Surviving Asymmetry in Capital Flows and the Business Cycles: Role of Prudential Capital Controls

Chin-Yoong Wong and Yoke-Kee Eng[*]

Abstract

Past literature of different strands has pointed to a potential asymmetry: while portfolio capital inflows are largely irrelevant to the economy, capital outflows can cause recession. In a model with convex investment and portfolio balance adjustment cost, and endogenous credit-in-advance constraint, we find that investment is determined solely by opportunity cost of physical capital unrelated to portfolio capital inflows when the constraint is slack. However, once credit availability is tightened up by capital outflows, negative liquidity constraint dominates opportunity-cost factor, causing an economic downturn. Financial fragility against capital outflows is an outcome of pecuniary externalities, which, however, can be moderated by prudential capital controls. Even when exchange rates float freely, capital controls ease the macro-stabilizing burden of monetary policy, as it helps shield the economy from financial instability. Prudential tax on foreign debt is most preferred, and works the best when exchange rates float is managed.

Keywords: Prudential capital controls; Capital flows; Foreign-currency debt; Occasionally binding constraint; Trilemma

1. Introduction

Cross-border capital flows have drawn enormous attentions from the academics and policymakers since the waves of capital account liberalization began in late 1980s. Much ink has been poured on the search for favorable effects of capital inflows on the economy. While some have documented benign growth effects of capital inflows, which have to be conditional on the existence of strong, good institutions (see, for instance, Friedrich et al., 2013; Alfraso et al., 2007; Bekaert et al., 2005), robust evidence can rarely be found, leaving alone unconditional positive effects (see Jeanne et al.,

[*] Chin-Yoong: Stockholm China Economic Research Institute (SCERI), Stockholm School of Economics, Sweden; Faculty of Business and Finance, Universiti Tunku Abdul Rahman, Jalan Universiti, Bandar Barat, 31900 Kampar, Perak, Malaysia. Tel.: 605-4688888. E-mail: wongcy@utar.edu.my. Yoke-Kee: Faculty of Business and Finance, Universiti Tunku Abdul Rahman, Malaysia. E-mail: engyk@utar.edu.my. The paper is written when the first author is hosted by SCERI as Visiting Research Fellow. He is grateful to SCERI for conducive research environment and Lars-Erik Thunholms Stiftelse For Vetenskaplig Forskning for generous funding. This research is also part of a project financially funded by Fundamental Research Grant Scheme (FRGS) from the Ministry of Education, Malaysia (FRGS/2/2013/SS07/UTAR/02/1). Earlier version of the paper has been presented at the International Conference on "Exchange Rates, Monetary Policy and Financial Stability in Emerging Markets and Developing Countries". The authors are grateful to two anonymous referees for constructive comments that help sharpen our own understanding on the model.

2012; Kose et al., 2009; Gamra, 2009 for more skeptical view). The influential Prasad et al. (2007) and Gourinchas and Jeanne (2006) even show that the fastest growing countries did so without much foreign capital inflows.

In fact, an easier task is to demonstrate the flipside of the coin: capital flows more often than not wreak havoc the economy that ends with a slump. Especially when the economy is loaded with piles of foreign-currency denominated debts, sudden capital reversal that crashes the value of local currency can devalue the worth of collateral for borrowing, instigating an unfavorable balance-sheet effect of depreciation that dominates the conventional favorable expenditure-switching effect of depreciation (Jeanne et al., 2012; Bordo et al., 2010). By using Hatemi-J's (2012) asymmetric Granger causality approach over selected Asian countries, Eng and Wong (2014) find that while the null hypothesis that capital inflows do not Granger cause economic expansion cannot be rejected, capital outflows precede economic slump with high statistical significance.

In short, we may live in a world of asymmetry: while rising tide may not lift all boats, retreating tide of capital flows may sink all boats. Understanding the mechanism of asymmetry thus becomes warranted given the fact that gross capital inflows and outflows are distinct in dynamics and implications (Forbes and Warnock, 2012; Broner et al., 2013). More importantly, it poses a challenge to the design of prudential capital controls as a tool to safeguard financial stability. Of relevant question is, for instance, should capital inflows or outflows be controlled?

Extended from Eng and Wong (2014), which focus on asymmetric growth effects of capital flows in a Schumpeterian growth model with credit imperfection, this paper sheds lights on asymmetric business cycle effects of gross capital flows, in particular portfolio and debt flows. We do so by laying out an otherwise standard two-country real business cycle model with convex investment and capital flow adjustment costs in Section 2. While the former setting allows us to derive Tobin's q in physical investment that can be easily expanded to explicitly capture the implications of credit-in-advance constraint, the latter gives us "Tobin's q" in gross capital inflows and outflows, and foreign debt inflows independently. The model is later on parameterized in Section 3.

That said, this paper has three theoretical novelties. First, we introduce an eternally binding credit-in-advance constraint that depends on the borrower's credit-worthiness, which, in turn, is conditional on her collateral-debt ratio with Frechet distribution. Having foreign currency denominated borrowing constraint modeled is nothing new indeed but in the spirit of literature on sudden stop (Bianchi, 2011; Mendoza, 2010; Korinek and Mendoza, 2014) and prudential capital control (Korinek, 2011; Jeanne and Korinek, 2012; Benigno et al., 2013). The novelty, however, lies in the way the constraint is modeled that enables us to generate a credit amplification mechanism that interestingly resembles the characteristics of an occasionally binding constraint without succumbing to the difficulty in solving a model with occasionally binding credit constraint.

More interesting is that the credit-in-advance constraint with endogenous credit-worthiness set the mechanism of asymmetry in motion, as elaborated in Section 4. Here is the intuition. When credit constraint is slack due to a stronger collateral value denominated in foreign currency vis-à-vis foreign borrowing, thanks to capital inflows that appreciate the local currency, physical investment decision is determined by the conventional opportunity cost of physical investment with no role for liquidity. However, in the incident of a persistent capital outflow that depreciates the local currency and hence foreign-currency value of the collateral, debt availability is limited by the lower bound of the credit-worthiness. The tightening liquidity effect is likely to dominate the opportunity cost channel, thereby constraining physical investment and causing accumulation of capital stock used as the collateral to slow down. When this happens, credit constraint is further tightened, as collateral-debt ratio is further lowered, setting the stage for business downturn.

Second, based on the concept that reversing the direction of capital flows incurs adjustment cost, we formalize the dynamics of gross portfolio capital and foreign debt inflows by foreign residents, and gross capital outflows by domestic residents. Such classification is coherent with Forbes and Warnock (2012) and Broner et al. (2013) which empirically shed lights on the dynamics of varied gross capital flows by different agents. While yield differentials between foreign bonds and debts govern foreign debt flows, yield differentials between domestic and foreign bonds adjusted for expected depreciation and adjustment cost drive portfolio capital flows. That modeled, capital flows become endogenous to the state of the economy: portfolio capital flows respond to the macroeconomic environments as bond interest is assumed to be directly determined by Taylor-rule type monetary policy, whereas foreign lending rate is conditional on the probability of loan default that are endogenous to borrower's credit-worthiness.

