter	0.0
ζ^*	Steady state of foreign demand shock	0.1037
R^*	Steady state of world interest rate	1.05
A	Steady state of TFP shock	1
κ_H	High leverage	0.25
κ_L	Low leverage	0.22
Policy variables		
τ_H	Subsidy to final goods producers	$\frac{1}{\theta-1}$
τ_W	Subsidy to wage setters	$\frac{1}{\theta_W-1}$
τ_N	Gross subsidy to exports	$\frac{1}{\rho-1}$

4.1 An unanticipated temporary deleveraging shock

We study an unanticipated shock to the leverage constraint which forces households and firms to sharply reduce borrowing and imports of intermediate inputs. We first describe the nature of the experiment. In the stochastic version of the model, the collateral constraint (5) will fluctuate between periods where it binds with periods when it is slack. The more risk averse are domestic households, the more they will engage in precautionary saving, and given the distribution of shocks, the less frequently will the constraint bind. In the perfect foresight model, there is no precautionary saving, so the constraint will bind in a steady state, since the calibration is based on households having a higher discount rate than the world interest rate (see Devereux, Young and Yu, 2015). This would mean that there exist persistent pecuniary externalities requiring policy response, even after the deleveraging shock has ended. In order to avoid confusing an optimal policy response to a crisis with the need to intervene due to a persistent pecuniary externality, we assume that after the shock expires, the small economy is restricted by an exogenous borrowing constraint which does not depend on asset prices. This ensures that, after the shock to the leverage constraint ends, and after wages and prices have adjusted to the shock, there is no further need for policy intervention - the policy maker will simply maintain a constant price level and abstain from imposing capital controls.

To be more specific, the experiment we study is as follows. We assume that there is (a) an endogenous borrowing constraint (endogenous asset prices) in place for the first two periods, say, $t = 1, 2$,

$$\kappa_t E_t \left(\frac{q_{t+1} k_{t+1}}{e_{t+1}} \right) + b^*_{t+1} - (1 + \tau_N) \vartheta Y_{F,t} \geq 0, \tag{27}$$

and (b) exogenous borrowing constraints given from period $t = 3$ onwards,

$$\kappa_t \bar{q} + b^*_{t+1} - (1 + \tau_N) \vartheta Y_{F,t} \geq 0. \tag{28}$$

As stated, with an exogenous borrowing constraint, there are no pecuniary externalities. Therefore, there is no need for policies to correct these externalities. So the authority will impose no capital controls and the monetary authority strictly targets price stability after the economy has adjusted to the initial shock.

For the optimal policy response under commitment, we can solve the constrained optimization problems directly, maximizing the present value of households utility from time $t = 1$. But for the case of discretion, we need to recognize the absence of policy commitment, and hence solve the implicit 'game' between the policy maker in period $t = 1$ and policy maker in future period $t = 2$.

We assume first that the model begins at its deterministic constrained steady state at period $t = 0$. We then consider a one-time unanticipated temporary negative shock to κ that hits the economy at period $t = 1$. The shock lasts for two periods and disappears after period $t = 2$. The economy then converges back to its steady state with an exogenous borrowing capacity in the long-run. We explore the responses of monetary policy alone, or monetary policy and capital controls under commitment versus discretion, both in the short run and medium run, under the alternative assumptions about the exchange rate regime.

4.2 Optimal policies under the floating exchange rate regime

We first consider an economy under a floating exchange rate regime, in which the monetary authority can freely adjust the nominal interest rate to respond to the shock, and allows the nominal exchange rate to adjust accordingly. Figure 1 illustrates the optimal capital flow tax and optimal monetary policy under discretion and commitment. We illustrate the monetary policy choice in terms of the dynamics of inflation in response to the shock (since absent the shock, inflation would be kept equal the target level of zero).

From the credit constraint (5), we can see that when the constraint is binding, the policy maker has an incentive to relax the constraint by increasing the future capital price relative to the real exchange rate q_{t+1}/e_{t+1}. This constitutes a policy goal based on relaxing pecuniary externalities. But at the same time, the deleveraging shock causes a fall in demand, which opens up a negative output gap. Moreover, because both wages and prices are sticky, the optimal response to demand shocks (in the absence of pecuniary externalities) involves a trade-off between the goal of price stability and output gap minimization. Hence, in general, the optimal policy mix will involve a trade-off among the goals of correcting pecuniary externalities, reducing output gaps, and stabilizing prices and wages.

First, we present the case of discretionary policy making. When monetary policy is the only policy instrument, the policy maker responds to the shock with an expansionary policy, stimulating inflation, thereby depreciating the domestic currency to boost foreign demand (the left panels in figure 1). With sticky nominal wages, the increase in inflation reduces the real wage and stabilizes employment, as shown in figure 3. At the same time, the expansionary monetary policy generates a larger real exchange rate depreciation than would occur under the inflation targeting benchmark. Compared with the competitive equilibrium with strict inflation targeting, output, imports and employment decline by less under the optimal monetary policy (this is shown in the left column in figure 2-3). Under discretion, the period 2 policymaker also stimulates inflation, but at a lower level. From period 3 onwards, inflation is back to its target at zero.

When both monetary policy and capital controls are available, the policy maker in both periods imposes a positive capital inflow tax. As discussed in Devereux, Young and Yu (2015), the incentive to impose a capital inflow tax in a crisis is to relax the binding collateral constraint through reducing current borrowing, and therefore raising the future period's price of capital, which represents the asset price relevant for the current period collateral constraint. In the absence of commitment, capital inflow taxes are positive in both periods of the crisis, but return to zero in period $t = 3$. Figure 2 shows that the combination of monetary policy and capital inflow taxes is quite effective in reducing the fall in output following the leverage shock. The real exchange rate depreciates sharply, and the fall in employment and intermediate imports is much less than in the absence of policy response. In addition, as can be seen from figure 3, the collateral constraint becomes much less binding due to the tax on current capital inflows, relative to the case where monetary policy alone is used.

We now move to the case with commitment. Under commitment, the optimal response for the period 1 policy maker will carry over to all future periods. Unlike the case of discretion, the policy maker can enforce 'promises' over the path of inflation and capital controls that can endure after the initial deleveraging shock has expired. How important is commitment in the optimal policy response to the crisis? Figures 2 -3 show that the answer depends on whether policy includes capital inflow taxes or not. Under optimal monetary policy alone, the optimal policy differs from that under discretion principally by the pattern of inflation response. Unlike the response under discretion, the monetary authority with commitment raises inflation at the onset of the crisis, but promises to deflate in the second period. The logic is that a commitment to a future deflation leads to a larger period $t = 2$ real exchange rate appreciation than would take place under pure inflation targeting. This therefore raises $\frac{q_{t+2}}{e_{t+2}}$ acts so as to relax the period $t + 1$ collateral constraint. Nevertheless, in terms of effectiveness and the response of macro aggregates, there is very little difference between the discretionary outcome and the commitment outcome when policy makers have access to monetary policy alone.

Note also that with commitment, inflation does not immediately go back to zero when the shock expires after period $t = 3$ onwards. But again, the practical effect of this on the path of output, employment, and imports is very small. Given our standard calibration, monetary policy does not generate much difference between strict inflation targeting and the optimal policy either under commitment or under discretion.

