

Capital controls and monetary policy in sudden-stop economies[☆]

Michael B. Devereux^{a,*}, Eric R. Young^b, Changhua Yu^c

^a*Vancouver school of economics, University of British Columbia, NBER and CEPR. 997 – 1873 East Mall, Vancouver, BC, Canada, V6T1Z1.*

^b*Department of Economics, University of Virginia, 242 Monroe Hall Charlottesville, VA 22904 Phone: Office (434) 924-3811 Fax: (434) 982-2904. Academy of Financial Research, Zhejiang University.*

^c*China Center for Economic Research, National School of Development, Peking University, 5 Yiheyuan Rd, Haidian, Beijing, China, 100871.*

Abstract

The dangers of high capital flow volatility and sudden stops have led economists to promote the use of capital controls as an addition to monetary policy in emerging market economies. This paper studies the benefits of capital controls and monetary policy in a small open economy with financial frictions, nominal rigidities, and sudden stops. Without commitment, the optimal monetary policy should sharply diverge from price stability. The policymakers will also tax capital inflows in a crisis, but such taxes may be welfare reducing. With commitment, capital controls involve a mix of current capital inflow taxes and future capital flow subsidies. The optimal policy will never involve macro-prudential capital inflow taxes or a departure from price stability, whether or not commitment is available.

Keywords: Sudden stops, Pecuniary externality, Monetary policy, Capital controls, Time-consistency

JEL Codes: E44, E58, F38, F41

[☆]This paper is the revised version of previously circulated paper “A New Dilemma: Capital Controls and Monetary Policy in Sudden Stop Economies”. We especially thank the insightful comments and suggestions by the editor Ricardo Reis and three anonymous referees. We are grateful to the thoughtful discussions by Gita Gopinath and Andres Drenik. We also thank seminar participants at the HKIMR, the UBC macro-lunch, the Board of Governors of the Federal Reserve System, the NBER International Finance and Macroeconomic Programme Meeting, LAEF meeting at UC Santa Barbara, the North American Meeting of Econometric Society, Philadelphia, HKUST-HKIMR-KEIO meeting, Federal Reserve Bank of San Francisco, AEA Annual meeting, CUHK (Shenzhen) and Tsinghua University for comments. Devereux thanks SSHRC, and the Royal Bank of Canada for financial support as well as support from ESRC award ES/1024174/1. Young thanks the financial support and hospitality of the HKIMR and the Bankard Fund for Political Economy at the University of Virginia. Yu thanks the National Natural Science Foundation of China 71303044, and the financial support and hospitality of the HKIMR. All errors are our own.

*Corresponding author. E-mail: devm@mail.ubc.ca

1. Introduction

Recent experience of financial crises in many countries has altered the traditional support for liberalized international capital markets. Many emerging market economies have opened up their financial markets in the last two decades and moved away from rigidly pegged exchange rates (see for instance [Levy-Yeyati and Sturzenegger, 2005](#); [Lane and Milesi-Ferretti, 2008](#)). Despite this greater openness, many of these countries have been subject to extremely volatile capital flows and crises associated with ‘sudden stops’ in capital inflows ([Bacchetta and van Wincoop, 2000](#); [Kaminsky et al., 2005](#); [Reinhart and Reinhart, 2009](#); [Fratzscher, 2012](#); [Broner et al., 2013a](#)). A new view has emerged suggesting that monetary policy alone cannot adequately manage the external shocks facing small emerging economies and must be supplanted with some type of capital control or macro-prudential policy ([Farhi and Werning, 2012, 2014](#); [Rey, 2015](#)). In the presence of financial frictions, the conventional welfare case for fully open capital markets may not apply. Capital controls may then constitute a second best optimal policy response.

Our paper revisits the case for capital controls in open economies with both financial frictions and nominal rigidities. We employ a simple model of a small open economy subject to occasional ‘sudden stops’. Monetary policy and capital controls are potentially useful as macroeconomic instruments, but in addition, both policies may be targeted towards correcting pecuniary externalities arising from financial frictions. We address two simple questions: first, how useful is monetary policy in responding to financial crises associated with ‘sudden stops’ in capital flows; and second, what are the benefits of capital controls in addition to monetary policy?

The combination of sticky prices and financial constraints that depend on asset prices offer the possibility that monetary policy and capital controls may be used in tandem as part of an optimal policy. A substantial empirical and theoretical literature makes the case that financial frictions render conventional monetary policy tools less effective (see [Céspedes et al., 2004](#); [Devereux et al., 2006](#); [Gertler et al., 2007](#); [Braggion et al., 2009](#)). At the same time, as we noted, a series of recent papers have noted the possibility that taxes on capital flows can correct pecuniary externalities associated with occasionally binding borrowing constraints ([Bianchi, 2011](#); [Benigno et al., 2013](#);

Bianchi and Mendoza, 2010, forthcoming; Jeanne and Korinek, 2010). In principle, we might expect that these two policy levers would support each other as part of an optimal policy package.

A closely related question is whether monetary policy and capital market interventions should ‘lean against the wind’, acting in advance to reduce the probability or severity of potential future crises. This type of ex-ante response is sometimes referred to as ‘macro-prudential’ policy.¹ Our model allows us to analyze in detail the case for monetary and capital inflow taxes as macro-prudential instruments.

Two features of the analysis turn out to be critical. The first is the degree of commitment in policy-making. As in previous literature, our baseline results assume a benevolent policy-maker that lacks commitment. Monetary and capital controls are chosen optimally under discretion, taking as given the choices of future policymakers. The second feature is the nature of the collateral constraint. Following Kiyotaki and Moore (1997), we assume that the collateral which determines the economy’s borrowing capacity is valued at the expected price of collateral which will obtain when the debt comes due. These two features shape our results in important ways.

We first derive a set of theoretical results on optimal monetary policy and capital flow taxation. Following that, we conduct a quantitative analysis of the model and compare the simulations to the experience of sudden stop events in a large sample of emerging market countries. Finally, we discuss the importance of commitment and the nature of the collateral constraint for our theoretical and quantitative results.

We find that in the absence of the collateral constraint on borrowing, the optimal monetary policy will always stabilize inflation around target. Departing from inflation stability is desirable only in order to address the pecuniary externalities associated with binding credit constraints. But more precisely, departing from target inflation is optimal only if production firms need to borrow to finance working capital loans. Absent this type of borrowing requirement, monetary policy is ineffective at correcting the pecuniary externality and therefore is left to focus on minimizing

¹We note that a complete description of ‘macro-prudential policy’ involves a much wider set of instruments and issues than capital controls. In our paper, we will use the term in a narrow sense, referring to capital inflow taxes.

inflation costs. This motivation for monetary policy is quite different from the standard output stabilization role implicit in New Keynesian models. In addition, we show that a departure from inflation stability is desirable only if financial constraints are currently binding; that is, there is no macro-prudential component to optimal monetary policy.

Extending the model to allow for capital controls, we show that capital inflow taxes fully replace monetary policy as part of an optimal policy design. Given the option to use capital taxes, monetary policy should focus exclusively on inflation stability. Then capital taxes are used to offset pecuniary externalities. For realistic parameter values, capital inflow taxes will be positive. But capital taxes will only be employed during a financial crisis - again there is no macro-prudential element to an optimal capital tax policy. Policy makers will not attempt to set inflow taxes in advance of a crisis in order to limit external borrowing.

In the quantitative analysis, we calibrate and solve the model using global solution methods, and compare the results to the experience of sudden stop events from an average of a large sample of emerging market countries. Under an optimal monetary policy, without using capital flow taxes, the authority should raise inflation sharply during a crisis, while keeping inflation equal to target outside of a crisis. The increase in inflation in a crisis generates a real exchange rate depreciation which reduces external borrowing. The effectiveness of monetary policy is quite modest though, given the degree of price rigidity inherent in our calibration. When both monetary policy and capital flow taxes are considered, inflation is kept equal to target all the time, and the tax on capital inflows is around 11 percent during a crisis. Capital flow taxes are more effective than monetary policy at reducing borrowing and cushioning the economy from the adverse consequences of the sudden stop.

But while capital inflow taxes form part of an optimal policy under discretion, they suffer from a severe time consistency problem. In a discretionary policy equilibrium capital inflow taxes are welfare reducing, relative to both a strict inflation targeting regime and to the allocation under optimal monetary policy. This time consistency problem can be understood intuitively from the fact that capital inflow taxes under discretion attempt to raise the expected future value of collateral, but ignore their effect on the current value of collateral. In a discretionary equilibrium, capital

inflow taxes are accordingly higher than socially optimal, the economy is more constrained by low collateral values, and net external debt is lower than optimal.

How would the situation differ if the policy makers could commit to a Ramsey optimal policy plan? While we do not solve the full quantitative stochastic model under commitment, we present some key features of the optimal policy under commitment and emphasize the difference from the outcome under discretion. First, under commitment, we demonstrate that monetary policy will generally depart from inflation stability during a crisis, even when firms do not require working capital loans. Secondly, the clear separation between monetary policy and capital flow taxes does not carry over to a commitment policy. In general, during a crisis, the optimal policy with commitment will involve both using capital inflow taxes or subsidies as well as departing from inflation stability. We show however that, even with commitment, optimal policy is never macro-prudential, either in monetary policy or capital inflow taxes. An optimal policy with commitment does not prescribe ‘leaning against the wind’ in advance of a crisis. We further illustrate that the optimal policy with commitment will generally involve a mix of current capital inflow taxes and future inflow subsidies at the onset of a crisis; this mix is the source of the time inconsistency problem. Finally, we posit a simple ad hoc policy rule which subsidizes capital inflows during a crisis and raises welfare relative to the competitive equilibrium.

A key feature of our results is in the nature of the collateral constraint whereby the expected future value of collateral determines the degree to which the constraint binds. If, by contrast, the current value of collateral appears in the constraint, our results would be quite different - notably there would be a case for macro prudential policy to tax inflows in advance of a crisis, and subsidize inflows during a crisis, and the time consistency problem in policy would be less extreme. A general implication of the analysis is hence that in designing optimal policy for economies with financial constraints, the details of the financial constraints are of critical importance.

This paper contributes to two growing branches of literature. First, it is related to the literature on the remedies for pecuniary externalities. During a financial crisis, the collateral constraint binds, which reduces the value of collateral, leading to an even tighter constraint, although private agents

do not internalize this effect when issuing debt. As a result, the economy displays overborrowing in competitive equilibrium, relative to a social planner's outcome (Bianchi, 2011). Bianchi and Mendoza (2010) demonstrate that state-contingent capital inflow taxes will prevent overborrowing, which can be interpreted as a form of Pigouvian taxation (Jeanne and Korinek, 2010). When there exist ex post adjustments of production between tradable and nontradable sectors, the economy could exhibit underborrowing relative to the constrained efficient outcome (Benigno et al., 2013). Korinek (2011) provides a comprehensive review on borrowing and macroprudential policies during financial crises. As for optimal capital controls, Bianchi and Mendoza (forthcoming) and Benigno et al. (2012, 2016) explore time-consistent macroprudential policy.²

The most closely related paper to ours is Bianchi and Mendoza (forthcoming). They also investigate the role of optimal, time-consistent capital controls in a model with occasionally-binding constraints. Our paper differs from Bianchi and Mendoza (forthcoming) along several dimensions. First we incorporate a useful role for monetary policy. Second, in our model, the constraint on borrowing depends upon the expectation of the future (resale) value of assets, following the tradition of Kiyotaki and Moore (1997) and Iacoviello (2005), whereas Bianchi and Mendoza (forthcoming) use the current value of assets. The different constraints lead to quite different incentives for policymakers. Bianchi and Mendoza (forthcoming) show that policymakers should impose a capital tax in periods in which the collateral constraint may bind tomorrow, and find that this policy raises welfare in their model. The reason is that a policymaker in their model needs to restrict capital inflows on the edge of a crisis in order to sustain current asset prices, which determine the value of collateral and the extent of access to international capital markets. As noted already, we find that it is never optimal to tax capital flows outside of a crisis and the use of capital controls lowers welfare. A final feature of our model that differs from Bianchi and Mendoza (forthcoming) is the endogeneity of the terms of trade. We explicitly account for the impact of sudden stops on the

²Korinek and Simsek (2016) study an aggregate demand externality at the zero lower bound, wherein the inability of the nominal interest rate to drop below zero when needed to stimulate consumption creates a positive role for macroprudential policy. Since their paper is in a closed-economy setting the particular policies they advocate are quite different from ones that are optimal in our model. In any case, our economy does not encounter the ZLB given a reasonable inflation target, so we can safely abstract from the issues they raise.

terms of trade. Empirically, we present movements in the terms of trade (or the real exchange rate) and important elements of sudden stop experiences in emerging economies. Our model tracks these movements quite well.

