Accounting for asymmetric growth effect of capital flows in a model with nonlinear credit constraint: Implications for prudential capital control

Yoke-Kee Eng* Chin-Yoong Wong

Department of Economics, Universiti Tunku Abdul Rahman, Malaysia

*Corresponding author. Faculty of Business and Finance, Universiti Tunku Abdul Rahman, Jalan Universiti, Bandar Barat, 31900 Kampar, Perak, Malaysia. Tel.: +6054688888 ext. 4337; fax: +6054667407. *Email address*: engyk@utar.edu.my (Eng Y.-K.)

Abstract

Empirical evidence of the causal relationship between capital flows and economic growth over the decades is largely indecisive. While the promised benefits to countries that open for capital inflows have not been realized, sudden and massive capital outflows often visibly wreak havoc on the economy. By using the recently developed asymmetric Granger causality test, we find overwhelming evidence across nine selected Asian countries in support of asymmetric effect of capital flow on economic growth in the sense that cumulative capital inflows are growth irrelevant, whereas cumulative capital outflows are growth destructive. Based on an open-economy real business cycle model expanded with a firm's occasionally binding credit-worthiness, we provide an economic intuition for the asymmetry. We also discuss the implications of asymmetry on the design of prudential capital control. In particular, tax on foreign currency borrowing and floodgate-type prudential capital-flow control work best for minimizing output loss to capital outflows.

Keywords: Capital flow; Economic Growth; Asymmetric Granger causality test; Occasionally binding constraint; Prudential capital control

1. Introduction

Prior to the onset of the Asian financial meltdown in 1997/98, East and Southeast Asian emerging economies that liberalized capital accounts in the early 1990s were the darlings of international investors. The fast and stable economic expansion during that time was often claimed to be the outcome of capital account liberalization. As the crisis unfolded and capital flows suddenly reversed from net inflow to outflow in 1997, one economy after another fell sharply into deep recession. With the benefit of hindsight, we now learn that while it remains empirically dubious to attribute the miraculous economic growth to massive capital inflows in the early 1990s, it is beyond controversy to associate the Asian economic recession with the drastic capital outflows.

In fact, the evidence of asymmetric relationships between capital flows and economic growth extends beyond Asia. From the one perspective, after decades of effort spent searching for answers to the question of whether capital account liberalization spurs growth, the evidence in support of this premise is weak. Although some have found a positive effect conditional on the existence of good institutions, legitimate doubts are often cast on the robustness and context-sensitivity of such a conditional effect. Prasad et al. (2007) and Gourinchas and Jeanne (2006) have even found that the fastest growing countries did so without much foreign capital.

On the other hand, a sudden stop in capital flows has been the recurring theme of financial and economic crises. A massive capital flow reversal depreciates the exchange rate and plunges asset prices, which, in turn, devalues the worth of collateral for borrowing, thus instigating an adverse balance-sheet effect on domestic agents indebted in foreign currency. The resulting contraction in aggregate demand amplifies the damaging deleveraging process (Jeanne et al., 2012). The common thread that links currency crash and financial and economic crises is foreign currency debt (see, for instance, Bordo et al., 2010; Bordo and Meissner, 2006). In other words, in the absence of foreign currency debt, a slump in the currency driven by capital outflows is not likely to trigger the balance-sheet effect and poses no immediate threat to the economy. This finding is evidenced by the resilience of emerging economies to weather the storm of capital flow reversals during the recent global financial crisis, despite the fact that disruption in cross-border capital flows seriously affected the advanced economies (Tille, 2012).

Motivated by these observations, the first goal of this paper is to formally investigate whether there is an asymmetric causal relationship between capital flow and economic growth. While our paper naturally fits into the larger literature on the growth effect of capital inflow, we hope it is useful in this enterprise by addressing different questions. We rethread the old song of "whether net capital flow precedes growth" with a new chorus: Does net capital flow *asymmetrically* precede growth? Are net capital inflows irrelevant to growth while net capital outflows are detrimental to growth? We address this question in Section 2 by using the asymmetric Granger causality testing procedures recently developed by Hatemi-J's (2012). We find overwhelming evidence, as elaborated in Section 3, across nine selected Asian countries in support of such asymmetry, in that cumulative capital inflows are found to be growth irrelevant whereas cumulative capital outflows are found to be growth destructive. The results also decisively reject the possibility of reverse causality from growth to capital flows.

Having quantified the asymmetry, our second goal is to find out why: What causes the asymmetry? The underlying mechanism is the firm's credit-worthiness, which is influenced by the occasionally binding collateral constraint that determines the slackness of the foreign-borrowing-in-advance constraint for physical investment, which we incorporate into a small open-economy real business cycle model in Section 4. The essential logic of the argument follows.

Suppose capital flows in and appreciates the currency. As a result, rising currency increases the foreign value of domestic collateral and enhances the firm's credit-worthiness for foreign borrowing. The collateral constraint is thus slack, and continuous capital inflows are irrelevant to investment and economic growth. In contrast, a fall in the currency driven by continuous capital outflows that erode the foreign value of domestic collateral places the firm's credit-worthiness in jeopardy. If the capital outflows are massive and prolonged, collateral constraints and, by default, credit-in-advance constraints become more likely to bind. Accordingly, a collapse in investment caused by the binding constraint would drag the economy into recession.

We end the discussion by taking stock of the policy implication of the asymmetry in Section 5. Interestingly, we find that an effective policy, one that extends the threshold of the firm's credit-worthiness below which cumulative capital outflows pose an immediate threat to economic growth and that weakens the balance-sheet effect of the exchange rate variability, resembles the prudential-oriented capital inflow control, as recently advocated by Jeanne and Korinek (2010) and Jeanne et al. (2011). More effective measure is to set up a floodgate, not just temporary sandbags, consisting of a tax on capital inflows during tranquil times and a subsidy on capital inflows during times of crisis, or alternatively, a subsidy on capital outflows during tranquil times and a tax on capital outflows during times of crisis. This finding responds to Klein's (2012) call for differentiating episodic from long-standing capital control measures. Above all, the most effective way to minimize the palpable pains of capital outflows is to silence the source of financial amplification. In other words, prudentially restrict the short-term foreign borrowing at all times.

2. Does capital flow precede growth? An asymmetric Granger causality approach

Consider a *p*-th order bivariate system of invertible stationary processes for output Y_t and net capital flow $\mathcal{CF}_t$, as in the following autoregressive representation:

$$\begin{bmatrix} Y_t \\ \mathcal{CF}_t \end{bmatrix} = \mathbb{a}_0 + \sum_{i=1}^{p} \begin{bmatrix} \alpha_{11,i} & \alpha_{12,i} \\ \alpha_{21,i} & \alpha_{22,i} \end{bmatrix} \begin{bmatrix} Y_{t-i} \\ \mathcal{CF}_{t-i} \end{bmatrix} + \begin{bmatrix} \varepsilon_{Y,t} \\ \varepsilon_{\mathcal{CF},t} \end{bmatrix} \tag{1}$$

where $\mathbb{a}_0$ is a vector of deterministic terms, $\alpha_{jk,i}$ for $j, k = 1,2$ are finite polynomials, $\varepsilon_{Y,t}\left(= \sum_{i=0}^{p} \varepsilon_{Y,t+i}\right)$ and $\varepsilon_{\mathcal{CF},t}\left(= \sum_{i=0}^{p} \varepsilon_{\mathcal{CF},t+i}\right)$ are taken to be two uncorrelated white-noise series where $E\left[\varepsilon_{\mathcal{CF},t}\varepsilon_{\mathcal{CF},s}\right] = E\left[\varepsilon_{Y,t}\varepsilon_{Y,s}\right] = 0$. Then, for $\alpha_{12,i} = 0$, where $i = 1,2, \dots, p$, we contend that capital flow is not Granger-causal for output growth as none of its lags appears in the Y_t equation. In other words, capital flow is Granger-causal for output growth if at least one of the $\alpha_{12,i}$ is not zero. This is the standard Granger causality test principle.

That said, the shortcomings of the standard Granger causality test are obvious. For example, the test has nothing to say about whether it is the capital inflow or outflow that Granger causes growth, it sheds no light on whether capital flow (either in or out) Granger causes positive or negative economic growth, and hence, it does not allow an asymmetric Granger causal relationship. To address this shortcoming, we make use of the asymmetric Granger causality test recently developed by Hatemi-J (2012). Hatemi-J (2012) extends the idea originated in Granger and Yoon (2002) of decomposing the stochastic disturbance terms into positive and negative shocks. With respect to our context, it means that we can now explicitly decompose the causal impact of positive changes in capital flows (which indicate net inflows) from the negative changes (which indicate net outflows).

The intuition is simple. Assume that capital flow and economic growth follow a random walk in such a way that

$$\mathcal{CF}_t = \mathcal{CF}_{t-1} + \varepsilon_{\mathcal{CF},t} = \mathcal{CF}_{10} + \sum_{i=1}^{t} \varepsilon_{\mathcal{CF}i} \quad (3)$$

$$Y_t = Y_{t-1} + \varepsilon_{\mathrm{Y},t} = Y_{20} + \sum_{i=1}^{t} \varepsilon_{Yi} \quad (4)$$

where $t = 1,2, \dots, T$ denotes discrete-time periods, the constants $\mathcal{CF}_{10}$ and Y_{20} indicate the initial values for capital flow and economic growth, respectively, and $\varepsilon_{\mathcal{CF}i}$ and ε_{Yi} are white-noise disturbance terms. We decompose the disturbance terms into positive and negative shocks

$$\varepsilon_{\mathcal{CF}i} = \varepsilon_{\mathcal{CF}i}^{+} + \varepsilon_{\mathcal{CF}i}^{-} \quad (5)$$

$$\varepsilon_{Yi} = \varepsilon_{Yi}^{+} + \varepsilon_{Yi}^{-} \quad (6)$$

where $\varepsilon_{\mathcal{CF}i}^{+} = \max(\varepsilon_{\mathcal{CF}i}, 0)$, $\varepsilon_{\mathcal{CF}i}^{-} = \min(\varepsilon_{\mathcal{CF}i}, 0)$, $\varepsilon_{Yi}^{+} = \max(\varepsilon_{\mathcal{Y}i}, 0)$, and $\varepsilon_{Yi}^{-} = \min(\varepsilon_{\mathcal{Y}i}, 0)$. Eqs. (3) and (4) can then be rewritten as

$$\mathcal{CF}_t = \mathcal{CF}_{t-1} + \varepsilon_{\mathcal{CF},t} = \mathcal{CF}_{10} + \sum_{i=1}^{t} \varepsilon_{\mathcal{CF}i}^{+} + \sum_{i=1}^{t} \varepsilon_{\mathcal{CF}i}^{-} \quad (7)$$

$$Y_t = Y_{t-1} + \varepsilon_{Y,t} = Y_{20} + \sum_{i=1}^{t} \varepsilon_{Yi}^{+} + \sum_{i=1}^{t} \varepsilon_{Yi}^{-} \quad (8)$$