When we extend the analysis under commitment to the consideration of both monetary policy and capital flow taxes, we see a dramatic difference between the commitment and discretionary outcomes. Under commitment, the policy maker imposes a capital inflow tax in period $t = 1$, but commits to a large capital inflow *subsidy* in periods $t = 2$ and $t = 3$. The capital inflow subsidy raises domestic consumption, and the period $t = 2$ asset price. In addition, the rise in period 2 demand generates a real exchange rate appreciation. The combination of the rise in the period $t = 2$ asset price and appreciation of the real exchange rate acts so as to significantly ease the degree to which the current collateral constraint is binding. As a result, the extent of deleveraging is reduced dramatically. The impact of the shock on output, employment and imports is significantly assuaged. For the current calibration, the fall in output at $t = 1$ is less than a quarter that experienced under strict inflation targeting, and half as much as experienced when policymakers use capital inflow taxes, but lack commitment ability. Thus, the ability to make commitments to the path of future asset prices through future capital flow subsidies becomes a major element in the optimal policy response to leverage shocks in this model. Nevertheless, it is clear from the previous discussion that in the absence of a binding commitment technology, these promises would be time inconsistent. The optimal policy involves subsidies which from the perspective of time $t = 1$ raise the value of $\frac{q_2}{e_2}$ and in doing so increase the time $t = 1$ borrowing capacity. But without commitment, the time $t = 2$ policy maker would have no incentive to continue with these subsidies, since, from the perspective of time $t = 2$, it is the period $t = 3$ asset price which constrains the borrowing capacity of the small economy. [6]

4.3 Optimal policies under the fixed exchange rate regime

How do the results differ in the case where monetary policy is constrained by a fixed nominal exchange rate? Figures 5-6 show the response of the economy to the shock under a pegged exchange rate. As is clear from equation (25), the real exchange rate adjustment under a pegged exchange rate has to arise gradually through adjustment in inflation. With sticky prices and wages, this process is costly. In the absence of capital controls, the impact of the shock on output, employment and intermediate imports is significantly

[6] One point to note about the sudden stop episodes in the model is that there is little persistence - GDP quickly returns to the steady state after the shock expires. In the model, this is due to the lack of intrinsic propagation, and the relatively fast adjustment of prices and wages over time. But this feature is unlikely to affect the qualitative ranking of policies in the model. In fact, empirically, there is evidence than many emerging market sudden stop episodes tend to be relatively transitory. This point is emphasized in Calvo, Izquierdo and Talvi (2006), who show that GDP in sudden stops for a large group of emerging markets is characterized by a 'V' shaped response.

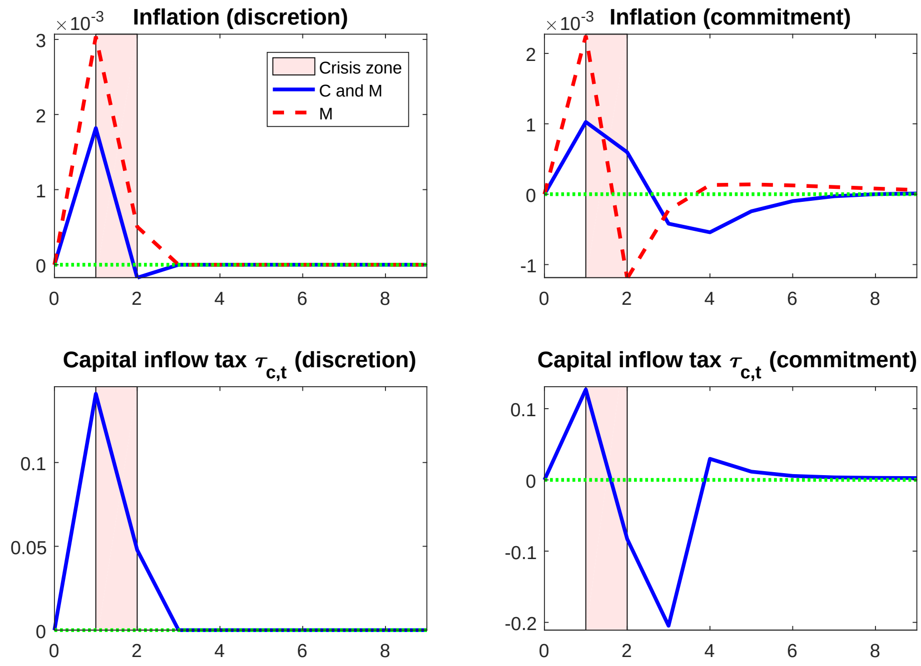

Figure 1: Optimal monetary and capital control policies under the floating regime. The dashed line is for monetary policy alone and the solid line is for both monetary policy and capital control.

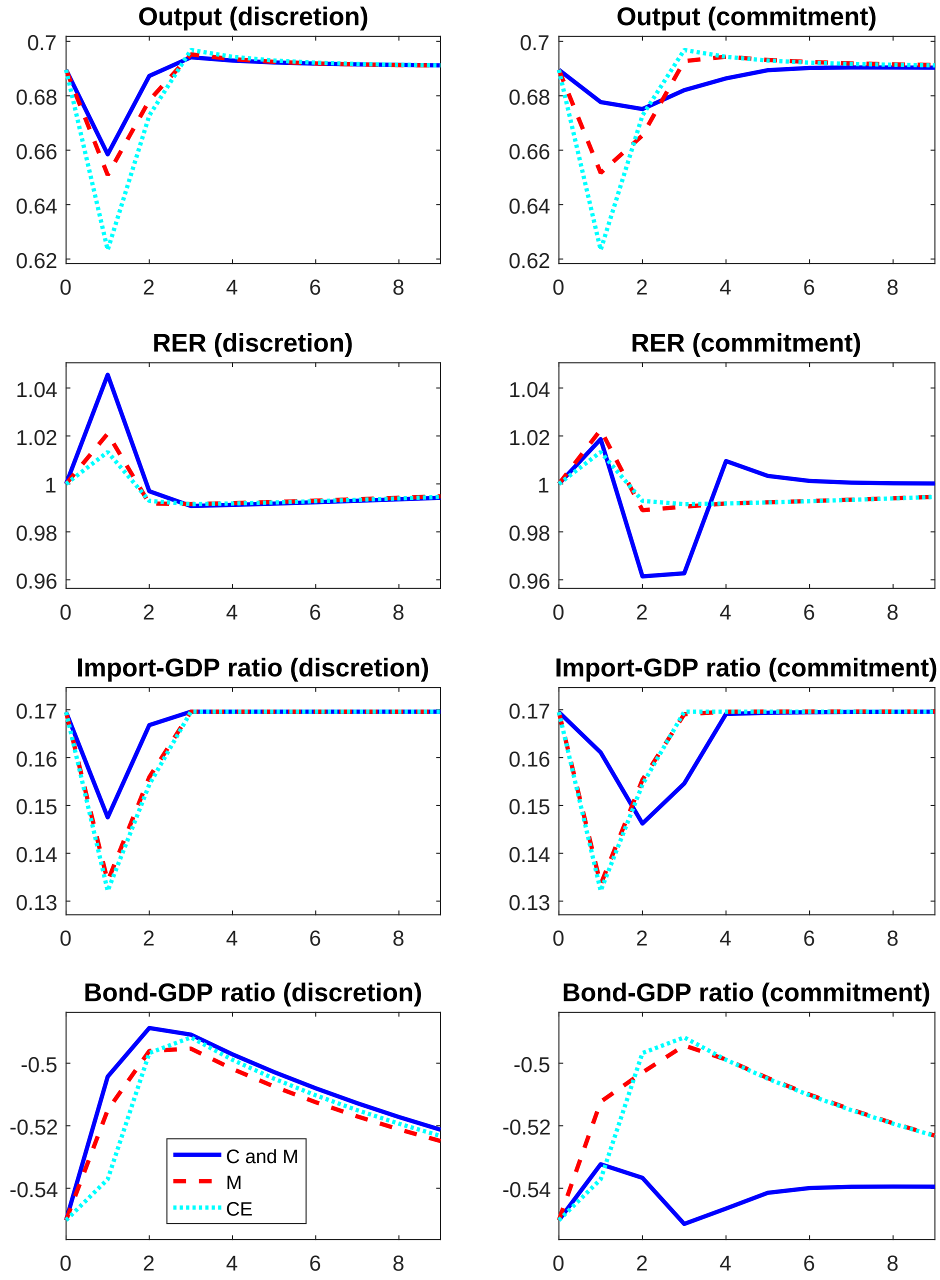

Figure 2: Responses of variables under the floating regime. The dotted line is for the competitive equilibrium with strict inflation targeting and no capital control, the dashed line is for monetary policy alone and the solid line is for both monetary policy and capital control.