Our paper is also related to recent studies exploring monetary policy in the context of financial crises. [Rey \(2015\)](#) and [Passari and Rey \(2015\)](#) present evidence that the global financial cycle constrains monetary policy even under the flexible exchange rate regime when capital flows are unrestricted, and recommend the use of capital flow management. [Bruno and Shin \(2015a,b\)](#) provide a linkage between cross-border bank capital flows and global factors, particularly US monetary policy. [Farhi and Werning \(2012, 2014\)](#) investigate optimal capital controls and monetary policy in a [Gali and Monacelli \(2005\)](#) type of small open economy model with risk premium shocks, and state that capital controls help restore monetary autonomy in a fixed exchange rate regime and work as terms of trade manipulation in a flexible exchange rate regime.³ Closely-related papers on exchange rate policy are [Fornaro \(2015\)](#), [Schmitt-Grohe and Uribe \(2015\)](#) and [Ottonello \(2015\)](#). [Fornaro \(2015\)](#) considers a small open economy similar to ours but focuses on simple policy rules, whereas our paper investigates the optimal monetary policy and optimal capital controls. [Schmitt-Grohe and Uribe \(2015\)](#) study a model with fixed exchange rates, downward nominal wage rigidities, and free capital mobility. In their paper, an optimal devaluation eliminates the effects of the wage rigidity. Building upon [Schmitt-Grohe and Uribe \(2015\)](#), [Ottonello \(2015\)](#) explores optimal exchange rate policy and capital controls. Policymakers in his model balance the use of nominal exchange rate movements to undo the nominal wage rigidity against the cost of devaluations that restrict international borrowing; because [Ottonello \(2015\)](#) uses a flow constraint similar to [Benigno et al. \(2016\)](#), devaluations cause declines in income that reduce the ability of agents to borrow internationally. All of these papers assume commitment, whereas we emphasize the role of discretion as well.

The rest of the paper is organized as follows. Section 2 presents the baseline model with

³Capital controls as terms of trade manipulation were first explored by [Costinot et al. \(2014\)](#) in a two-country deterministic endowment economy.

sticky prices and characterizes the competitive equilibrium under a certain set of policy. Section 3 characterizes allocations under optimal monetary policy and optimal capital controls. Section 4 calibrates the model and section 5 quantitatively conducts the positive and normative analysis of the baseline model. Section 6 presents some results on the outcome for monetary policy and capital flow taxes under full commitment in policy. The last section concludes.

2. The Model

We consider a monetary version of a small open economy akin to [Mendoza \(2010\)](#) and [Céspedes, Chang, and Velasco \(2004\)](#). There exist infinitely-lived firm-households with unit measure. 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 by domestic monopolistically competitive final goods producers, which are then aggregated into a consumption composite. These composites are either consumed by domestic households or exported to the rest of the world. Domestic households can trade only foreign currency denominated, non-state contingent bonds with foreigners.

Wholesale good production is Cobb-Douglas

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

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

The price of intermediate inputs in the rest of world is exogenous to the small economy (and normalized to unity). Foreign demand for domestic consumption composites, X_t , is

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

ζ_t^* stands for a foreign demand, \mathcal{E}_t represents the nominal exchange rate, and P_t^* is the foreign CPI

price level, which we normalize to unity hereafter. $\rho > 1$ is the elasticity of substitution between imports and locally produced goods in the foreign consumption basket.⁴ The share of foreign spending on imports from the home country remains small enough that we can take aggregate foreign expenditure as given.

2.1. Firm-households

A representative firm-household has preferences given by

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

where E_0 is the conditional expectations operator, and β is the subjective discount factor. The utility function takes the GHH (Greenwood, Hercowitz, and Huffman, 1988) form

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

Similar to Mendoza (2010), households borrow from abroad, in foreign currency, in order to finance consumption and imported intermediate inputs.⁵ ⁶ Borrowing from abroad requires capital k_{t+1} as collateral:

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

B_{t+1}^* stands for domestic purchases of foreign currency bonds in dollar terms at the end of period t .

This is negative if the economy is a net intertemporal borrower. The term τ_N captures the presence

⁴This foreign demand function can be derived from a world economy as in Gali and Monacelli (2005). ρ characterizes the elasticity of substitution among varieties produced in the world.

⁵We follow the literature (see for instance Mendoza, 2010) by assuming working capital is used to finance imported inputs. Other types of working capital, used for instance to finance the wage bill or to rent physical capital, would work in the same way. We note also that it is essential to introduce working capital in the credit constraint for the model to generate an import-GDP ratio comparable with the data.

⁶Empirical evidence shows that emerging economies have borrowed primarily in foreign currency (for instance see, Jeanne, 2003) and do so using short term bonds (see Broner, Lorenzoni, and Schmukler, 2013b). In the literature this situation is called ‘liability dollarization’ and plays an important role in the financial accelerator that leads to sudden stops in our model. If bonds were denominated in local currency, during a sudden stop the value of outstanding debt would fall, mitigating the effects of crises. We do not explicitly model the currency composition of foreign debts, as in Engel and Park (2017), for instance.

of a fiscal tax on intermediate imports, which is discussed below. 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. 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 \(1997\)](#).⁷

Firm-households are equal owners of domestic firms and consequently they make identical consumption and borrowing decisions. We write the decisions for the wholesale good producer explicitly. The representative firm-household faces the budget constraint

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

$$+ [P_{M,t} M(Y_{F,t}, L_t, K_t) - (1 + \tau_N) Y_{F,t} P_{F,t}^* \mathcal{E}_t - W_t L_t - R_{K,t} K_t] + D_t. \quad (6)$$

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 $B_{t+1}^* \mathcal{E}_t / R_{t+1}^*$. As in the literature ([Bianchi and Mendoza, 2010](#); [Farhi and Werning, 2012](#); [Farhi and Werning, 2014](#)), we assume that the 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 (if $\tau_{c,t}$ is negative this represents a subsidy to foreign borrowing). The right-hand side shows various income sources, including labor income $W_t l_t$, (W_t is the nominal wage) 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 . As noted above, we assume that wholesale producers are taxed by the fiscal authorities on their purchases of imported intermediate inputs at rate τ_N . This tax is set so as to reduce the demand for intermediate

⁷The 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 \(2016\)](#). Online Appendix F gives a micro-founded rationale for this collateral constraint.

imports to the level where the country optimally exploits its monopoly power in its export good. Online Appendix B provides a formal derivation of the tax.⁸ The wholesale good production M_t is given by equation (1).

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., $q_t = Q_t/P_t$, $w_t = W_t/P_t$. The CPI gross inflation rate is defined as $\pi_t = P_t/P_{t-1}$ and the real exchange rate (also the terms of trade) is $e_t = \mathcal{E}_t P_t^*/P_t$. Higher e_t implies depreciation of the real exchange rate. The household optimality condition for labor supply reads

$$w_t = \chi l_t^\nu. \quad (7)$$

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

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

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

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

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

⁸This is a technical device which allows us to isolate the terms of trade externality from the pecuniary externality specific to the borrowing constraint. τ_N is set at a level so that in normal times, the policy authorities have no further incentive to manipulate the economy's terms of trade. In fact, the endogenous movement in the terms of trade is not necessary for the key results of the paper. In particular, even without endogenous terms of trade, the key results on capital controls and the absence of macroprudential policy remain. We can see this in the analysis below by looking at the special case where $\rho \rightarrow \infty$.

comes from a looser borrowing constraint when $\mu_t > 0$.

The optimal demand for intermediate inputs, labor, and capital for is given implicitly by

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

$$p_{M,t} \frac{\alpha_L M_t}{L_t} = w_t, \quad (12)$$

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

Note that (11) implies that the cost to the household-firm of importing intermediate inputs is increasing in the real exchange rate (which is also equivalent to the terms of trade in this setting) 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. w_t denotes the real cost of labor faced by a firm.

Finally, the complementary slackness condition becomes

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

where we have replaced the 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. 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 $Y_t(i)$

$$Y_t(i) = \left(\frac{P_t(i)}{P_t} \right)^{-\theta} Y_t. \quad (15)$$

The technology employed by a firm i is linear

$$Y_t(i) = M_t(i). \quad (16)$$

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 $\phi \left(\frac{P_t(i)}{P_{t-1}(i)} \right)$ (see [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 final good producers. In the cost function $\phi(\cdot)$, ϕ_P characterizes the Rotemberg price adjustment cost (see [Rotemberg, 1982](#)) and γ captures the asymmetry of price adjustment cost. ⁹

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 (15) and the production technology (16). The stochastic discount factor is given by $\Lambda_{h,t} = \beta^{t-h} U_c(t) / U_c(h)$ with $h \leq t$.

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

⁹When $\gamma > 0$, the price adjustment displays a pattern of upward rigidity, while $\gamma < 0$ is for downward rigidity. One can show that the second-order approximation to $\phi(\cdot)$ is $\frac{\phi_P}{2} \left(\frac{P_t(i)}{P_{t-1}(i)} - \pi \right)^2$, which is exactly the Rotemberg quadratic price adjustment cost. The asymmetry of price adjustment cost follows from the third-order component of $\phi(\cdot)$, $\frac{\phi_P \gamma}{6} \left(\frac{P_t(i)}{P_{t-1}(i)} - \pi \right)^3$.

for price-setting can be simplified as

$$Y_t [(1 + \tau_H) - \theta (1 + \tau_H - p_{M,t})] - \phi_P Y_t \pi_t \frac{\exp(\gamma(\pi_t - \pi)) - 1}{\gamma} + E_t \left[\Lambda_{t,t+1} \phi_P \pi_{t+1} Y_{t+1} \frac{\exp(\gamma(\pi_{t+1} - \pi)) - 1}{\gamma} \right] = 0. \quad (17)$$

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

$$\int_0^1 Y_t(i) di = \int_0^1 M_t(i) di = M_t. \quad (18)$$

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

$$Y_t [1 - \phi(\pi_t)] = C_t + X_t. \quad (19)$$

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

2.4. Government policy

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

$$T_t = - \left(\tau_H Y_t + \tau_N Y_{F,t} e_t + \frac{\tau_{c,t} b_{t+1}^* e_t}{R_{t+1}^*} \right) P_t \quad (20)$$

The government chooses the production subsidy τ_H , 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:

$$R_{t+1} = R \left(\frac{\pi_t}{\pi} \right)^{\alpha_\pi} \left(\frac{Y_t}{Y} \right)^{\alpha_Y}. \quad (21)$$

A variable without a superscript denotes the value of that variable at the deterministic steady state.

Combining firm-households' budget constraints (6) with the relevant market clearing conditions and taxation policy (20), we see that trade surpluses lead to net foreign asset accumulation:

$$X_t - e_t Y_{F,t} = \left(\frac{b_{t+1}^*}{R_{t+1}^*} - b_t^* \right) e_t. \quad (22)$$

In the main analysis below, we assume that exogenous shocks follow Markov processes and focus on the stationary competitive equilibrium.

Definition 1. *A **recursive stationary competitive equilibrium** consists of policy functions for allocations $C(b^*; Z)$, $k'(b^*; Z)$, $b'(b^*; Z)$, $b^{*'}(b^*; Z)$, $L(b^*; Z)$, $Y_F(b^*; Z)$, $K(b^*; Z)$, $M(b^*; Z)$, $Y(b^*; Z)$ and policy functions for prices $w(b^*; Z)$, $q(b^*; Z)$, $\mu(b^*; Z)$, $r_K(b^*; Z)$, $e(b^*; Z)$, $\pi(b^*; Z)$, $p_M(b^*; Z)$, with exogenous state vector $Z = (A, \kappa, R^*)$ and future variables with t , given fiscal subsidies τ_H and τ_N , monetary policy $R'(b^*; Z)$ and capital inflow tax $\tau_c(b^*; Z)$ chosen by the fiscal authority and monetary authority, such that*

1. *The allocation $C(b^*; Z)$, $k'(b^*; Z)$, $b'(b^*; Z)$, $b^{*'}(b^*; Z)$, and $L(b^*; Z)$ solves households' problem, given prices and capital control policy $\tau_c(b^*; Z)$;*
2. *The allocation $L(b^*; Z)$, $Y_F(b^*; Z)$, $K(b^*; Z)$, and $M(b^*; Z)$ solves wholesale producers' problem, given prices and import subsidy τ_N ;*
3. *The final good producers optimally set price inflation $\pi(b^*; Z)$ and output $Y(b^*; Z)$, given other prices and pricing subsidy τ_H ;*
4. *Wages and prices $w(b^*; Z)$, $q(b^*; Z)$, $r_K(b^*; Z)$, $p_M(b^*; Z)$, $e(b^*; Z)$ clear labor market, capital market, rental market, wholesale good market and final good market respectively. $\mu(b^*; Z)$ satisfies collateral constraint.*

3. Time Consistent Optimal Policies

This section starts with formal definitions of optimal policy problems under discretion, and then provides the main analytical results of the paper. All of proofs of the results below are delegated to the Online Appendix.