The cumulative positive and negative shocks, respectively, constitute capital inflows (economic growth) and capital outflows (economic downturn) in such a way that

$$\mathcal{CF}_t^+ = \sum_{i=1}^{t} \varepsilon_{\mathcal{CF}i}^+ \quad (9)$$

$$\mathcal{CF}_t^- = \sum_{i=1}^{t} \varepsilon_{\mathcal{CF}i}^- \quad (10)$$

$$Y_t^+ = \sum_{i=1}^{t} \varepsilon_{Yi}^+ \quad (11)$$

$$Y_t^- = \sum_{i=1}^{t} \varepsilon_{Yi}^- \quad (12)$$

This implies that each shock has a long-lasting effect on the underlying variable. With these variables, we can test for asymmetric causality using the standard vector autoregressive model of order *p*, VAR(*p*). Suppose we are interested to test the causal relationship between capital inflows and economic growth. Eq. (1) now reads

$$\mathbb{y}_t^+ = \mathbb{a}_0 + \mathrm{A}_1 \mathbb{y}_{t-1}^+ + \cdots + \mathrm{A}_p \mathbb{y}_{t-p}^+ + \mathbb{u}_t^+ \quad (13)$$

where $\mathbb{y}_t^+ = [Y_t^+ \quad \mathcal{CF}_t^+]'$ and $\mathbb{u}_t^+$ is a 2 x 1 vector of the cumulative sum of positive error terms. The null hypothesis that capital *inflow* is not Granger-causal for *economic growth* can be tested depending on whether row j, column k elements in A_r, where $j = 1, k = 2$, equal zero for $r = 1, \dots, p$. By the same token, we can test whether *capital outflow* Granger-cause *economic downturn* by examining

$$\mathbb{y}_t^- = \mathbb{a}_0 + \mathrm{A}_1 \mathbb{y}_{t-1}^- + \cdots + \mathrm{A}_p \mathbb{y}_{t-p}^- + \mathbb{u}_t^- \quad (14)$$

In this paper, we test four combinations for each direction of causality.

The optimal lag order (*p*) is selected based on the information criteria suggested by Hatemi-J (2003), which proves to be robust for the ARCH effect and performs well when the VAR model is used.

$$\text{HJC} = \ln\left(\left|\widehat{\Omega}_j\right|\right) + j\left(\frac{n^2 \ln T + 2n^2 \ln(\ln T)}{2T}\right) \quad (15)$$

where $j = 0, \dots, p$, $\left|\widehat{\Omega}_j\right|$ is the determinant of the estimated variance-covariance matrix of the error terms in the VAR (j) model, n is the number of equations the VAR model has, and T is the number of observations. As suggested in Hatemi-J (2012) and following Toda and Yamamoto (1995), additional unrestricted lag is added to the VAR model to accommodate the effect of one unit root. Given the short time span of data, we apply the bootstrapping simulation technique as detailed in Hatemi-J (2008). This technique helps to achieve better size and power properties compared to the test that is based on asymptotical distribution. The bootstrapped critical values are generated at three different levels of significance based on ten thousand repetitions of the simulation. Interested readers can refer to Hatemi-J (2012) for technical details.

3. Empirical findings

3.1 The data

We collect annual time-series data that spans over 32 years, 1980 to 2011, for nominal gross domestic products (GDP), current account, and capital account for nine Asian countries, including China, India, Indonesia, Japan, Republic of Korea, Malaysia, the Philippines, Singapore and Thailand. The data are sourced from International Financial Statistics and Balance of Payments Statistics issued by the International Monetary Fund. Divided by population, the resultant per capita nominal GDP is then adjusted for purchasing power parity (PPP) in terms of the U.S. dollar and takes the form of a natural logarithm. In short, we call PPP-adjusted per capita GDP the per capita real GDP.

Current account and capital account as a share of GDP are used as two different proxies for net capital flows. While the former encompasses both official and private capital flows, the latter reflects pure private capital flows. Last, we turn the value of the current account balance to the opposite sign so that current account surplus (deficit) can be easily interpreted as capital outflow (inflow). The time plots of the current account as a share of GDP (-CA/GDP) and the capital account as a share of GDP (KA/GDP), along with real GDP growth rate, are as shown in Figure 1, and the time plots of the real GDP per capita in logarithm value are shown in Figure 2. Figure 3 describes the cumulative positive and negative sums of per capita real GDP and capital flows represented by -CA/GDP and KA/GDP, respectively. Causality that runs from capital flow (in and out) to the economy (growth and downturn), and vice versa, for each country are formally tested. As each direction of causality involves four hypotheses with two different proxies for capital flow, there are a total of 144 causality tests to be conducted.

[INSERT FIGURES 1, 2, and 3 HERE]

Before proceeding to formal testing, it is worthwhile to eyeball the asymmetric relationship between capital flows and real economic growth over time in Figure 1. At first glance, there are many instances in which capital outflows are associated with falling economic growth, particularly during the Asian currency and financial crises. However, a case such as Thailand, where capital inflows are clearly associated with rising economic growth, is the exception rather than the norm. More puzzling is the observation that capital outflows occur along with rising economic growth. China's economic expansion after year 2000, for instance, has witnessed continuous capital outflows as did Malaysia, the Philippines, and Singapore after the year 2002.

3.2 Pre-testing

Preceding asymmetric causality testing, we need to determine whether unit roots are present in the time series. To do so, we use the Dickey-Fuller generalized least squares (DF-GLS) test. This test dominates the ordinary DF test in terms of small sample size and power (Elliott et al., 1996). Though not shown (but available upon request), the series are all difference-stationary. However, the causality test between integrated series remains to be implemented within the VAR-in-level framework without pre-testing for co-integration. Gospodinov et al. (2013) have recently shown that VAR-in-level specification is robust to the potential uncertainty about exact integration and co-integration properties of the data. This is supported by the seminal Toda and Yamamoto (1995) that co-integration does not matter with respect to causality testing when additional lags of each variable based on the maximum order of integration are added to the model.

3.3 Results

Table 1 reports the results of the asymmetric causality test when –CA/GDP is used as a proxy for capital flows. The findings are overwhelmingly in favor of the asymmetric relationship between capital flow and economic growth in that cumulative capital inflows ($\mathcal{CF}_t^+$) do not Granger-cause economic growth ($\mathcal{Y}_t^+$), whereas cumulative capital outflows ($\mathcal{CF}_t^-$) Granger-cause economic downturn ($\mathcal{Y}_t^-$) with strong statistical significance. Meanwhile, with very few exceptions, other null hypotheses for different combinations of cumulative capital flows and economic growth cannot be rejected at any widely accepted level of significance. Table 1 also convincingly demonstrates that economic growth performance does not Granger-cause capital flow. All these findings are robust to different proxies for capital flows. Table 2 shows the results of the asymmetric causality test when KA/GDP, which considers only private capital flows, is used in the tests. The finding that capital outflow is growth-crashing remains true and that capital inflow is growth-irrelevant also holds.

[INSERT TABLES 1 and 2 HERE]

4. Modeling the asymmetry

What causes the asymmetry? In this section, we will present a simple open-economy real business cycle model to account for the asymmetric relation between capital flows and economic growth. The key property is the occasionally binding collateral constraint embedded in the credit-in-advance constraint for physical investment. The tour starts from a frictionless economy.

4.1 A frictionless economy

Consider that a representative household chooses the path of consumption C, domestic B and foreign bonds B^* to maximize the utility function

$$U = E_0\left\{\sum_{i=0}^{\infty}\left[\beta^{t+i}\frac{(C_{t+i})^{1-\sigma}}{1-\sigma}\right]\right\} \tag{16}$$

subject to the flow budget constraint

$$\frac{B_t+S_tB_t^*}{P_t} = (1+r_{t-1})\frac{B_{t-1}}{P_t} + S_t(1+r_{t-1}^*)\frac{B_{t-1}^*}{P_t} + Y_t - C_t - (K_t-(1-\delta)K_{t-1}) \tag{17}$$

where

$$Y_t = AK_{t-1} \tag{18}$$

r_t and r_t^*, respectively, denote yield on domestic and foreign bonds, S_t is the nominal exchange rate defined as domestic currency per unit of foreign currency, Y_t is aggregate output, K_t is the fixed capital stock accumulated at the end of period t, and δ denotes depreciation rate. The term $K_t - (1-\delta)K_{t-1}$ equals investment I_t. The parameter σ governs the attitude towards risk.

The consumption basket comprises domestic and foreign consumer goods with unit elasticity of substitution, $C_t = \left(C_{h,t}\right)^{\rho}\left(C_{fh,t}\right)^{1-\rho}$, where the parameter ρ denotes the preference toward home goods. Denoting $P_{h,t}$ and $P_{fh,t}$, respectively, as price of domestic and imported goods, optimal demand function for domestic and imported foreign consumer goods takes the form $C_{h,t} = \rho\left(P_{h,t}/P_t\right)^{-1}C_t$ and $C_{fh,t} = (1-\rho)\left(S_t P_{fh,t}/P_t\right)^{-1}C_t$. $P_t\left(= \left(\frac{P_{h,t}}{\rho}\right)^{\rho}\left(\frac{S_t P_{fh,t}}{1-\rho}\right)^{1-\rho}\right)$ is the utility-based consumer price index (CPI).

The market equilibrium reads

$$Y_t = C_{h,t} + I_t + C_{hf,t} = C_t + I_t + C_{hf,t} - C_{fh,t} \tag{19}$$

where $C_t \equiv C_{h,t} + C_{fh,t}$. $C_{hf,t}$ refers to the export of domestically produced consumer goods to foreign country. Eq. (19) can also be interpreted as aggregate value added that corresponds to the concept of gross domestic product (GDP). In conjunction with this Eq. (19), given the holding of domestic bonds, the flow constraint (17) implies that foreign assets are accumulated when domestic absorption is less than the national output, and vice versa. In other words, trade surplus (deficit) mirrors capital outflow (inflow).

