



**DETERMINANTS OF THE PROBABILITY OF ABRUPT CONTRACTION IN  
GROSS CAPITAL INFLOWS TO EMERGING MARKET ECONOMIES**

***Key points***

- *Gross capital inflows to emerging market economies (EMEs) were unprecedentedly large in the years immediately following the global financial crisis. This fuelled a build-up of financial imbalances, which has now become a major risk concern of EMEs as any sudden contraction in capital inflows along with an unwinding of financial imbalances could be disruptive.*
- *Using a conditional probability model based on different episodes of a sudden contraction in gross capital inflows to EMEs in Asia, Europe and Latin America from the late 1990s to 2016, we estimate the determinants of such a contraction. Our results show that an economy with higher levels of debt denominated in foreign currencies faces a greater probability of a sudden stop in gross capital inflows. At the same time, weaker global growth and a relatively more volatile equity market in EMEs increase the chance of a sudden stop in all EMEs. For EMEs in Asia and Europe (but not in Latin America), a narrowing in growth differential between EMEs and the US and a decrease in foreign reserves also raise the likelihood of a sudden halt to gross capital inflows.*
- *With the estimated conditional probability model, we also develop an indicator to give a warning signal to such a scenario. Our signal outperforms similar indicators in other literature.*

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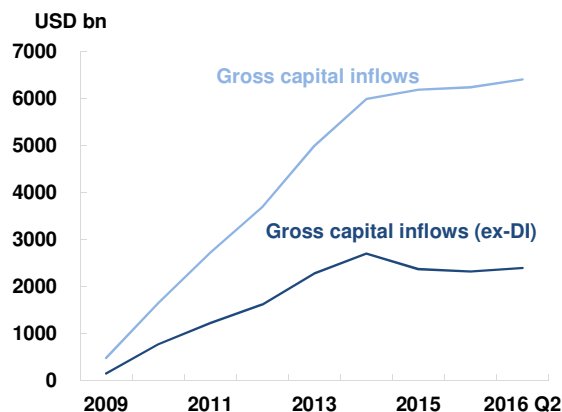
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## I. INTRODUCTION

Gross capital inflows to EMEs were unprecedentedly large for some years immediately after the global financial crisis (GFC), before starting to moderate from late 2014 (Chart 1). Amid the extremely accommodative monetary conditions associated with excess global liquidity, many EMEs built up significant financial imbalances (Tarashev et al., 2016). According to statistics from the Bank for International Settlements (BIS), the debt-to-GDP ratio of non-financial corporates in EMEs increased from less than 60% on aggregate in 2006 to about 110% in 2015, surpassing that of advanced economies (Chart 2). The high foreign currency debt exposure associated with the credit boom also exposed EMEs to foreign exchange risk (IMF, 2015) (Chart 3). In historical perspective, such a credit boom could end abruptly associated with a sudden reversal of capital inflows, which was usually followed by a deep and costly economic recession (Elekdag and Wu, 2011).

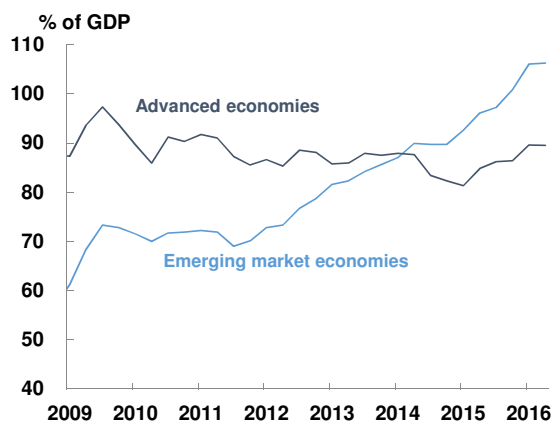
From the surveillance point of view, the recent moderation in capital inflows to EMEs has raised some concerns on whether this is a prelude to a sudden stop. Therefore, a better understanding of the causes of a sudden contraction in capital flows is important for policymakers to formulate appropriate pre-emptive policies, if any, to avoid any costly economic fallout.

**Chart 1: Cumulated gross capital inflows in EMEs**



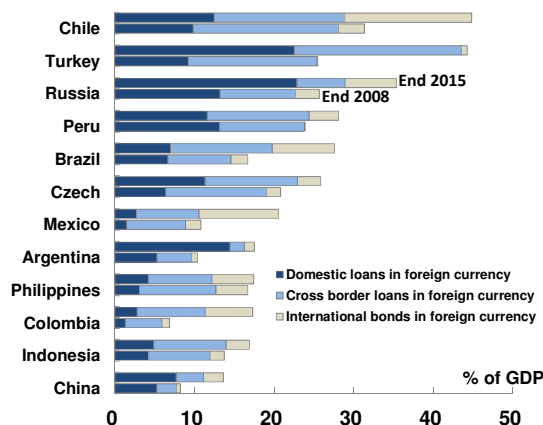
Notes: Cumulated gross capital inflows to 18 EMEs since 2009.  
DI refers to direct investment inflows.  
Source: IMF.

**Chart 2: Debt-to-GDP ratio of non-financial corporates in EMEs**



Source: BIS.