3.1. Optimal monetary policy

We first explore the case where the policy-maker's options are restricted to monetary policy. The monetary authority maximizes a representative household's lifetime utility. The optimal policy is implemented only by a monetary policy instrument, the nominal interest rate R_{t+1} , within a regime of flexible exchange rates. We solve for the optimal, time-consistent optimal policy under discretion and look for a Markov-perfect equilibrium. The current planner takes as given the decisions of future planners but internalizes how those choices depend on the future debt level b_{t+1}^* , which is chosen today.

The competitive equilibrium is constrained by the two constant tax/subsidy rates $\tau_H = 1/(\theta - 1)$ and $\tau_N = 1/(\rho - 1)$ as defined above. Given these tax-subsidies, the monetary authority chooses the path for the domestic nominal interest rate R_{t+1} to maximize a representative household's life-time utility. Let the value function for a representative domestic firm-household be $V(b_t^*, Z_t)$ where Z_t represents the set of exogenous state variables. The problem faced by the monetary planner is defined as follows,

Definition 2. (*Optimal monetary policy under discretion.*) *The planner chooses optimal domestic nominal interest rate R' as the policy instrument to maximize utility of the representative household, $V(b^*, Z)$, expressed as*

$$V(b^*, Z) = \max_{\{\Xi\}} U(\tilde{C}) + \beta E_t V(b^*, Z'), \quad \text{with } \tilde{C} \equiv C - \chi \frac{L^{1+\nu}}{1+\nu}$$

with

$$\Xi \equiv \{L, C, M, Y_F, Y, b^*, q, \mu, r_K, e, p_M, \pi, R'\},$$

subject to the set of competitive equilibrium conditions (1), (6)-(14), (16)-(17) and market clearing conditions.¹⁰

The planner takes as given the function that determines future control variables (such as C' and q') as functions of b^{*t} ; for this reason, a key aspect of decision-making under discretion is how the choice of debt issued today will affect the choices of future governments.

The model contains two types of frictions: sticky prices, and price sensitive collateral constraints. An optimal monetary policy must represent a balance between the two. In addition, since the dynamics of the economy with a binding collateral constraint are quite different from the case when the constraint is slack (as shown in section 5 below), we would expect that the optimal monetary policy depends on whether the constraint binds or not.

The model has three kinds of shocks: productivity shocks, foreign interest rate shocks, and shocks to the collateral constraint (or ‘leverage shocks’). Given this structure, we can infer that absent any financial frictions (or equivalently, if the credit constraint (5) is never binding), then the optimal monetary policy will be characterized by an inflation rate always equal to the target. That is, $\pi_t = \pi$ will hold continually. This follows from the standard properties of New Keynesian models where (with appropriate taxes/subsidies to remove steady state distortions), price stability (or in this case, inflation equal to target) eliminates all ‘gaps’. Nevertheless, one may expect that the introduction of financial constraints may alter this conclusion. With occasionally-binding collateral constraints, there is another distortion or market failure in the economy, due to a pecuniary externality. Individual household-firms will ignore the effect of their consumption-savings decisions on asset prices, while, with binding collateral constraints, these asset price changes have first order effects on welfare. The question is whether optimal monetary rule will depart from price stability in order to correct this pecuniary externality.

The following proposition provides the answer to this question.

Proposition 1. *Without working capital in the collateral constraint ($\vartheta = 0$), the optimal monetary*

¹⁰The full set of first order conditions for this optimization problem are listed in Online Appendix A.

policy under discretion strictly stabilizes inflation $\pi_t = \pi$.

The formal proof of the proposition is shown in the Online Appendix. The intuition is quite easy to see however. A deviation from inflation stability is useful in this model only insofar as it can relax the collateral constraint facing household-firms (either now or in the future). While private agents take the expected future price of capital as given, the monetary authority recognizes that the expression $\left\{ \frac{q_{t+1}k_{t+1}}{e_{t+1}} \right\}$ in the collateral constraint (5) depends on b_{t+1}^* , the level of foreign bonds brought into period $t + 1$. If the collateral constraint is binding, the monetary authority wants to increase b_{t+1}^* above the competitive equilibrium level in order to relax the collateral constraint. Without working capital in the collateral constraint, we can rewrite constraint (5) in the form

$$-b_{t+1}^* \leq \kappa_t E_t \left\{ \frac{q_{t+1}k_{t+1}}{e_{t+1}} \right\}. \quad (23)$$

In a discretionary equilibrium, the monetary authority takes the right-hand side of this expression as a given function of b_{t+1}^* . As a result, from the perspective of the monetary authority equation (23) completely determines b_{t+1}^* if the constraint binds, and thus, b_{t+1}^* cannot be affected by a deviation from inflation stability. The constrained optimal policy is thus to maintain strict inflation stability.

If working capital appears in the credit constraint (5), strictly stabilizing inflation in crisis is no longer an optimal policy, in general. In that case, monetary policy is able to shift external borrowing across periods by altering intra-period borrowing–working capital when the collateral constraint is binding (proposition 2). Moreover, we show in the quantitative analysis below (see section 4) that the monetary authority raises inflation above target during a crisis (when the collateral constraint is binding). A higher rate of inflation will lead to a real depreciation and an increase demand for intermediate imports. The increased use of working capital will in effect crowd out private sector borrowing, allowing the monetary authority to partially correct the pecuniary externality associated with inter-temporal borrowing. We summarize this argument in the following proposition:

Proposition 2. *If there exists working capital in the collateral constraint $\vartheta > 0$, the optimal*

monetary policy under discretion strictly stabilizes inflation $\pi_t = \pi$ when $\mu_t = 0$, while it deviates from its target $\pi_t \neq \pi$ if $\mu_t > 0$.

The proposition contains an important further implication of the optimal discretionary monetary policy. When the collateral constraint is non-binding, the monetary authority will maintain strict inflation stability, whatever is the probability that the constraint will bind in the future.¹¹ An intuitive way to see the reason for this is that in the case of a non-binding constraint, the private sector Euler equation is independent of $E_t\mu_{t+1}$ (or any function of μ_{t+1}). Since the future multiplier does not appear in any of the other first order necessary conditions, there is no reason for the current monetary authority to depart from inflation stabilization, when the collateral constraint does not currently bind.

Proposition 2 then implies that there is no role for monetary policy as a macro-prudential tool. The monetary authority should not try to ‘lean against the wind’ in advance of a financial crisis, when policy is made in the absence of commitment. Departing from inflation stabilization has no benefit unless the economy is currently borrowing-constrained.

3.2. Optimal monetary and capital control policies

We now contrast the planner’s problem with an expanded policy menu where the policy maker chooses both monetary policy and a policy for capital flow taxes. We focus again on the time-consistent optimal Markov policy under discretion. However we now allow the optimal policy to be implemented both by a monetary policy instrument R_{t+1} and a capital inflow tax $\tau_{c,t}$. The problem is equivalent to the optimal monetary policy problem except that the Euler equation for foreign bonds is omitted as a constraint.

Definition 3. (*Optimal monetary policy and capital control under discretion.*) *The planner chooses the nominal interest rate R' and the capital inflow tax τ_c to maximize a represen-*

¹¹The Online Appendix shows that if the constraint binds for the private sector’s decision it must simultaneously bind for the monetary authority.

tative household's welfare, $V(b^*, Z)$,

$$V(b^*, Z) = \max_{\{\Xi\}} U(\tilde{C}) + \beta E_t V(b^*, Z'), \quad \text{with } \tilde{C} \equiv C - \chi \frac{L^{1+\nu}}{1+\nu}$$

with

$$\Xi \equiv \{L, C, M, Y_F, Y, b^*, q, \mu, r_K, e, p_M, \pi, R'\},$$

subject to the set of competitive equilibrium conditions (1), (6)-(9), (11)-(14), (16)-(17) and market clearing conditions.

Given the solution to the extended planners problem, the optimal capital inflow tax τ_c is inferred from the consumer Euler equation for external borrowing. The solution is summarized in proposition 3 below.

Proposition 3. *When the social planner sets monetary policy and the capital inflow tax without commitment, a) the optimal monetary policy strictly stabilizes inflation $\pi_t = \pi$, and b) the intertemporal capital inflow tax satisfies,*

$$1 = E_t \left\{ \beta \frac{U_c(t+1)}{U_c(t)} \frac{e_{t+1}}{e_t} R_{t+1}^* \right\} + \mu_t R_{t+1}^* + \tau_{c,t}, \quad (24)$$

with

$$\tau_{c,t} \equiv \frac{\mu_t R_{t+1}^*}{\rho} \left[-1 + (\rho - 1) \kappa_t \frac{\partial(q_{t+1}/e_{t+1})}{\partial b_{t+1}^*} \right], \quad (25)$$

given constant import tax $\tau_N = \frac{1}{\rho-1}$ and constant pricing subsidy $\tau_H = \frac{1}{\theta-1}$.

Part a) is quite intuitive given Propositions 1 and 2. Monetary policy departs from inflation stability only to exploit the presence of working capital in the collateral constraint, so as to influence foreign borrowing. An optimal capital inflow tax can achieve this more effectively, leaving the monetary authority free to stabilize inflation and avoid the distortions that arise when inflation departs from its target level.

For part b) of the proposition, first focus on condition (24). The left hand side measures the cost

of increasing saving in the current period (accumulating net foreign assets) in terms of the foreign good. The right hand side measures the benefits as perceived by the planner. These are three-fold. First, there is the increase in net wealth brought into the next period, which increases utility through an increase in consumption. Second, there is the benefit to private households in terms of relaxing the current collateral constraint, measured by the second expression on the right hand side. The third expression, denoted $\tau_{c,t}$, decomposed in equation (25), captures the net additional benefit to foreign assets perceived by the planner, and thus represents the incentive for the planner to intervene directly in capital flows. We see this term is comprised of two parts, one negative and one positive. Thus, in principle, the planner may wish to set a negative or positive tax on capital inflows (subsidize or tax foreign borrowing). Moreover, the relative strength of the two components depends on the foreign elasticity of demand for home exports ρ . With a very low elasticity, it is more likely that $\tau_{c,t} < 0$, so that foreign borrowing is subsidized. On the other hand, as ρ rises, given that $E_t(\partial(q_{t+1}/e_{t+1})/\partial b_{t+1}^*) > 0$, it is more likely that $\tau_{c,t} > 0$.

To see the logic behind equation (25), take the first component of $\tau_{c,t}$. This arises due to the presence of the constant import tax $1 + \tau_N$ designed to offset the terms of trade externality. With an import tax, private households face a different marginal benefit of an additional unit of borrowing than does the planner. When the collateral constraint binds, private households perceive an additional unit of debt has a cost μ_t/e_t in terms of domestic consumption. But the planner facing the same calculation takes into account that an additional unit of debt will increase consumption by $e_t(1 + \tau_N)$, which is the marginal product of intermediate imports in production. As a result, the planner's cost of debt is $\mu_t/(e_t(1 + \tau_N))$, which is lower than that of the private sector. For this reason alone, the planner would wish to *subsidize* borrowing, when the collateral constraint binds. The lower is ρ , the elasticity of foreign demand for domestic exports, the higher is τ_N , and the higher is the motivation to subsidize foreign borrowing.

Against this, nonetheless, is the fact that when the collateral constraint binds, the planner will wish to take actions to relax the constraint. She can do this by increasing net foreign assets brought into the next period, thereby increasing period $t + 1$'s capital price, since $\partial(\frac{q_{t+1}}{e_{t+1}})/\partial b_{t+1}^* > 0$. This

effect depends on the planner explicitly taking account of the equilibrium mapping from net foreign assets to future asset prices, which is implicit in the time-consistent policy choice. These choices in turn relax the collateral constraint in the current period. This margin is not taken into account by private households (since it is a pecuniary externality), so the desire to raise period $t + 1$ capital price through this channel leads the planner to impose a capital inflow tax if the period t collateral constraint binds. In the calibrated model below, we find that the second factor is dominant, so that the time consistent planner will impose a capital inflow tax if $\mu_t > 0$.

Result 1. *When ρ is large enough, $\tau_{c,t} > 0$ if $\mu_t > 0$ under discretion, given constant import tax $\tau_N = \frac{1}{\rho-1}$ and constant pricing subsidy $\tau_H = \frac{1}{\theta-1}$.*

Note that the planner ignores the impact of a capital tax on the current asset price q_t , since this has no direct bearing on the planner's problem.