Denoting φ_t as the marginal utility of wealth, the marginal utility of consumption and of wealth are given by

$$\beta^t (C_t)^{-\sigma} = \varphi_t \tag{20}$$

$$\varphi_t P_{t+1} = \varphi_{t+1}(1+r_t)P_t \tag{21}$$

$$S_t \varphi_t P_{t+1} = E_t S_{t+1} \varphi_{t+1} (1 + r_t^*) P_t \tag{22}$$

Eqs. (21) and (22) combined give us the uncovered interest rate parity condition (UIPC),

$$(1 + r_t) = (1 + r_t^*) \left(\frac{E_t S_{t+1}}{S_t} \right) \tag{23}$$

while Eqs. (20) and (21) jointly give us the expected consumption growth rate.

$$\frac{E_t C_{t+1}}{C_t} = \left[\beta (1 + r_t) \left(\frac{P_t}{P_{t+1}} \right) \right]^{\frac{1}{\sigma}} \tag{24}$$

By the same token, foreign expected consumption growth rate reads

$$\frac{E_t C_{t+1}^*}{C_t^*} = \left[\beta (1 + r_t^*) \left(\frac{P_t^*}{P_{t+1}^*} \right) \right]^{\frac{1}{\sigma}} \tag{25}$$

Combining Eqs. (23) to (25), we can obtain the typical international risk sharing condition

$$\frac{C_t}{C_t^*} = \frac{S_t P_t^*}{P_t} \tag{26}$$

In a frictionless economy where the law of one price holds, exchange rate pass-through into export and import prices is complete. Nominal exchange rate variability that proportionally translates into CPI affects neither the distribution of world consumption (26) nor the expected consumption growth (24). Trade balance also remains unchanged. Given the aggregate value added (19), we can infer that nominal exchange rate variability is irrelevant to output growth. With respect to capital flow, this means that the inflows and outflows of portfolio capital induced by varying yield differentials that vary nominal exchange rates are also disconnected from output growth in a frictionless economy.

4.2 Firm's occasionally binding credit-worthiness as a mechanism of asymmetric causality

The economy is rarely frictionless. Enlightened by the empirical findings in Section 3, we know that while capital outflow precedes economic downturn, capital inflow is immaterial to economic growth. To account for these facts, we depart from a frictionless economy by making two extensions to the canonical RBC model (see Quadrini, 2011 for a thorough review of the common approaches in modeling financial frictions). First, we assume that firms need external financing for investments. Before investing at period t to acquire physical capital stock for production in period $t+1$, the firm must borrow in a global capital market at time $t-1$. The credit-in-advance constraint for physical investment is written as

$$K_t - (1-\delta)K_{t-1} \leq \omega_{t-1} \times \frac{S_t L_{t-1}^*}{P_t} \tag{27}$$

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 (27) binds eternally.

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

$$\omega_{t-1} = 1 - \exp(-\omega \mathcal{C}_t) \tag{28}$$

where $\mathcal{C}_t \left(= \frac{K_t}{R_{L,t-1}^* S_{t-1} L_{t-1}^*}\right)$ indicates the firm's credit-worthiness. $R_{L,t-1}^* \left(= 1 + r_{L,t-1}^*\right)$ refers to the gross foreign lending rate when debt is incurred, and ω is simply a scale factor. Firms are credit-worthy if the ratio between the value of collateral (which is the physical capital stock invested using the credits) denominated in foreign currency and the total foreign debt obligation (collateral-to-debt ratio, in short) is greater than the threshold value. More simply, a firm's credit-worthiness deteriorates when the collateral-to-debt ratio falls below the threshold value. In particular, nominal depreciation that erodes the foreign value of collateral and a rising foreign lending rate that amplifies the debt burden can jeopardize the firm's credit-worthiness with respect to external borrowing.

In conjunction with Eq. (28), the credit-in-advance constraint (27) becomes

$$I_t = \{1 - \exp(-\omega \mathcal{C}_t)\} \frac{S_t L_{t-1}^*}{P_t} \tag{29}$$

There are two interesting features about Eq. (29). First, the investment is now affected by the nominal exchange rate variability in that depreciation reduces the collateral value denominated in foreign currency, thereby worsening the firm's credit worthiness for external loans. As a result, the credit-constrained investment reduces the aggregate value added (19) on the one hand, and slows down capital stock accumulation and thus future aggregate production (18) on the other hand[1].

Second, and most interestingly, Eq. (29) resembles the characteristics of an occasionally binding constraint in the physical investment that underlies the asymmetric causal relationship between capital flows and economic growth, as proposed herein.

PROPOSITION 1: *Nominal appreciation is irrelevant to physical investment. Nominal depreciation, however, erodes collateral value, reduces the firm's ability to raise international credit, and causes physical investment to fall at increasing rate.*

Proof. To see this, we obtain the first and second partial derivatives of I_t against S_{t-1} as follows:

$$\frac{\partial I_t}{\partial S_{t-1}} = -\omega\mathcal{C}_t\left(\frac{S_t}{S_{t-1}}\right)\left(\frac{L_{t-1}^*}{P_t}\right)\exp(-\omega\mathcal{C}_t) \tag{30}$$

$$\frac{\partial^2 I_t}{\partial S_{t-1}^2} = 2\left(\frac{\partial I_t}{\partial S_{t-1}}\right)\left(\frac{1}{2}\omega\mathcal{C}_t - 1\right)\frac{1}{S_{t-1}} \tag{31}$$

Together with Eq. (29), Eq. (30) is

$$\frac{g_{I,t}}{\Delta_{t-1}} \equiv \frac{\partial I_t/I_t}{\partial S_{t-1}/S_{t-1}} = \frac{-\omega\mathcal{C}_t\exp(-\omega\mathcal{C}_t)}{1-\exp(-\omega\mathcal{C}_t)} \tag{32}$$

(i) When the firm is credit-worthy, that is, when $\mathcal{C}_t \to \infty$, which is due to a low debt-to-collateral ratio, low foreign interest rate, or strong foreign value of collateral, then $\exp(-\omega\mathcal{C}_t)$ approximates zero. As such, $\frac{\partial I_t}{\partial S_{t-1}} = \frac{\partial^2 I_t}{\partial S_{t-1}^2} = 0$.

(ii) In contrast, when a firm's credit-worthiness deteriorates as a result of too much leverage, the tumbling foreign value of collateral, or a rising interest burden, $\mathcal{C}_t \to 0$ and thus $\exp(-\omega\mathcal{C}_t)$ approximates the unit value. Accordingly, $\frac{\partial I_t}{\partial S_{t-1}} < 0$ and $\frac{\partial^2 I_t}{\partial S_{t-1}^2} > 0$. Q.E.D

4.3 A complete picture

[1] We maintain the assumptions of a complete exchange rate pass-through and flexible price such that the role of exchange rate as a conduit that couples capital flows and economic growth is highlighted.

In the presence of a credit-in-advance constraint for an investment that is endogenous to an occasionally binding collateral constraint, the flow budget constraint (17) is rewritten as

$$\frac{B_t+S_tB_t^*}{P_t}=(1+r_{t-1})\frac{B_{t-1}}{P_t}+S_t(1+r_{t-1}^*)\frac{B_{t-1}^*}{P_t}+\frac{S_tL_t^*}{P_t}+Y_t-C_t$$

$$-\left\{1+r_{L,t-1}^*+1-\exp(-\omega\mathcal{C}_t)\right\}\frac{S_tL_{t-1}^*}{P_t} \qquad (33)$$

In addition to the first-order conditions (20) to (22), we obtain the following marginal utility of loans

$$\varphi_tS_tP_{t+1}=\varphi_{t+1}S_{t+1}P_t\big(1+r_{L,t}^*+1-(1+\omega\mathcal{C}_{t+1})\exp(-\omega\mathcal{C}_{t+1})\big) \qquad (34)$$

Combined with Eq. (20), the Euler consumption equation reads

$$C_t=C_{t+1}\left\{\beta\big(1+r_{L,t}^*+1-(1+\omega\mathcal{C}_{t+1})\exp(-\omega\mathcal{C}_{t+1})\big)\right\}^{-\frac{1}{\sigma}} \qquad (35)$$

Eq. (35) enables us to establish the following proposition:

PROPOSITION 2: *Nominal depreciation that erodes collateral value tightens credit-constrained investment, thus resulting in a slower pace of capital stock accumulation. This slows down production and income generation for consumption. As a result, the expected consumption growth rate decreases. The collateral constraint, however, is not binding when the value of currency is increasing. Nominal appreciation is thus irrelevant to consumption.*

Proof. As in the proof for Proposition 1, we differentiate C_{t+1} against S_t in Eq. (35) to obtain

$$\frac{g_{C,t+1}}{\Delta_t}\equiv\frac{\partial C_{t+1}/C_{t+1}}{\partial S_t/S_t}=-\frac{1}{\sigma}[\beta(1+r_t^*)]^{\frac{1-\sigma}{\sigma}}\times(\omega\mathcal{C}_{t+1})^2\exp(-\omega\mathcal{C}_{t+1}) \qquad (36)$$

where $1+r_t^*=1+r_{L,t}^*+1-(1+\omega\mathcal{C}_{t+1})\exp(-\omega\mathcal{C}_{t+1})$. Identical to the proof for Proposition 1, $\exp(-\omega\mathcal{C}_{t+1})$ approximates zero when $\mathcal{C}_{t+1}\to\infty$. Hence, $\frac{g_{C,t+1}}{\Delta_t}=0$. For deteriorating $\mathcal{C}_{t+1}\to 0$, $\exp(-\omega\mathcal{C}_{t+1})$ approximates the unit value, and $\frac{g_{C,t+1}}{\Delta_t}<0$. Q.E.D

In the context of growth, the aggregate value added (19) that fits the concept of the gross domestic product (GDP) can be written as

$$g_{Y,t}\equiv\frac{\partial Y_t}{Y_t}=\left(\frac{C}{Y}\right)\frac{\partial C_t}{C_t}+\left(\frac{I}{Y}\right)\frac{\partial I_t}{I_t}+\left(\frac{C_{\hbar\not{f}}}{Y}\right)\frac{\partial C_{\hbar\not{f},t}}{C_{\hbar\not{f},t}}-\left(\frac{C_{\not{f}\hbar}}{Y}\right)\frac{\partial C_{\not{f}\hbar,t}}{C_{\not{f}\hbar,t}} \qquad (37)$$

When the exchange rate pass-through is complete, variability in the nominal exchange rate has no effect on trade balance. In conjunction with Eqs. (32) and (36), the relationship between economic growth and exchange rate variability is finally given by

$$\frac{g_{Y,t}}{\Delta_{t-1}} = -\omega\mathcal{C}_t \exp(-\omega\mathcal{C}_t)\left\{\frac{C}{Y}\left(\frac{1}{\sigma}\omega\mathcal{C}_t[\beta(1+r_{t-1}^*)]^{\frac{1-\sigma}{\sigma}}\right) + \frac{I}{Y}\left(\frac{1}{1-\exp(-\omega\mathcal{C}_t)}\right)\right\} \tag{38}$$

Consistent with Propositions 1 and 2, variability in exchange rate is irrelevant to economic growth, $\frac{g_{Y,t}}{\Delta_{t-1}} \approx 0$, when $\mathcal{C}_t \to \infty$ due to nominal appreciation. However, nominal depreciation that causes $\mathcal{C}_t \to 0$ can cause an economic recession.

5. Calibration and simulation

To simulate Eqs. (32), (36) and (38), we calibrate the parameters on the following values: the consumption-GDP ratio is 0.7, the investment-GDP ratio takes the value of 0.3, the foreign interest rate is 5% per annum, the subjective discount rate is 8% per annum, and the scale factor is set at 50 consistent with Brzoza-Brzezina et al. (2012). Figure 4 vividly illustrates how growth rates of GDP, consumption, and investment, respective of Eqs. (38), (36) and (32), are asymmetrically associated with the variability in exchange rates. Given the calibrated parameters, the threshold value of the collateral-to-debt ratio below which depreciation becomes contractionary is approximately 0.2. As evidenced, a cumulative nominal appreciation that strengthens the firm's credit-worthiness leaves no mark on the growth of the GDP, whereas cumulative nominal depreciation that weakens the firm's credit-worthiness may cause the economy to plummet.