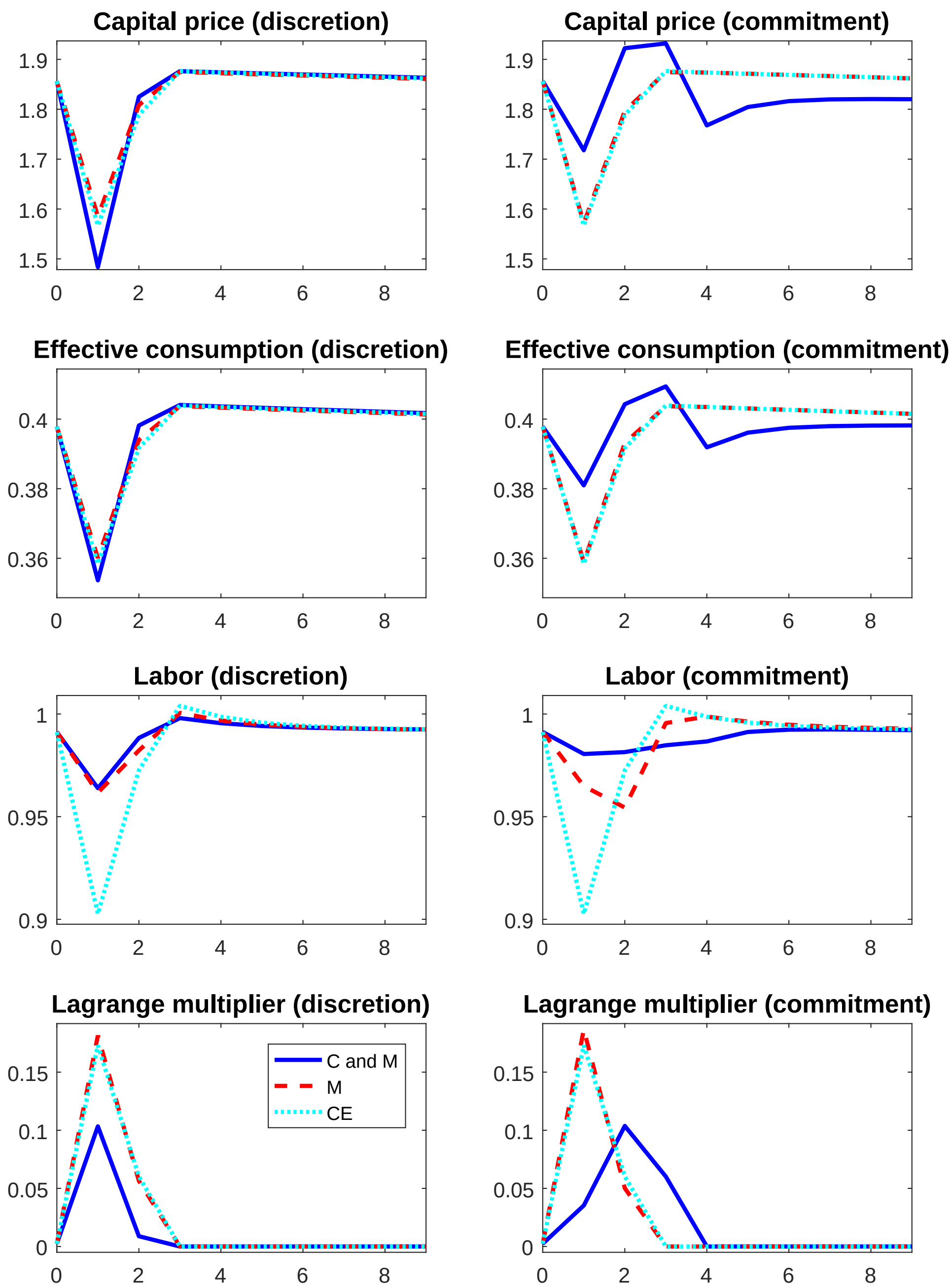

Figure 3: Responses of variables under the floating regime (continued). The dotted line is for the competitive equilibrium with strict inflation targeting and no capital control, the dashed line is for monetary policy alone and the solid line is for both monetary policy and capital control.

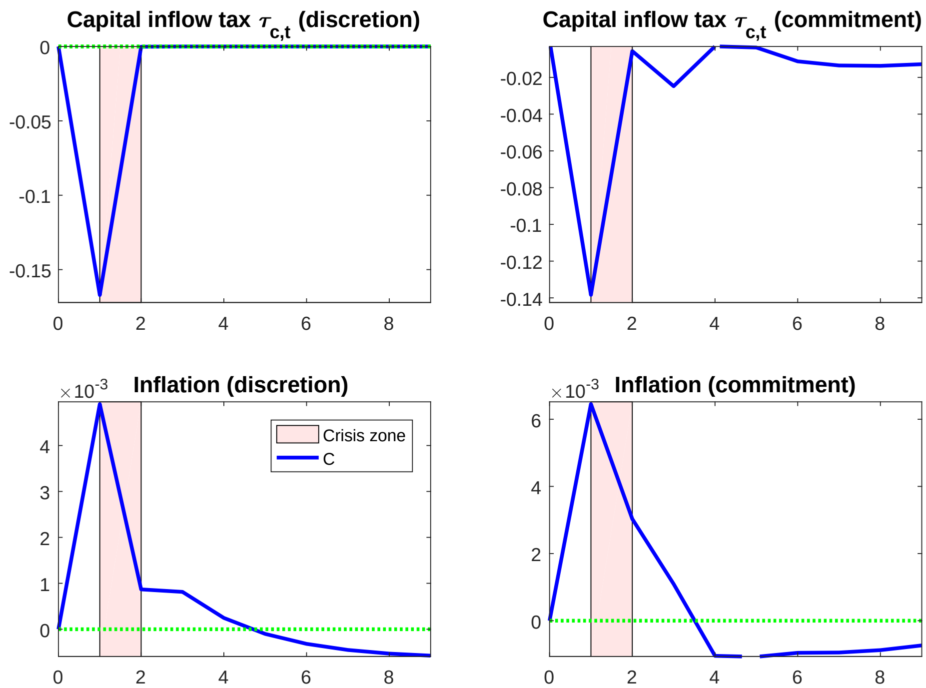

Figure 4: Optimal capital control policies under the pegged regime. The solid line is for optimal capital controls.

greater under the exchange rate peg than under the floating regime. In light of our discussion regarding the trade-off between the goals of eliminating pecuniary externalities versus closing output gaps, this suggests that the policy maker under a pegged exchange rate would be more concerned about the latter.

Figure 4 shows this conjecture to be correct. The figure shows the optimal capital inflow taxes and inflation rates under both commitment and discretion when in response to the deleveraging shock under the nominal exchange rate peg. We see a striking difference in the response of capital controls to a crisis. Unlike the floating exchange rate case, the optimal response is now to pursue an immediate capital inflow subsidy, under both discretion and commitment.

The capital inflow subsidy generates an immediate boost to borrowing, raising aggregate demand, and reducing the impact of the shock on output. The rise in aggregate demand raises inflation, which actually generates a real exchange rate appreciation, in the absence of nominal exchange rate adjustment. For the current calibration, the capital inflow subsidy is successful in reducing by half the impact of the shock on output. Employment falls by less than a quarter of the fall in the absence of the subsidy. Interestingly however, we see that imports actually fall by more than under the competitive equilibrium (without