Result 2. *If $\mu_t = 0$, then $\tau_{c,t} = 0$, given constant import tax $\tau_N = \frac{1}{\rho-1}$ and constant pricing subsidy $\tau_H = \frac{1}{\theta-1}$.*

The intuition for this result is similar to the case with monetary policy. Suppose the constraint is not binding today $\mu_t = 0$ but may bind in some state in period $t + 1$. While we might anticipate that the planner would wish to take actions to reduce the probability of a binding constraint in the next period, in fact, the period $t + 1$ multiplier μ_{t+1} does not appear in the planner's first order conditions. As a result, when $\mu_t = 0$, a capital inflow tax will reduce current consumption by reducing borrowing. But since the constraint is not binding there is no offsetting increase in borrowing capacity that would allow higher current consumption. Moreover, the effect of a current capital inflow tax on q_{t+1} through the indirect mechanism in equation (8) above has no direct benefit in terms of relaxing next period's constrained borrowing. While the planner would like to increase q_{t+2} , this price is not under her control, since it depends on the next period's planner's actions. Hence, when the current collateral constraint does not bind, there is no benefit to a capital inflow tax.

3.3. Alternative forms of collateral constraints

An important feature of our results is the nature of the collateral constraint (5). In particular, our framework requires collateral to be valued at the expected price of capital in the period the loan is due, q_{t+1} . Many of the results would be different if collateral were instead valued at q_t , which is the constraint used in [Bianchi and Mendoza \(forthcoming\)](#). In Online Appendix G, we illustrate how a simple version of the model with current-valued collateral alters two key results of our paper. First, if the constraint is currently binding, the planner generally wishes to subsidize rather than tax capital inflows, as a subsidy to capital inflows increases the current value of collateral through its effect on the stochastic discount factor. Secondly, the Lagrange multiplier μ_{t+1} directly enters the planner's first order conditions, and the planner can then directly influence the constraint in the next period by altering the level of foreign debt. Thus, when $E_t\mu_{t+1} > 0$, the planner would engage in ex ante interventions even if $\mu_t = 0$; thus, whether one obtains macroprudential policy or not depends critically on which price is relevant for the valuation of collateral.

4. The Quantitative Model

We now move on to a quantitative analysis of the model. We first discuss the calibration and the data sample used as a comparison for the model simulations.

4.1. Calibration

We benchmark the quantitative model against a group of emerging market economies. One set of parameters is calibrated using standard estimates from the existing literature, while a second set is estimated from our data sample. Table 1 lists parameter values in our baseline model.

In the first set of parameters, we include the subjective discount factor, β , which we set equal to 0.9, in line with the literature for emerging economies ([Uribe and Yue, 2006](#); [Aguiar and Gopinath, 2007](#)), implying an annual real interest rate of 10%. 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 set of parameters is estimated from macro data on emerging market economies. We use these data to characterize a typical sudden stop scenario for emerging countries.¹² Online Appendix I provides detailed information about variables we use. Following the literature, we define a “sudden stop” as an event where, relative to trend, (1) the current account reversal exceeds 1.5 standard deviations, and (2) GDP falls (relative to trend) more than 1.5 standard deviations.

Parameters in the production function are set to match the average import share of 12% of GDP, labor share of 65% of GDP, and the external debt-GDP ratio 55% in our data sample. These ratios are also consistent with the literature (Hanson, 2012 and Mendoza, 2010). Given the leverage specification above and relevant ratios, 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).¹³ The equilibrium labor supply in normal times (without credit constraints) is normalized to be one, which implies that $\chi = 0.4$.

Although inflation experiences in emerging market economies are quite heterogeneous, stabilizing inflation is still a primary goal for central banks in these economies. For simplicity, we set the target inflation 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%.

The real exchange rate is normalized to be one in a deterministic steady state when the collateral constraint binds, which requires $\zeta_t^* = 0.1037$.

¹²Our data sample covers 26 emerging market economies, including Argentina, Bangladesh, Brazil, Bulgaria, Chile, China, Colombia, Egypt, India, Indonesia, Kazakhstan, Malaysia, Mexico, Mauritius, Nigeria, Pakistan, Peru, Philippines, Romania, Russia, South Africa, Thailand, Turkey, Ukraine, Venezuela and Vietnam for the period of 1980 – 2014.

¹³Note that ϑ captures the role of working capital only when credit constraints bind. This value is higher than Mendoza (2010) and Bianchi and Mendoza (forthcoming), but is consistent with Uribe and Yue (2006).

We model both domestic productivity and the foreign interest rate as AR(1) processes:

$$\ln(A_{t+1}) = (1 - \rho_A) \ln(A) + \rho_A \ln(A_t) + \epsilon_{A,t+1} \quad (26)$$

$$\ln(R_{t+1}^*) = (1 - \rho_R) \ln(R^*) + \rho_R \ln(R_t^*) + \epsilon_{R,t+1}. \quad (27)$$

Mean productivity is normalized to be one $A = 1$ and the world yearly real interest rate $R^* = 1.05$ (Mendoza, 2010). We assume that the local productivity shock is uncorrelated with the the foreign interest rate shock.¹⁴

The parameters of (26) and (27) are determined as follows. We estimate the persistence and innovation parameters for (26) based on the total factor productivity for emerging economies in our data sample, and obtain the standard deviation of innovations $\sigma_A = 0.0295$ and persistence $\rho_A = 0.60$. For (27), we use of the real effective federal funds rate in the US as the foreign interest rate faced by the small economy. This gives us a a standard deviation $\sigma_R = 0.0133$ and persistence $\rho_R = 0.42$. We then discretize the continuous AR(1) process into a two-state Markov chain based on Tauchen and Hussey (1991) in the computation of the model.

The leverage shock κ_t determines the borrowing capacity of a country. A sudden decline of leverage κ_t contracts external borrowing directly. We use the change of κ_t to match the change of external debt-GDP ratios in the data sample. To simplify the calculation, we take a two-state Markov chain to capture the leverage shock: $\kappa_L = 0.31$ and $\kappa_H = 0.52$.¹⁵ The transition matrix is given by

$$\Pi = \begin{bmatrix} p_{L,L} & 1 - p_{L,L} \\ 1 - p_{H,H} & p_{H,H} \end{bmatrix}.$$

We set $p_{L,L} = 0.7323$ and $p_{H,H} = 0.9722$ so that the duration of a high leverage regime equals 9

¹⁴Allowing for correlated shocks would slightly change households' precautionary savings but would not alter the main message of the paper.

¹⁵The credit constraint does not bind at high leverage κ_H , so the value of κ_H does not matter. Mendoza (2010) uses a similar leverage $\kappa_t = 0.2$ and $\kappa_t = 0.3$ in his analysis. These two states are also consistent with the leverage change from pre-crisis period to crisis period for the corporate leverages in Asian emerging economies (IMF, 2014) as well.

years and the unconditional probability of a low leverage regime is 9.4%. The model matches the frequency of sudden stops in our data sample: the probability of a financial crisis generated by the model is 3.8 percent, close to the 4.3 percent in the data, implying that a typical leverage crisis will happen every ten years.

4.2. *Solution method*

We solve the model using time iteration, as in [Coleman \(1990\)](#) and [Benigno et al. \(2013\)](#). When necessary, we use a homotopy algorithm to solve the system of nonlinear equations ([Eaves and Schmedders, 1999](#); [Devereux and Yu, 2014](#)). To solve the planner’s problems we follow [Benigno et al. \(2012, 2016\)](#) and solve the nonlinear optimization problem using feasible sequential quadratic programming.¹⁶ All functions are approximated using B-splines. Online Appendix H provides details about the algorithm for solving the model.

5. Quantitative Results

We now move on to the quantitative results of this paper. We first present the results in the competitive equilibrium with strict inflation targeting and then the results under optimal monetary policy alone. The scenario of optimal monetary and capital controls policies is followed next. The last subsection compares welfare under various policy combinations.

5.1. *Competitive equilibrium with strict inflation targeting*

We first assume a simple policy rule whereby the central bank sets inflation equal to the target: i.e. an inflation targeting rule. This rule is equivalent to the Taylor rule described above, but with a very high weight on inflation deviations from target. From [Proposition 1](#), we already know that this is an optimal monetary rule in the case of $\vartheta = 0$, and also, from [Proposition 2](#), strict inflation targeting is optimal when the collateral constraint is not binding.

¹⁶Specifically, we use the NLPQLP routine developed by [Schittkowski \(2014\)](#), who we thank for providing the code.

The model exhibits the characteristics of Fisherian debt-deflation described in previous literature. A leverage shock that causes the collateral constraint to bind leads to a spike in the Lagrange multiplier, forcing debt to fall, leading also to a fall in import demand, output, and current and expected future asset prices. This in turn exacerbates the shock by further tightening the collateral constraint.

Figure 1, illustrates the policy mapping from initial debt levels to the endogenous variables of the model, conditional on different shock outcomes. This figure displays the effect of a shift from the best shock to the worst shock, given the existing level of assets b_t^* .¹⁷ The panels of the figure 1 present the outcomes for current asset prices, the real exchange rate, the Lagrange multiplier and borrowing. Both q_t and $E_t(q_{t+1}/e_{t+1})$ declines sharply when b_t^* is in the region where the constraint binds. In each panel we see that the collateral constraint is substantially more likely to bind, for given b_t^* , for the worst shock states. As the collateral constraint becomes binding, there is a kink in the policy function. For instance, given the realization of κ_t a fall in b_t^* which precipitates a binding constraint causes the mapping $b_{t+1}^*(b_t^*)$ to become flatter, as the collateral constraint reduces the borrowing capacity of the economy. By contrast, the mapping from b_t^* to production and output becomes steeper, as the binding collateral constraint increases the effective cost of imports.

What role does the real exchange rate play in the dynamics? From Figure 1, we see that as debt increases, for a given exogenous state, the economy experiences continued real exchange rate depreciation. Intuitively, given higher initial debt levels, the path of consumption must be lower and lower, and in order to replace this fall in demand for domestic goods, the real exchange rate must depreciate. This is associated with a gradual fall in intermediate imports, employment and output. As debt rises above the threshold where the collateral constraint binds, there is a sharper fall in consumption, and a steeper relationship between debt and the real exchange rate.

However, the real exchange rate plays an additional role in the borrowing constraint. As we noted above, the one period ahead expected value $E_t(q_{t+1}/e_{t+1})$ begins to decline sharply as external

¹⁷The ‘best shock’ refers to scenarios when domestic households face low foreign interest rate, high domestic productivity and high domestic leverage, while the ‘worst shock’ is the case with high foreign interest rate, low domestic productivity and low domestic leverage.

debt approaches the point where the collateral constraint will bind. An expectation that the collateral constraint will bind in the immediate future implies an anticipated future real exchange rate depreciation, which leads to a tightening of the present collateral constraint.

We can see the dynamics of a crisis in Figure 2, which presents a consecutive five-period window of ‘event analysis’. The event is defined in the following way: collateral constraints do not bind in the first two periods $t = -2, -1$, and then bind at period $t = 0$ and there are no restrictions on collateral constraints in the last two periods $t = 1, 2$. As the constraint binds in period 0 there is a sharp rise of the Lagrange multiplier, which precipitates a persistent decline in foreign debt and a steep fall in imported intermediates, labor, output, and consumption. The price of capital also falls sharply, and as noted, there is a substantial real exchange rate depreciation.

To compare the model with the data, we plot similar sudden stop events based on the average experiences of the emerging market economies over 30 years in our data sample. The dashed lines in figure 2 show that the competitive equilibrium with strict inflation targeting can basically capture the dynamics of output, the real exchange rate, import-GDP ratio and external debt-GDP ratio in the data.¹⁸

5.2. *Optimal monetary policy*

The quantitative analysis so far assumed that monetary policy follows a strict inflation targeting rule, whether the economy is in crisis or not (whether the collateral constraint is binding or not). We now explore the time consistent optimal monetary policy in the model with occasionally binding collateral constraints. As described in sub-section 3.1 above, we focus attention solely on the use of a monetary policy instrument (e.g. the nominal interest rate), for the moment assuming no possibility of a capital flow tax.

The equilibrium policy functions for the time consistent planner’s equilibrium are similar to figure 1 except for inflation (see figure 3). Again these policy functions describe the equilibrium mapping from net foreign assets to the endogenous variables, conditional on different values for the

¹⁸We could alternatively use the ratio of net foreign asset positions to GDP as a measure of current account reversal generated by the sudden stop. The event outcome looks very similar to the external debt-GDP ratio.

leverage shocks, but now this represents the mapping implied by the optimal monetary rule. Recall from Proposition 2 that when the collateral constraint does not bind (for instance, in the figure this requires that $b_t^* \geq -0.17$ for the worst shock), the optimal monetary rule is identical to strict inflation targeting.

As debt rises above the threshold level though, so that the collateral constraint is binding, monetary policy does diverge from the strict inflation targeting rule. Higher working capital induced by expansionary monetary policy crowds out external borrowing, when the credit constraint is binding, and allows the monetary authority, indirectly, to correct the pecuniary externality implicit in the credit constraint. Lower external debt implies higher future consumption and higher value of collateral, which in turn relaxes the current credit constraint. Figure 3 shows that in the case of the worst shock realization, as b_t^* falls below -0.17 , the policy maker raises the inflation rate above zero by less than one percent, and inflation rises monotonically with the level of external debt.

