b
UNIVERSITÄT
BERN

Faculty of Business, Economics
and Social Sciences

Department of Economics

Sudden Stop regimes and output: a Markov switching analysis

Andreas Bachmann
Stefan Leist

13-07

November 2013

DISCUSSION PAPERS

Schanzeneckstrasse 1
Postfach 8573
CH-3001 Bern, Switzerland
http://www.vwi.unibe.ch

Sudden stop regimes and output: a Markov switching analysis

Andreas Bachmann* Stefan Leist†

November 1, 2013

Abstract

Sudden stops in capital inflows were a main characteristic of the emerging market crisis during the 1990's. Concerns about them have recurred in the light of recently increased global stability risk and the quantitative easing that led to substantial capital inflows in emerging economies. We add to the empirical literature that relies on a univariate approach by using a multivariate framework to assess the effect of sudden stops on economic growth and by the identification of sudden stop shocks using a Markov switching VAR and sign restrictions. The Markov switching VAR approach dates sudden stop periods comparable to the existing literature. It reveals a significant negative influence of the regime switch on economic growth that is robust across different estimation methods. Moreover, the Markov switching VAR also indicates that the reaction of macroeconomic variables to the identified shock based on sign restrictions is regime dependent.

JEL classification: F32; F41
Keywords: sudden stops; current account; sign restriction; Markov switching

---

*Department of Economics, University of Bern, Schanzeneckstrasse 1, P.O. Box 8573, CH-3001 Bern, Switzerland. Email: `andreas.bachmann@vwi.unibe.ch`

†State Secretariat for Economic Affairs SECO, Holzikofenweg 36, CH-3003 Bern, Switzerland. Email: `stefan.leist@seco.admin.ch`

We thank Dario Caldara, Fabrice Collard, Klaus Neusser, and participants at the PhD Workshop of the University of Bern for much appreciated comments. All remaining errors are ours.

1 Introduction

In this paper, we analyze the effect of sudden stops on output under various specifications. Sudden stops, defined as abrupt declines in net capital inflows, were identified as a common feature of the crises in the emerging markets during the 1990s (Calvo et al., 2006b). The recently increased global stability risk as well as the quantitative easing by industrial countries has renewed the interest on sudden stops (e.g., IMF, 2011). The quantitative easing led to a large increase of capital inflows to emerging economies which could come to a sudden stop as remarked by Agosin and Huaita (2012). These sudden stops are believed to be accompanied, among others, by severe drops in output, consumption and investment. Hence, countries like e.g. Brazil have already implemented policy measures to dampen these inflows.

The effects of sudden stops are controversially discussed in the theoretical literature. On the one hand, general equilibrium models with collateral constraints and working capital loans are able to produce the drop in output, consumption and investment due to a sudden stop (e.g., Neumeyer and Perri, 2005; Jaimovich and Rebelo, 2008; Mendoza, 2010). On the other hand, Chari et al. (2005), and Kehoe and Ruhl (2009) argue that sudden stops lead to an increase in output, but that this effect is overwhelmed by the negative effect of these frictions. Furthermore, Kehoe and Ruhl (2009) notice that the output reduction is due to a drop in labor and not due to a decline in total factor productivity. Given these different theoretical results, an empirical analysis of the effect of sudden stops may yield useful insights regarding modeling strategies. However, the existing empirical literature relies only on a univariate approach. Edwards (2004), Hutchison and Noy (2006) and Bordo et al. (2010) estimate a growth equation to determine the effect of sudden stops on output growth. They find either a negative effect on the GDP growth rate or a negative effect on the GDP trend growth. Following Calvo (1998) and Calvo et al. (2004), the sudden stops are identified as a decline in the change of net capital inflows exceeding minus two standard deviations below the prevailing mean. Bordo et al. (2010) find that their results do not depend on the specification of sudden stops as exogenous or endogenous events. Therefore, we are going to treat sudden stops as exogenous events.