**Chart 3: Foreign currency exposure of EMEs**

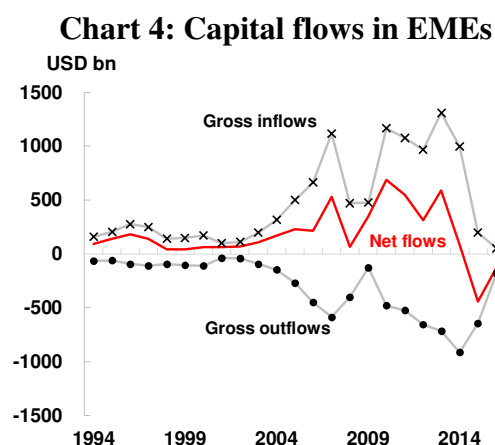


Sources: BIS, CEIC and central banks.

The capital flow of any country can be understood from its balance of payments (BoP) statistics. In the BoP convention, gross capital inflows are defined as the changes in liabilities owed by residents to foreign investors, while gross capital outflows are defined as the changes in foreign assets owned by residents. In past studies, the focus was mostly on net capital flows, defined as the difference between gross inflows and gross outflows.<sup>1</sup>

<sup>1</sup> The causes and effects of changes in net capital flows have been well examined in other literature. For instance, some studies found that a sudden contraction in net capital flows, if associated with a significant depreciation in the real exchange rate and adjustment in the current account balance, would result in a large output loss (Calvo, 1998; Calvo et al., 2004; Guidotti et al., 2004)

In those EME studies, the focus on net capital flows before the early 2000s related almost exclusively to gross capital inflows, as net capital flows were mainly driven by gross capital inflows given the relatively small amount of overseas investment by residents in EMEs in earlier years (Chart 4). Subsequently, with the significant increase in both gross capital inflows and outflows in EMEs since the mid-2000s, some important information in understanding the underlying dynamics of international capital flows was missed in focusing only on the net figures, as different types of gross capital flows must be determined by the behaviour of domestic and foreign investors separately with different driving factors (Forbes and Warnock, 2012). In fact, more recent studies have already started to shift their focus on different types of gross capital flows (Broner et al., 2013; Calderón and Kubota, 2013; Forbes and Warnock, 2012). Among them, some have highlighted the importance of gross capital flows in assessing the financial vulnerabilities of the recipient economies rather than net flows (Borio and Disyatat, 2011); and others have shown the potential disruption to the financial market and the broader economic system that might be brought about by a sudden change in the gross capital flows, even when the net flows are stable (Bruno and Shin, 2012 and Bruno and Shin 2015).



Note: Aggregated capital flows in 18 EMEs.  
Source: IMF.

To better understand the determinants of a sudden change in different types of gross capital flows, Forbes and Warnock (2012) proposed a new taxonomy to identify episodes of an abrupt increase and decrease in both types of gross capital flows, and estimate the key drivers of the flows in these episodes separately. Their study finds that while global risk sentiment and output growth drive almost all types of episodes of a sudden change in gross flows, liquidity factors, such as global interest rates and money supply in major advanced economies, are less relevant in the episodes of abrupt change in gross capital flows. Using the same identification method, Cavallo et al. (2015) analysed the impact of different types of sudden contraction in gross capital flows on real economic output. Their study shows that a sudden drop in gross capital inflows, regardless of whether it is associated with a decrease in net flows, tends to be more disruptive to the real output than a sudden surge in gross capital outflows. This empirical result is consistent with the recent experience during the “taper tantrum” in 2013. Many emerging Asian economies experienced a sudden surge in gross capital outflows in the months following the “tapering talk” by the then Fed chairman, while gross capital inflows were relatively stable and positive. Despite this bout of volatility in the region’s financial markets, such sudden surges in gross capital outflows have not caused significant damage to the real output in subsequent periods (Cheung et al., 2014). These results highlight the important relationship between gross capital inflows and real activity, and have recently stimulated further studies into the impact of a sudden contraction in gross capital inflows.<sup>2</sup>

In view of the importance of gross capital inflows connecting to the disruptive effect of an abrupt drop in capital flows on real output, the first objective of this study is to identify the determinants of a sudden contraction in gross capital inflows to the EMEs (i.e. sudden stop). To meet one particular concern related to the heightened foreign exchange risk in EMEs, as a result of the elevated level of foreign exchange exposure in recent years, we empirically ascertain how this level of exposure affects the likelihood of a sudden stop occurring. To do this we include a variable of “foreign currency denominated debt” in a conditional probability model of a sudden stop.<sup>3</sup> The significance of this effect on all EMEs in general, and in Asia, Europe and Latin America specifically, will be estimated separately.

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<sup>2</sup> For example, focusing on episodes of sudden contraction in gross capital inflows to EMEs, Comelli (2015) shows that these are more likely to happen when global growth slows, risk aversion rises and vulnerabilities increase. However, the significance of these factors varies across different EMEs in Asia, Eastern Europe and Latin America.

<sup>3</sup> The variable of “foreign currency denominated debt” is an aggregation of bond, cross-border loans and domestic credit denominated in foreign currencies.

In addition, for surveillance purposes, the second objective of this study is to provide a warning signal for a sudden stop in gross capital inflows based on the estimated conditional probability model. This warning signal could provide policymakers in EMEs a system that more accurately assesses the chance of a sudden contraction occurring in gross capital inflows in the coming quarter, thus helping them formulate and impose appropriate pre-emptive measures to avoid any costly economic consequences.

The method of identifying episodes of a sudden stop, the conditional probability model, the data we use and the empirics of the model are discussed in Section 2. This is followed by the out-of-sample forecast of conditional probability of a sudden stop and the derivation of a warning signal in Section 3. Concluding remarks are given in Section 4.