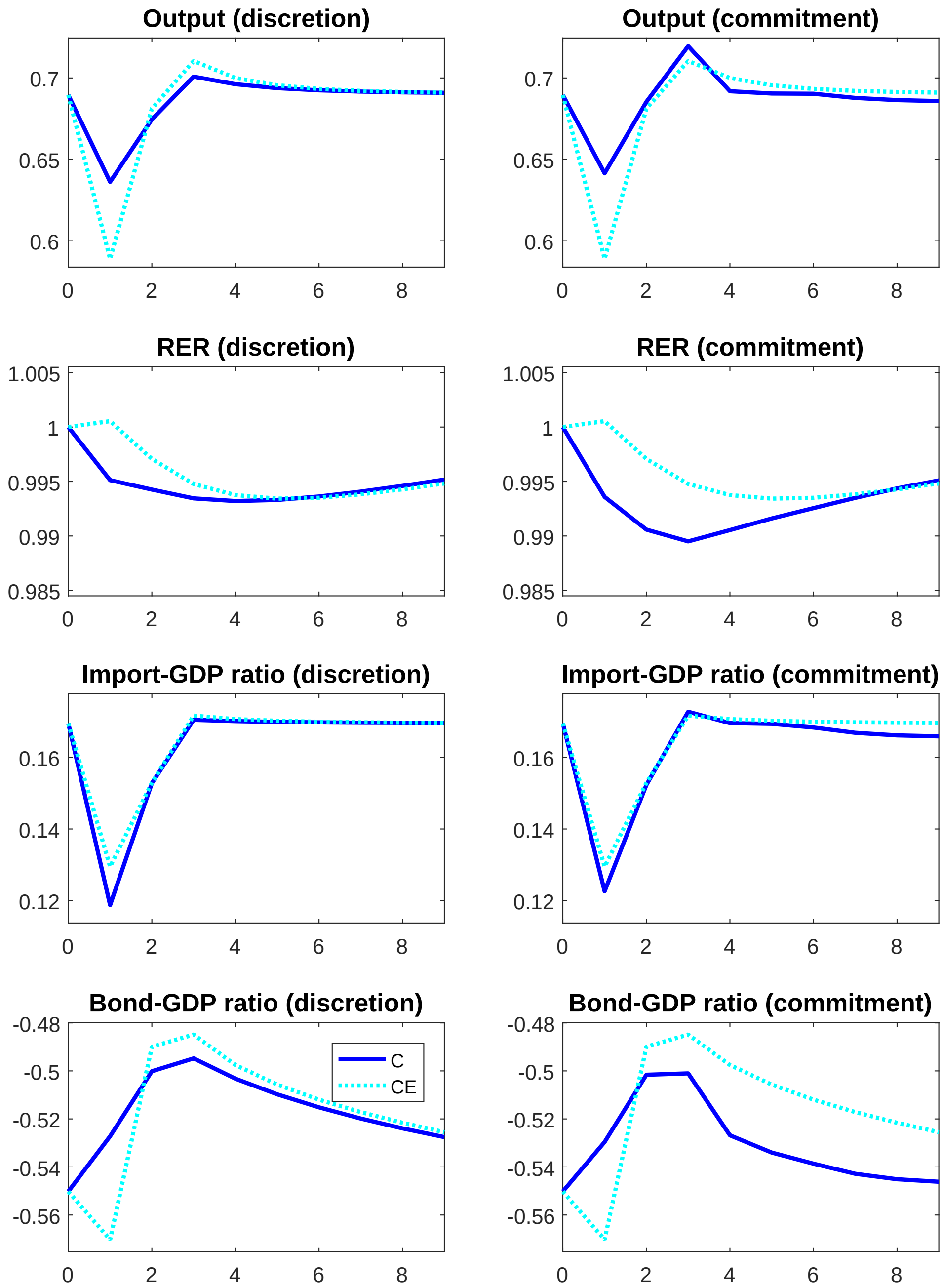

Figure 5: Responses of variables under the pegged regime. The dotted line is for the competitive equilibrium with no capital control, and the solid line is for optimal capital control.

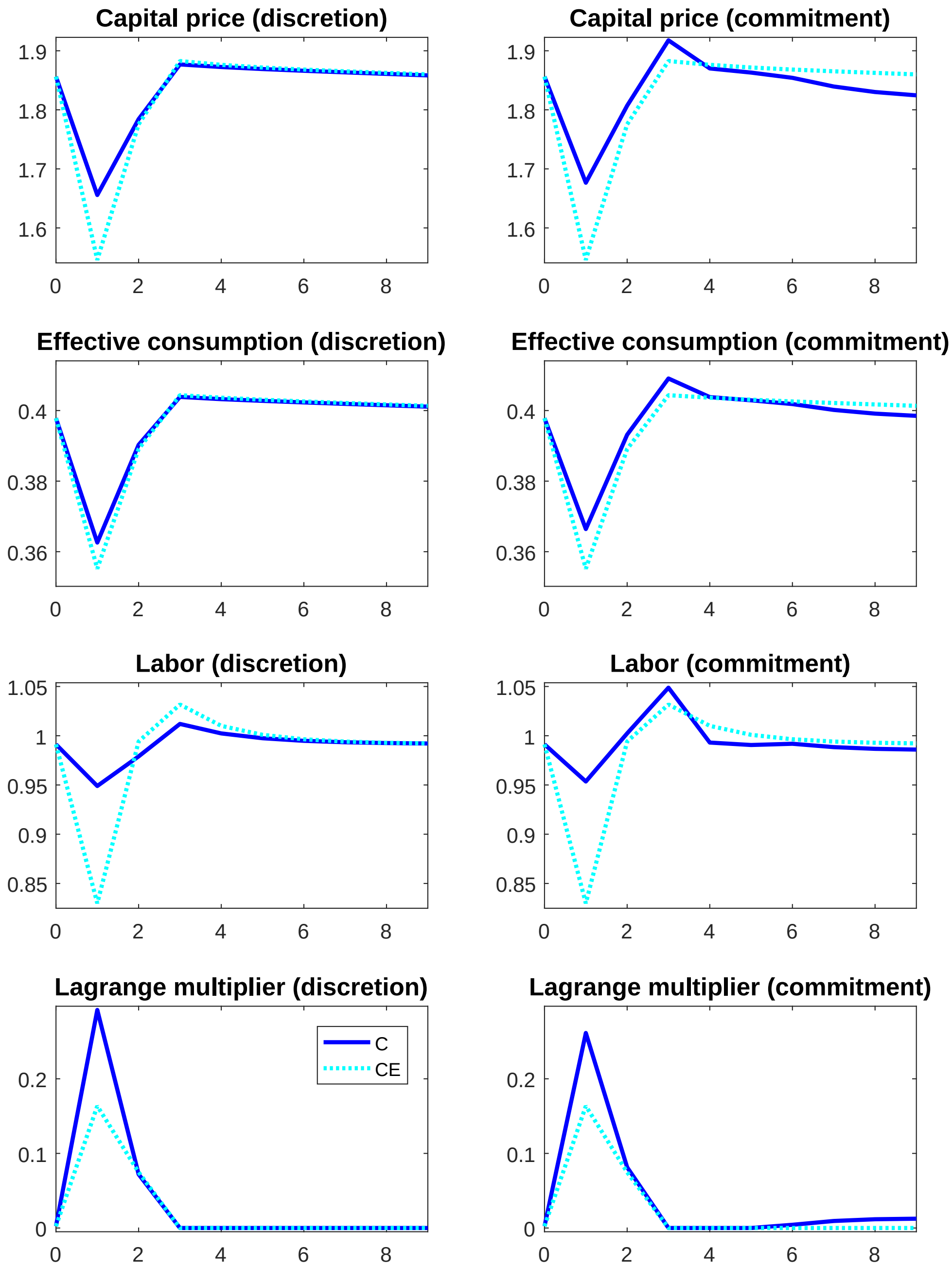

Figure 6: Responses of variables under the pegged regime. The dotted line is for the competitive equilibrium with no capital control, and the solid line is for optimal capital control.

subsidy) under pegged exchange rates. The explanation for this can be seen in the last panel in figure 6. The large capital inflow subsidy tightens the borrowing constraint, relative to the case in the competitive equilibrium. This increases the shadow price of importing intermediate goods, and as a result the firm meets the higher demand with increased employment and slightly lower use of intermediate imports.

How does the degree of commitment make a difference in the response of policy under a pegged exchange rate? Here we see a sharp difference between the floating and fixed exchange rate regimes. In this case, there is little difference in the behaviour of the capital inflow subsidy or the overall economy under commitment relative to the case under discretion when nominal exchange rates are fixed. In both cases, the optimal policy is to impose an immediate capital inflow subsidy to stimulate demand and to close output gaps. Since the elimination of pecuniary externalities in financial constraints takes second place to macro stabilization motives, there is less benefit for the policy maker in being able to commit to a pattern of capital controls. Figure 4 indicates that the optimal capital subsidy is effectively temporary, and imposed in the first period of the shock, both under commitment and discretion. As a result, the degree of commitment is less important under pegged exchange rates.