[INSERT FIGURE 4 HERE]

With respect to capital flows that corroborate our empirical findings, we derive to the following corollary:

COROLLARY 1: *Cumulative capital inflows that continuously enhance the value of domestic currency and improve the firm's credit-worthiness have no effect on economic growth, whereas* *cumulative capital outflows that continuously depreciate the value of domestic currency and undermine the firm's credit-worthiness may cause the economy to go into recession.*

6. Extensions

Does asymmetry matter for the design of policy in mitigating the mess of abrupt capital flows? Drawing upon the model, we provide our intuitive answers to three of the most fundamental and intensely debated policy questions.

6.1 To control capital inflows or outflow?

Interest in the use of capital controls among emerging economies gained momentum in the aftermath of the Asian financial crisis. The implementation of capital outflow control in Malaysia has specifically instigated waves of rethinking about the unconditional capital account liberalization. The retrenchment increased when measures to control capital inflow were introduced and enforced even among small developed open economies in response to massive capital inflows that were induced by the zero-interest rate policy of the Federal Reserve (Ostry et al., 2011). These measures were created as sandbags to slow down the flood of capital and to mitigate the undesirable effect on currency appreciation and asset price bubbles. The question then is, given the asymmetric causal relationship, should capital inflow be restricted or can capital outflow control be trusted to minimize the potential damaging effect of sudden capital outflow on growth?

We address this question of inflow-or-outflow control by extending the model for tax on portfolio capital inflows and outflows. We first consider a tax on capital inflows denominated in domestic currency $\tau_{I,t}\left(\frac{B_{t-1}^{*}-B_{t}^{*}}{P_t}\right)S_t$, which will be rebated to households as a lump sum transfer $\Omega_t = \max\left\{\tau_{I,t}\left(\frac{B_{t-1}^{*}-B_{t}^{*}}{P_t}\right)S_t, 0\right\}$. The household budget constraint is then rewritten as $\frac{B_t+(1-\tau_{I,t})S_t B_t^{*}}{P_t} =$

$(1 + r_{t-1})\frac{B_{t-1}}{P_t} + S_t(1 + r^*_{t-1} - \tau_{I,t})\frac{B^*_{t-1}}{P_t} + \frac{S_t L^*_t}{P_t} + Y_t + \Omega_t - C_t - \{1 + r^*_{L,t-1} + 1 - \exp(-\omega\mathcal{C}_t)\}\frac{S_t L^*_{t-1}}{P_t}$. While the marginal utility of loans remains identical to Eq. (34), the marginal utility of wealth becomes $\varphi_t S_t P_{t+1}(1 - \tau_{I,t}) = \varphi_{t+1} S_{t+1} P_t(1 + r^*_t - \tau_{I,t+1})$, which yields a foreign interest rate spread in the form of $\frac{1+r^*_t - \tau_{I,t+1}}{1-\tau_{I,t}} = 1 + r^*_{L,t} + 1 - (1 + \omega\mathcal{C}_{t+1})\exp(-\omega\mathcal{C}_{t+1})$. Together with the Euler consumption equation (35), we obtain the following modified relationship between rates of consumption growth and exchange rates variability:

$$\frac{g_{C,t+1}}{\Delta_t} = -\frac{1}{\sigma}\left[\beta\left(\frac{1+r^*_t - \tau_{I,t+1}}{1-\tau_{I,t}}\right)\right]^{\frac{1-\sigma}{\sigma}} \times (\omega\mathcal{C}_{t+1})^2 \exp(-\omega\mathcal{C}_{t+1}) \tag{39}$$

We next consider a tax on capital outflows denominated in local currency $\tau_{O,t}\left(\frac{B^*_t - B^*_{t-1}}{P_t}\right)S_t$. Tax revenue is also rebated to households as a lump sum transfer $\Omega_t = \max\left\{\tau_{O,t}\left(\frac{B^*_t - B^*_{t-1}}{P_t}\right)S_t, 0\right\}$. The household budget constraint then reads as follows: $\frac{B_t + (1+\tau_{O,t})S_t B^*_t}{P_t} = (1 + r_{t-1})\frac{B_{t-1}}{P_t} + S_t(1 + r^*_{t-1} + \tau_{O,t})\frac{B^*_{t-1}}{P_t} + \frac{S_t L^*_t}{P_t} + Y_t + \Omega_t - C_t - \{1 + r^*_{L,t-1} + 1 - \exp(-\omega\mathcal{C}_t)\}\frac{S_t L^*_{t-1}}{P_t}$. In association with a foreign interest rate spread that accounts for tax on capital outflow, the relationship between rates of consumption growth and exchange rates variability now becomes

$$\frac{g_{C,t+1}}{\Delta_t} = -\frac{1}{\sigma}\left[\beta\left(\frac{1+r^*_t + \tau_{O,t+1}}{1+\tau_{O,t}}\right)\right]^{\frac{1-\sigma}{\sigma}} \times (\omega\mathcal{C}_{t+1})^2 \exp(-\omega\mathcal{C}_{t+1}) \tag{40}$$

Substituting Eqs. (39) and (40) for consumption growth in Eq. (37), respectively, yields an amended asymmetric relationship between rates of economic growth and exchange rate variability driven by capital flows when price-based capital inflow and outflow controls are in place.

For the sake of discussion, we coin the measures for capital control at time t as an ex-ante intervention that refers to periods of cumulative capital inflows and currency appreciation (tranquil time), whereas those at time $t + 1$ are coined as ex-post intervention during the periods of cumulative capital outflows and currency depreciation (crisis time). Assume that a 3.5% tax is imposed on capital that flows in or out during a 2-week period. The annualized tax rate, being imposed either by the time it flows in or flows out, is approximately 90%. In conjunction with other calibrated parameter values, Panel (a) in Figure 5 depicts the effect of tax on capital inflows and outflows, ex-ante and ex-post, respectively, on the relationship between growth and exchange rate.

[INSERT FIGURE 5 HERE]

Two points stand out. First, if the economy is "normal" in the sense that the firm's credit-worthiness is robust (values greater than 0.2) by the time the firewall is established, it does not matter whether capital inflow or outflow is restricted, ex-ante or ex-post. The economic fundamental is solid and can withstand abruptions in capital flows.

However, the performance of each policy varies if the economy has already worsened (values smaller than 0.2) when the measures are implemented. Clearly, ex-post capital outflow control works almost equally well as ex-ante capital inflow control does, in the sense that the threshold of the firm's credit-worthiness below which cumulative capital outflows become growth destructive is extended and the negative link between the exchange rate variability and growth is weakened.

The logic is simple. A reduction in cumulative capital inflows as a direct consequence of tax on capital inflows actually implies smaller cumulative capital outflows in the future. Similarly, because an expectation regarding the implementation of capital outflow controls ex post can disincentive capital inflows ex ante, a reduction in cumulative capital inflow as an indirect consequence of the expectation of tax on capital outflow ex post also minimizes cumulative capital outflows in the future. Furthermore, both inflows and outflows weaken the negative balance-sheet effect of depreciation on economic growth. On the other hand, an ex-post capital inflow control performed poorly. As one needs to either curb capital outflow or attract capital inflow during the turbulent period with fragile firm's credit-worthiness, ex-post capital inflow restriction only serves to pour salt on the wound.

6.2 Ex-ante prevention or ex-post management?

Closely related to the question of inflow-or-outflow control is the debate of ex-ante versus ex-post intervention. The influential Benigno et al. (2013) argue that ex-post intervention during a time of crisis is likely to be more important than ex-ante prudential measures in tranquil times if the policymaker has the tool to relocate labor from a non-tradable to a tradable sector during a crisis to attain social planner equilibrium. In social planner equilibrium with a smaller non-tradable production, the price of non-tradable goods increases, the real exchange rate appreciates, and credit constraint is eased during a crisis. By internalizing the fact that the probability and severity of crises can be reduced with efficient ex-post measures, a social planner will save less and borrow more during tranquil times. The policy implication is thought-provoking in that while ex-ante capital inflows control, i.e., tax on foreign borrowing, yields a probability of a crisis as low as ex-post intervention, it is welfare-reducing as it also lowers average consumption.

Of question is what tools can a policymaker use to induce labor relocation from a non-tradable to a tradable sector to mimic social planner allocation? Exchange rate devaluation is apparently the easiest way, providing the subsidy to a tradable production is another candidate. Both policies make the tradable sector more attractive by making exports more profitable. In the context of a one-sector model, as trade surplus mirrors a capital account deficit, subsidizing capital outflows ex post is effectively a dose of devaluation and export subsidy. To see its effectiveness, we assume a 3.5% subsidy on capital outflows that flowed in 2 weeks ago during a time of crisis to obtain an annualized subsidy rate equivalent to a tax rate of 90%. As illustrated in Panel (b) of Figure 5, this ex-post intervention is definitely not beneficial as it amplifies the severity of capital outflows by shortening the threshold that divides tranquil and crisis times and strengthens the contractionary effect of depreciation.

Despite the fact that preventive ex-ante tax on capital inflow is most effective in mitigating the financial amplification, as illustrated in Panel (b) of Figure 5, our model still calls for a combination of an ex-ante prudential policy and an ex-post curing policy. The former prevents excessive cumulative capital inflows that trigger the destructive debt deleveraging process if the flows reverse, and the latter supports the exchange rate to keep the firm's balance sheet floating. Panel (b) of Figure 5 depicts that ex-ante tax on capital inflows cum ex-post subsidy on capital inflows, or ex-ante subsidy on capital outflow cum ex-post tax on capital outflows, performs equally well if not slightly better than the ex-ante capital inflow control per se. This result corroborates the general findings in the literature (see Benigno et al., 2013, and especially Korinek, 2011 and Jeanne and Korinek, 2011).

6.3 Debt flow or portfolio capital flow control?

The discussion on capital controls in previous sections solely focuses on portfolio capital flow, which has no direct consequence on the incentive to raise foreign borrowing. Based on the perking order of riskiness to financial fragility, portfolio capital flow has been the least risky after foreign direct investment, while short-term foreign borrowing is determined to be the most fragile (Ostry et al., 2011). In this last section, we take stock of the effectiveness of restricting short-term foreign borrowing in terms of mitigating the unwarranted growth impact of sudden capital reversal.