## **II. EMPIRICAL ANALYSIS**

### *2.1 Identification of sudden stop episodes*

Similar to the pioneer studies by Calvo (1998) and Calvo et al. (2004), we define a sudden stop in capital flows as an episode with a significant but unexpected slowdown in capital flows from its recent average level – the key element here is a *large* and *unexpected* fall. This is instead of gauging the risk by the level of capital flows or external position, for example by defining a crisis when the amount of capital flows falls below a pre-determined threshold regardless of the recent trend and momentum of the flows; or to set a threshold of current account balance as a percentage of GDP. In fact, as shown in many recent studies, the abnormality in flows is more relevant than the absolute level of flows because an economic recession could be due to a sudden stop in capital inflows even when the external position appears to be sound (Calvo, 1998).<sup>4</sup>

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<sup>4</sup> Despite a high national savings rate and low current account deficit (about 2.5% of GDP in Indonesia and Hong Kong in 1996, and even a current account surplus in Taiwan), these Asian economies were hard hit during the 1997 Asian financial crisis.

In practice, the definition of a “sudden stop” can be likened to answering the age old question of: how ‘large’ is large? Only in this context it relates to a decrease in capital flows. In their recent pioneering work, Forbes and Warnock (2012) provided an answer to this question by defining a sudden stop episode in gross capital inflows using the following criteria:

- i. The episode begins if the year-on-year change in the four-quarter rolling-sum of gross capital inflows falls below its previous-five-year average by more than two standard deviations.
- ii. The episode continues as long as the year-on-year change in the four-quarter rolling-sum of gross capital inflows stays below its previous-five-year average by more than one standard deviation.

These conditions give a more functional definition of the idea of a *large* and *unexpected* fall in capital flows and thus are widely used in subsequent studies. In this paper, we follow the Forbes and Warnock criteria to identify episodes of sudden stops in gross capital inflows to EMEs.

For an economy  $i$ , the quarterly gross capital inflows at time  $t$  ( $GI_{i,t}$ ) are annualised by the inflows in the present and past three quarters as Equation (1)<sup>5</sup>:

$$CI_{i,t} = \sum_{k=0}^3 GI_{i,t-k} \quad (1)$$

Then the change in flows is derived by comparing the annualised flows at time  $t$  ( $CI_{i,t}$ ) with its value a year ago as below:

$$\Delta_4 CI_{i,t} = CI_{i,t} - CI_{i,t-4} \quad (2)$$

At time  $t$ , the average value and standard deviation of  $\Delta_4 CI_i$  over the previous five years (i.e. 20 quarters) are denoted by  $\mu^{i,t-20,t-1}$  and  $\sigma^{i,t-20,t-1}$  respectively.<sup>6</sup> Therefore, the thresholds in the criteria I and II above are defined by Equations (3) and (4):

$$A = \mu^{i,t-20,t-1} - \sigma^{i,t-20,t-1} \quad (3)$$

$$B = \mu^{i,t-20,t-1} - 2\sigma^{i,t-20,t-1} \quad (4)$$

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<sup>5</sup> Capital inflows are annualised to remove any seasonality; this approach is also analogous to the literature’s focus on one year of flows.

<sup>6</sup> The *recent* average and standard deviation are calculated over the past 20 quarters, which means that episodes are always defined relative to the *recent* trend.

As in Forbes and Warnock (2012), the occurrence of a sudden stop in gross capital inflows to an economy  $i$  at time  $t$  ( $SS_{i,t} = 1$ ) is defined by Equation (5):

$$SS_{i,t} = \begin{cases} 1 & \text{if } \begin{cases} \Delta_4 CI_{i,t} \leq B, & OR \\ SS_{i,t-1} = 1 \text{ and } A \geq \Delta_4 CI_{i,t} > B \end{cases} \\ 0 & \text{if } \begin{cases} \Delta_4 CI_{i,t} > A, & OR \\ SS_{i,t-1} = 0 \text{ and } A \geq \Delta_4 CI_{i,t} > B \end{cases} \end{cases} \quad (5)$$