4.4 Welfare comparisons

Table 2 shows the implications for welfare (in terms of the consumption gains) from optimal policy, relative to the competitive equilibrium (i.e. strict inflation targeting under floating exchange rates, and the pegged exchange rate under the fixed exchange rate regime). We see that in all cases, there are positive welfare gains from optimal policy. As is usual in these models, the welfare gains are quite small. But when monetary and capital controls are in place, the gains under commitment dominate the gains without commitment.

Table 2: Welfare gains relative to the competitive equilibrium

	With commitment	
	Monetary policy	Monetary policy and capital control
Floating regime	1.44E-04	0.0012
Pegged regime		8.72E-04
	Without commitment	
	Monetary policy	Monetary policy and capital control
Floating regime	1.89E-04	1.54E-04
Pegged regime		5.39E-04

4.5 Macro-prudential policies

The discussions above focus on the optimal policies in response to an unexpected deleveraging shock. Much of the recent discussion about the interplay between monetary policy and capital controls has revolved around the need for macro-prudential policy to act in advance of crises. Typically, the argument would involve the policy-maker intervening by either raising interest rates or imposing capital market restrictions as the probability of future crises increases. In the simplified environment analyzed here, the analogue to macro-prudential policy evaluation is most simply described as the incentive for the policy maker to take actions in advance when a leverage crisis is anticipated.

In this regard, we consider a path of leverage in which credit constraints are anticipated to bind in period $t = 3$ and $t = 4$, but do not bind in periods $t = 1$ and $t = 2$. As before, after period 4, the economy is restricted by the exogenous credit constraints (28).

In the case of anticipated shocks, households will act in advance of the crisis, reducing their borrowing gradually until the end of the crisis. Both consumption and the capital price decline before the beginning of the crisis. Despite this, the onset of the crisis is still associated with a steep decline in output, employment, consumption, and the capital price.

How does policy respond to an anticipated deleveraging shock? In particular, to what extent does the ability to respond in a 'macro-prudential' fashion improve the ability of policy makers to respond to the crisis? In this discussion, we assume that policy is made with full commitment, since clearly policy commitment will enhance the effectiveness of macro-prudential policy. First we consider the floating exchange rate regime. Figure 7 echos a result presented in (Devereux, Young and Yu, 2015). That is, when price stickiness is the only nominal rigidity, there is no benefit for either monetary policy and capital controls to act in advance of the crisis. Neither monetary policy nor capital controls are macro-prudential. This is due to the fact that the sole source of departure from price stability in the case of price stickiness alone is due to the need to correct pecuniary externalities. Absent pecuniary externalities, the optimal policy with price stickiness as the only nominal rigidity would be to maintain a zero inflation rate. But the form of the pecuniary externalities inherent in equation (5) make it undesirable for a policy maker to act in advance of a crisis, since when the constraint is not binding, there is no direct benefit to departing from the price stability policy.

Nevertheless, when both price and wage stickiness are present, ex post policies alone cannot achieve the constrained efficient allocation. Consequently, we observe from figure 8 that the policy maker will raise the inflation rate and impose a small capital inflow subsidy before the onset of a crisis. This makes the response of employment, output, consumption and the capital price somewhat smoother when the crisis occurs in period $t = 3$. Nevertheless in comparing the response of the major aggregates under figure 8, where macro-prudential policy is used, with figure 2-3, in the case with commitment (the right hand side panels), we see that there is little difference between the two cases. Even in the situation with nominal rigidities in both wages and prices, the benefits of macro-prudential policy in avoiding the steep fall in economy activity generated by the crisis are very slight. By the same token, the contemporaneous response of monetary policy and capital inflow taxes during the crisis are almost identical in the case where the crisis is known to occur in advance with those of an unanticipated crisis.

One interesting aspect of the anticipated crisis implied by figure 8 is that the response of the capital price and private consumption under the optimal policy is significantly dampened in advance of the shock, relative to the case of no policy response (the price stability rule). That is, even though macro prudential policy in itself does little to alter the impact of the shock, the aggressive response of policy *during* the crisis that is anticipated by households and investors significantly dampens the response of asset prices and consumption to the announcement of the future crisis.

Figures 10-11 illustrate the use of macro-prudential policy when policy is constrained by a pegged exchange rate. In this case, we see a significant difference to the case of floating exchange rates. We see that the policy maker will aggressively subsidize capital inflows and create inflation before the onset of crisis, with or without wage stickiness. The advance capital subsidy leads to an immediate rise in the asset price, whereas the price would fall sharply in the absence of macro-prudential policy. At the same time, the subsidy significantly reduces the immediate fall in consumption and output that would occur as soon as the crisis is anticipated. Hence, in contrast to the case with flexible exchange rates, we see that macro-prudential policy plays an active role in the policy framework under a pegged exchange rate, and the use of macro-prudential policy makes a significant difference to the aggregate response to a crisis, when the option of nominal exchange rate adjustment is absent.[7]

[7] In the case of the pegged exchange rate, the policy maker needs to trade off the desire to respond to pecuniary externalities, nominal rigidities and and the absence of monetary autonomy. In order to study the separate roles of monetary autonomy and pecuniary externalities, we explored the effect of eliminating pecuniary externalities by assuming that the economy always faces an exogenous credit as equation (28). The results, not reported here, indicate that an optimal policy still requires aggressive capital inflow subsidies in period $t = 2, 3$ (one is immediately before the crisis and the other is the start period of a crisis), as in figure 10-11. Hence, the implication is that the benefits of macro prudential policy in a pegged exchange rate regime mainly result from the motive of restoring monetary autonomy rather than responding to pecuniary externalities.

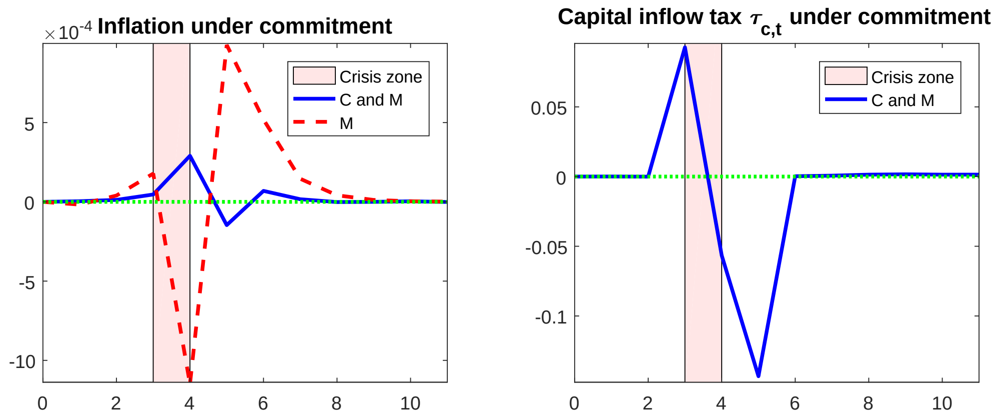

Figure 7: Optimal monetary and capital control policies under the floating regime when price stickiness is the only nominal rigidity. The dashed line is for monetary policy alone and the solid line is for both monetary policy and capital control. Credit constraints don't bind in period $t = 1, 2$.