Different from the tax on portfolio capital flows, tax is imposed on each unit of foreign borrowing incurred such that $\Omega_t = \tau_{L,t}\left(\frac{S_t}{P_t}\right)(L_{t-1}^* + L_t^*)$, and it is rebated to the household as a lump-sum transfer Ω_t. The marginal utility of the loan can then be inferred as

$$\frac{\varphi_t}{\varphi_{t+1}} = \left(\frac{S_{t+1}P_t}{S_t P_{t+1}}\right)\left\{\frac{1+r_{L,t}^*+1+\tau_{L,t+1}-\exp(-\omega\mathcal{C}_{t+1})(1+\omega\mathcal{C}_{t+1})}{1-\tau_{L,t}}\right\} \tag{41}$$

In association with Eqs. (20) and (21), the Euler consumption function now becomes $\frac{C_{t+1}}{C_t} = \left(\beta\left\{\frac{1+r_{L,t}^*+1+\tau_{L,t+1}-\exp(-\omega\mathcal{C}_{t+1})(1+\omega\mathcal{C}_{t+1})}{1-\tau_{L,t}}\right\}\right)^{\frac{1}{\sigma}}$, which gives us the following relationship between consumption growth rate and exchange rate variability.

$$\frac{g_{C,t+1}}{\Delta_t} = -\frac{1}{\sigma}\left(1 + r_t^* + \tau_{L,t+1}\right)^{\frac{1}{\sigma}-1}\left(\beta\{1-\tau_{L,t}\}\right)^{-\frac{1}{\sigma}} \times \exp(-\omega\mathcal{C}_{t+1})\,(\omega\mathcal{C}_{t+1})^2 \tag{42}$$

What is the optimal tax rate on foreign borrowing? The tax rate must be high enough to prudentially reduce the adverse balance-sheet impact of sudden capital reversal but low enough not to hold back the investment. We draw on the concept of pecuniary externalities delineated in Jeanne and Korinek (2012) and Korinek (2011), wherein decentralized borrowers and a constrained planner have different valuations of credit. While the economic environment and constraints faced are similar, the constrained planner internalizes the externalities of their individual borrowing on aggregate foreign borrowing that results in the fragility of credit-worthiness to depreciation driven by cumulative capital reversals. However, the decentralized borrowers do not.

PROPOSITION 3: *Decentralized borrowers facing occasionally binding collateral constraints that are endogenous to the level of foreign borrowing and the exchange rate undervalue the marginal benefit of (unavailable) credit during a time of crisis compared to the constrained planner. Hence, decentralized agents tend to over-borrow with a lower value of collateral during tranquil times compared to the constrained planner.*

Proof. Suppose the decentralized borrowers value the marginal benefit of credit as in Eq. (41), V_{db}. As a response to each unit change in foreign borrowing, the marginal benefit of credit varies by $V'_{db} \equiv \frac{\partial V_{cb}}{\partial L^*} = -\exp(-\omega \mathcal{C}_{t+1}) \frac{(\omega \mathcal{C}_{t+1})^2}{L_t^*}$. Meanwhile for the constrained planner who internalizes externalities, she also cares about the contractionary balance-sheet effect of variability in the exchange rate. By perceiving a marginal benefit of credit according to Eq. (41), V_{cp}, the constrained planner evaluates change in the marginal benefit of loan in response to the unit change in foreign borrowing *and the exchange rate* in such a way that $V'_{cp} = -\exp(-\omega \mathcal{C}_{t+1})\,(\omega \mathcal{C}_{t+1})^2 \left\{\frac{1}{L_t^*} - \frac{1}{S_t}\left(\frac{g_{L^*,t}}{\Delta_t}\right)^{-1}\right\} = V'_{db} L_t^* \left\{\frac{1}{L_t^*} - \frac{1}{S_t}\left(\frac{g_{L^*,t}}{\Delta_t}\right)^{-1}\right\}$. If there is no endogenous collateral constraint, $\frac{g_{L^*,t}}{\Delta_t} = 0$, $V'_{cp} = V'_{db}$. However, in the presence of a collateral constraint, where $\frac{g_{L^*,t}}{\Delta_t} < 0$, $V'_{cp} > V'_{db}$, meaning that $L^*_{cp} < L^*_{db}$, and thus $\mathcal{C}_{cp} > \mathcal{C}_{db}$. Q.E.D

To alleviate the over-borrowing syndrome during tranquil times and to strengthen the firm's credit-worthiness, policymakers can levy a tax on foreign borrowing such that the level of foreign borrowing and the firm's credit-worthiness mimic those obtained under a constrained planner equilibrium, where $L_{cp}^{*}\left(1+\tau_{L,t}\right)=L_{db}^{*}$ and $\mathcal{C}_{cp}=\mathcal{C}_{db}\left(1+\tau_{L,t}\right)$. Eq. (29) can be rewritten as

$$I_t'=\left\{1-\exp\left(-\frac{\omega\mathcal{C}_t}{1+\tau_{L,t}}\right)\right\}\frac{S_tL_{t-1}^{*}}{P_t}\left(1+\tau_{L,t}\right) \tag{43}$$

The investment growth rate reads

$$\frac{g_{I,t}}{\Delta_{t-1}}=\frac{-\left(\frac{\omega\mathcal{C}_t}{1+\tau_{L,t}}\right)\exp\left(-\frac{\omega\mathcal{C}_t}{1+\tau_{L,t}}\right)}{1-\exp\left(-\frac{\omega\mathcal{C}_t}{1+\tau_{L,t}}\right)}\left(1+\tau_{L,t}\right) \tag{44}$$

The GDP growth rate is the weighted average of Eqs. (42) and (44). According to Eq. (37), Panel (c) of Figure 5 depicts that tax on foreign borrowing is clearly more effective than all the alternatives in disconnecting economic growth from exchange rate variability. A *contingent policy* that imposes a combination of small ex-ante taxes on foreign borrowing, i.e., 0.85% for a 2-week term or the equivalent 22% for a one-year foreign borrowing, and a higher ex-post tax on foreign borrowing at a magnitude identical to tax on capital inflow (3.5% for a two-week term) performs equally well as capital inflow control in mitigating the adverse growth impact of capital reversal. More interestingly, by taxing very short-term foreign-currency borrowing during times of both tranquility and crisis uniformly at 3.5% per two weeks (a *uniform policy*), cumulative capital inflows and outflows are barely relevant to economic growth (unless $\mathcal{C}<0.1$). This result suggests that consistently restricting short-term foreign currency borrowing is likely the most effective way to shelter the real economy from a disastrous capital flow bonanza.

7. Conclusion

When financial liberalization with unrestricted capital flows was promoted as the recipe for economic development in developing countries in the 1990s, the promise was largely grounded on untested theoretical good will. With the benefit of hindsight, it is now determined that the output gain to capital inflows is largely elusive. However, we are constantly reminded by the lessons from the Asian financial crisis of 1997/98, as well as the global financial crisis of 2008, that abrupt capital outflows can easily wreak havoc on the economy.

This paper contributes to the literature with respect to empirics, modeling, and policy design. First, by using an asymmetric Granger causality test on a sample of Asian countries, we find statistically significant empirical evidence that corroborates our conjecture that while capital inflows hardly Granger-cause economic growth, capital outflows Granger-cause economic downturn. Next, through the perspective of a small open-economy real business cycle model, we have identified firm's occasionally binding credit-worthiness as a novel propagation mechanism through which capital flows can have asymmetric impacts on economic growth.

Because physical investment requires external financing and the ability to raise foreign funds is conditional on the firm's credit-worthiness, as the intuition goes, capital flows that vary the currency will affect a firm's credit-worthiness that feeds back to the investment capacity in an asymmetric fashion. In particular, an increase in currency made possible by capital inflows that improve the foreign value of the firm's credit-worthiness hardly adds to the capacity for investment, whereas capital outflow that plunges the currency worsens the firm's credit-worthiness and ability to raise funds, thereby draining its capacity for investment. As a consequence, the output gain to capital inflow is elusive, but the output loss to capital outflow is real.

Third, in terms of policy response, prudentially taxing short-term foreign currency borrowing is the most effective way to minimize the output loss due to capital outflows. Prudential capital flow control, specifically a continuous control that aims to stabilize the size of flow across tranquil and crisis times, is also an effective way to minimize output loss.

In short, the novelty of this paper is that it has outlined a unified framework that coherently accounts for the asymmetric causal relationship between capital flows and economic growth found in the empirical evidence and provides policy insights. By doing so, it brings together three areas of literature that address the growth effect of capital flows, that emphasizes the role of occasionally binding constraints, and that argues for prudential capital control.

Needless to say, both theoretical and empirical lessons have their limitations. Future research should investigate the asymmetric causality between gross rather than net capital flows and economic growth. The patterns of asymmetric causality with respect to foreign direct investment, portfolio investment, and bank credit flows are supposed to be varying and have their own specific mechanisms. While our mechanism can be embedded within a full-fledged model for formal quantitative assessment, it is our hope that this paper with a relatively simple model may draw more attention to the asymmetric nature of the interaction between capital flows and economic growth and the underlying mechanism.

References

Alfaro, L., Kalemli-Ozcan, S., Volosovych, V., 2007. Capital flows in a globalized world: The role of policies and institutions. In Sebastian, E. (ed.) Capital Controls and Capital Flows in Emerging Economies: Policies, Practices, and Consequences. National Bureau of Economics Research, University of Chicago Press.

Bekaert, G., Harvey, C.R., Lundblad, C., 2005. Does financial liberalization spur growth? Journal of Financial Economics 77, 3-55.

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.

Bordo, M.D., Meissner, C.M., 2006. The role of foreign currency debt in financial crises: 1880-1913 versus 1972-1997. Journal of Banking & Finance 30, 3299-3329.

Bordo, M.D., Meissner, C.M., Stuckler, D., 2010. Foreign currency debt, financial crises and economic growth: A long-run view. Journal of International Money and Finance 29, 642-665.

Brzoza-Brzezina, M., Kolasa, M., Makarski, K., 2013. A penalty function approach to occasionally binding credit constraints. Dynare Working Paper No. 27, Paris: CEPREMAP.

Eichengreen, B., Leblang, D., 2003. Capital account liberalization and growth: Was Mr. Mahathir right? International Journal of Finance and Economics 8, 205-224.

Elliott, G., Rothenberg, T.J., Stock, J.H., 1996. Efficient tests for an autoregressive unit root. Econometrica 64(4), 813-836.