The contribution of this paper to the empirical literature on sudden stops is threefold. Firstly, we extend the univariate approach to a multivariate framework. This allows for transmission channels as taken into account by general equilibrium models. Secondly, the ad hoc empirical implementation of sudden stops is replaced by estimating a vector autoregression (VAR) with sign restrictions. This enables us to identify shocks that may qualify as sudden stops by merely imposing the sign restriction that the shock has a negative effect on net capital inflows and terms of trade. Thirdly, we use a Markov switching VAR approach to identify sudden stops, to estimate the impact of rare switches to the sudden stop regime on GDP and to analyze differing dynamics across the "normal" and the sudden stop regime. We perform these estimations for Mexico and Indonesia using data on real GDP, the ratio of net capital inflows to GDP, the terms of trade and the risk premium.

With the Markov switching VAR approach, we are able to identify sudden stop periods that meet the definition of sudden stops and are comparable to the sudden stop dates in the literature. Our findings show that the switch from the "normal" to the sudden stop regime has a significantly negative impact on GDP. Moreover, the results indicate that the response of GDP growth to net capital inflows shocks depends on the regime. Shocks that have a large negative effect on net capital inflows on impact lead to a significant decline of GDP growth only in sudden stop regimes. For Mexico, the response of GDP is even positive for large responses of net capital inflows in the "normal" regime. Furthermore, the importance of regime switches is stressed by the difference of impulse responses which allow for regime switches and impulse response functions conditional on staying in a regime. Finally, a counterfactual analysis for historical sudden stop events using the Markov switching VAR approach indicates that the switch to the sudden stop regime combined with regime-dependent responses of macroeconomic variables to structural shocks led to massive declines of GDP in these periods.

The outline of the paper is as follows. Section 2 discusses the data sources. Section 3 motivates the chosen estimation methods and provides a short discussion of these. The results of the Markov switching VAR are presented in section 4. Moreover, this section contains some robustness checks. Finally, section 5 concludes.

2 Data

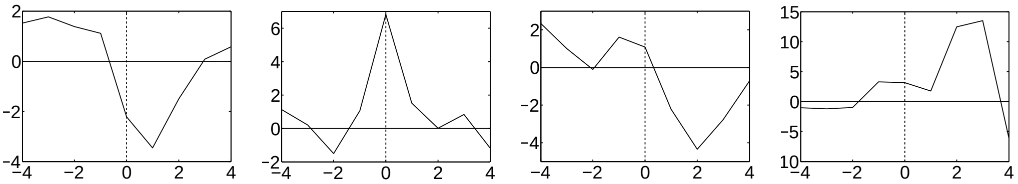
We use quarterly data on real GDP, the ratio of nominal net capital inflows to nominal GDP (CAP/GDP), the terms of trade (ToT) and a proxy for the risk premium (RP). The inclusion of GDP and a measure of net capital flows follows directly from the aim of this paper to investigate the effect of sudden stops on economic growth. Terms of trade are defined as the ratio of export deflator to import deflator. Because a drop in net capital inflows can be due to a positive terms of trade shock as noted by Calvo et al. (2004), we need to control for terms of trade in our VAR estimation. This will allow us to distinguish between sudden stops and terms of trade shocks. The risk premium is included as we regard it, in the light of Mendoza (2010), as potentially important for the impact of sudden stop shocks on GDP. We approximate it as the difference between the overnight interest rates of the respective country and the overnight interest rates of the US.

The choice of the countries Mexico, (M), and Indonesia, (I), is motivated by two reasons: data availability and the experience of sudden stop episodes in the past (see Calvo et al., 2006a). Furthermore, the literature typically finds sudden stop events for Latin American and Asian countries. With Mexico and Indonesia, we consider one country from each region. All data are taken from the OECD statistics database. The time series are transformed to ensure stationarity.[1] The sample of the transformed series contains 123 quarters of observations for Mexico (1980:2 to 2010:4) and 85 quarters for Indonesia (1990:2 to 2011:2).

To provide some information about the behavior of the macroeconomic variables as well as for robustness checks (see subsection 4.3), we identify sudden stop episodes closely following the literature (e.g. Calvo et al., 2004). In particular, a necessary requirement for a sudden stop episode is that it contains a quarter in which the change of the net capital inflows to GDP ratio falls at least two standard deviations below the prevailing sample mean. The length of this episode is determined based on the threshold of one standard deviation below the mean. It starts when the change in the net capital inflows to GDP ratio crosses the threshold from above and ends when the series crosses the threshold from below. We make sure that identified periods using this approach do not coincide with positive terms of trade shocks. Periods where terms of trade increase more than two standard deviations above the prevailing mean are not labeled as sudden stops.