This brings us to our third novelty. By establishing a feedback loop between portfolio and debt flows and the state of the economy, the model embodies a pecuniary externality in a way that individual borrowers do not internalize the negative externality of their current borrowing decisions on aggregate credit-worthiness and the flows of capital, which affect the economy as a whole. This is where macroprudential policies come into play (Korinek and Mendoza, 2014). We introduce prudential capital controls as a tax on the difference between marginal benefit of easing credit constraint for decentralized borrower and constrained planner to prevent over-borrowing, in the spirit of Jeanne and Korinek (2012), and Korinek (2011), in a simple and transparent manner as in Section 5.

Summarizing our results in Section 5, we argue that prudential capital controls potentially serve as a "good institution" for capital inflows to be favorable to the economy in two inter-related dimensions. On one spectrum, capital controls that help internalize the externality reduce over-borrowing incentive, minimizing the abruption of adverse balance-sheet effect of capital outflows even in the presence of nonlinear credit-in-advance constraint and foreign borrowings. In particular, prudential tax on foreign borrowings works most effectively among the tools considered, and capital outflows control outperforms inflows control.

On the other end, by shielding the economy from over-borrowing and financial-instability risk, prudential capital controls moderate the burden of macroeconomic stabilization for monetary policy. This implies that prudential capital controls are desirable even when exchange rate is flexible. By further disconnecting borrower's credit-worthiness from exchange rate fluctuations when the latter is managed by monetary policy, the economy responds favorably to capital outflows in the presence of prudential tax on foreign borrowings.

This paper can be placed simultaneously in two strands of literature. By modeling nonlinear binding constraint with focus on the use of capital controls to shore up financial stability, it is closely related to Korinek (2011), Jeanne and Korinek (2012), Benigno et al. (2013), and Bianchi (2011). By studying the effectiveness of capital controls as well as its role in monetary autonomy amid different flexibilities in exchange rates, it contributes to the recent debates in policy "dilemma or trilemma" (Farhi and Werning, 2013; Klein and Shambaugh, 2013; Rey, 2013).

2. The Model

The basic framework is a standard two-country, one-sector real business cycle model, which consists of firm, household, and central bank. It is "real" in the sense that no money is involved, price is flexible, and market is perfectly competitive. Because home and foreign countries are basically identical in the economic structure, except when it comes to foreign lending in later session, discussion is mainly on home country. Whenever it is deemed necessary, a superscripted asterisk indicates transaction that occurs in foreign country, whereas subscripted h and f indicate origin of production.

Firm

A representative firm at time t hires laborer service N_t and installs capital stock with one-period time to build K_{t-1} at the given real wage w_t and rental on capital $r_{k,t}$. By using Cobb-Douglas production function, the firm's problem is to maximize profit $\Pi_t = \exp(Z_t^a)\, K_{t-1}^{\alpha} N_t^{1-\alpha} - w_t N_t - r_{k,t} K_{t-1}$, where $Z_t^a (= \rho_a Z_{t-1}^a + \sigma^a \varepsilon_t^a)$ is a first-order autoregressive shock with an i.i.d shock ε_t^a at constant volatility σ^a. Marginal product of capital stock and labor can be easily derived as $\alpha Y_t / K_{t-1} = r_{k,t}$ and $(1-\alpha) Y_t / N_t = w_t$, respectively. Market clears when the final output Y_t is consumed locally $C_{h,t}$, exported for foreign consumption $C^*_{h,t}$, and purchased by household as investment goods I_t to accumulate capital stock repurchased by the firm for next-period production, $Y_t \equiv C_{h,t} + C^*_{h,t} + I_t$.

Households: Modeling Gross Capital Outflows and Inflows

A representative household receives human and non-human incomes. The former comprises wage compensation and lump-sum transfer from the firm (as household owns the firm), while the latter consists of total real value of financial investment on one-period domestic bonds $(1 + r_{t-1})\, B_{t-1}/P_t$ and foreign bonds $(1 + r^*_{t-1})S_t\, B_{t-1}/P_t$ denominated in domestic currency, and of physical investment $(1 + r_{k,t})K_{t-1}$. S_t refers to nominal exchange rate defined as domestic currency per foreign currency (meaning a rise in S_t implies an appreciation for foreign currency). The household spends on consumption goods, which consists of domestic and imported final goods $C_{f,t}$, and investment goods, and purchases new domestic and foreign bonds throughout the period. It is easily imagine that each and every purchase of foreign bonds by definition constitutes a portfolio capital outflow denominated in local currency by domestic resident during period t, $KO_t \equiv S_t(B^*_t - B^*_{t-1})/P_t$.

To explicitly model investment dynamics and capital outflows, we introduce convex adjustment cost in the purchase of investment goods $\Phi_{I,t}$ and foreign bonds $\Phi_{KO,t}$. In particular, the adjustment cost takes the form

$$\Phi_{I,t} = \frac{b_I}{2}\left(\frac{I_t}{K_{t-1}} - \delta\right)^2 \tag{1}$$

$$\Phi_{KO,t} = \frac{b_{KO}}{2}\left(\frac{KO_t}{S_t B^*_{t-1}/P_t} - \gamma_{KO}\right)^2 \tag{2}$$

where b_i is the scale parameter, δ is the depreciation rate, and γ_{KO} is capital outflows at steady state. The household's problem can then be formulated as maximizing her utility function (3) subject to flow budget constraint (4), law of motion of physical capital accumulation (5), and dynamics of capital outflows (6) as follows:

$$\max E_0 \sum_{i=0}^{\infty} \beta^i \exp(Z_t^c)\left\{(1-\sigma)^{-1} C_t^{1-\sigma} - a_N \exp(Z_t^N)\,(1+\chi)^{-1} N_t^{1+\chi}\right\} \tag{3}$$

$$-\lambda_t \begin{Bmatrix} \frac{B_t-(1+r_{t-1})B_{t-1}}{P_t} + C_t + I_t - \left[\left(1+r_{k,t}\right) - \Phi_{I,t}\right] K_{t-1} \\ +KO_t - \left[(1+r_{t-1}^*) - \Phi_{KO,t}\right] \frac{S_t B_{t-1}^*}{P_t} - w_t N_t - \Pi_t \end{Bmatrix} \tag{4}$$

$$-\Omega_t\{K_t - (1-\delta)K_{t-1} - \exp(Z_t^I)\, I_t\} \tag{5}$$

$$-\Lambda_t \left\{\frac{S_t}{P_t}(B_t^* - B_{t-1}^*) - \exp(Z_t^{KO})\, KO_t\right\} \tag{6}$$

where

$$C_t = \left(\varphi^{\frac{1}{\eta}} C_{h,t}^{\frac{\eta-1}{\eta}} + (1-\varphi)^{\frac{1}{\eta}} C_{f,t}^{\frac{\eta-1}{\eta}}\right)^{\frac{\eta}{\eta-1}} \tag{7}$$

Z_t^c, Z_t^N, Z_t^I, and Z_t^{KO} are first-order autoregressive disturbance to preference, labor supply, investment-specific technology, and capital outflows, respectively, with an i.i.d shock. λ_t, Ω_t, and Λ_t, respectively, indicate shadow price of wealth, physical investment, and capital outflows. The parameters β, σ and χ, respectively, denote household's subjective discount rate, attitude toward risk, and (inverse) wage elasticity of labor supply, whereas a_N is a scale parameter, η denotes the elasticity of substitution between domestic and foreign final goods, and φ indicates the share of home-produced goods in constant-elasticity-of-substitution consumption bundles, both of home and foreign households.