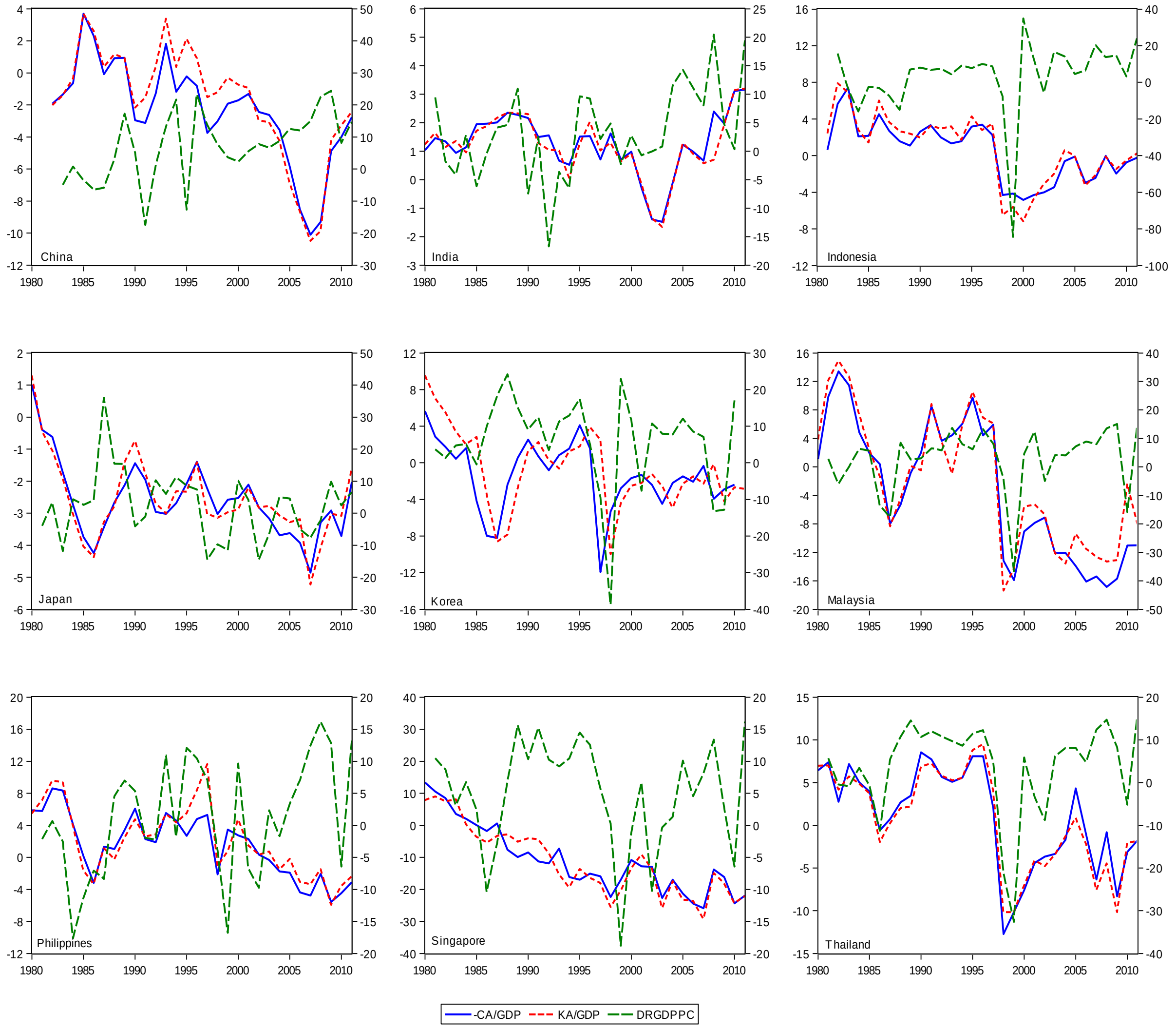
Friedrich, C., Schnabel, I., Zettelmeyer, J., 2012. Financial integration and growth: Why is emerging Europe different? Journal of International Economics, doi:10.1016/j.jinteco.2012.07.003.

Gamra, S.B., 2009. Does financial liberalization matter for emerging East Asian economies growth? Some new evidence. International Review of Economics and Finance 18, 392-403.

Granger, C.W.J., Yoon, G., 2002. Hidden cointegration. Royal Economic Society Annual Conference 2002, Royal Economic Sociey.

Gourinchas, P., Jeanne, O., 2006. The elusive gains from international financial integration. Review of Economic Studies 73(3), 715-741.

Gospodinov, N., Herrera, A.M., Pesavento, E., 2013. Unit roots, cointegration and pre-testing in VAR models. Mimeo, Concordia University.
Hatemi-J, A., 2003. A new method to choose optimal lag order in stable and unstable VAR models. Applied Economics Letter 10(3), 135-137.
Hatemi-J, A., 2008. Forecasting properties of a new method to choose optimal lag order in stable and unstable VAR models. Applied Economics Letter 15(4), 239-243.
Hatemi-J, A., 2012. Asymmetric causality tests with an application. Empirical Economics 43(1), 447-456.
Honig, A., 2008. Addressing causality in the effect of capital account liberalization on growth. Journal of Macroeconomics 30, 1602-1616.
Jeanne, O., Korinek, A., 2010. Excessive volatility in capital flows: A Pigouvian taxation approach. American Economic Review Papers and Proceedings 100(2), 403-407.
Jeanne, O., Korinek, A., 2012. Managing credit booms and busts: A Pigouvian taxation approach. John Hopkins University, mimeo.
Jeanne, O., Korinek, A., 2011. Macroprudential regulation versus mopping up after the crash. University of Maryland, mimeo.
Jeanne, O., Subramanian, A., Williamson, J., 2012. Who Needs to Open the Capital Account? Peterson Institute for International Economics.
Klein, M.W., 2012. Capital controls: Gates versus walls. Brooking Papers on Economic Activity, fall, 317-355.
Klein, M.W., Olivei, G.P., 2008. Capital account liberalization, financial depth, and economic growth. Journal of International Money and Finance 27, 861-875.
Korinek, A., 2011. The new economics of prudential capital controls: A research agenda. IMF Economic Review 59(3), 523-561.
Kose, M.A., Prasad, E.S., Wei, S.-J., Rogoff, K., 2009. Financial globalization: A reappraisal. IMF Staff Papers 56(1), 8-62.
Kose, M.A., Prasad, E.S., Terrones, M.E., 2009. Does openness to international financial flows raise productivity growth? Journal of International Money and Finance 28, 554-580.
Kyaw, K.S, MacDonald, R., 2009. Capital flows and growth in developing countries: A dynamic panel data analysis. Oxford Development Studies 37(2), 101-122.
Masten, A.B., Coricelli, F., Masten, I., 2008. Non-linear growth effects of financial development: Does financial integration matter? Journal of International Money and Finance 27, 295-313.
Ostry, J.D., Ghosh, A.R., Habermeier, K., Chamon, M., Qureshi, M.S., Laeven, L., Kokenyne, A., 2011. Managing capital inflows: what tools to use? IMF Staff Discussion Note 11/06, Washington, DC: International Monetary Fund.
Prasad, E.S., Rajan, R.G., Subraminian, A., 2007. Foreign capital and economic growth. Brooking Papers on Economic Activity 1, 153-230.
Quadrini, V., 2011. Financial frictions in macroeconomic fluctuations. Economic Quarterly, Federal Reserve Bank of Richmond 97(3), 209-254.
Tille, C., 2012. Sailing through this storm? Capital flows in Asia during the crisis. Pacific Economic Review 17(3), 467-488.
Toda, H.Y., Yamamoto, T., 1995. Statistical inference in vector autoregressions with possibly integrated processes. Journal of Econometrics 66, 225-250.



Notes: -CA/GDP: current account as a share of GDP; KA/GDP: capital account as a share of GDP; DRGDPPC: Per capita real GDP growth rate. Declining –CA/GDP and KA/GDP indicates capital outflows, and vice versa.