[1] See appendix for details.

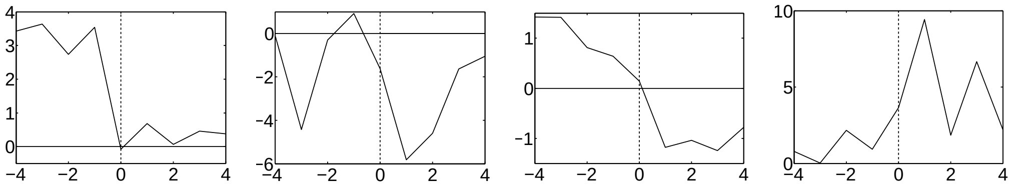
Indonesia



(a) CAP/GDP (b) $\Delta \log$ (ToT) (c) $\Delta \log$ (GDP) (d) Δ RP

Figure 1: Macroeconomic variables (Indonesia) around sudden stop that occurs at t=0. Timeline (quarters) on x-axis.

Mexico



(a) CAP/GDP (b) $\Delta \log$ (ToT) (c) $\Delta \log$ (GDP) (d) Δ RP

Figure 2: Macroeconomic variables (Mexico) around sudden stop that occurs at t=0. Timeline (quarters) on x-axis.

Figure 1 and figure 2 plot the key macroeconomic variables around sudden stops for Indonesia and Mexico. We use the identified sudden stop periods based on the approach described above. For these periods, we compute the average of the series and plot them at t=0. Furthermore, for each variable we compute the average behavior for the four quarters before and after the identified sudden stop periods. By construction, net capital inflows decline around the sudden stop at t=0. Although the terms of trade increase for Indonesia, this increase is not bigger than two standard deviations of the prevailing mean. As we can infer from figure 1 and figure 2, GDP growth drops after the occurrence of a sudden stop while the change in risk premium increases substantially after a sudden stop. This finding holds for Indonesia and Mexico. In summary, there seems to be a massive reaction of macroeconomic variables to sudden stops. This descriptive evidence calls for a more rigorous analysis using an econometric model. We consider the Markov Switching VAR model appropriate for this analysis as it allows for effects of the regime switch itself and for differing dynamic interactions of macroeconomic variables across different regimes. In contrast to the literature, our identification of sudden stops is not based on the ad hoc definition that looks at periods where the decline in CAP/GDP exceeds two standard deviations below the prevailing sample mean.

3 Estimation Methods

We employ a Markov switching VAR (MSVAR) estimation procedure in combination with sign restrictions. The latter allow to identify shocks that have a negative effect on net capital inflows on impact and a non-positive effect on terms of trade on impact. Therefore, we can directly implement the notion of sudden stops without imposing any ad hoc assumption. This is in contrast to the empirical implementation currently adopted in the literature, which labels net capital inflows changes that exceed minus two standard deviations below the mean as sudden stops. However, sign restrictions allow us to identify only conventional shocks as they occur during usual business cycles. Since sudden stops are extreme and rare events nested within normal business cycles, we estimate a MSVAR model in order to take into account these non-linearities. This allows for regime dependent impulse responses, which is closer to Mendoza (2010), who shows a switch in the dynamics of a nonlinear DSGE model with credit frictions. We aim at identifying a "normal" and a sudden stop regime. This will allow us to analyze the effect of a rare shock, the regime switch, in addition to the analysis of the identified net capital inflows shock based on the sign restriction approach.