By deriving and rearranging the first order conditions, the conventional optimal decisions on labor supply and intertemporal consumption allocation are as follows, respectively.

$$a_N \exp(Z_t^N)\, N_t^{\chi} C_t^{\sigma} = w_t \tag{8}$$

$$\exp(Z_t^C)\left(\frac{P_{t+1}}{P_t}\right) = \beta \exp(Z_{t+1}^C)\,(1+r_t)\left(\frac{C_t}{C_{t+1}}\right)^{\sigma} \tag{9}$$

Eqs. (10) and (11), respectively, indicate Tobin's q, defined as the market value of firm capital relative to the replacement cost, and the corresponding investment decisions.

$$q_{k,t}\left(\equiv \frac{\Omega_t}{\lambda_t}\right) = \left(\frac{P_{t+1}}{P_t}\right)\left(\frac{1}{1+r_t}\right)\left\{1 + r_{k,t+1} - \frac{b_I}{2}\left(\frac{I_{t+1}}{K_t} - \delta\right)^2 + b_I\left(\frac{I_{t+1}}{K_t} - \delta\right)\left(\frac{I_{t+1}}{K_t}\right)\right\} \quad (10)$$

$$I_t = \left(\left(\exp(Z_t^I)\, q_{k,t} - 1\right)b_I^{-1} + \delta\right)K_{t-1} \quad (11)$$

Viewed together, we get at picture on how equilibrium investment decision in a financially frictionless world depends solely on the opportunity cost of holding capital stock. When capital stock is relatively more rewarding in that $q_{k,t} > 1$, investment risers. Because $q_{k,t}$ is driven by expected marginal return on capital and bond rates, which is directly determined by monetary policy rates that react toward inflation variability and economic condition (see Eq. (19)), equilibrium investment decision is thus endogenous to the state of the economy.

By identical intuition, the derived and rearranged first-order conditions give us Eqs. (12) and (13), which, respectively, capture "Tobin's *q*" in foreign bonds and the corresponding equilibrium decision for gross capital outflows.

$$q_{ko,t}\left(\equiv \frac{\Lambda_t}{\lambda_t}\right) = \left(\frac{S_{t+1}}{S_t}\right)\left(\frac{1}{1+r_t}\right)\left\{1 + r_t^* - \frac{b_{KO}}{2}\left(\frac{KO_{t+1}}{S_{t+1}B_t^*/P_{t+1}} - \gamma_{KO}\right)^2 + b_{KO}\left(\frac{KO_{t+1}}{S_{t+1}B_t^*/P_{t+1}} - \gamma_{KO}\right)\left(\frac{KO_{t+1}}{S_{t+1}B_t^*/P_{t+1}}\right)\right\} \quad (12)$$

$$KO_t = \left(\left(\exp(Z_t^{KO})\, q_{ko,t} - 1\right)b_{KO}^{-1} + \gamma_{KO}\right)\left(\frac{S_t B_{t-1}^*}{P_t}\right) \quad (13)$$

Marginal benefit of capital "flight" by domestic residents, according to Eq. (12), is driven by the difference between cost-adjusted interest rate differentials and expected depreciation. Resembling the standard interpretation on Tobin's *q* in physical investment, Eq. (13) shows that when widening differentials and/or expected depreciation raises "Tobin's *q* in gross capital outflows" above one, *ceteris paribus*, gross capital outflows occur. With this framework, capital outflows are more than just an exogenous shock captured by $\exp(Z_t^{KO})$, as it responds to the economic fundamentals and expectation. And interestingly, gross capital outflows are self-reinforcing as convex outflows adjustment cost makes "retrenchment" costly, unless if there is significant reversal in the push factors.

Likewise, we can easily derive "Tobin's q in domestic bonds" by foreign residents and the following dynamics of gross capital inflows as below.

$$q_{ki,t}\left(\equiv \frac{\Lambda_t^*}{\lambda_t^*}\right) =$$

$$\left(\frac{S_t}{S_{t+1}}\right)\left(\frac{1}{1+r_t^*}\right)\left\{1+r_t-\frac{b_{KI}}{2}\left(\frac{KI_{f,t+1}}{B_t/S_{t+1}P_{t+1}^*}-\gamma_{KI}\right)^2+b_{KI}\left(\frac{KI_{f,t+1}}{B_t/S_{t+1}P_{t+1}^*}-\gamma_{KI}\right)\left(\frac{KI_{f,t+1}}{B_t/S_{t+1}P_{t+1}^*}\right)\right\} \tag{14}$$

$$KI_{f,t}=\left(\left(\exp(Z_t^{KI})\,q_{ki,t}-1\right)b_{KI}^{-1}+\gamma_{KI}\right)\left(\frac{B_{t-1}}{S_tP_t^*}\right) \tag{15}$$

Aggregate resource constraint, or aggregate demand in short, takes the form

$$AD_t(\equiv Y_t)=C_t+I_t-\Phi_{I,t}+C_{h,t}^*-C_{f,t} \tag{16}$$

where

$$C_{h,t}^*=\varphi\left(\frac{P_{h,t}^*}{P_t^*}\right)^{-\eta}C_t^* \tag{17}$$

$$C_{f,t}=(1-\varphi)\left(\frac{P_{f,t}}{P_t}\right)^{-\eta}C_t \tag{18}$$

$P_t\left(=\left(\varphi P_{h,t}^{1-\eta}+(1-\varphi)P_{f,t}^{1-\eta}\right)^{\frac{1}{1-\eta}}\right)$ and $P_t^*\left(=\left(\varphi {P_{h,t}^*}^{1-\eta}+(1-\varphi){P_{f,t}^*}^{1-\eta}\right)^{\frac{1}{1-\eta}}\right)$ are utility-based consumer price index for home and foreign household, respectively. The model is closed by a Taylor-rule type monetary policy.

$$r_t/\bar{r}=(r_{t-1}/\bar{r})^{\rho_r}\left(\left(\frac{1+\pi_t}{1+\bar{\pi}}\right)^{\theta_\pi}\left(\frac{AD_t}{AD_{t-1}}\right)^{\theta_{AD}}\right)^{1-\rho_r}\exp(\sigma^r\varepsilon_t^r) \tag{19}$$

where $\bar{r}$, $\bar{\pi}$, ρ_r, θ_π, and θ_{AD}, respectively, refers to steady-state interest rate, targeted inflation rate, interest-rate persistence, and policy weight on inflation variability and aggregate demand growth. ε_t^r is an i.i.d shock with constant volatility σ^r. Note that policy rate that responds to the state of the economy directly determines bond rates.