Fig. 1 Asymmetric relationship between capital flows and economic growth

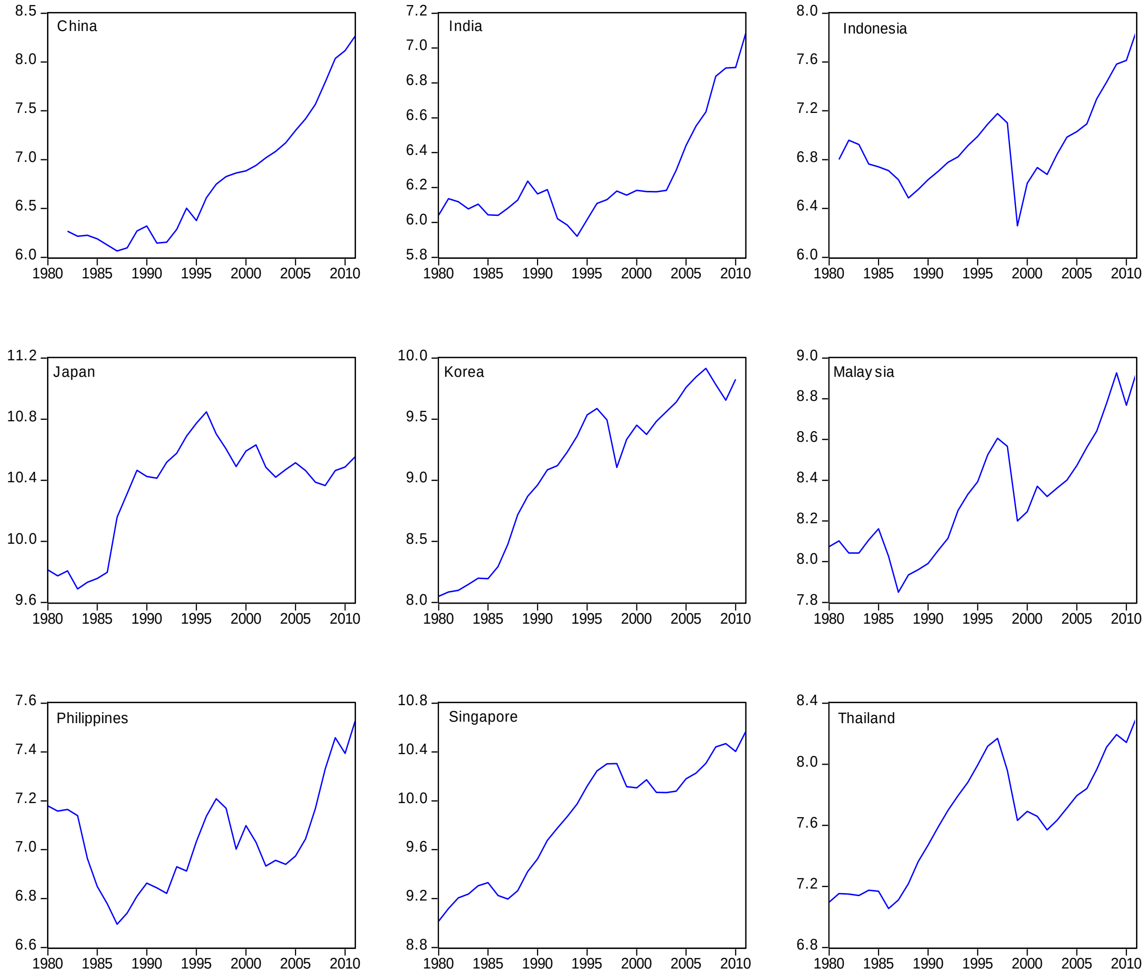
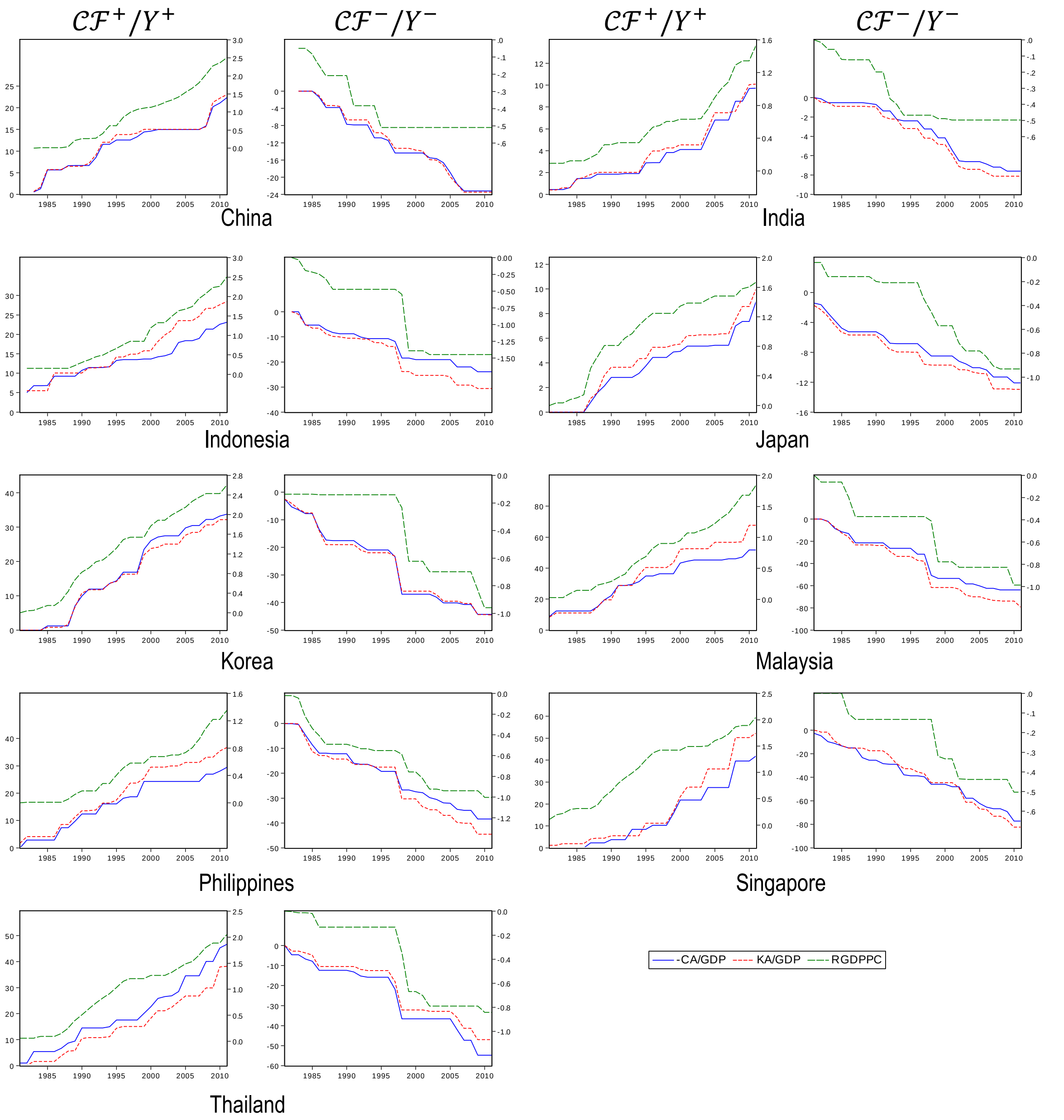
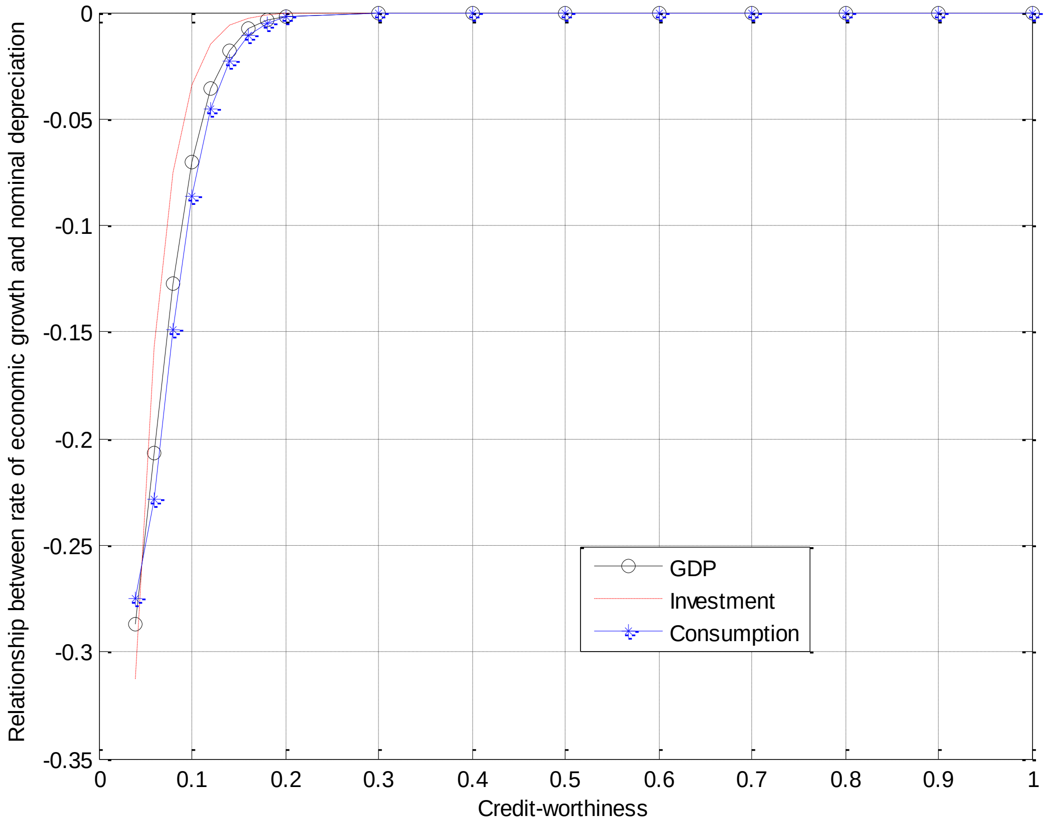


Fig. 2 Time plots of per capita real gross domestic product for selected Asian countries



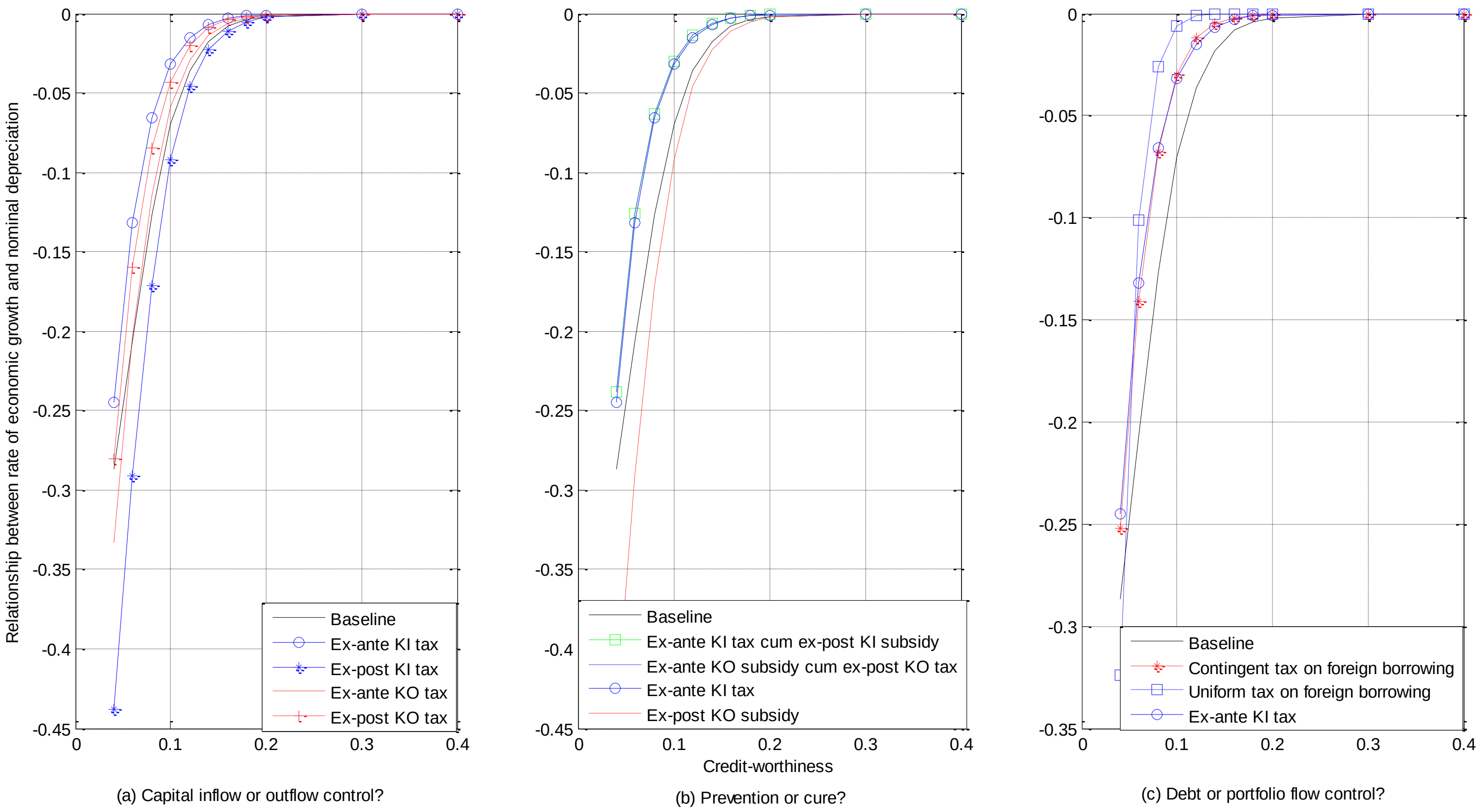
Notes: $\mathcal{CF}$ denotes capital flows proxied by –CA/GDP and KA/GDP, Y denotes per capita real GDP (RGDPPC). The sign + indicates cumulative positive sum and – indicates cumulative negative sum.