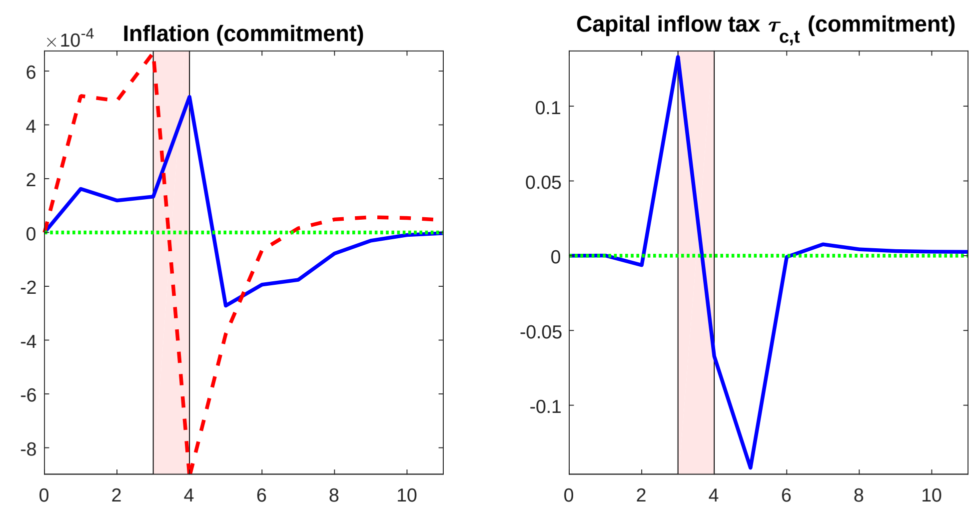

Figure 8: Optimal monetary and capital control policies under the floating regime when both price and wage stickiness are present. The dashed line is for monetary policy alone and the solid line is for both monetary policy and capital control. Credit constraints don't bind in period $t = 1, 2$.

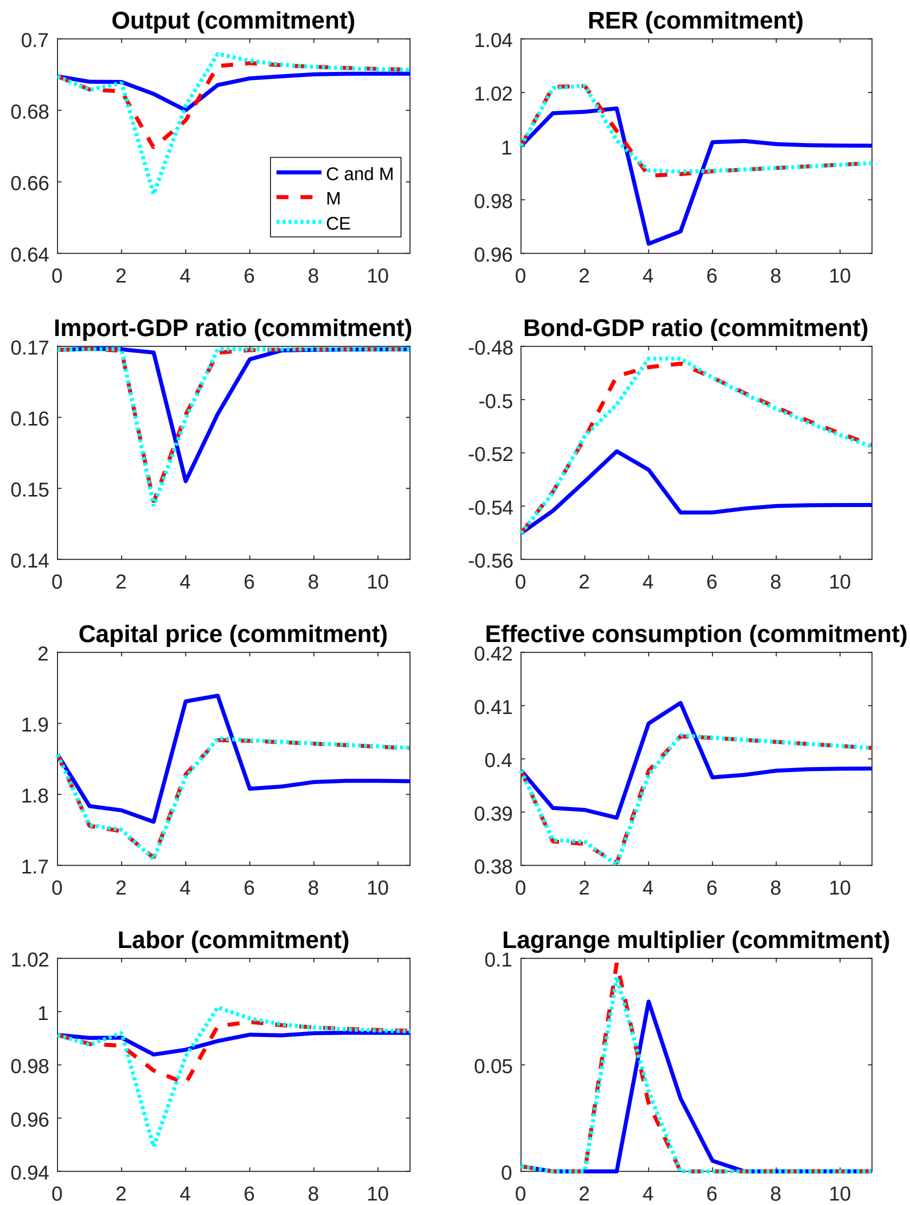

Figure 9: Responses of variables under the floating regime when both price and wage stickiness are present. The dotted line is for competitive equilibrium with strict inflation targeting. The dashed line is for monetary policy alone and the solid line is for both monetary policy and capital control. Credit constraints don't bind in period $t = 1, 2$.

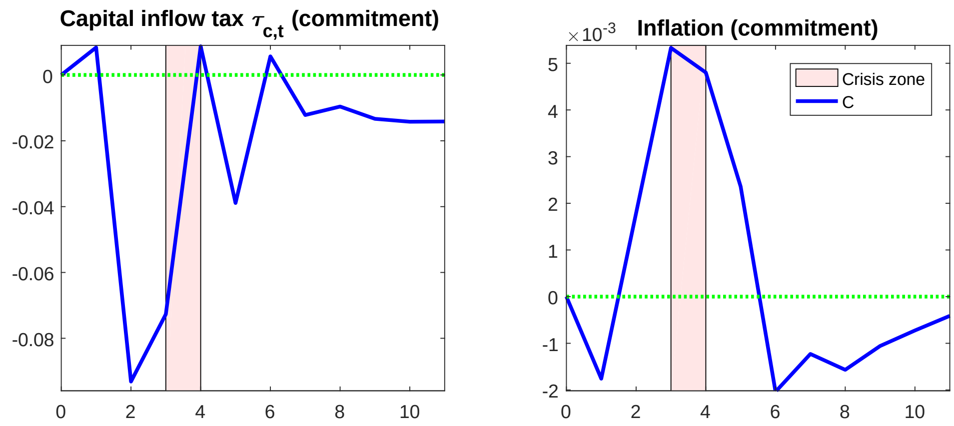

Figure 10: Optimal capital control policies under the pegged regime when price stickiness is the only nominal rigidity. The solid line is for optimal capital controls. Credit constraints don't bind in period $t = 1, 2$.

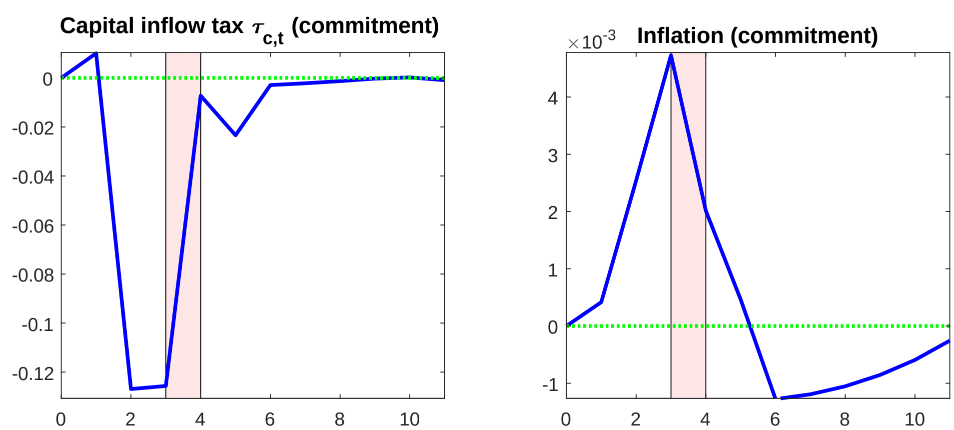

Figure 11: Optimal capital control policies under the pegged regime when both price and wage stickiness are present. The solid line is for optimal capital controls. Credit constraints don't bind in period $t = 1, 2$.