Modeling the asymmetry: Role of firm's nonlinear credit-in-advance constraint

We make two extensions to the canonical real business cycle model. First, we assume that household as firm owner needs external financing in advance to purchase investment goods. In other words, before investing at period t to accumulate physical capital stock for production in period $t+1$, household must borrow in a global capital market at time $t-1$. The credit-in-advance constraint for physical investment is written as

$$K_t - (1-\delta)K_{t-1} \leq \omega_{t-1} \times \frac{S_t L^*_{t-1}}{P_t} \tag{20}$$

where L^*_{t-1} denotes the international credits denominated in foreign currency and ω_{t-1} denotes the condition of the financial market. A good financial market condition enables the firms to raise more funds for investment, thus fostering expected future output growth. We assume Eq. (20) binds eternally.

That brings us to the second extension that the condition of financial market is endogenous to borrower's credit-worthiness, which depends on the ratio between the value of collateral denominated in foreign currency and the total foreign debt obligations (collateral-to-debt ratio, in short) such that

$$\omega_{t-1} = 1 - \exp(-\omega\mathfrak{C}_t) \tag{21}$$

where $\mathfrak{C}_t \left(= \frac{K_t}{R^*_{L,t-1} S_{t-1} L^*_{t-1}/P_t}\right)$ indicates the firm's credit-worthiness. $R^*_{L,t-1}\left(\equiv 1 + r^*_{L,t-1}\right)$ refers to the gross foreign lending rate when debt is committed, and ω is simply a scale factor. In conjunction with Eq. (21), the credit-in-advance constraint (20) becomes

$$I_t = \{1 - \exp(-\omega\mathfrak{C}_t)\} \frac{S_t L^*_{t-1}}{P_t} \tag{22}$$

When collateral-to-debt ratio rises, borrower becomes more credit-worthy in the sense that $\uparrow \mathfrak{C} \rightarrow \exp(-\omega\mathfrak{C}_t) \cong 0$. As a result, $\omega \rightarrow 1$, implying a favorable financial market condition. Further improvements in borrower's credit-worthiness would have no implication on the financial market condition since the constraint is already slack.

Reversely, a borrower's credit-worthiness deteriorates when the collateral-to-debt ratio falls below the threshold value, which can be attributed to nominal depreciation driven by capital outflows, and global factors such as rising foreign interest rate and debt inflow bonanza. As

$\downarrow \mathfrak{C} \rightarrow \exp(-\omega\mathfrak{C}_t) \cong 1$, ω_t will be nose-diving toward zero. When this happens, deteriorating financial condition shrinks the capacity to carry out investment, adversely affecting the economy.

That said, the credit amplification mechanism of Eq. (22) interestingly resembles the characteristics of an occasionally binding constraint in the physical investment without succumbing to the difficulty in solving a model with occasionally binding credit constraint. We have a linear credit-in-advance constraint with endogenous collateral constraint that behaves as a nonlinear credit-in-advance constraint.

As a borrower, household now would need to repay the one-period foreign debt committed in last period. She maximizes her utility function (3) subject to the following expanded flow budget constraint (23) and the credit-in-advance constraint (24) in addition to the conventional constraints (5) and (6).

$$\lambda_t \begin{Bmatrix} \frac{B_t-(1+r_{t-1})B_{t-1}}{P_t} + C_t + I_t - \left[(1+r_{k,t}) - \Phi_{I,t}\right] K_{t-1} \\ +KO_t - \left[(1+r^*_{t-1}) - \Phi_{KO,t}\right] \frac{S_t B^*_{t-1}}{P_t} - w_t N_t - \Pi_t + \frac{R^*_{L,t-1} S_t L^*_{t-1}}{P_t} \end{Bmatrix} \tag{23}$$

$$\mu_t^{db} \left\{ I_t - \{1-\exp(-\omega\mathfrak{C}_t)\} \frac{S_t L^*_{t-1}}{P_t} \right\} \tag{24}$$

where μ_t indicates marginal benefit of easing credit constraint as a decentralized borrower. A constrained utility maximization against L_t^* gives us

$$-\beta\lambda_{t+1}\left(\frac{R^*_{L,t} S_{t+1}}{P_{t+1}}\right) + \beta\mu^{db}_{t+1}\{1-\exp(-\omega\mathfrak{C}_{t+1})\}\left(\frac{S_{t+1}}{P_{t+1}}\right) = 0 \tag{25}$$

which can be simplified to

$$q_{L^*,t}\left(\equiv \frac{\mu_t^{db}}{\lambda_t}\right) = \frac{R^*_{L,t-1}}{1-\exp(-\omega\mathfrak{C}_t)} \tag{26}$$

We close the loop by assuming that foreign lending rate equals risk-free foreign bond rate plus a risk premium conditional on the probability of loan default, which in turn, is endogenously determined by borrower’s credit-worthiness.

$$R^*_{L,t} = (1+r^*_t)(1+\exp(-\omega\mathfrak{C}_t)) \tag{27}$$

Marginal benefit of easing credit constraint becomes greater when market liquidity starts freezing up due to rising cost of borrowing or deteriorating credit-worthiness, as shown in Eq. (26). These two forces are self-reinforcing, as rising cost of borrowing worsens credit-worthiness, whereas a deteriorating credit-worthiness urges the foreign lenders to impose a higher risk premium.

While household's optimal decisions largely remain identical to Eqs. (8) to (13), investment dynamics are now governed not only by Tobin's q but also the marginal benefit of relaxing credit constraint. Eq. (11) is re-derived as

$$I_t/K_{t-1} = \left(\underbrace{\exp(Z_t^I)\, q_{k,t} - 1}_{\substack{Opportunity \\ cost}} \underbrace{-q_{L^*,t}}_{\substack{Liquidity \\ constraint}} \right) b_I^{-1} + \delta \tag{28}$$

Here is where the asymmetry comes. Suppose a persistent nominal appreciation following continuous gross capital inflows has strengthened borrower's credit-worthiness and created a favorable financial market condition in the sense that $\mathfrak{C}_{t+1}$ surpasses a high enough threshold value that leads to $\exp(-\omega\mathfrak{C}_{t+1}) \cong 0$. From Eqs. (26) and (27), we know then $q_{L^*,t}$ equals $R^*_{L,t-1}$, which is equivalent to foreign policy rates. Because marginal return on capital and the setting of policy rates are not determined by gross capital inflows, the real economy is thus disconnected from the latter.

To the contrary, nominal depreciation driven by gross capital outflows that worsens borrower's credit-worthiness shrinks the value of $\mathfrak{C}_{t+1}$, causing $\exp(-\omega\mathfrak{C}_{t+1})$ to fall toward zero and $q_{L^*,t}$ to rise. Moreover, worsening collateral-to-debt ratio also prompts foreign lender to impose risk premium on top of the risk-less rate, further pushing up $q_{L^*,t}$. As a consequence, when contractionary effect of tightening liquidity constraint overtakes opportunity-cost channel, investment activities slow down, instigating an economic slump. In short, capital outflows can take a toll on the economy.