Fig. 3 Cumulative positive and negative sum of capital flow and economic growth



Notes: *GDP*: Rate of real GDP growth over nominal depreciation that corresponds to Eq. (38)
Investment: Rate of investment growth over nominal depreciation that corresponds to Eq. (32)
Consumption: Rate of consumption growth over nominal depreciation that corresponds to Eq. (36)

Fig. 4 Firm's endogenous credit-worthiness as the mechanism for asymmetric relationship between economic growth and exchange-rate variability



Notes: Ex-ante KI tax cum ex-post KI subsidy: $\tau_{I,t} = 3.5\% + \tau_{I,t+1} = -3.5\%$ on 2-week portfolio capital inflows (KI);
Ex-ante KO subsidy cum ex-post KO tax: $\tau_{O,t} = -3.5\% + \tau_{I,t+1} = 3.5\%$ on 2-week portfolio capital outflows (KO);
Ex-ante KI tax: $\tau_{I,t} = 3.5\%, \tau_{I,t+1} = 0$ on 2-week portfolio capital inflows;
Ex-post subsidy on KO: $\tau_{O,t} = 0, \tau_{O,t+1} = -3.5\%$ on 2-week portfolio capital outflows;
Contingent tax on foreign borrowing: $\tau_{L,t} = 0.85\%$ and $\tau_{L,t+1} = 3.5\%$ on 2-week foreign-currency borrowing;
Uniform tax on foreign borrowing: $\tau_{L,t} = \tau_{L,t+1} = 3.5\%$ on 2-week foreign-currency borrowing

Fig. 5 Managing capital flows

Table 1
Results of asymmetric causality tests

	China	India	Indonesia	Japan	Korea	Malaysia	Philippines	Singapore	Thailand
Ho: CF^{+}≠>$RGDPC^{+}$									
Wstat	0.395	3.05*	1.932	0.328	2.266	1.207	0.45	0.014	1.295
Bootstrap CV 1%	8.52	7.525	15.003	9.937	7.916	7.834	8.629	7.169	8.531
Bootstrap CV 5%	4.244	4.391	9.641	4.72	4.214	4.38	4.45	4.079	4.771
Bootstrap CV 10%	2.902	3.026	7.222	3.101	2.955	3	2.967	2.947	3.313
Ho: CF^{+}≠>$RGDPC^{-}$									
Wstat	5.984*	3.945*	30.598***	3.947	16.616***	0.355	1.120	0.014	0.576
Bootstrap CV 1%	12.507	8.491	18.375	12.357	11.846	7.629	7.776	7.169	7.48
Bootstrap CV 5%	7.14	4.575	10.385	7.249	7.018	4.206	4.277	4.079	4.154
Bootstrap CV 10%	5.285	3.161	7.797	5.299	5.24	2.94	2.997	2.947	2.933
Ho: CF^{-}≠>$RGDPC^{+}$									
Wstat	0.292	0.310	0.049	0.001	2.11	0.251	3.908	0.053	0.592
Bootstrap CV 1%	12.921	8.608	9.43	10.005	15.062	8.69	12.163	10.709	9.338
Bootstrap CV 5%	5.232	4.366	4.6	4.986	5.972	4.331	7.031	4.241	4.659
Bootstrap CV 10%	3.04	3.044	2.94	3.217	3.403	2.835	5.126	2.658	3.001
Ho: CF^{-}≠>$RGDPC^{-}$									
Wstat	11.733**	1.087	23.027***	0.489	50.180***	19.65***	15.351***	1.375	22.513***
Bootstrap CV 1%	13.055	8.646	14.529	7.912	24.873	15.898	9.751	10.128	15.944
Bootstrap CV 5%	7.477	4.376	5.098	4.318	10.731	5.721	4.972	4.503	8.362
Bootstrap CV 10%	5.466	2.897	2.992	2.903	6.854	3.229	3.186	2.928	5.749
	China	India	Indonesia	Japan	Korea	Malaysia	Philippines	Singapore	Thailand
Ho: $RGDPC^{+}$≠>CF^{+}									
Wstat	0.888	0.281	2.068	2.159	1.293	0.656	0.175	0.319	0.045
Bootstrap CV 1%	8.545	8.188	17.146	9.66	9.261	8.058	7.968	8.823	8.477
Bootstrap CV 5%	4.478	4.374	10.429	4.51	4.733	4.558	4.279	4.638	4.592
Bootstrap CV 10%	3.064	3.02	7.815	2.94	3.221	3.087	2.951	3.196	3.197
Ho: $RGDPC^{+}$≠>CF^{-}									
Wstat	0.003	0.121	0.613	0.383	1.008	5.231**	0.276	0.319	0.505
Bootstrap CV 1%	11.665	8.168	10.027	8.581	11.524	10.568	12.649	8.823	10.016
Bootstrap CV 5%	5.139	4.342	4.889	4.548	4.839	4.521	7.262	4.638	4.709
Bootstrap CV 10%	3.118	2.895	3.073	2.985	2.922	2.906	5.282	3.196	3.038
Ho: $RGDPC^{-}$≠>CF^{+}									
Wstat	7.641**	0.001	1.017	6.715*	0.909	0.614	0.187	2.966	0.001
Bootstrap CV 1%	12.813	8.351	14.358	12.762	11.664	7.921	7.981	12.432	8.231
Bootstrap CV 5%	7.257	4.387	8.736	7.075	6.915	4.293	4.521	7.417	4.6
Bootstrap CV 10%	5.262	3.064	6.691	5.284	5.171	2.928	3.053	5.577	3.33
Ho: $RGDPC^{-}$≠>CF^{-}									
Wstat	0.091	2.156	0.021	1.665	0.305	2.541	0.047	0.066	1.499
Bootstrap CV 1%	11.807	10.261	9.828	8.602	12.898	8.205	8.168	8.427	12.785
Bootstrap CV 5%	7.015	4.827	4.305	4.485	7.782	4.364	4.305	4.271	7.658
Bootstrap CV 10%	5.229	3.074	2.812	3.039	5.828	2.915	2.912	2.923	5.64

Notes: RGDPC denotes per capita real GDP (in log) and CF denotes capital flow proxied by current account as a share of GDP (-CA/GDP). The sign + denotes cumulative positive shock which indicates capital inflow and positive economic growth, whereas the sign – denotes negative cumulative shock that implies capital outflow and negative economic growth, respectively. Wstat and CV stand for Wald statistics and critical value, respectively. The denotation ≠> indicates "does not Granger cause". ***, **, *, respectively, denote 1%, 5%, and 10% level of significance.

Table 2
Further results of asymmetric causality test

	China	India	Indonesia	Japan	Korea	Malaysia	Philippines	Singapore	Thailand
Ho: CF^{+}≠>$RGDPC^{+}$									
Wstat	0.303	4.082*	0.101	0.362	3.172*	3.358*	0.087	2.825	4.769
Bootstrap CV 1%	8.547	8.634	8.42	8.267	7.845	7.648	8.395	16.028	13.577
Bootstrap CV 5%	4.265	4.332	4.36	4.62	4.224	4.242	4.47	10.023	7.849
Bootstrap CV 10%	2.88	3.01	2.986	3.13	2.894	2.94	3.078	7.591	5.852
Ho: CF^{+}≠>$RGDPC^{-}$									
Wstat	0.591	0.635	17.322**	2.160	21.103***	0.861	1.135	2.825	0.378
Bootstrap CV 1%	8.465	8.585	17.957	14.567	12.034	7.549	7.705	16.028	7.11
Bootstrap CV 5%	4.554	4.602	10.099	7.768	6.999	4.055	4.119	10.023	4.106
Bootstrap CV 10%	3.11	3.081	7.575	5.406	5.293	2.849	2.936	7.591	2.898
Ho: CF^{-}≠>$RGDPC^{+}$									
Wstat	0.224	1.082	0.000	0.604	2.038	0.441	11.021**	0.048	0.198
Bootstrap CV 1%	13.555	8.908	12.478	9.896	13.67	9.518	11.472	11.184	12.634
Bootstrap CV 5%	5.379	4.591	4.638	4.749	6.03	4.42	6.768	4.214	4.759
Bootstrap CV 10%	3.062	3.066	2.926	3.159	3.547	2.856	5.044	2.675	2.821
Ho: CF^{-}≠>$RGDPC^{-}$									
Wstat	9.531***	1.847	59.601***	0.047	38.262***	29.147***	27.108***	1.315	25.076***
Bootstrap CV 1%	8.411	8.074	23.463	9.207	22.671	18.006	10.511	9.328	15.66
Bootstrap CV 5%	4.265	4.226	8.625	4.521	9.688	6.734	4.946	4.624	8.063
Bootstrap CV 10%	2.929	2.862	5.559	2.961	6.068	3.696	3.08	3.02	5.7
	China	India	Indonesia	Japan	Korea	Malaysia	Philippines	Singapore	Thailand
Ho: $RGDPC^{+}$≠>CF^{+}									
Wstat	2.011	3.322*	6.603**	1.377	3.141*	1.035	0.634	5.139	0.768
Bootstrap CV 1%	8.868	8.199	9.402	8.928	8.808	8.138	8.394	18.086	12.956
Bootstrap CV 5%	4.567	4.147	4.536	4.572	4.623	4.436	4.539	10.893	7.594
Bootstrap CV 10%	3.078	2.825	3.014	3.084	3.13	3.135	3.187	8.29	5.626
Ho: $RGDPC^{+}$≠>CF^{-}									
Wstat	0.009	0.031	0.126	0.99	0.343	3.549*	0.220	5.139	0.129
Bootstrap CV 1%	13.212	8.253	10.865	8.779	10.935	10.16	11.567	18.086	11.087
Bootstrap CV 5%	5.37	4.35	4.706	4.474	4.663	4.42	7.035	10.893	4.854
Bootstrap CV 10%	3.037	2.927	2.945	3.045	2.897	2.827	5.081	8.29	2.966
Ho: $RGDPC^{-}$≠>CF^{+}									
Wstat	1.594	0.457	1.254	2.544	1.030	0.312	0.463	0.107	0.132
Bootstrap CV 1%	8.113	8.68	13.515	13.737	11.766	7.894	7.785	8.853	7.999
Bootstrap CV 5%	4.418	4.548	8.301	7.437	6.934	4.321	4.311	4.668	4.596
Bootstrap CV 10%	3.03	3.146	6.326	5.186	5.177	3.024	2.976	3.152	3.265
Ho: $RGDPC^{-}$≠>CF^{-}									
Wstat	0.072	0.062	2.081	0.329	0.301	1.226	0.038	0.005	1.447
Bootstrap CV 1%	8.73	9.471	13.701	8.847	12.979	7.772	7.886	8.204	12.876
Bootstrap CV 5%	4.456	4.587	7.967	4.386	7.612	4.123	4.375	4.336	7.716
Bootstrap CV 10%	3.006	3.022	5.864	2.92	5.743	2.822	2.905	2.969	5.644

Notes: Capital account as a share of GDP is used as proxy for capital flow (CF). RGDPC denotes per capita real GDP (in log). The sign + denotes cumulative positive shock which indicates capital inflow and positive economic growth, whereas the sign – denotes negative cumulative shock that implies capital outflow and negative economic growth, respectively. Wstat and CV stand for Wald statistics and critical value, respectively. The denotation ≠> indicates "does not Granger cause". ***, **, *, respectively, denote 1%, 5%, and 10% level of significance.