To give a better picture of the magnitudes of changes induced by optimal monetary policy, Figure 3 illustrates for each panel the ratio of the optimal monetary policy variable to the strict inflation targeting variable for the worst shock case. The panels in this figure state, for the worst shock case, the relative response of imports, employment, the real exchange rate, the price of capital, and external debt implied by the optimal monetary policy compared with the strict inflation targeting policy. Under the optimal monetary policy, imports and employment increase relative to the strict inflation targeting. The real exchange rate depreciates by more, and external debt is lower. However the quantitative effects of the monetary policy deviation from inflation targeting in the model are very small. With inflation costs exponentially increasing in the deviation of inflation from target, the welfare gains from addressing the pecuniary externality are quickly dominated by the departure from inflation targeting itself. Previous papers have noted that in many calibrated DSGE models of sticky prices, the quantitative departure from inflation stability implied by optimal policy is very minor (e.g. Goodfriend and King, 2001; Siu, 2004). In a model with both wage and price rigidity, inflation stability is not fully optimal, even without pecuniary externalities (see Devereux, Young, and Yu, 2015), and the impact of the monetary policy stimulus on real magnitudes during a crisis

can be much larger.

5.3. *Optimal monetary and capital controls*

We now combine monetary policy with capital controls, where the policy-maker may employ capital inflow controls with monetary policy responses. Proposition 3 established that capital controls will be used in place of active monetary policy in order to alleviate the pecuniary externality associated with the collateral constraint, when the constraint is binding. But given the nature of the collateral constraint, the key target for capital controls is the expected future collateral price, rather than the current price. As we now show, this opens up a key problem of time-consistency in policy.

We start by examining an ‘out of equilibrium’ choice of capital controls by a policy-maker who would choose to deviate from the optimal monetary policy equilibrium. Figure 4 describes the policy functions implied by the following experiment. Imagine that all future planners follow the time-consistent optimal monetary policy alone, without capital controls. But then, allow the current planner to choose an optimal capital flow tax, in addition to optimal monetary policy, conditional on the initial debt level and the exogenous state of the world. While this is not an equilibrium policy setting, since the current planner has a policy menu wider than do future planners, the experiment illustrates the incentive to use capital inflow taxes. Figure 4 shows that the planner will raise the capital inflow tax from zero, but will keep inflation equal to the target in all states. The rise in the capital tax raises net foreign assets, and increases expected next period capital price, relative to that in the optimal monetary policy. The relaxation of the collateral constraint implies that intermediate imports, labor and output fall by less in the crisis than under the optimal monetary policy. Nevertheless, Figure 4 also shows that the current capital price will fall relative to that in the optimal monetary policy case. The time t planner is indifferent to this however, since the collateral constraint at time t is unaffected by the time t capital price.

Nevertheless Figure 4 does not represent the equilibrium policy functions. In equilibrium, the planner in every period will have access to the capital inflow tax. How do the results change in an equilibrium where the capital tax is utilized in all periods with binding constraints? Figure

5 illustrates the results for the equilibrium policy game. Here we see a striking difference from Figure 4. Both the price of capital and the expected capital price to real exchange rate ratio (which governs the degree to which the collateral constraint binds) are systematically *lower* than that of the optimal monetary policy, even in states where the collateral constraint does not bind. As a corollary to this, net debt is everywhere below that of the optimal monetary policy; the economy has systematically lower borrowing in the time-consistent equilibrium with capital taxes. Since the capital price is lower in the economy with inflow taxes, the threshold debt level which causes the collateral constraint to bind is lower in this equilibrium as well. Finally, we see that, conditional upon the level of debt, the time-consistent equilibrium involves higher capital inflow taxes than the taxes chosen in the out-of-equilibrium experiment described above.

The key feature of capital inflow taxation is that in this setting, time-consistent optimal taxes are deployed in any state where the collateral constraint is binding, taking into account their ability to influence expected future asset prices, but ignoring their impact on current asset prices. In an equilibrium, this lowers asset prices uniformly, since financial markets are forward looking, and the possibility of future crisis events which trigger a rise in capital inflow taxes will reduce the equilibrium price of assets at any given period. With lower asset prices on average, at any given level of debt, the collateral constraint is more likely to be binding, conditional on the state of the world. This in turn leads households to increase precautionary saving, and the average debt level for the economy falls.

In the out-of-equilibrium experiment discussed above, we noted that the capital inflow tax cushioned the impact of a crisis on the real economy, leading to a higher level of output, labor and intermediate imports conditional on a given level of debt, and state of the world. Nonetheless in the equilibrium with time consistent inflow taxes, this situation is no longer necessarily the case. Figure 5 shows that, since the crisis is triggered at lower levels of debt, output, employment and imports may be lower than in the optimal monetary policy equilibrium conditional on the level of debt and the state of the world. Likewise, the real exchange rate is systematically higher, given a lower level of consumption and aggregate demand.

Figure 6 illustrates the crisis event analysis in the equilibrium with capital controls, and compares this with the outcome of the competitive equilibrium and the optimal monetary policy. The definition of a crisis is equivalent to that of Figure 2. With capital taxes, the policy maker completely eschews active monetary policy, and maintains a strict inflation targeting at all times. Instead, as described above, when the collateral constraint binds, the policymaker imposes a capital inflow tax here equal to approximately 11 percent. The tax leads to a fall in net external debt, which allows for a relaxation of the collateral constraint (the Lagrange multiplier rises by less than in the social planner’s equilibrium with optimal monetary policy). As a result the average crisis is less severe with the capital inflow tax.

5.4. Welfare gains

We now compare conditional welfare levels across the different policy regimes. The lifetime utility for a representative household in the small economy, conditional on the initial debt level and exogenous shocks, reads

$$Wel(b_0^*, Z_0) \equiv E_0 \left\{ \sum_{t=0}^{\infty} \beta^t U(\tilde{C}_t) \right\} = E_0 \left\{ \sum_{t=0}^{\infty} \beta^t \frac{\tilde{C}_t^{1-\sigma} - 1}{1-\sigma} \right\}. \quad (28)$$

We define a certainty equivalence of effective consumption $\widetilde{C}(b_0^*, Z_0)$ in a policy regime as

$$Wel(b_0^*, Z_0) = E_0 \left\{ \sum_{t=0}^{\infty} \beta^t \frac{\widetilde{C}(b_0^*, Z_0)^{1-\sigma} - 1}{1-\sigma} \right\} = \frac{\widetilde{C}(b_0^*, Z_0)^{1-\sigma} - 1}{1-\sigma} \frac{1}{1-\beta}.$$

Rearranging the equation yields

$$\widetilde{C}(b_0^*, Z_0) = [Wel(b_0^*, Z_0)(1-\sigma)(1-\beta) + 1]^{\frac{1}{1-\sigma}}. \quad (29)$$

Figure 7 shows the welfare gains for the “best” and “worst” states as previously described.¹⁹

¹⁹Let \tilde{C}^j denote the consumption certainty equivalence in regime j . Then $\left(\frac{\tilde{C}^j}{\tilde{C}^i} - 1\right) \times 100$ measures the percentage increase of effective consumption in regime i such that the household’s welfare in regime i is the same as that in

This figure presents welfare relative to that in the competitive equilibrium with strict inflation targeting, and as before, the evaluation is conditional on net external assets. Welfare for the optimal monetary policy is almost identical to that of the competitive equilibrium, but optimal policy does raise welfare very slightly relative to the competitive equilibrium, particularly for very high levels of net external debt where crises are more likely (recall that only in those periods does optimal policy deviate from inflation targeting).

By contrast, Figure 7 shows that welfare is unambiguously lower in the time-consistent planner's equilibrium with both optimal monetary and capital control policy. Moreover, the welfare losses are greater, the higher is the level of net external debts. Welfare gains are similar in shape across states, although are a bit larger in bad times. Furthermore, the relative welfare losses associated with capital controls are much larger in the bad state than in the good one.

6. Policy under Commitment

We have shown that without commitment, capital inflow taxes will be imposed in a crisis, and welfare will be lower, relative to a regime of optimal monetary policy without capital controls. How would the results differ in the case of commitment? While a full quantitative characterization of optimal policy under commitment is beyond the scope of our paper, in this section we explore several special cases which can illustrate the key differences between capital control policy under discretion and commitment in our environment. The Ramsey planner's problems for optimal monetary policy, and optimal monetary and capital control policies are defined in the Online Appendix.²⁰

We first present three general results implied by the optimal monetary and capital controls policy with commitment. These results can be inferred from the first order conditions for optimal policy under commitment, and do not require an explicit numerical solution of the model.

regime j .

²⁰Solving for the full stochastic Ramsey optimal policy under commitment would require a large increase in the number of state variables. [Farhi and Werning \(2014\)](#) study optimal capital controls under commitment in a world economy of many small open economies akin to [Gali and Monacelli \(2005\)](#) but with risk premium shocks. They find that dealing with a sudden stop requires a temporary subsidy on inflows and a tax on outflows.

Proposition 4. *The optimal policies under full commitment have the following properties: (i) When the policy maker uses only monetary policy, the optimal monetary policy will not follow inflation stability, even without working capital loans in the collateral constraint. (ii) When the policy maker uses both monetary policy and a capital inflow tax, the optimal monetary policy will not generally follow inflation stability. (iii) Neither monetary policy nor the capital inflow tax is macro-prudential.*

The proposition above makes it clear that the time-consistent optimal policy exhibits some special features - notably that of inflation stability. With commitment, where the policymaker takes into account past promises, it is in general desirable to depart from inflation stability (note that, absent any collateral constraint, inflation stability would be optimal with commitment, and no capital controls would be used). Moreover, this deviation will continue to hold even if the policy authority can impose capital inflow taxes in addition to changing interest rates.

The last claim in the proposition establishes one property of the model that remains unchanged - the policy authority is not forward looking, in the sense that neither active monetary policy nor capital controls will be followed in advance of a binding collateral constraint. By the nature of the constraint, whereby future asset prices determine the degree to which collateral for borrowing is valued, it is always better to wait until the constraint is binding before imposing capital taxes or departing from inflation stability. In the case of the capital tax, for instance, under commitment, the current government can promise to increase the capital price q_{t+2} , but it does so by using $\tau_{c,t+1}$; there is no reason to ‘move early’ since the current level of consumption does not need to be distorted and the future level of consumption only needs to be adjusted if the constraint actually turns out to bind.²¹ While the monetary authority may deviate from the inflation target if the credit constraint is not currently binding due to *past* commitment, that deviation reflects the memory of policy rather than the *forward looking* macroprudential role of policy.

²¹In [Jeanne and Korinek \(2013\)](#), collateral is valued at the *worst* asset price that obtains tomorrow; ex ante policy arises in their model because the government lacks sufficient instruments to deal with the binding constraint tomorrow. Imposing their constraint in our model would not change our results, but would substantially complicate the solution due to the possibility of discontinuities in the decision rules.

6.1. A simplified perfect foresight model

Now we go to a particular case of the model to illustrate how capital inflow taxes would be set under full commitment in policy making. We take a simpler version of the model with perfect foresight, and make the following additional two assumptions; a) prices are fully flexible and b) there is just one good in the world economy, so there is no terms of trade movements (equivalently, $\rho \rightarrow \infty$ in the original model). What is critical however, is that the future price of capital remains the determinant of the borrowing limit in the collateral constraint, as in equation (5).

To clearly illustrate the time inconsistency problem, we focus on a particular path for the economy in which (a) the collateral constraint does not bind for a large number of time periods such that the shadow values on the time t inter-temporal constraints are zero in the Ramsey planner's problem, (b) the collateral constraint binds at period t , $\mu_t > 0$ (μ_t is the private Lagrange multiplier for the collateral constraint), and (c) the constraints don't bind for the next few periods, $\mu_{t+1} = \mu_{t+2} = 0$. The optimality conditions and results are in Online Appendix E. We first establish that in this case, the Ramsey planner taxes capital inflows in period t . The tax rate is described by

$$\tau_{c,t} \frac{U_c(t)}{R_{t+1}^*} = -\beta \lambda_{2,t+1} q_{t+1} U_{cc}(t+1) > 0 \quad (30)$$

where $\lambda_{2,t+1}$ is the planner's Lagrange multiplier (shadow value) for the consumption Euler equation for capital in period $t+1$, and we can prove that $\lambda_{2,t+1} = \frac{\mu_t K_t}{\beta U_c(t+1)} > 0$, and $U_{cc}(t+1)$ the derivative of marginal utility of consumption. This equation states that the marginal cost of tax equals the marginal benefit from relaxing current credit constraint.