Lastly, before turning to model calibration and simulation, it is worthwhile to spill ink on dynamics of foreign debt flow. What determines a foreign lender's decision? To address this question, we adopt a similar modeling strategy in the sense that channeling foreigner's funds into the home country as debt flow $DI_{f,t}$ incurs a convex adjustment cost, which appears in foreign household's flow budget constraint, $\Phi_{di,t} = \frac{b_{DI}}{2}\left(\frac{DI_{f,t}}{L^*_{t-1}/P^*_t} - \gamma_{DI}\right)^2$, where γ_{DI} refers to steady-state debt inflow. Together with dynamics of foreign lending captured by $\frac{L^*_t}{P^*_t} = \frac{L^*_{t-1}}{P^*_t} + \exp(Z^{*DI}_t)\, DI_{f,t}$, where Z^{*DI}_t is AR(1) disturbance with an i.i.d shock, foreign household chooses allocations that maximize her utility subject to the constraints that are counterparts to Eqs. (4) to (7). In addition to optimal decisions that correspond to Eqs. (8) to (11), (14) and (15), optimal decision to lend to home borrower by foreign resident is derived as

$$DI_{f,t} = \left(\frac{L^*_{t-1}}{b_{DI}}\right)\left\{\exp(Z^{*DI}_t)\left(\frac{1}{1+r^*_t}\right)\left(1 + r^*_{L,t} - \frac{b_{DI}}{2}\left(\frac{DI_{f,t+1}}{L^*_t/P^*_{t+1}} - \gamma_{DI}\right)^2 + b_{DI}\left(\frac{DI_{f,t+1}}{L^*_t/P^*_{t+1}} - \gamma_{DI}\right)\left(\frac{DI_{f,t+1}}{L^*_t/P^*_{t+1}}\right)\right) - 1\right\} \quad (29)$$

Clearly, decision to lend is driven by yield differentials between foreign lending and bonds, which are endogenous to the borrowers' credit-worthiness and economic conditions of both home and foreign countries.

3. Parameterization and Calibration

In section 2 we lay out an open-economy real business cycle model with trade in final goods and convex adjustment cost in all sorts of capital flows. By doing so, we now have a simple model ready to inspect the implications on the economy of gross portfolio capital and debt inflows by foreign residents, as well as gross portfolio capital outflow by domestic residents.

Table 1 reports the values of parameter and volatility of shocks adopted for model simulation, which happen to be those widely used in the literature. For instance, we assume a risk-averse household with 4% risk-free interest rate per year. We take an annual capital depreciation rate of 10% and a capital income share of 40%. We assume that labor is indivisible (Hansen 1985;

Liu and Wang 2014), which implies that $\chi = 0$. We set adjustment cost parameter for investment $b_I = 10$, which is in between the Bayesian estimates in Albonico et al. (2014) and the calibrated value in Unsal (2013). We allow the efficient shocks, which include shocks to preference, labor supply, total factor productivity, and investment-specific technology, to be slightly more persistence by setting $\rho = 0.8$ compared to persistence in capital flows. At steady state, $B_t^* = B_{t-1}^* = \bar{B}^*$ and $B_t = B_{t-1} = \bar{B}$, implying a zero steady-state capital flows, $\gamma_{KI} = \gamma_{KO} = 0$. Current account is thus balanced over the long-run equilibrium.

Lastly, by setting $\varepsilon_{i,t} = 1$ for each shock (twelve shocks altogether in this two-country model), we calibrate the volatility of shocks so that the model is able to reasonably match the empirical regularities for emerging economies on average as documented in Aguiar and Gopinath (2007). The model is solved at second order approximation with steady state as initial value by using Dynare version 4.4.3. Simulated data are Holdrick-Prescott filtered using a smoothing parameter of 1600. Table 2 summarizes some key simulated moments. Except for autocorrelation for aggregate demand and ratio between volatility of investment and of aggregate demand, which appear to be too low in both cases, given the relatively simple structure, the calibrated model performs reasonably well on average in replicating some actual moments to provide a more reliable quantitative analysis.

[INSERT TABLES 1 & 2 HERE]

4. Asymmetric Business-Cycle Effect of Gross Capital Flows

Suppose there is a 1% shock to gross capital inflows by foreign resident and to gross capital outflows by domestic resident, respectively. Given the parameterized model structure, Figure 1 illustrates dynamic responses of aggregate demand (AD), consumption (C), physical investment (I), nominal exchange rates (S), and interest rate (r) in the absence (*Baseline*) and presence of credit-in-advance constraint with nonlinear collateral constraints (*Asymmetry*), respectively. Depicted are responses relative to the dynamics of capital flows to facilitate comparisons, which applies to all subsequent figures.

Overall, the model demonstrates dynamics as one would reasonably anticipate. In baseline scenario, capital inflows appreciate nominal exchange rates, pushing down the interest rate, stimulating consumption and investment, which altogether brings a favorable response of the economy. On the flipside, capital outflows that depreciate the currency raise interest rate but slash consumption and investment. As a consequence, aggregate demand falls on impact. Note that magnitude of responses to capital inflows and outflows are approximately alike. Aggregate demand, for instance, increases by 0.02% on impact when capital flows in as it falls when capital flows out.

This is in stark contrast to the case wherein investment is constrained by endogenous credit in advance. While dynamic responses of the economy relative to capital inflows are so obviously trivial, as one can hardly detect any responses vis-à-vis the financially frictionless economy illustrated in the left vertical panel of Figure 1, adverse effects of capital outflows on the economy are actually strengthened. One sees greater depreciation with larger increase in interest rates. The former worsens collateral worth and thus credit-worthiness for external borrowings, restricting borrower's ability to raise debt for investment. The latter tilts intertemporal consumption reallocation unfavorably against the current. Together, capital outflows drag the economy more persistently and to greater extent.

[INSERT FIGURE 1 HERE]

Would the asymmetry be strengthened or nullified when shocks to capital flows are temporary, larger, or more volatile? We address these questions by changing the nature of the shocks. First, we assume a less persistent capital flows by setting $\rho_{KI} = \rho_{KI} = 0.1$. Though not shown here due to space constraint but are available upon request, we find that asymmetry is still alive. Next, by maintaining all the parameter values, we double the absolute size of the shocks.

Again, asymmetry survives with relative responses of the economy identical to the previous simulation.

Last, we multiply the volatility of shock to capital inflows and outflows by 20 times, that is $\sigma^{KI} = \sigma^{KO} = 0.1$. Although dynamic responses of the economy relative to capital inflows have found to be also amplified when capital flows become more volatile, it is far less than the damaging effects facing the economy when capital outflows are equally volatile. Specifically, aggregate demand is lifted by 0.01% but is pulled down by 2% contemporaneously in the face of 1% shock to capital inflows and outflows, respectively.

Summing up, two interesting features emerge. First, asymmetry is always there, despite the nature of the shocks to capital flows, so far as there is a credit friction. Second, volatility of capital flows seems to be more impactful than the persistence and absolute size of capital flows. While sudden but temporary, or sudden and larger, surge in capital outflows hurts the economy in absolute term, relative damages remain approximately identical. However, volatile outflows wreak havoc the economy not only absolutely but also relatively to the size of flows.