3.1 Markov Switching VAR

We estimate a MSVAR to allow for regime dependent dynamics. No restrictions on the dynamics of switches and characteristics of the regimes are imposed. Hence, we do not enforce anything that ensures the existence of a "normal" and a sudden stop regime. Therefore, finding these regimes would imply that the VAR is well specified as it is able to differentiate between normal and sudden stop regimes. The general setup for the Markov switching estimation is the following reduced form simultaneous equation system:[2]

$$\Phi(L)(s_t)X_t = c(s_t) + Z_t(s_t), \quad Z_t|s_t \sim iidN(0, \Sigma(s_t)), \tag{3.1}$$

where $\Phi(L)(s_t) = (I - \Phi_1(s_t)L - \Phi_2(s_t)L^2 - \ldots - \Phi_p(s_t)L^p)$ is the state dependent lag polynomial, $X_t = [\Delta \log ToT_t, (CAP/GDP)_t, \Delta \log GDP_t, \Delta RP_t]'$ denotes a vector of macroeconomic variables, $c(s_t)$ is the state dependent constant and the state variable s_t evolves according to the following transi-

[2]The reduced form shocks $Z_t(s_t)$ are a function of the regime dependent structural coefficients and the independent structural shocks.

tion probabilities:[3]

$$P = \begin{pmatrix} p_{11} & 1-p_{11} \\ 1-p_{22} & p_{22} \end{pmatrix}.$$

This setup allows for switches in the coefficients as well as in the variances. The underlying assumption is that the equation system is linear in each regime. We rely on the information criterion BIC to determine the lag length p.

In order to estimate the Markov switching model, a Bayesian Markov Chain Monte Carlo (MCMC) approach with Gibbs sampler is chosen.[4] This approach has the advantage that it delivers the posterior distribution of the reduced form coefficients. Draws from the posterior distribution can then be used to compute the impulse responses based on sign restrictions as suggested by Rubio-Ramírez et al. (2005). In a first step, equation (3.1) is estimated for the whole sample without imposing any regime switches to get the initital values for the Gibbs sampling procedure. Secondly, the priors are set for the Bayesian estimation procedure. A hierarchical prior is used to compute the covariance matrix $\Sigma(s_t)$ in order to prevent problems with small sample sizes in one regime. Therefore, the regime specific variances are computed as the product of a common scale and a regime specific scale component and thus are scales of the common variance. The common scale is computed using the full sample with a non-informative prior, while the regime specific scale is based on a informative prior. A non-informative prior is used for the coefficients. Thirdly, the Gibbs Sampling proceeds as follows:[5]

1. The common covariance matrix Σ is drawn given the regime specific covariance matrix $\Sigma(s_t)$.
2. Given the common covariance matrix, the regime specific covariance matrix is drawn.
3. Using a multivariate normal distribution, the coefficients Φ are drawn given the covariance matrix and the regimes.

[3]The variable s_t follows a Markov process with fixed transition probabilities. We also estimated the MSVAR with time varying transition probabilities in the spirit of Filardo and Gordon (1998). We assumed that they depend on the lagged variables of the VAR. Note that this also includes the net capital inflows. Thus, we allow for booms of capital inflows that can lead to sudden stops as pointed out by Agosin and Huaita (2012). The coefficients in the equation of the transition probabilities were jointly insignificant. Therefore, we decided to rely on exogenous fixed transition probabilities.

[4]The estimation is performed using RATS.

[5]The first 2'000 draws are discarded while the next 10'000 draws are used throughout this paper.

4. Using a forward-backward filtering approach, the predicted, updated and smoothed probabilities are computed.

3.2 Sign Restrictions

Sign restrictions can be used to identify negative net capital inflows shocks which may qualify as sudden stops. We will only restrict the contemporaneous effect of these shocks. A major advantage of using sign restrictions for identification is its consistency with general equilibrium logic. DSGE models usually imply that the immediate impact of all shocks is non-zero in general, but that the responses of economic variables to particular shocks have specific signs. Hence, these models provide qualitative restrictions that can be imposed in the estimation process.

To identify a structural net capital inflows shock, we impose the sign restrictions that the immediate responses of the net capital inflows to GDP ratio and of the terms of trade are negative. The first restriction follows immediately from the definition of a sudden stop. The second restriction serves to distinguish the net capital inflows shock from a positive terms of trade shock. This distinction is necessary because a drop in net capital inflows may be the consequence of a positive terms of trade shock (Calvo et al., 2004). An improvement in the terms of trade has a positive effect on the current account and therefore affects net capital inflows negatively. To distinguish such events, which are not considered to be a sudden stop, from actual sudden stops, the restriction of a negative terms of trade response to a net capital inflows shock is necessary.