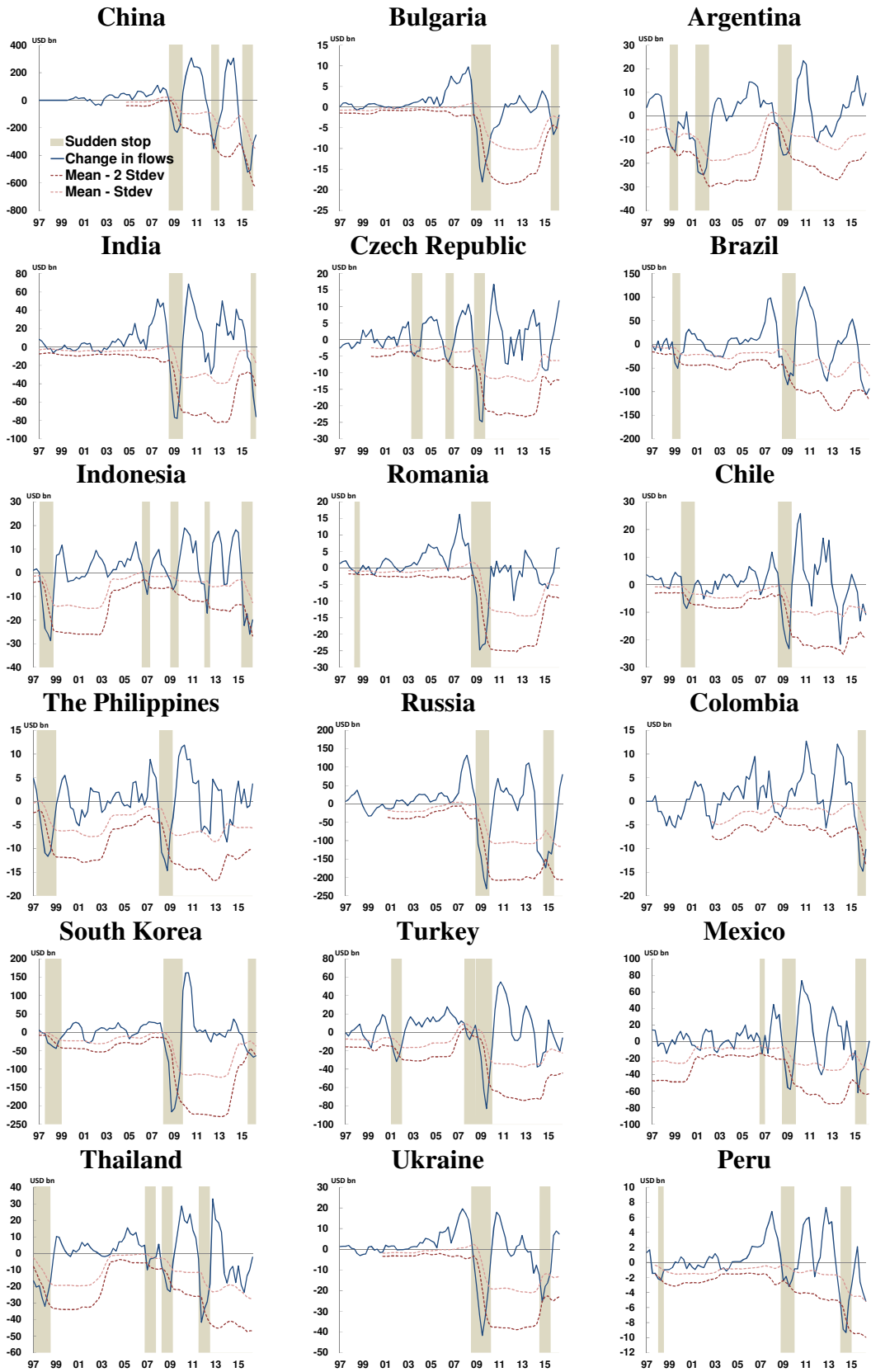
Chart 5 shows the identified episodes of a sudden stop with the corresponding change in capital flows in different EMEs. Altogether we identified 46 episodes of sudden stops in the 18 EMEs between the first quarter of 1997 and the second quarter of 2016.<sup>7</sup> Many Asian economies experienced sudden stops during the Asian financial crisis, followed by episodes in Latin American economies during that region's economic crisis between the late 1990s and early 2000s. In subsequent years, capital flows became largely stable until the onset of the global financial crisis. Almost all EMEs in the sample encountered sudden stops during the GFC. In the years since, the change in capital flows has become more volatile, with only some EMEs facing sudden stops in late 2015 and early 2016.

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<sup>7</sup> The episode of sharp gross capital outflows from Mexico during the Tequila Crisis in 1994 is not included in the sample due to data availability. For Mexico, in particular, data on domestic credit denominated in foreign currencies, which is a major explanatory variable in our conditional probability model, is available only after 1997.



Chart 5: Episodes of sudden stops



Source: Authors' estimation

## 2.2 Empirical framework for the estimation of the determinants of a sudden stop

Similar to that of Forbes and Warnock (2012) and Comelli (2015), a panel model is used to estimate the conditional probability of a sudden stop with the binary series of the identified episodes ( $SS_{i,t}$ ) as the dependent variable, and a parsimonious list of explanatory variables as follows:

$$\Pr(SS_{i,t} = 1) = F(X_{t-1}^{glob} B^{glob} + X_{i,t-1}^{dome} B^{dome} + X_{i,t-1}^{rela} B^{rela} + X_{i,t-1}^{cont} B^{cont}) \quad (6)$$

$F(\cdot)$  is the cumulative density function (cdf) of the probability of an occurrence of a sudden stop episode, contributed by four groups of explanatory variables, namely global factors ( $X^{glob}$ ), domestic factors ( $X^{dome}$ ), relative factors ( $X^{rela}$ ) and contagion effect ( $X^{cont}$ ). Global factors consist of world economic growth and global liquidity growth. Domestic factors include a change in foreign exchange reserves; domestic loans denominated in domestic currency; and debts denominated in foreign currencies, which is an aggregate of bond, cross-border loans and domestic credit denominated in foreign currencies. Relative factors consist of growth differential between the EME  $i$  and the US and ratio of financial market volatility in the US to that in the EME  $i$ . Contagion effect refers to the occurrence of sudden stops in other economies in the same region. Details of explanatory variables are elaborated in Table 1.