Furthermore, the Ramsey planner will commit to subsidize capital inflows in period $t+1$,

$$\tau_{c,t+1} \frac{U_c(t+1)}{R_{t+2}^*} = \frac{\lambda_{2,t+1} q_{t+1} U_{cc}(t+1)}{R_{t+2}^*} + \beta \lambda_{2,t+1} U_{cc}(t+2) r_{K,t+2} < 0. \quad (31)$$

This equation states that the marginal cost of subsidy equals the marginal benefit from honouring the commitment. When the shadow values of the time t intertemporal constraints equal zero ($\lambda_{2,t} = 0$), the Ramsey planner at period t only considers the effect of its policy on current and

future periods. When the credit constraint binds at period t , the best response is to tax capital inflows to reduce future debt repayments and increase the future value of collateral, and thereby relax the current borrowing constraint. At the same time, the Ramsey planner will commit to a future capital inflow subsidy, even when the collateral constraint does not bind in the future. Such a subsidy increases future capital prices and consequently relaxes the current borrowing constraint.²²

This example shows a stark contrast with our previous results under policy discretion. In that case the planner will never impose capital controls (positive or negative) if the credit constraint is not currently binding ($\mu_t = 0$). By contrast, with commitment the planner will subsidize capital inflows immediately in the immediate aftermath of the binding constraint. This tension is the source of the time-inconsistency of optimal policy, since a planner with discretion would ignore the promise to subsidize the inflows once the crisis has passed.

6.2. *Ad hoc capital inflow subsidies*

In order to establish the potential welfare benefits of commitment, we now return to the full dynamic quantitative model and postulate a simple rule for setting capital inflow subsidies that raises welfare relative to the competitive equilibrium without capital controls.

We conjecture a simple but operational capital inflow subsidy, $\tau_{c,t} = -\varsigma\mu_t$, for a small positive constant ς , together with monetary policy of strict inflation targeting.²³ This capital inflow subsidy is tied to the severity of a crisis. A deeper crisis requires a larger subsidy to restore borrowing capacity and to maintain a higher consumption than that without a subsidy in consequence. We assume that policymakers honor this capital control policy in each period. Although the rule is in effect only in a crisis (and thereupon, from the previous example, it is unlikely to be a fully optimal rule with commitment), the capital inflow subsidy affects households' borrowing and consumption both in crises and in normal times.

²²We verify that $-\tau_{c,t+1} > \tau_{c,t}$ in Online Appendix E. That is, the future capital inflow subsidy would be more aggressive than the current tax in relaxing the current collateral constraint.

²³We also try alternative simple rules, including small constant subsidy $\tau_{c,t} = -\varsigma$, subsidy in normal times $\tau_{c,t} = -\varsigma I_{\mu_t=0}$, with indicator function $I = 1$ if $\mu_t = 0$. All of these rules together with strict inflation target monetary policy generate higher welfare than the optimal monetary policy alone.

Figure 8 displays policy functions under commitment with $\varsigma = 0.2$ when monetary policy maintains inflation strictly equal to the targets, and the exogenous shocks lead to the worst possible state.²⁴ Subsidizing capital inflows in a crisis increases effective consumption for every given level of debt. Higher effective consumption leads to a higher current capital price and expected ratio of future capital price to future real exchange rate, which in turn expands borrowing capacity and increases the cutoff debt level that triggers the binding collateral constraint. Compared with the competitive equilibrium without capital inflow tax/subsidy, imports, employment and output are higher when capital inflow subsidy is in place. Therefore, a higher borrowing capacity and a higher effective consumption imply higher welfare for domestic households (see figure 9).

7. Conclusion

The dangers of high capital flow volatility and sudden stops have led economists to promote the use of capital controls as an addition to monetary policy in emerging market economies. This paper has studied the optimal conduct of monetary policy and capital controls during a ‘Sudden Stop’ engineered by a binding collateral constraint. We highlight several main results here in the conclusion. First, inflation targeting is optimal outside Sudden Stops, while during a financial crisis it is optimal to generate some domestic inflation; this result comes from the absence of a tool designed specifically to deal with the underlying causes of the crisis (the financial accelerator). Second, capital controls are suboptimal but will be used in a time-consistent equilibrium, and consequently should not be placed under the control of the monetary authority. Third, the case for ex ante intervention is heavily dependent on arbitrary choices regarding the valuation of collateral and therefore could be related to the optimal choice of financial regulation.

There are many extensions that we plan to consider going forward. First, it’s worth to explore the full dynamics of the optimal policy under commitment. Second, many emerging economies combine interest rate rules with capital and reserve requirements as monetary policy. To that end,

²⁴We do not explore the optimal level of ς . For smaller or larger than $\varsigma = 0.2$ capital inflow subsidies, we obtain the same qualitative results.

it's important to incorporate such financial regulation as part of macro-prudential instruments into a full dynamic model. Third, emerging markets face monetary and fiscal spill-overs from advanced economies. It would be interesting to explore how policy makers in emerging markets respond to such spill-overs when there are financial market imperfections.

- Aguiar, M., Gopinath, G., 2007. Emerging Market Business Cycles: the Cycle is the Trend. *Journal of Political Economy* 115, 69–102.
URL <http://ideas.repec.org/a/ucp/jpolec/v115y2007p69-102.html>
- Aruoba, S. B., Cuba-Borda, P., Schorfheide, F., July 2013. Macroeconomic Dynamics Near the ZLB: A Tale of Two Countries. Working Paper 19248, National Bureau of Economic Research.
URL <http://www.nber.org/papers/w19248>
- Bacchetta, P., van Wincoop, E., March 2000. Capital Flows to Emerging Markets: Liberalization, Overshooting, and Volatility. In: *Capital Flows and the Emerging Economies: Theory, Evidence, and Controversies*. NBER Chapters. National Bureau of Economic Research, Inc, pp. 61–98.
URL <https://ideas.repec.org/h/nbr/nberch/6165.html>
- Benigno, G., Chen, H., Otrok, C., Rebucci, A., Young, E., Oct. 2012. Optimal Policy for Macro-Financial Stability. CEP Discussion Papers dp1172, Centre for Economic Performance, LSE.
URL <http://ideas.repec.org/p/cep/cepdps/dp1172.html>
- Benigno, G., Chen, H., Otrok, C., Rebucci, A., Young, E. R., 2013. Financial Crises and Macro-prudential Policies. *Journal of International Economics* 89 (2), 453–470.
URL <http://ideas.repec.org/a/eee/inecon/v89y2013i2p453-470.html>
- Benigno, G., Chen, H., Otrok, C., Rebucci, A., Young, E. R., 2016. Optimal capital controls and real exchange rate policies: A pecuniary externality perspective. *Journal of Monetary Economics* 84 (C), 147–165.
URL <https://ideas.repec.org/a/eee/moneco/v84y2016icp147-165.html>
- Bianchi, J., December 2011. Overborrowing and Systemic Externalities in the Business Cycle. *American Economic Review* 101 (7), 3400–3426.
URL <http://ideas.repec.org/a/aea/aecrev/v101y2011i7p3400-3426.html>
- Bianchi, J., Mendoza, E. G., Jun. 2010. Overborrowing, Financial Crises and 'Macro-prudential' Taxes. NBER Working Papers 16091, National Bureau of Economic Research, Inc.
URL <http://ideas.repec.org/p/nbr/nberwo/16091.html>
- Bianchi, J., Mendoza, E. G., forthcoming. Optimal Time-Consistent Macroprudential Policy. *Journal of Political Economy*.
URL <http://ideas.repec.org/a/aea/aecrev/v101y2011i7p3400-3426.html>
- Braggion, F., Christiano, L. J., Roldos, J., 2009. Optimal Monetary Policy in a 'Sudden Stop'. *Journal of Monetary Economics* 56 (4), 582 – 595.
URL <http://www.sciencedirect.com/science/article/pii/S0304393209000452>
- Broner, F., Didier, T., Erce, A., Schmukler, S. L., 2013a. Gross Capital Flows: Dynamics and Crises. *Journal of Monetary Economics* 60 (1), 113 – 133, carnegie-NYU-Rochester Conference.
URL <http://www.sciencedirect.com/science/article/pii/S0304393212001675>
- Broner, F. A., Lorenzoni, G., Schmukler, S. L., 01 2013b. Why Do Emerging Economies Borrow Short Term? *Journal of the European Economic Association* 11, 67–100.
URL <http://ideas.repec.org/a/bla/jeurec/v11y2013ip67-100.html>

- Brumm, J., Grill, M., Kubler, F., Schmedders, K., 02 2015. Collateral Requirements And Asset Prices. *International Economic Review* 56, 1–25.
URL <https://ideas.repec.org/a/wly/iecrev/v56y2015ip1-25.html>
- Bruno, V., Shin, H. S., 2015a. Capital Flows and the Risk-taking Channel of Monetary Policy. *Journal of Monetary Economics* 71 (C), 119–132.
URL <https://ideas.repec.org/a/eee/moneco/v71y2015icp119-132.html>
- Bruno, V., Shin, H. S., 2015b. Cross-Border Banking and Global Liquidity. *Review of Economic Studies* 82 (2), 535–564.
URL <https://ideas.repec.org/a/oup/restud/v82y2015i2p535-564.html>
- Céspedes, L. F., Chang, R., Velasco, A., September 2004. Balance Sheets and Exchange Rate Policy. *American Economic Review* 94 (4), 1183–1193.
URL <http://ideas.repec.org/a/aea/aecrev/v94y2004i4p1183-1193.html>
- Chen, H. A., Levy, D., Ray, S., Bergen, M., May 2008. Asymmetric Price Adjustment in the Small. *Journal of Monetary Economics* 55 (4), 728–737.
URL <http://ideas.repec.org/a/eee/moneco/v55y2008i4p728-737.html>
- Christiano, L. J., Eichenbaum, M., Evans, C. L., February 2005. Nominal Rigidities and the Dynamic Effects of a Shock to Monetary Policy. *Journal of Political Economy* 113 (1), 1–45.
URL <http://ideas.repec.org/a/ucp/jpolec/v113y2005i1p1-45.html>
- Coleman, W. J., 1990. Solving the Stochastic Growth Model by Policy-Function Iteration. *Journal of Business and Economic Statistics* 8 (1), 27–29.
- Costinot, A., Lorenzoni, G., Werning, I., 2014. A Theory of Capital Controls as Dynamic Terms-of-Trade Manipulation. *Journal of Political Economy* 122 (1), 77 – 128.
URL <http://ideas.repec.org/a/ucp/jpolec/doi10.1086-674425.html>
- Devereux, M. B., Lane, P. R., Xu, J., 2006. Exchange Rates and Monetary Policy in Emerging Market Economies. *The Economic Journal* 116 (511), 478–506.
URL <http://dx.doi.org/10.1111/j.1468-0297.2006.01089.x>
- Devereux, M. B., Young, E. R., Yu, C., Dec. 2015. A New Dilemma: Capital Controls and Monetary Policy in Sudden Stop Economies. NBER Working Papers 21791, National Bureau of Economic Research, Inc.
URL <https://ideas.repec.org/p/nbr/nberwo/21791.html>
- Devereux, M. B., Yu, C., 2014. International Financial Integration and Crisis Contagion. NBER Working Papers 20526, National Bureau of Economic Research, Inc.
URL <http://ideas.repec.org/p/nbr/nberwo/20526.html>
- Eaves, B. C., Schmedders, K., September 1999. General Equilibrium Models and Homotopy Methods. *Journal of Economic Dynamics and Control* 23 (9-10), 1249–1279.
URL <http://ideas.repec.org/a/eee/dyncon/v23y1999i9-10p1249-1279.html>

- Engel, C., Park, J., 2017. Debauchery and original sin: the currency composition of sovereign debt. Working paper, University of Wisconsin-Madison.
- Farhi, E., Werning, I., Jun. 2012. Dealing with the Trilemma: Optimal Capital Controls with Fixed Exchange Rates. NBER Working Papers 18199, National Bureau of Economic Research, Inc.
URL <http://ideas.repec.org/p/nbr/nberwo/18199.html>
- Farhi, E., Werning, I., November 2014. Dilemma not Trilemma? Capital Controls and Exchange Rates with Volatile Capital Flows. IMF Economic Review 62 (4), 569–605.
URL <https://ideas.repec.org/a/pal/imfecr/v62y2014i4p569-605.html>
- Fornaro, L., 2015. Financial Crises and Exchange Rate Policy. Journal of International Economics 95 (2), 202–215.
URL <https://ideas.repec.org/a/eee/inecon/v95y2015i2p202-215.html>
- Fratzcher, M., 2012. Capital Flows, Push versus Pull Factors and the Global Financial Crisis. Journal of International Economics 88 (2), 341 – 356, {NBER} Global.
URL <http://www.sciencedirect.com/science/article/pii/S0022199612000931>
- Gali, J., 2015. Monetary Policy, Inflation, and the Business Cycle: An Introduction to the New Keynesian Framework. the Second Edition, Princeton University Press.
- Gali, J., Monacelli, T., 2005. Monetary Policy and Exchange Rate Volatility in a Small Open Economy. The Review of Economic Studies 72 (3), 707–734.
URL <http://restud.oxfordjournals.org/content/72/3/707.abstract>
- Gertler, M., Gilchrist, S., Natalucci, F. M., 2007. External Constraints on Monetary Policy and the Financial Accelerator. Journal of Money, Credit and Banking 39 (2/3), pp. 295–330.
URL <http://www.jstor.org/stable/4494253>
- Goodfriend, M., King, R. G., Aug. 2001. The Case for Price Stability. NBER Working Papers 8423, National Bureau of Economic Research, Inc.
URL <https://ideas.repec.org/p/nbr/nberwo/8423.html>
- Greenwood, J., Hercowitz, Z., Huffman, G. W., June 1988. Investment, Capacity Utilization, and the Real Business Cycle. American Economic Review 78 (3), 402–17.
URL <http://ideas.repec.org/a/aea/aecrev/v78y1988i3p402-17.html>
- Hanson, G. H., Spring 2012. The Rise of Middle Kingdoms: Emerging Economies in Global Trade. Journal of Economic Perspectives 26 (2), 41–64.
URL <http://ideas.repec.org/a/aea/jecper/v26y2012i2p41-64.html>
- Iacoviello, M., 2005. House Prices, Borrowing Constraints, and Monetary Policy in the Business Cycle. The American Economic Review 95 (3), 739–764.
- Imbs, J., Mejean, I., July 2015. Elasticity Optimism. American Economic Journal: Macroeconomics 7 (3), 43–83.
URL <https://ideas.repec.org/a/aea/aejmac/v7y2015i3p43-83.html>