5. Can Prudential Capital Controls Eliminate Asymmetry?

Because borrower usually does not internalize the potential implications of incurring individual external debt on the fragility of credit-worthiness to capital outflows for the economy as a whole, over-borrowing tends to occur. And here comes the role of prudential capital controls.

In the spirit of Jeanne and Korinek (2012), and Korinek (2011), we model prudential capital control as a tax on the difference between marginal benefit of easing credit constraint for decentralized borrower μ_t^{db} and constrained planner μ_t^{SP}. For decentralized borrower, μ_t^{db} is shown in Eq. (25), which gives Eq. (26). For constrained planner who would internalize the impact of foreign borrowings on credit-worthiness, marginal benefit of easing credit constraint can be derived as

$$-\beta\lambda_{t+1}\left(\frac{R_{L,t}^{*}S_{t+1}}{P_{t+1}}\right)+\beta\mu_{t+1}^{SP}\{1-\exp(-\omega\mathfrak{C}_{t+1})\}\left(\frac{S_{t+1}}{P_{t+1}}\right)+\beta\mu_{t+1}^{SP}\left(\frac{S_{t+1}}{P_{t+1}}\right)\exp(-\omega\mathfrak{C}_{t+1})\,\omega\mathfrak{C}_{t+1}$$

$$=0$$

which can be simplified to

$$\tilde{q}_{L^*,t}\left(\equiv\frac{\mu_t^{CP}}{\lambda_t}\right)=\frac{R_{L,t-1}^{*}}{1-\exp(-\omega\mathfrak{C}_t)\underbrace{+\exp(-\omega\mathfrak{C}_t)\,\omega\mathfrak{C}_t}_{\substack{internalization\\ of\ pecuniary\ externality}}}$$

As decentralized borrower doesn't need to consider the social cost of borrowing, it is reasonable to say that private's marginal benefit of easing credit constraint is greater than constrained planner's one. This implies $q_{L^*,t}>\tilde{q}_{L^*,t}$. An optimal tax can be imposed in such a way that $q_{L^*,t}=(1+\tau_{i,t})\tilde{q}_{L^*,t}$, which reads

$$\tau_{i,t}=\frac{1-\exp(-\omega\mathfrak{C}_t)+\exp(-\omega\mathfrak{C}_t)\omega\mathfrak{C}_t}{1-\exp(-\omega\mathfrak{C}_t)}-1 \tag{30}$$

When borrower's credit-worthiness is fundamentally strong in that $\exp(-\omega\mathfrak{C}_t)\cong 0$, tax on capital flows is unnecessary, as $\tau_{i,t}=0$. However, for a weakening credit-worthiness in that $\exp(-\omega\mathfrak{C}_t)>0$, $\tau_{i,t}>0$ requires an imposition of tax on capital flows. More fragile is the credit-worthiness to the state of the economy, higher is the tax. In this respect, such tax is obviously *prudential* in the sense that capital controls are tightened to limit financial instability nurtured by capital surges, and are then loosened when such instability is trivial (Ostry et al., 2012; Forbes et al., 2013).

We impose a prudential tax of Eq. (30), alternatively, on gross capital outflow, gross capital inflows, and external debt inflows in such a way that tax on capital outflows $\tau_{KO,t}$ reduces marginal benefit of purchasing foreign bonds by domestic resident in Eq. (12), tax on capital inflows $\tau_{KI,t}$ reduces marginal benefit of purchasing domestic bonds by foreigner in Eq. (14), tax on debt inflows $\tau_{DI,t}$ increases cost of incurring foreign debt by domestic borrower in Eq. (26) and the return on lending to domestic borrower by foreign lender in Eq. (27). Figure 2 illustrates dynamic responses of the economy relative to capital outflows under permanent and temporary shocks to capital outflows when different types of prudential tax are imposed.

[INSERT FIGURE 2 HERE]

Judging from the magnitude of responses, when compared to Figure 1, one can infer that prudential capital control is able to eliminate the asymmetry even in the presence of credit friction. Take the case of tax on capital inflows, for instance, as depicted in the left vertical panel of Figure 2. It minimizes the adverse effect of capital outflows on investment and aggregate demand to a level identical to the effects of capital inflows on the economy. And the economy responds more favorably when shock to capital outflow is temporary.

Another interesting observation is that capital outflows control seems performing better than capital inflows control. In addition to the fact that it eliminates the asymmetry, capital outflows control actually supports the economy especially in the face of persistent capital outflows. The firewall disincentives capital outflows by domestic resident. In conjunction with un-gated capital inflows by foreigners, nominal exchange rates and the corresponding credit-worthiness are supported. Falling interest rate bolsters current consumption and thus the economy. This finding in spirit (though with very different mechanism) echoes the finding of Benigno et al. (2013) that ex-post intervention during a time of crisis is likely to be more important than ex-ante prudential measures in tranquil times.

Viewed differently, capital outflow controls also play the role of ex-ante prevention. The logic is simple. By expecting the implementation of a prudential tax on capital outflows *ex post*, especially when continuous capital inflows are followed by credit booms which may deteriorate overall credit-worthiness, foreign investors would be discouraged to flood domestic financial market *ex ante* (Eng and Wong, 2014). As a result, a reduction in cumulative capital inflows due to the expectation of tax on capital outflows minimizes the probability of over-borrowing *ex ante*, limiting the size and the damages of capital outflows *ex post*, and making the prudential tax unnecessary *ex post*.

Most effective is certainly prudential tax on debt flows itself. As Figure 2 has vividly depicted, not only that the economy with prudential tax on external debt flows responds equally favorable as the one under prudential capital outflows control, magnitude of the benign effects is larger, though still trivial relatively, irrespective of the persistence of shocks. Despite the slump in current consumption, thanks to rising interest rate amid persistent capital outflows, without over-borrowing and thus the fragility of credit-worthiness, investment and aggregate demand react favorably to nominal depreciation.

Rounding the Corner of Trilemma: Role of Stabilizing Exchange Rates

By comparing the dynamic responses of interest rate under vertical panel on capital outflows in Figure 1 and those under forth row panel in Figure 2 across different types of prudential capital controls, we find an interesting point: a more stabilized economy is attained in the presence of capital controls with less monetary bullets in that interest rate responds to a smaller extent. This finding is coherent with Farhi and Werning's (2013) argument formulated in a standard New Keynesian model of a small open economy that capital controls are also desirable even when the exchange rate is completely flexible. Prudential capital controls lean against the wind and help smooth out the effect of capital outflows by reducing the amplification effect of nonlinear credit-in-advance constraint. Monetary policy thus carries smaller burden of adjustment.