**Table 1: Explanatory variables**

<b>Variable</b>	<b>Definition</b>	<b>Expected effect on <math>\Pr(SS_{i,t} = 1)</math></b>
<i>Global factor:</i> Global economic growth	Growth in world GDP (%)	Better global growth implies better global investment conditions and stronger sentiment to invest in EMEs, so the sign of the coefficient is expected to be negative.
<i>Global factor:</i> Global liquidity growth	Growth in money supply (broad money) in the US, the Euro area and Japan (%).	Larger growth in money supply in major economies implies more global liquidity which is likely to reduce the probability of a sudden stop, so the expected sign of the coefficient is negative.
<i>Domestic factor:</i> Change in foreign exchange reserves	Change in foreign exchange reserves over the last quarter (% of GDP).	Increase in foreign reserves means stronger repayment ability of the economy to external liability, which is likely to reduce the probability of a sudden stop, so the expected sign of the coefficient is negative.
<i>Domestic factor:</i> Domestic loans denominated in domestic currency	The level of domestic credit denominated in domestic currency in economy $i$ (% of GDP).	Economy with a high level of domestic credit is considered to face high domestic vulnerability and may be overheated. An overheating economy is likely to be more prone to a reversal of capital inflows. Therefore, the expected sign of the coefficient is positive.
<i>Domestic factor:</i> Debts denominated in foreign currencies	Total liability of an economy $i$ denominated in foreign currencies at time $t$ . It is the sum of: cross-border loans in major currencies (domestic loans in economy $i$ denominated in foreign currencies; and international bonds denominated in foreign currencies) issued by entities in an economy $i$ (% of GDP).	Economy with a high level of foreign currency denominated debts is expected to be more vulnerable to external shocks and thus more prone to a sudden reversal of capital flows. Therefore, the expected sign of the coefficient is positive.

<b>Variable</b>	<b>Definition</b>	<b>Expected effect on <math>\Pr(SS_{i,t} = 1)</math></b>
<i>Relative factor:</i> Change in growth differential between economy <i>i</i> and the US	Change in growth differential between an economy <i>i</i> and the US over the last quarter. Growth differential is calculated as growth in an economy <i>i</i> minus that in the US (percentage point).	Larger growth differential implies better economic performance in an economy <i>i</i> compared to the US, making economy <i>i</i> more attractive to foreign investors. Therefore, the expected sign of the coefficient is negative.
<i>Relative factor:</i> Ratio of financial market volatility in the US to that in economy <i>i</i>	The ratio of the CBOE VIX index to the 30-day standard deviation of the return of the MSCI index of the corresponding regions (ratio).	It gauges the sentiment of investors towards the EMEs relative to that towards the US. By construction, the ratio increases when the US market is more volatile than the emerging markets. Therefore, the expected sign of the coefficient is negative.
<i>Contagion effect:</i> Regional contagion	Binary variable that equals to one if one or more economies within the same region of an economy <i>i</i> is in an episode of sudden stop; zero otherwise (either 1 or 0).	Investors appear to be less discriminative among emerging economies in the same region when there is fallout in any one of the regional economies. Therefore, the expected sign of the estimated coefficient is positive.

### 2.3 Data

There are 18 EMEs in the sample of this study, including six Asian economies, six European economies and six Latin American economies. The data of gross capital inflows are retrieved from the IMF's International Financial Statistics (IFS) (via CEIC). The starting point of the data series of gross capital inflows varies across economies as shown in Table 2.<sup>8</sup>

**Table 2: EMEs in the sample**  
(Starting point of data series of gross capital inflows in parentheses)

<b>Asia</b>		<b>Europe</b>		<b>Latin America</b>	
China	(1998 Q1)	Bulgaria	(1991 Q1)	Argentina	(1990 Q1)
India	(1990 Q1)	Czech Republic	(1993 Q1)	Brazil	(1990 Q1)
Indonesia	(1990 Q1)	Romania	(1991 Q1)	Chile	(1991 Q1)
The Philippines	(1990 Q1)	Russia	(1994 Q1)	Colombia	(1996 Q1)
South Korea	(1990 Q1)	Turkey	(1990 Q1)	Mexico	(1990 Q1)
Thailand	(1990 Q1)	Ukraine	(1994 Q1)	Peru	(1991 Q1)

<sup>8</sup> This study focuses on episodes of sudden stop in EMEs since the 1990s, as the economic structure and the associated pattern of capital flows in EMEs have evolved substantially in the past couple of decades and, therefore, including data from those earlier years might distort the diagnosis of flows in recent years.

The data of economic growth, the change in foreign reserves and money supply are retrieved from the IFS and the CEIC. Data of domestic credit are from central banks and the CEIC. Data of cross boarder loans and international bonds are from the BIS locational banking statistics and debt securities statistics respectively. The starting point of the data series varies across economies, with the earliest beginning from the first quarter of 1997 and the latest from the fourth quarter of 2004. Therefore, the panel is unbalanced.

## 2.4 *Estimation results*

We estimate Equation (6) with a complementary logarithmic framework (cloglog), which assumes  $F(\cdot)$  is the cdf of an extreme value distribution. The cloglog framework is selected instead of other commonly used probabilistic modelling frameworks such as probit and logit models as the episodes of sudden stop are rare events, accounting for about 12% of the sample period.<sup>9</sup>

We estimate the model with the panel of all EMEs first, and then repeat the estimation of the model with the sub-samples of Asian, European and Latin American economies separately. Table 3 shows the estimation results.<sup>10</sup> Below are some key observations:

1. Most of the estimated coefficients of the explanatory variables in the estimation with all EMEs are significant at 5% levels and their signs are consistent with expectation.
2. Higher debts denominated in foreign currencies bolster the likelihood of a sudden stop in all regions of EMEs. Nevertheless, domestic credit denominated in domestic currency does not significantly affect the probability of a sudden stop in EMEs.

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<sup>9</sup> As there is no unbiased way to include the fixed effect in the cloglog model, Equation (6) is estimated without fixed effect. In fact, country dummy variables should not be needed if we capture all the country-specific factors determining whether a country has an episode. See Forbes and Warnock (2012) and Janus and Riera-Crichton (2011) for more discussions.