- IMF, April 2014. Regional Economic Outlook: Asia and Pacific. World Economic and Financial Surveys, International Monetary Fund, Washington, D.C., 20090, USA. International Monetary Fund, Publication Services, Washington, D.C., 20090, USA, Ch. Chapter 2. Corporate Leverage in Asia: A Fault Line?, pp. 33–46.
URL https://www.imf.org/external/pubs/ft/reo/2014/apd/eng/c2_0414.pdf
- Jeanne, O., Sep. 2003. Why Do Emerging Economies Borrow in Foreign Currency? IMF Working Papers 03/177, International Monetary Fund.
URL <http://ideas.repec.org/p/imf/imfwpa/03-177.html>
- Jeanne, O., Korinek, A., May 2010. Excessive Volatility in Capital Flows: A Pigouvian Taxation Approach. American Economic Review 100 (2), 403–07.
URL <http://ideas.repec.org/a/aea/aecrev/v100y2010i2p403-07.html>
- Jeanne, O., Korinek, A., Jan. 2013. Macroprudential Regulation Versus Mopping Up After the Crash. NBER Working Papers 18675, National Bureau of Economic Research, Inc.
URL <https://ideas.repec.org/p/nbr/nberwo/18675.html>
- Kaminsky, G. L., Reinhart, C. M., Vegh, C. A., March 2005. When It Rains, It Pours: Pro-cyclical Capital Flows and Macroeconomic Policies. In: NBER Macroeconomics Annual 2004, Volume 19. NBER Chapters. National Bureau of Economic Research, Inc, pp. 11–82.
URL <https://ideas.repec.org/h/nbr/nberch/6668.html>
- Kim, J., Ruge-Murcia, F. J., April 2009. How Much Inflation is Necessary to Grease the Wheels? Journal of Monetary Economics 56 (3), 365–377.
URL <http://ideas.repec.org/a/eee/moneco/v56y2009i3p365-377.html>
- Kiyotaki, N., Moore, J., April 1997. Credit Cycles. Journal of Political Economy 105 (2), 211–48.
URL <http://ideas.repec.org/a/ucp/jpolec/v105y1997i2p211-48.html>
- Korinek, A., 2011. The New Economics of Prudential Capital Controls: A Research Agenda. Imf economic review, International Monetary Fund.
URL <http://dx.doi.org/10.1057/imfer.2011.19>
- Korinek, A., Simsek, A., March 2016. Liquidity Trap and Excessive Leverage. American Economic Review 106 (3), 699–738.
URL <https://ideas.repec.org/a/aea/aecrev/v106y2016i3p699-738.html>
- Lane, P. R., Milesi-Ferretti, G. M., 2008. The Drivers of Financial Globalization. The American Economic Review 98 (2), pp. 327–332.
URL <http://www.jstor.org/stable/29730042>
- Levy-Yeyati, E., Sturzenegger, F., August 2005. Classifying Exchange Rate Regimes: Deeds vs. Words. European Economic Review 49 (6), 1603–1635.
URL <https://ideas.repec.org/a/eee/eecrev/v49y2005i6p1603-1635.html>
- Liu, Z., Miao, J., Zha, T., 2016. Land prices and unemployment. Journal of Monetary Economics 80 (C), 86–105.
URL <https://ideas.repec.org/a/eee/moneco/v80y2016icp86-105.html>

- Liu, Z., Wang, P., Zha, T., 05 2013. LandPrice Dynamics and Macroeconomic Fluctuations. *Econometrica* 81 (3), 1147–1184.
URL <https://ideas.repec.org/a/ecm/emetrp/v81y2013i3p1147-1184.html>
- Mendoza, E. G., 2010. Sudden Stops, Financial Crises, and Leverage. *American Economic Review* 100 (5), 1941–1966.
- Ottonello, P., 2015. Optimal exchange rate policy under collateral constraints and wage rigidity. Manuscript, University of Michigan.
- Passari, E., Rey, H., 2015. Financial Flows and the International Monetary System. *The Economic Journal* 125 (584), 675–698.
URL <http://dx.doi.org/10.1111/eoj.12268>
- Peltzman, S., June 2000. Prices Rise Faster than They Fall. *Journal of Political Economy* 108 (3), 466–502.
URL <http://ideas.repec.org/a/ucp/jpolec/v108y2000i3p466-502.html>
- Reinhart, C., Reinhart, V., March 2009. Capital Flow Bonanzas: an Encompassing View of the Past and Present. In: NBER International Seminar on Macroeconomics 2008. NBER Chapters. National Bureau of Economic Research, Inc, pp. 9–62.
URL <https://ideas.repec.org/h/nbr/nberch/8229.html>
- Rey, H., May 2015. Dilemma not Trilemma: the Global Financial Cycle and Monetary Policy Independence. Working Paper 21162, National Bureau of Economic Research.
URL <http://www.nber.org/papers/w21162>
- Rotemberg, J. J., October 1982. Monopolistic Price Adjustment and Aggregate Output. *Review of Economic Studies* 49 (4), 517–31.
URL <http://ideas.repec.org/a/bla/restud/v49y1982i4p517-31.html>
- Schittkowski, K., April 2014. NLPQLP: A fortran implementation of a sequential quadratic programming algorithm with distributed and non-monotone line search - user’s guide, version 4.2, report, Department of Computer Science, University of Bayreuth.
- Schmitt-Grohe, S., Uribe, M., 2015. Downward Nominal Wage Rigidity, Currency Pegs, and Involuntary Unemployment. forthcoming, *Journal of Political Economy*.
- Simonovska, I., Waugh, M. E., 2014. The elasticity of trade: Estimates and evidence. *Journal of International Economics* 92 (1), 34–50.
URL <https://ideas.repec.org/a/eee/inecon/v92y2014i1p34-50.html>
- Siu, H. E., April 2004. Optimal fiscal and monetary policy with sticky prices. *Journal of Monetary Economics* 51 (3), 575–607.
URL <https://ideas.repec.org/a/eee/moneco/v51y2004i3p575-607.html>
- Tauchen, G., Hussey, R., March 1991. Quadrature-Based Methods for Obtaining Approximate Solutions to Nonlinear Asset Pricing Models. *Econometrica* 59 (2), 371–96.
URL <http://ideas.repec.org/a/ecm/emetrp/v59y1991i2p371-96.html>

Uribe, M., Yue, V. Z., June 2006. Country Spreads and Emerging Countries: Who Drives Whom? *Journal of International Economics* 69 (1), 6–36.

URL <http://ideas.repec.org/a/eee/inecon/v69y2006i1p6-36.html>

Varian, H. R., 1975. A Bayesian Approach to Real Estate Assessment. *Studies in Bayesian Econometrics and Statistics in Honor of Leonard J. Savage*, 195–208.

Tables and Figures

Table 1: Parameter values

Parameter		Values
<i>Preference</i>		
β	Subjective discount factor	0.90
σ	Relative risk aversion	2
ν	Inverse of Frisch labor supply elasticity	1
χ	Parameter in labor supply	0.4
<i>Production</i>		
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
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
ρ_A	Persistence of TFP shocks	0.60
σ_A	Standard deviation of TFP shocks	0.0295
ρ_R	Persistence of foreign interest rate shocks	0.42
σ_R	Standard deviation of foreign interest rate shocks	0.0133
$p_{H,H}$	Transitional probability of high leverage to high leverage	0.9722
$p_{L,L}$	Transitional probability of low leverage to low leverage	0.7323
κ_L	Low leverage	0.31
κ_H	High leverage	0.52
<i>Policy variables</i>		
α_π, α_Y	$(\infty, 0)$	
τ_H	Subsidy to final goods producers	$\frac{1}{\theta-1}$
τ_N	Gross subsidy to exports	$\frac{1}{\rho-1}$

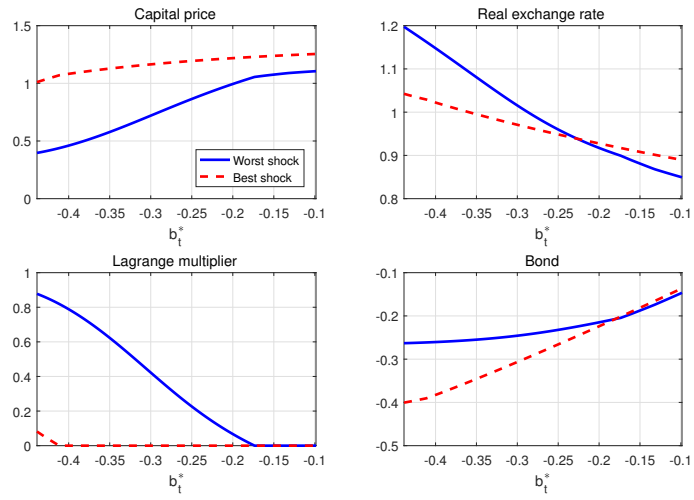


Figure 1: Policy functions in the competitive equilibrium with strict inflation targeting.

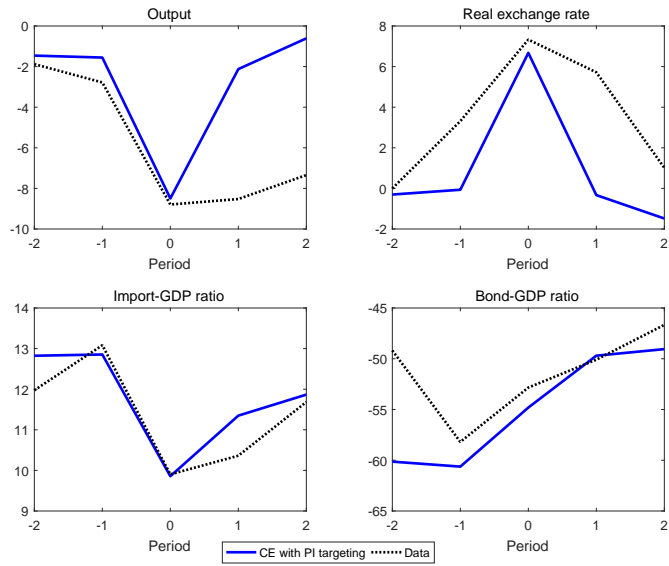


Figure 2: Event analysis in the competitive equilibrium with strict inflation targeting. Each panel reports the percent deviation from the unconditional mean of that variable except for the Import-GDP ratio and Bond-GDP ratio. The solid lines are for the model and the dashed lines for the data.