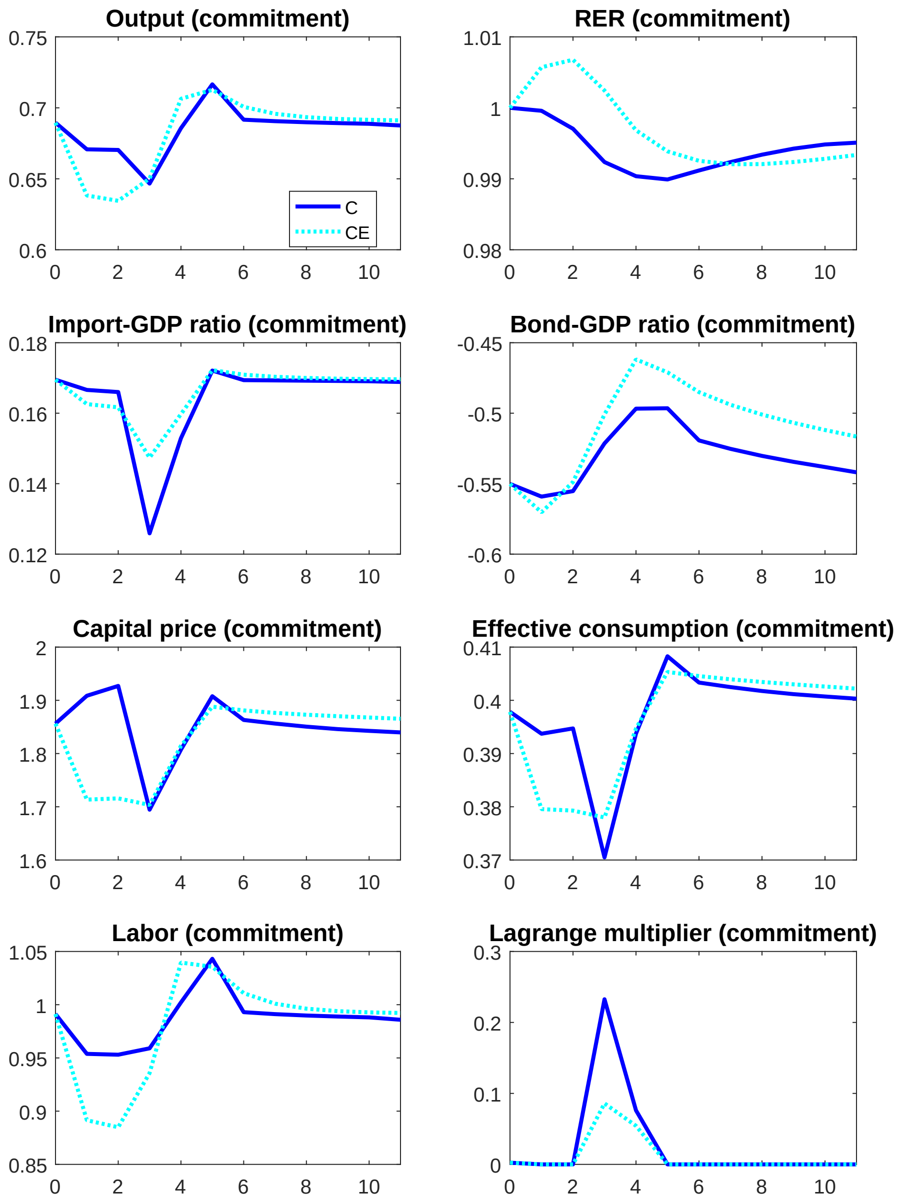

Figure 12: Responses of variables under the pegged regime when both price and wage stickiness are present. The dotted line is for competitive equilibrium and the solid line is for optimal capital controls. Credit constraints don't bind in period $t = 1, 2$.

5 An alternative valuation of collateral

This section explores optimal monetary policy and capital controls for an alternative collateral valuation. Now we assume that the market uses the end of period value of capital as collateral as in Bianchi and Mendoza (forthcoming).

The only model difference comes from the timing of collateral,

$$\kappa_t \left(\frac{q_t k_{t+1}}{e_t} \right) + b^*_{t+1} - (1+\tau_N)\vartheta Y_{F,t} \geq 0, \tag{29}$$

and the optimality condition for capital price,

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

with complementary slackness condition in equilibrium,

$$e_t \mu_t \left[\kappa_t \frac{q_t}{e_t} + b^*_{t+1} - \vartheta Y_{F,t}(1+\tau_N) \right] = 0,$$

$$\mu_t \geq 0.$$

The parameters in this version of collateral constraint are the same as those in the baseline case. We focus on the qualitative differences between our baseline case and this alternative. Since the literature has intensively discussed time-consistent policies, we explore optimal policies with commitment.

First we consider optimal monetary policy under the floating exchange rate regime. Figure 13 shows that the monetary authority will raise inflation at the onset of the crisis. Given the model specification and parameter values, there is little difference between the case with strict inflation targeting and that under optimal monetary policy under commitment when both price and wage stickiness are present (as shown in figure 14).[8]

Now consider both optimal monetary policy and capital controls. Figure 13 shows that the policy

[8] Nevertheless, this is not necessarily the case. For the results with sticky prices only (not reported here), the monetary authority will deflate the domestic economy at the onset of a crisis. The reason is that deflation help appreciate the domestic currency, which leads to higher value of collateral when expressed in foreign currency. When the borrowing constraint is relaxed in crisis (lowering the Lagrange multiplier), working capital becomes cheaper, providing a stimulus to output. After the crisis, however, the monetary authority will switch to inflation and depreciate domestic currency to bring capital price, consumption and output to their deterministic long run steady state.

maker imposes a macro-prudential capital inflow tax before the onset of a crisis, while subsidizing capital inflows in crisis period $t = 3, 4$, and the monetary authority creates inflation before and in the crisis to complement capital control policies. The joint optimal policies significantly reduce the credit constraint in period $t = 3$, which leads to a substantial increase in consumption and the capital price (seen in figure 14). Output and employment are higher than those under the optimal monetary policy alone due to the slack credit constraint in period $t = 3$. As we know, under commitment, policy makers balance the effect of policies on the whole path of an economy. In order to bring the economy back to long-run steady state, the policy maker will tax capital inflows at a small rate immediately after the crisis periods (period $t = 5$). The conclusion then, in contrast to the results with the baseline collateral constraint, is that there is a greater role for macro-prudential policy when collateral is valued at current asset prices.

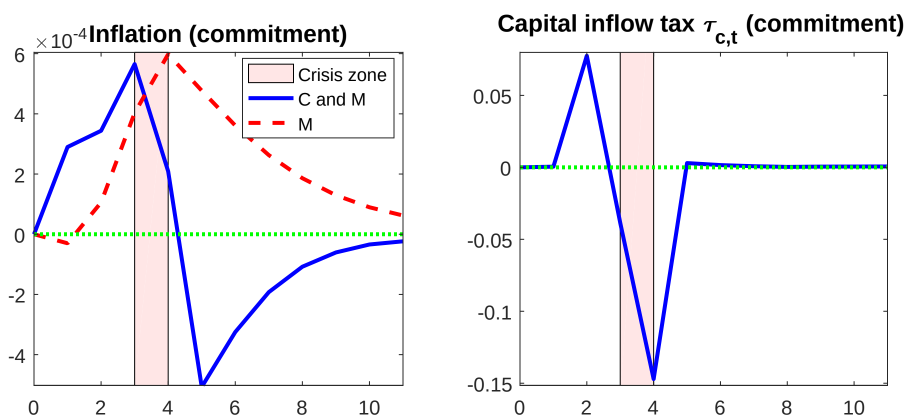

Figure 13: Optimal monetary and capital control policies under the floating regime when the collateral is valued as $\frac{q_t k_{t+1}}{e_t}$. The dashed line is for monetary policy alone and the solid line is for both monetary policy and capital control.