<sup>10</sup> The marginal effects of explanatory variables on the conditional probability of sudden stops are not available as the random effect, which is needed to derive the marginal effects, has been integrated out (i.e. has not been estimated) in the estimation of the CDF. See Chapter 18 of Cameron and Trivedi (2009) for details.

3. In Asia and Europe, a sudden stop is less likely to happen if foreign exchange reserves increase and growth differential widens. These effects are not significant in Latin America.
4. The likelihood of a sudden stop decreases when the stock market in EMEs is relatively less volatile than that in the US.
5. Stronger world economic growth reduces the probability of a sudden stop in gross capital inflows in all regions.
6. Contagion effect is significant among Asian EMEs, but not significant in Europe and Latin America.
7. The change in money supply in major advanced economies does not affect the likelihood of a sudden stop.<sup>11</sup>

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<sup>11</sup> In a recent IMF study, Comelli (2015) attained a similar result, showing that the change in money supply in advanced economies has an insignificant effect on the probability of sudden stops. He suggested that, given the capital inflows to EMEs from advanced economies are dominated by the FDI inflows which tend to be less sensitive to liquidity conditions than portfolio flows and banking flows, the effect of change in money supply in major advanced economies on the probability of sudden stops in EMEs may not be significant.

**Table 3: Estimation results of Equation (6)**

<b>Dependent variable: Binary variable of sudden stop</b>				
<b>Sample period: Varies across EMEs; earliest starting point is 1997 Q1, latest starting point is 2004 Q4; ending point is 2016 Q2</b>				
	<b>All EMEs</b>	<b>Asia</b>	<b>Europe</b>	<b>Latin America</b>
<b>Global growth</b>	-0.589***	-0.353*	-0.816***	-0.845***
<b>Global liquidity growth</b>	-0.020	-0.034	-0.006	-0.037
<b>Change in foreign reserves</b>	-0.320***	-0.466***	-0.295**	-0.164
<b>Change in growth differential</b>	-0.108***	-0.095**	-0.088*	-0.098
<b>Ratio of equity market volatility</b>	-1.740***	-1.23*	-3.607***	-1.794**
<b>Domestic loans denominated in domestic currency</b>	0.007	0.000	0.000	-0.010
<b>Debts denominated in foreign currencies</b>	0.021***	0.028**	0.030*	0.033**
<b>Regional contagion effect</b>	0.766**	2.014***	-0.053	-0.065
<i>Number of economies</i>	<i>18</i>	<i>6</i>	<i>6</i>	<i>6</i>
<i>Number of observations</i>	<i>1190</i>	<i>396</i>	<i>358</i>	<i>436</i>

Note: \*\*\*, \*\* and \* indicates that the estimated coefficients are significant at 1%, 5% and 10% level respectively; standard errors are robust.