We apply the algorithm proposed by Rubio-Ramírez et al. (2010), which is based on the QR decomposition, in order to identify a structural net capital inflows shock using sign restrictions.[6] Let $\hat{\Sigma}(s_t)$ denote the estimated covariance matrix of the VAR residuals. The reduced form residuals $Z_t(s_t)$ are linear combinations of the structural shocks V_t, i.e. $Z_t(s_t) = B_0(s_t)V_t$. Normalizing the variance of the structural shocks to one, the following relation holds:

$$\hat{\Sigma}(s_t) = \hat{B}_0(s_t)\hat{B}_0(s_t)'. \tag{3.2}$$

The basic idea of identification using sign restrictions consists in finding matrices $\hat{B}_0(s_t)$ such that (i) equation (3.2) holds, (ii) the structural shocks are orthogonal and (iii) the specified pattern of signs is satisfied. The algorithm

[6]See appendix for a more detailed description of the algorithm.

by Rubio-Ramírez et al. (2010) yields the elements of $\hat{B}_0(s_t)$ satisfying these three constraints.

Note that the sign restrictions used for identification of the net capital inflows shock are very weak. In particular, we only use two restrictions that follow immediately from the definition of sudden stops. The advantage of using weak restrictions comes at the cost of substantial imprecision in estimating the matrix $B_0(s_t)$ and hence, at the cost of possibly imprecise results. However, as shown in section 4, we find significant results based on these weak restrictions. Thus, we find no need for imposing additional identifying restrictions.

3.3 Impulse Responses

We compute impulse response functions (IRFs) both to a regime switch and to a negative net capital inflows shock occuring in a given regime. The former are useful for the interpretation of different regimes and for assessing the impact of the switch itself. The latter reveal differences in the dynamic responses to a shock depending on which regime is in place. Both types of impulse responses are computed conditional on staying in a given regime as well as unconditional, i.e. allowing for regime switches after the initial shock.

3.3.1 Conditional Impulse Response Functions to Regime Switch

The conditional impulse response functions to a regime switch capture the dynamic changes of the variables under the assumption that no further regime switch occurs in the future. The analysis of these IRFs is useful for the interpretation of the regimes. However, this is a purely hypothetical exercise because none of the two states is absorbing, so there will be further regime changes after the initial switch. Therefore, we additionally estimate the unconditional IRFs allowing for subsequent regime switches (see section 3.3.2). These IRFs measure the expected effect of a regime change on the endogenous variables.

The computation of the conditional IRFs is as follows:

1. 10'000 draws from the posterior of the VAR coefficients (Φ, Σ, P) are made. For every draw, the following steps 2 and 3 are repeated.

2. The expected values of X conditional on a constant regime are calculated as $\mu(s = SS) = (I - \Phi_1)^{-1}c_1$ and $\mu(s = N) = (I - \Phi_2)^{-1}c_2$.

3. We compute

$$Y_0^{(SS)} = c_1 + \Phi_1\mu(s = N),$$
$$Y_0^{(N)} = c_2 + \Phi_2\mu(s = SS).$$

The response to a switch from the sudden stop regime (SS) to the normal regime (N) on impact is given by

$$IRF_0^{(N)} = Y_0^{(N)} - \mu(s = SS),$$

where the superscript (N) refers to the switch to regime N. Analogously,

$$IRF_0^{(SS)} = Y_0^{(SS)} - \mu(s = N)$$

is the response to a switch from regime N to regime SS. Note that the IRFs to a switch from SS to N are in general not the mirror image (with reversed sign) of a switch from N to SS because the autoregressive parameters depend on the regime.