We take one more step in this last section to probe into the role of managing exchange rates in tandem with the imposition of capital controls. We expand Taylor-rule monetary policy for home country in Eq. (19) to include rate of depreciation

$$r_t/\bar{r} = (r_{t-1}/\bar{r})^{\rho_r} \left(\left(\frac{1+\pi_t}{1+\bar{\pi}} \right)^{\theta_\pi} \left(\frac{AD_t}{AD_{t-1}} \right)^{\theta_{AD}} \left(\frac{S_t}{S_{t-1}} \right)^{\theta_S} \right)^{1-\rho_r} \exp(\sigma^r \varepsilon_t^r) \quad (31)$$

We set $\theta_S = 1.5$ to indicate high tendency of the central bank to stabilize variation in nominal exchange rates. Figure 3 depicts the dynamics responses of the economy to capital outflows under free floating and managed floating regimes.

[INSERT FIGURE 3 HERE]

On average, the economy has been fully stabilized when prudential capital inflows and outflows controls are imposed and nominal exchange rate fluctuations are managed. In fact, by managing exchange rates, interest rate responses are even smaller vis-à-vis those under free floating regime across three types of capital controls. The intuition is that exchange rate management has further insulated borrower's credit-worthiness from the exchange rate fluctuations. Together with prudential capital controls that help smooth out the adverse effects of capital outflows, they disconnect the economy from the financial friction, facilitating the role of monetary policy. This finding in a way conforms to the conventional belief of trilemma that greater monetary autonomy is gained when capital flows are restricted while exchange rate flexibility is limited (Klein and Shambaugh, 2013; Magud et al., 2014. See Yu et al., 2014 for contradictory empirical findings).

Lastly but interestingly, unlike the case of capital outflows control wherein benign effect on consumption and aggregate demand has also been smoothened out following exchange rate stabilization, the economy still responds favorably toward capital outflows when exchange rate flexibility is limited alongside a prudential tax on foreign debt. Exchange rate stabilization even helps bolster consumption. Tax on foreign debt flow seems to be a better tool vis-à-vis tax on portfolio capital flows in rounding the corners of policy trilemma.

6. Conclusion

We have found that the presence of an endogenous credit-in-advance constraint for carrying out investment, which we believe to be a common financial friction for firms in developing economies, can bring about an asymmetric effect of capital flows on the economy. It is asymmetric in such a way that while capital inflows can hardly spur the economy, capital outflows can cause a recession.

That triggers the asymmetry is borrowers' credit-worthiness that is endogenous to the variation in exchange rates. Given the foreign borrowings, a nominal depreciation due to capital outflows reduces the collateral value denominated in local currency, thereby worsening the borrowers' credit-worthiness and limiting her ability to raise debt and to invest. A nominal appreciation due to capital inflows, however, is irrelevant when borrowers' credit-worthiness is strong, making the constraint irrelevant.

Because decentralized borrowers tend to over-borrow when ignoring the implications of individual foreign borrowing on building up financial fragility of the economy toward capital outflows and depreciation, prudential capital controls come into play. We found that prudential capital controls do lean against the wind, and help smooth out the adverse effects of capital outflows. In other words, it silences the asymmetry. Of all types of capital controls considered, prudential tax on foreign debt works most effectively, followed closely by capital outflows control, which not only serves as *ex post* management but also *ex ante* preventive measure.

By setting up a firewall against the virulent capital outflows, prudential capital controls lighten the burden of monetary policy as a stabilization tool, even when exchange rate is flexible. By moderating exchange rate fluctuations, the economy can further be shielded from adverse effects of capital outflows, as the borrowers' credit-worthiness is disconnected from exchange rate variations.

However, it is too early to seal any solid conclusion given a minimal model. In future work, we intend to study the effectiveness of prudential capital control in an open-economy model that incorporates different mechanisms of asymmetry, i.e., different composition of investment and nominal rigidities, and trade structure. Such model allows for a more thorough analysis on capital controls and the policy trilemma.

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Table 1. Parameters and Shocks

Household		
Subjective discount rate (Quarterly)	β	0.99
Risk aversion	σ	2
Utility weight for leisure	a_N	1
Inverse Frish elasticity of labor supply	χ	0
Els between home and foreign goods	η	1.5
Share of home goods in CES consumption bundle	φ	0.5
Production		
Share of capital stock	α	0.4
Depreciation rate (quarterly)	δ	0.025
Convex adjustment cost parameter		
Physical investment	b_I	10
Capital flows	b_{KO}, b_{KI}	30
Debt flows	b_{DI}	10
Shock persistence		
Efficient shocks	$\rho_a, \rho_c, \rho_N, \rho_I$	0.8
Capital flows	$\rho_{KI}, \rho_{KO}, \rho_{DI}$	0.7
Volatility of shocks		
Preference,	σ^c	1×10^{-6}
Labor supply, monetary policy, Total factor productivity	$\sigma^N, \sigma^M, \sigma^a$	1×10^{-5}
Investment-specific technology	σ^I	7×10^{-5}
Capital flows	$\sigma^{KI}, \sigma^{KO}, \sigma^{DI}$	0.005
Monetary policy		
Persistence	ρ_r	0.8
Inflation	θ_π	1.5
Aggregate demand growth	$\theta_{\Delta AD}$	0.125

Table 2. Comparing Simulated Data with Stylized Facts

	Data	Model Simulation
$\sigma(AD)$	2.74	2.87
$\rho(AD)$	0.76	0.38
$\sigma(C)/\sigma(AD)$	1.45	1.17
$\sigma(I)/\sigma(AD)$	3.91	0.89
$\rho(C,AD)$	0.72	0.89
$\rho(I,AD)$	0.77	0.93