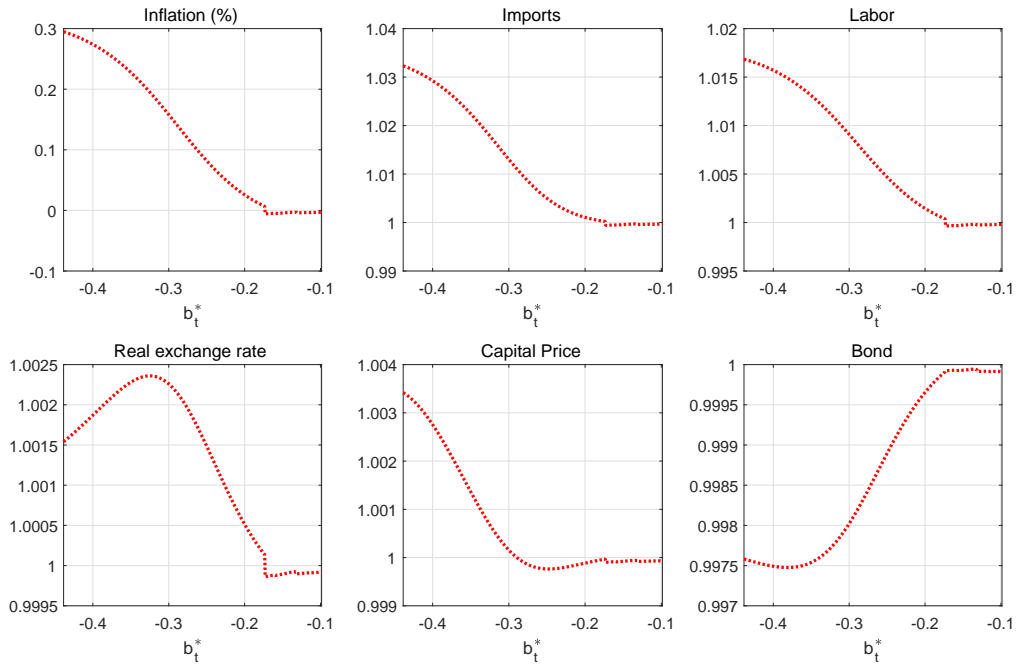


Figure 3: The ratios of policy functions in the optimal monetary policy without capital controls to those in the competitive equilibrium with strict inflation targeting (CE) in the worst state.

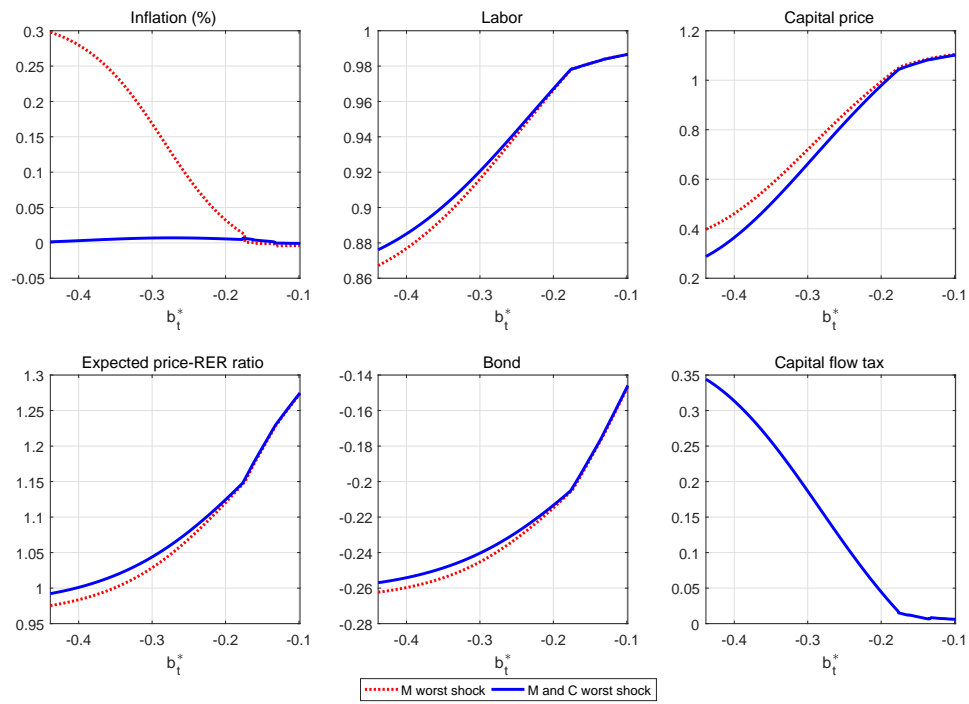


Figure 4: This graph reports the optimal responses of period t planner with both monetary and capital control instruments (M and C) given period $t + 1$ planner choosing optimal monetary policy only (M).

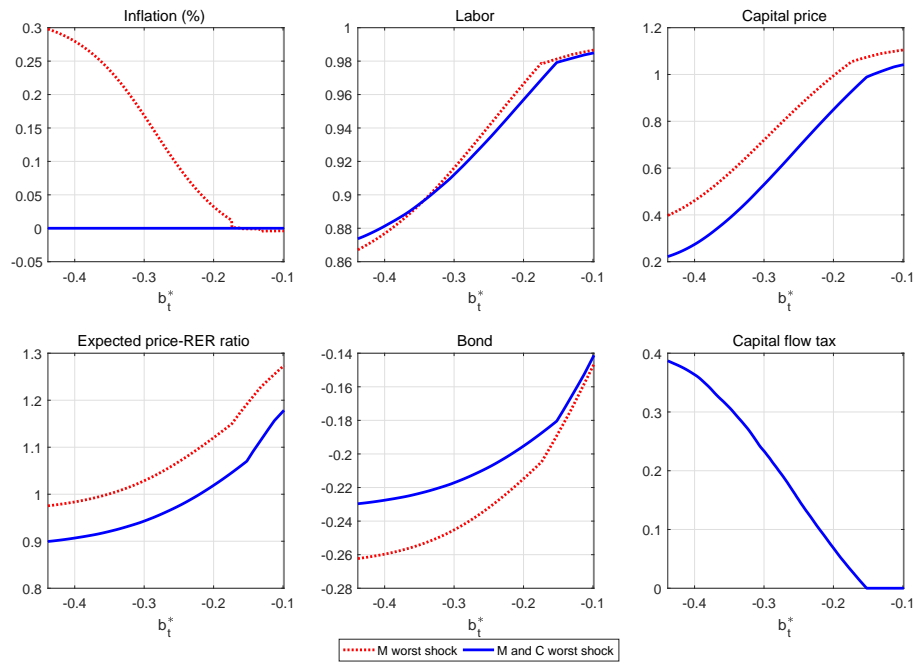


Figure 5: Policy functions for the optimal monetary policy without capital controls (M) and optimal monetary and capital controls (M and C).

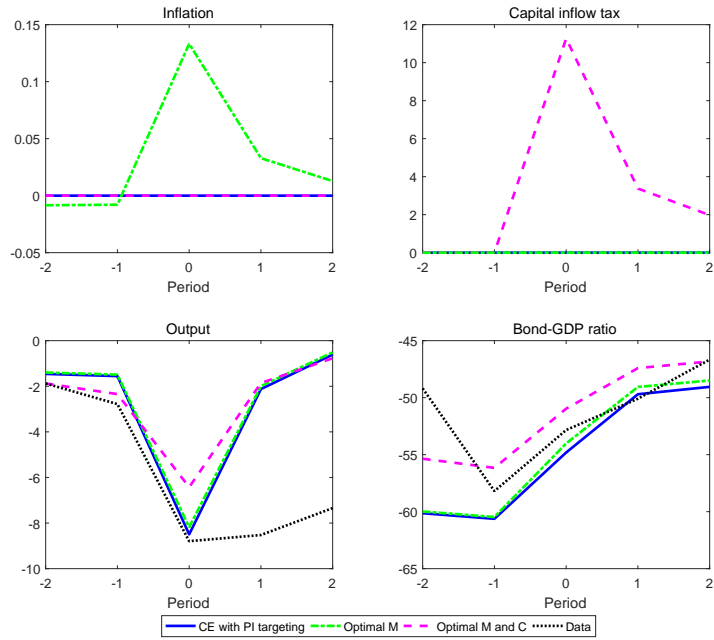


Figure 6: Event analysis in the optimal monetary policy without capital controls (M), optimal monetary and capital controls (M and C), and the competitive equilibrium with strict inflation targeting (CE). Each panel reports the percent deviation from the unconditional mean of that variable except for the capital inflow tax and Bond-GDP ratio.

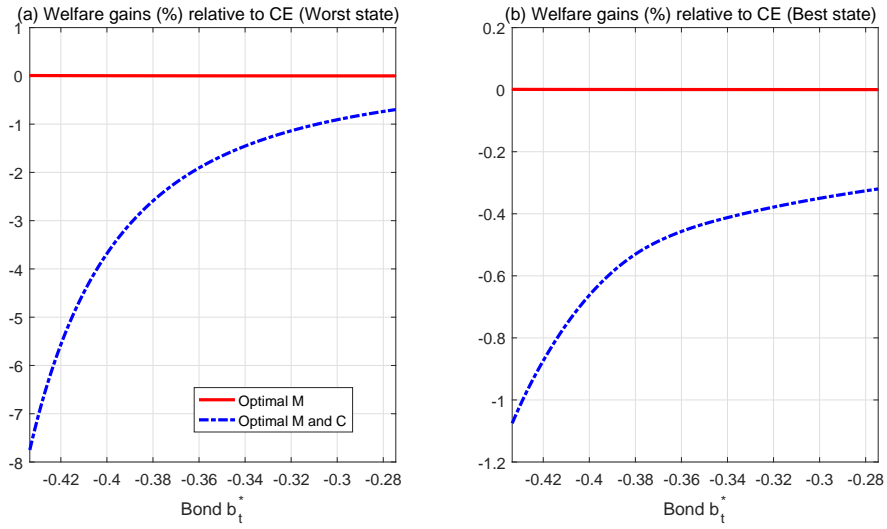


Figure 7: Welfare gains in the optimal monetary policy without capital controls (M) and optimal monetary and capital controls (M and C), relative to the competitive equilibrium with strict inflation targeting (CE). Welfare gains are measured by the percentage changes of certainty equivalence of effective consumption across policy regimes.

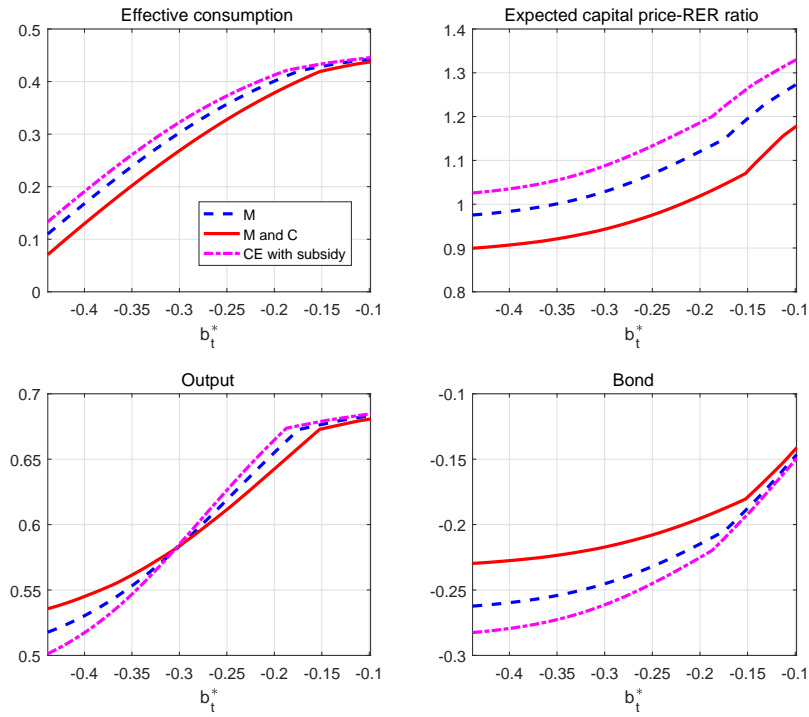


Figure 8: Policy functions in the optimal monetary policy without capital controls (M), optimal monetary and capital controls (M and C), and a competitive equilibrium with strict inflation targeting and an ad hoc state-contingent capital inflow subsidy $\tau_{c,t} = -0.2\mu_t$ (CE with subsidy) in the ‘worst shock’ scenario.

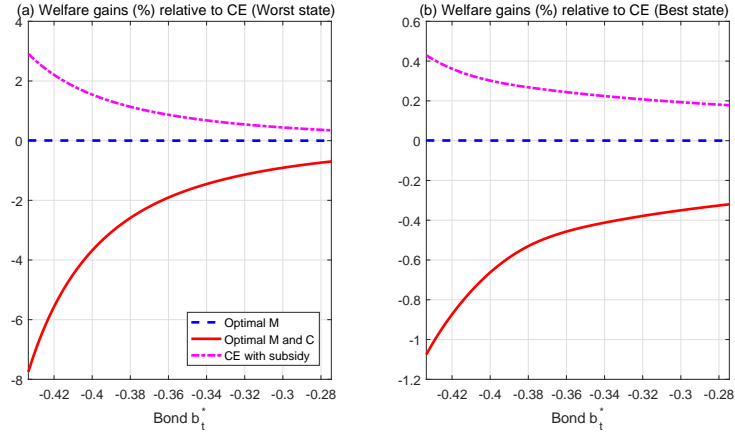


Figure 9: Welfare gains in the optimal monetary policy without capital controls (M), optimal monetary and capital controls (M and C), and a competitive equilibrium with strict inflation targeting and an ad hoc state-contingent capital inflow subsidy $\tau_{c,t} = -0.2\mu_t$ (CE with subsidy), relative to the competitive equilibrium with strict inflation targeting (CE).