After $h > 0$ periods, the impulse responses are given by

$$IRF_h^{(N)} = Y_h^{(N)} - \mu(s = SS) \quad \text{and} \quad IRF_h^{(SS)} = Y_h^{(SS)} - \mu(s = N)$$

where

$$Y_h^{(N)} = c_2 + \Phi_2 Y_{h-1}^{(N)} \quad \text{and} \quad Y_h^{(SS)} = c_1 + \Phi_1 Y_{h-1}^{(SS)}.$$

3.3.2 Unconditional Impulse Response Functions to Regime Switch

Following Krolzig (2006), the responses to regime shifts allowing for further subsequent shifts are defined in the spirit of the concept of generalized impulse responses (Koop et al., 1996):

$$\mathbb{E}\left[X_{t+h}|s_t = SS, X_{t-1}\right] - \mathbb{E}\left[X_{t+h}|s_t = N, X_{t-1}\right] \qquad \forall h \geq 0. \tag{3.3}$$

Given the structure of the MSVAR, (3.3) can be rewritten as

$$c_1 - c_2 + (\Phi_1 - \Phi_2)X_{t-1} \qquad \text{for } h = 0 \tag{3.4}$$

and

$$\begin{aligned}
&P(s_{t+h} = SS|s_t = SS)\left(c_1 + \Phi_1\mathbb{E}\left[X_{t+h-1}|s_t = SS, X_{t-1}\right]\right)\\
+&P(s_{t+h} = N|s_t = SS)\left(c_2 + \Phi_2\mathbb{E}\left[X_{t+h-1}|s_t = SS, X_{t-1}\right]\right)\\
-&P(s_{t+h} = SS|s_t = N)\left(c_1 + \Phi_1\mathbb{E}\left[X_{t+h-1}|s_t = N, X_{t-1}\right]\right)\\
-&P(s_{t+h} = N|s_t = N)\left(c_2 + \Phi_2\mathbb{E}\left[X_{t+h-1}|s_t = N, X_{t-1}\right]\right) \qquad \text{for } h > 0
\end{aligned} \tag{3.5}$$

These impulse responses are a function of the history X_{t-1}. We compute the expectation of (3.4) and (3.5) with respect to the empirical distribution of X_{t-1} and we refer to the resulting IRFs as unconditional IRFs to a regime switch. The procedure for computing the unconditional IRFs is as follows:

1. 10'000 draws from the posterior of the VAR coefficients (Φ, Σ, P) are made. For each draw, the following steps 2 to 4 are repeated.

2. Let ξ_t denote a (2×1) state vector equal to $\begin{pmatrix}1\\0\end{pmatrix}$ if $s_t = SS$ and $\begin{pmatrix}0\\1\end{pmatrix}$ if $s_t = N$. Using the properties of Markov chains, the h period ahead forecast of the state vector is given by

$$\mathbb{E}[\xi_{t+h}|\xi_t] = \begin{pmatrix} P(s_{t+h} = SS|s_t = SS) & P(s_{t+h} = SS|s_t = N) \\ P(s_{t+h} = N|s_t = SS) & P(s_{t+h} = N|s_t = N) \end{pmatrix} = P^h \xi_t.$$

3. We compute

$$\begin{aligned} Y_t^{(SS)} =& c_1 + \Phi_1 X_{t-1}, \\ Y_t^{(N)} =& c_2 + \Phi_2 X_{t-1}, \end{aligned}$$

where $Y_t^{(SS)}$ is the vector of simulated variables in the sudden stop regime, $Y_t^{(N)}$ is the vector of simulated variables in the "normal" regime and X_{t-1} denotes an arbitrary vector of observations in our sample. The response on impact is given by

$$IRF_t^{(SS)} = Y_t^{(SS)} - Y_t^{(N)} = c_1 - c_2 + (\Phi_1 - \Phi_2) X_{t-1}.$$

The impulse responses for $h > 0$ are computed as

$$\begin{aligned} IRF_{t+h}^{(SS)} &= Y_{t+h}^{(SS)} - Y_{t+h}^{(N)}, \\ \text{where} \quad Y_{t+h}^{(SS)} =& P(s_{t+h} = SS|s_t = SS)(c_1 + \Phi_1 Y_{t+h-1}^{(SS)}) \\ &+ P(s_{t+h} = N|s_t = SS)(c_2 + \Phi_2 Y_{t+h-1}^{(SS)}) \\ \text{and} \quad Y_{t+h}^{(N)} =& P(s_{t+h} = SS|s_t = N)(c_1 + \Phi_1 Y_{t+h-1}^{(N)}) \\ &+ P(s_{t+h} = N|s_t = N)(c_2 + \Phi_2 Y_{t+h-1}^{(N)}). \end{aligned}$$

4. Step 3 is repeated for each possible starting value X_{t-1} based on our sample. We compute the mean of the IRFs resulting from different starting values.