Notes: Aguiar and Gopinath (2007) and authors' simulation

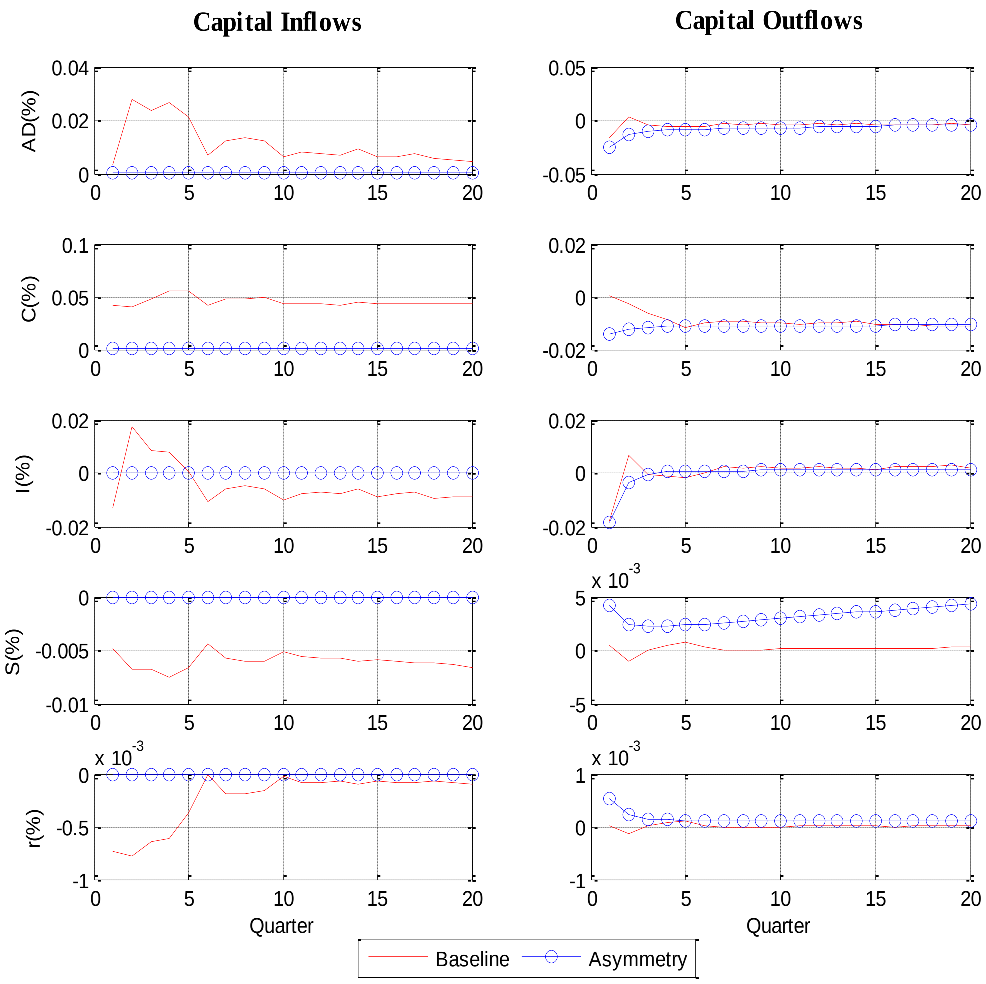

Figure 1. Dynamic Responses (Relative to Dynamics of Capital Flows) to 1% Increase in Capital Flows

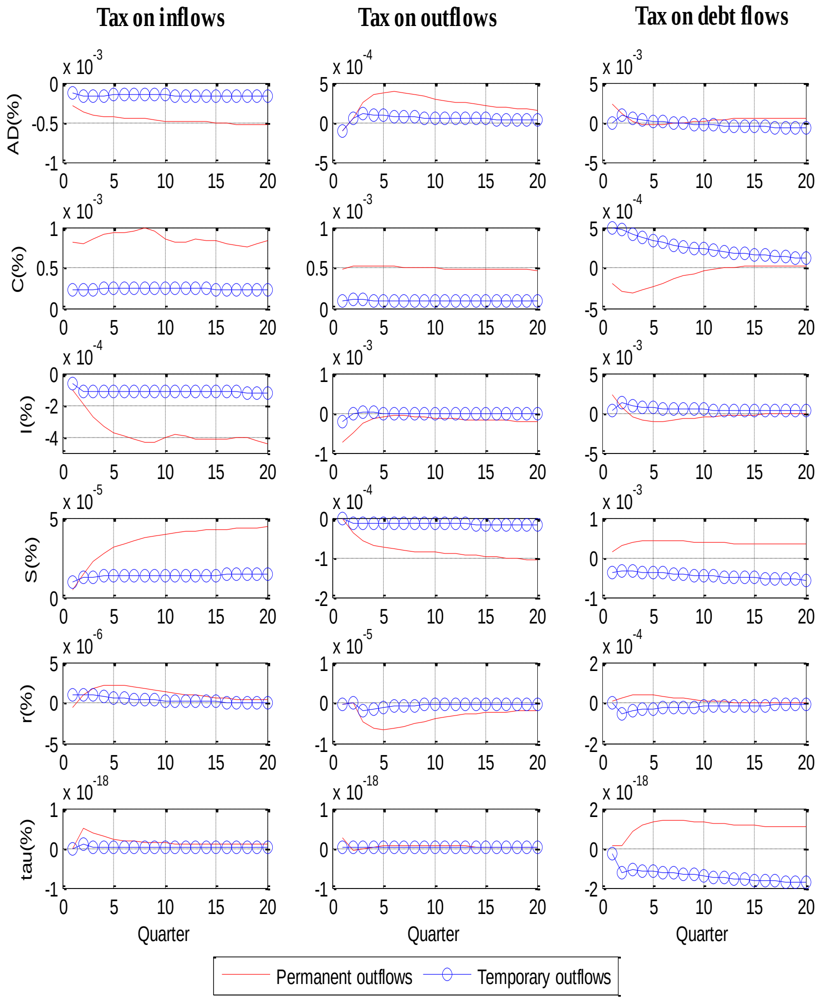

Figure 2. Effectiveness of Different Prudential Capital Controls

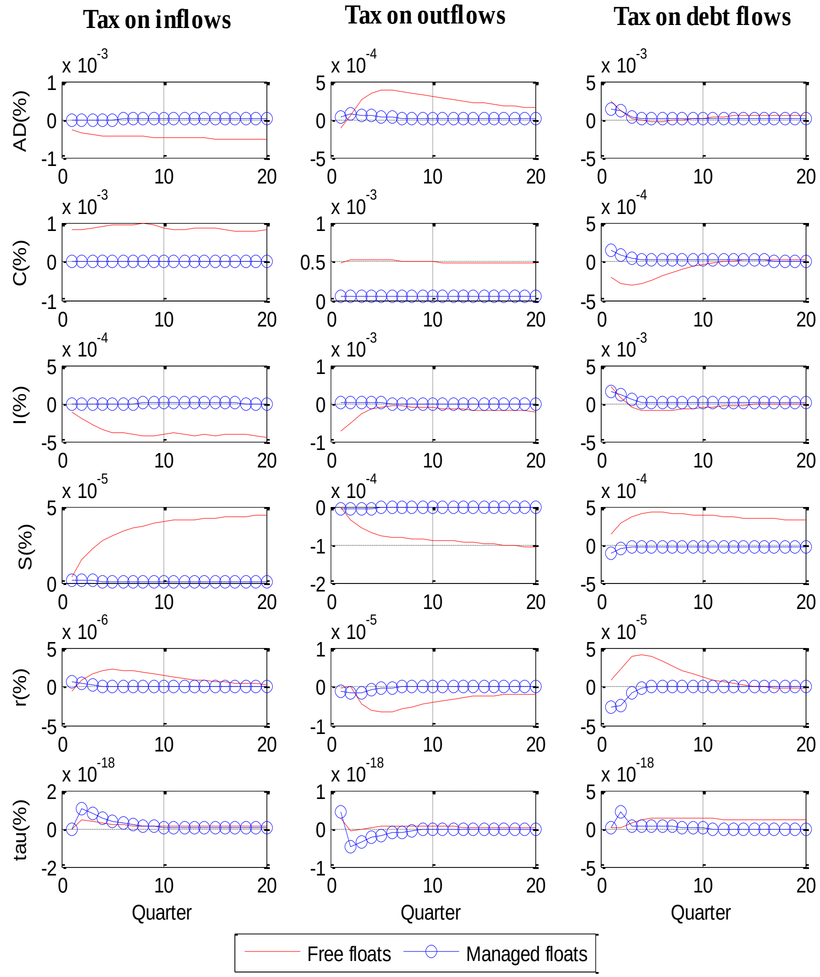

Figure 3. Managing Exchange Rates Does Matter