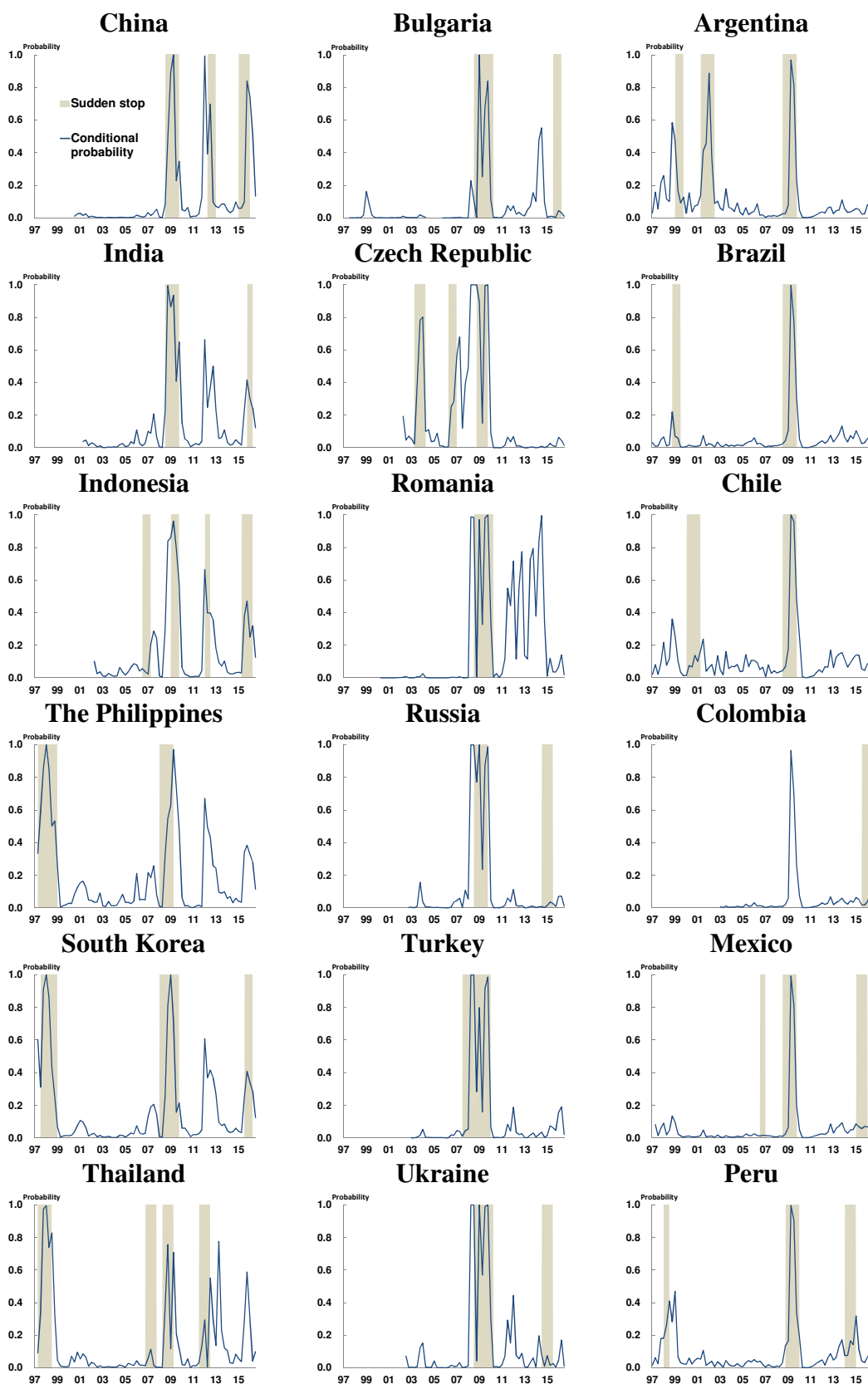
### **III. PREDICTIVE POWER OF THE WARNING SIGNAL OF SUDDEN STOPS**

#### *3.1 Out-of-sample forecast*

To examine the performance of the estimated model in predicting the probability of a sudden stop episode, we perform an out-of-sample forecast. The full sample is partitioned into two sub-samples, with the first part, ranging from the starting point of the estimation to the fourth quarter of 2008, for an in-sample estimation. The out-of-sample one-quarter-ahead forecast is performed with data in the period between the first quarter of 2009 to the third quarter of 2016. In practice, we expand the sample by one quarter in each turn (i.e. recursive sample) and estimate the one-quarter-ahead conditional probability of a sudden stop. Chart 6 shows the predicted probability. In general, the model performs well both in terms of in-sample and out-of-sample forecasts, with the predicted probability spiking during the episodes of sudden stops and staying at the close-to-zero level in most of the tranquil periods.



Chart 6: Predicted probability



Source: Authors' estimation.

### 3.2 Warning signal of a sudden stop

To obtain the signal of a sudden stop from the predicted probability, we need to identify a threshold value  $\theta$  ( $0 < \theta < 1$ ) which, when the predicted probability at time  $t$  exceeds  $\theta$ , gives the signals of a sudden stop from time  $t$  to  $t+2$  (i.e. the signalling period).<sup>12</sup> An optimal  $\theta$  should maximise the correct number of signals, i.e. minimise the number of missed calls and false alarms. Such optimisation involves a trade-off between two types of errors, as a lower threshold value reduces the number of missed calls, but at the same time increases the number of false alarms, and vice versa. A common approach is to optimise the objective function which defines the trade-off between the errors. The noise-to-signal ratio is a conventional objective function in this context: the threshold is set to minimise the noise-to-signal ratio as low noise (i.e. small number of false alarms) is a desired trait. This objective function, however, weighs much more on the minimisation of false alarms and ignores the costs inflicted by missed calls. As such, the approach generally leads to an unjustifiably high  $\theta$  and thus issuing too few signals.

In this study, we adopt a more balanced approach in identifying  $\theta$ . Instead of minimising the noise-to-signal ratio, we minimise the general loss function:

$$L(\theta) = \mu MC(\theta) + (1 - \mu)FA(\theta) \quad (7)$$

where  $L(\theta)$  is the loss function,  $MC(\theta)$  is the missed call rate (i.e. ratio of number of missed calls to the total number of quarters of sudden stops) and  $FA(\theta)$  is the false alarm rate (i.e. ratio of number of false alarms to the total number of tranquil periods). The parameter  $\mu$  is the weight of missed calls in the loss function (i.e.  $0 < \mu < 1$ ) and therefore the weight of false alarms is one minus  $\mu$ . Having no preference on either type of error, we assign equal weight (i.e.  $\mu = 0.5$ ) on missed calls and false alarms.

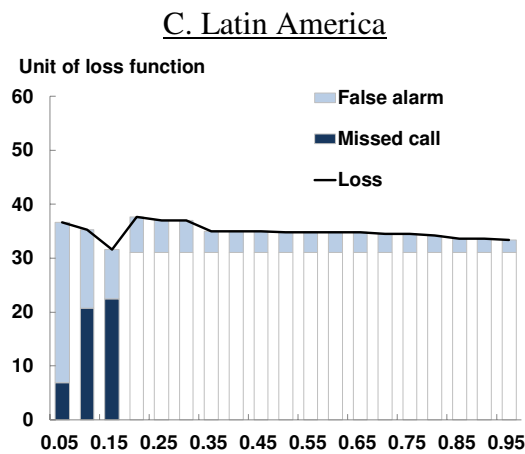
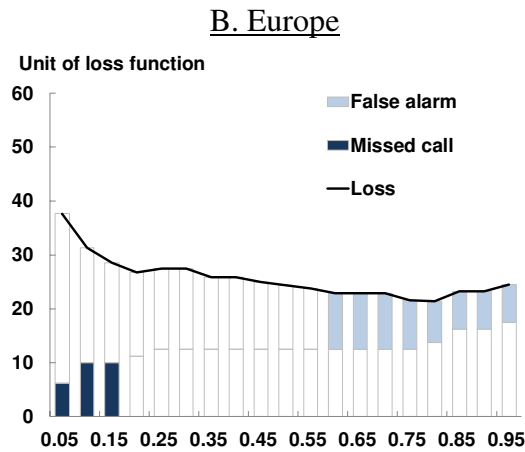
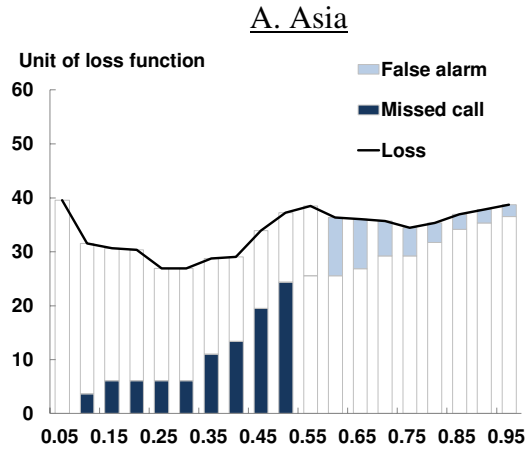
Charts 7A, 7B and 7C show  $L(\theta)$  of the sudden stop signal generated by the out-of-sample estimation of the predicted probability for Asia, Europe and