6 Conclusions

This paper has explored the role of policy commitment and the need for macro-prudential policy in emerging market crises under a variety of assumptions about the nature of financial constraints, the exchange rate regime, and the degree of nominal rigidity in prices and wages. Our results indicate that the benefit of policy commitment depend sensitively on the instruments available to the policy makers (whether monetary policy alone or monetary policy and capital controls) as well as the exchange rate regime. Under a floating exchange rate, commitment is highly desirable when capital controls are to be

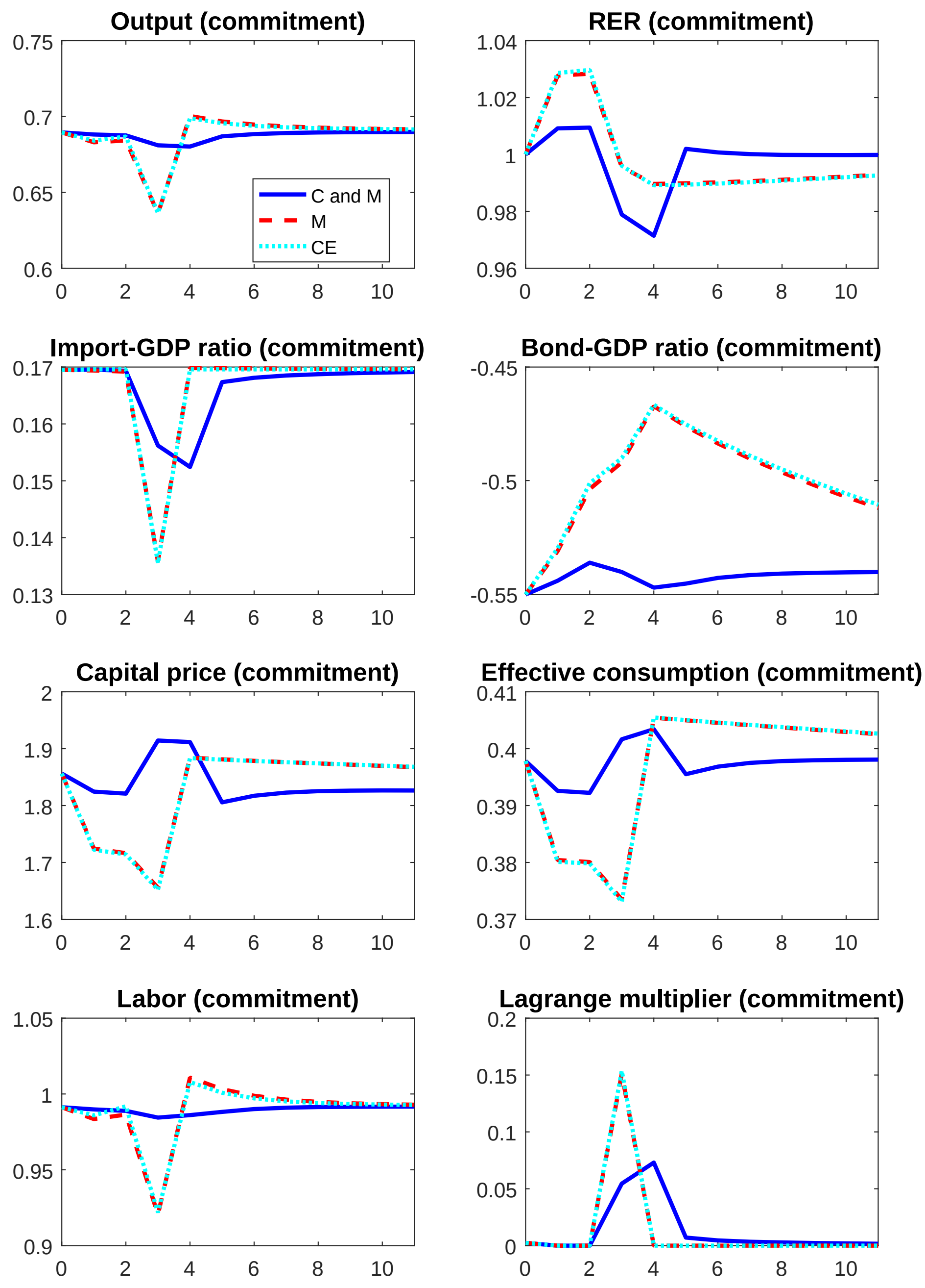

Figure 14: Responses of variables under the floating regime when the collateral is valued as $\frac{q_t k_{t+1}}{e_t}$. The dotted line is for the competitive equilibrium with strict inflation targeting and no capital control, the dashed line is for monetary policy alone and the solid line is for both monetary policy and capital control.

used actively. In a pegged regime, commitment is less important. As regards macro-prudential policy, we find that it is important principally under a pegged exchange rate regime. Moreover, the results show that the direction of the optimal responses of capital controls during a crisis will depend on the exchange rate regime. With flexible exchange rates, policy makers will impose an inflow tax immediately at the onset of a crisis. Under pegged exchange rates, they will impose a capital inflow subsidy.

Future extensions of the model could introduce alternative pricing assumptions, such as local currency pricing and dominant currency pricing (Gopinath, Itskhoki and Rigobon, 2010, Gopinath, 2015), or alternative assumptions about the denomination of debt. It is likely that this would alter some of our conclusions.

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A The list of equations in competitive equilibrium under PCP

A system of competitive equilibrium conditions are listed as follows:

$$
\begin{aligned}
0 \quad = \quad & \theta_W \left(\frac{\chi l_t^{\nu}}{w_t} \right) - (\theta_W - 1)(1 + \tau_W) - \frac{\pi_{W,t}}{\pi_t^{\varphi}} \frac{\phi_W}{\gamma_W} \left[\exp\left(\gamma_W \left(\Omega_t^{int} - 1 \right) \right) - 1 \right] + \\
& \beta E_t \left[\frac{U_c(t+1)}{U_c(t)} \frac{\pi_{W,t+1}^2}{\pi_{t+1}^{1+\varphi}} \frac{l_{t+1}}{l_t} \frac{\phi_W}{\gamma_W} \left[\exp\left(\gamma_W \left(\Omega_{t+1}^{int} - 1 \right) \right) - 1 \right] \right],
\end{aligned}
$$

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

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

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

$$w_t = \frac{\pi_{W,t}}{\pi t} w_{t-1},$$

$$(1 + \tau_N) e_t (1 + \mu_t \vartheta) Y_{F,t} = \alpha_F p_{M,t} Y_t,$$

$$w_t L_t = \alpha_L p_{M,t} Y_t,$$

$$r_{K,t} K_t = \alpha_K p_{M,t} Y_t,$$

$$e_t \mu_t \left[\kappa_t E_t \left(\frac{q_{t+1} K_{t+1}}{e_{t+1}} \right) + b_{t+1}^* - \vartheta Y_{F,t} (1 + \tau_N) \right] = 0,$$

$$\mu_t \geq 0$$

$$\kappa_t E_t \left(\frac{q_{t+1} K_{t+1}}{e_{t+1}} \right) + b_{t+1}^* - (1 + \tau_N) \vartheta Y_{F,t} \geq 0$$

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

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

$$Y_t - \phi(\pi_t) Y_t - w_t L_t \psi \left(\Omega_t^{int} \right) = C_t + e_t^{\rho} \zeta_t^* + q_t (K_{t+1} - K_t),$$

$$(e_t)^{\rho} \zeta_t^* - Y_{F,t} e_t = \left(\frac{b_{t+1}^*}{R_{t+1}^*} - b_t^* \right) e_t,$$

$$K_{t+1} = K_t = 1$$

$$\text{Fiscal policies: } \tau_H = \frac{1}{\theta - 1}, \tau_W = \frac{1}{\theta_W - 1}, \tau_N = \frac{1}{\rho - 1}$$

Monetary and capital control policies: $\tau_{c,t}, R_{t+1}$under the floating or under the peg.