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<sup>12</sup> There is no rule of thumb or consensus on the length of the signalling period. In principle, a longer period would lead to less missed calls at the cost of more false alarms. A longer signalling period provides earlier warning signals, which might be a critical concern for surveillance if there is a long time-lag in the explanatory variables. For instance, the signalling period of the early warning signal in Comelli (2015) is two years (i.e. 8 quarters). In our study, given that the time lag of explanatory variables is about two quarters, we define a three-quarter signalling period ( $t$ ,  $t+1$  and  $t+2$ ) to facilitate timely signal issuance.

Latin America respectively, with  $\theta$  ranging from 0.05 to 0.95 (with interval equals to 0.05). As shown in the charts, the thresholds which minimise  $L(\theta)$  are 0.25, 0.80 and 0.15 for Asia, Europe and Latin America respectively.

**Chart 7: Loss function of sudden stop signals**



Source: Authors' estimation.

The performance of sudden stop signals derived from the out-of-sample estimation based on the selected  $\theta$  is summarised in Table 4. As shown, at the corresponding optimal  $\theta$ , the signals miss about 12% in Asia, 28% in Europe, and 45% in Latin America, while the false alarm rates are 42%, 15% and 18% in Asia, Europe and Latin America respectively. In terms of the loss function, our sudden stop signals outperform those of previous studies.<sup>13</sup>

Based on the data up to the second quarter of 2016, the predicted probability of sudden stops in the third quarter of 2016 in all EMEs are lower than their corresponding  $\theta$ , so there is no sudden stop signal for the third and fourth quarters of 2016, or the first quarter of 2017.

**Table 4: Performance of sudden stop signals**

<b>Out-of-sample forecast period: 2008 Q1 – 2016 Q2</b>			
	<b>Asia</b>	<b>Europe</b>	<b>Latin America</b>
<b>Total no. of sudden stop periods (no. of qtr.)</b>	41	40	29
<b>Correct signal (no. of qtr.)</b>	36	29	16
<b>Missed call (no. of qtr.)</b>	5	11	13
<b>Missed call (%)</b>	12.2	27.5	44.8
<b>Total no. of tranquil periods (no. of qtr.)</b>	163	164	175
<b>Correct “no signal” (no. of qtr.)</b>	95	139	143
<b>False alarm (no. of qtr.)</b>	68	25	32
<b>False alarm (%)</b>	41.7	15.2	18.3
<b>Loss function</b>	27.0	21.4	31.6
<b><i>Number of economies</i></b>	6	6	6
<b><i>Number of observations</i></b>	204	204	204

<sup>13</sup> The values of loss function of the sudden stop signals of Comelli (2015) were 55.0, 24.8 and 41.4 for Asia, Eastern Europe, Central Asia and Africa aggregate, and Latin America respectively.

#### **IV. CONCLUDING REMARKS**

In this study, we estimate the determinants of a sudden contraction in gross capital inflows to EMEs in different regions. The estimated conditional probability model shows that stronger global growth and relatively less volatile equity markets in EMEs reduce the chance of sudden stops in all EMEs. Increases in foreign exchange reserves also lower the likelihood of sudden stops occurring in Asian and European EMEs, but the effect is not significant in Latin America. Our results also indicate that economies with higher levels of debt denominated in foreign currencies face a greater probability of sudden stops in gross capital inflows in all EMEs, while the level of domestic loans denominated in domestic currency appears to be irrelevant.

The estimated effect of increased debts denominated in foreign currencies provides further evidence in literature that a high level of foreign currency exposure is a harbinger of instability. The result suggests policymakers should keep a close eye on the change in debts denominated in foreign currencies and formulate appropriate policy responses, whenever necessary, to reduce the chance of sudden stops and the subsequent economic fallout.

Based on the estimated conditional probability model, we have developed a warning signal for a sudden stop in gross capital inflows. The derived signal performs well in Asia and Europe, registering low rates of missed calls and false alarms in the one-quarter-ahead, out-of-sample forecast, but not so well in Latin America. However, it is still more reliable than that in similar previous studies. Overall, in practical operation, this warning signal could serve as part of a toolkit for monitoring external vulnerabilities.

Our research also provides the groundwork for future studies into this important issue. First, instead of studying the sudden contraction in overall gross capital inflows, future studies could focus on particular types of flows, for instance portfolio flows, banking flows and direct investment flows, which could be driven by different factors and their abrupt changes could have other implications for the recipient economies. Secondly, with the increasing use by EMEs of macro-prudential measures to address elevated financial vulnerabilities, further research on the effect of these measures on the likelihood of a sudden contraction in gross capital flows could help policymakers evaluate the effectiveness of the measures.

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