3.3.3 Conditional Impulse Response Functions to Net Capital Inflows Shock

In addition to the responses to a regime switch, we estimate regime-dependent IRFs to a net capital inflows shock. Again, we consider IRFs both conditional and unconditional on staying in a regime because the former are more informative about distinct features of the regimes while the latter correspond to responses we expect to observe in reality.

Following Ehrmann et al. (2003), we compute impulse responses (IRFs) conditional on staying in a given regime j. Hence, the estimated impulse responses of a Markov switching VAR(1) are given by

$$IRF_{j,h} = \hat{\Phi}(s_t = j)^h \hat{B}_0(s_t = j) u_0, \tag{3.6}$$

where the subscript j refers to IRFs conditional on regime j, h is the time horizon, and u_0 is the initial structural shock. We present estimated impulse responses to a net capital inflows shock of the size of one standard deviation, which implies $u_0' = [0, 1, 0, 0]$. These IRFs provide us with information on the reaction of the variables if we stayed in the given regime without being affected by the dynamics of the other regime.

3.3.4 Unconditional Impulse Response Functions to Net Capital Inflows Shock

The procedure to estimate impulse responses which allow for further regime switches is as follows:

1. 10'000 draws from the posterior of the VAR coefficients (Φ, Σ, P) are made. For each draw, the following steps 2 to 6 are repeated.

2. Identification by sign restrictions is implemented as discussed in section 3.2.

3. The shocks are computed and used as baseline series. To construct the alternative scenario, we increase the element of the identified net capital inflows shock by one standard deviation.

4. Using the draw of P, the h period ahead forecast of the Markov states is computed as described above in step 2 of the procedure for the unconditional IRFs to a regime switch.

5. We condition on the regime ($s_t = j$) for the period in which the shock occurs in order to make statements about the response to a shock that occurred when a particular regime was in place. Hence, we define

$$\begin{aligned}\tilde{Y}_{j,t} =&(1-s_t)(c_1+\Phi_1 X_{t-1}+\tilde{Z}_{1,t})+s_t(c_2+\Phi_2 X_{t-1}+\tilde{Z}_{2,t})\\ Y_{j,t} =&(1-s_t)(c_1+\Phi_1 X_{t-1}+Z_{1,t})+s_t(c_2+\Phi_2 X_{t-1}+Z_{2,t}),\end{aligned}$$

where $\tilde{Z}_{j,t} = B_0(j)\tilde{V}_t$ is the shocked reduced form residual of regime j, $\tilde{V}_t$ denotes the structural shock of the alternative scenario[7], and X_{t-1} denotes a vector of observations, where t is an arbitrary period in our sample. The regime on impact, s_t, is fixed to zero or one. The response on impact is given by

$$IRF_{j,t} = \tilde{Y}_{j,t} - Y_{j,t} = \begin{cases}\tilde{Z}_{1,t} - Z_{1,t} & \text{if } j = SS\\ \tilde{Z}_{2,t} - Z_{2,t} & \text{if } j = N\end{cases}$$

The impulse responses after impact are given by

$$\begin{aligned} IRF_{j,t+h} =&\tilde{Y}_{j,t+h} - Y_{j,t+h} \quad \forall h > 0,\\ \text{where} \quad \tilde{Y}_{j,t+h} =&\mathbb{E}[Y_{t+h}|s_t = j, X_{t-1}, \tilde{Z}_{j,t}]\\ =&\sum_k P(s_{t+h} = k|s_t = j)(c_k + \Phi_k \mathbb{E}[Y_{t+h-1}|s_t = j, X_{t-1}, \tilde{Z}_{j,t}])\\ \text{and} \quad Y_{j,t+h} =&\mathbb{E}[Y_{t+h}|s_t = j, X_{t-1}, Z_{j,t}]\\ =&\sum_k P(s_{t+h} = k|s_t = j)(c_k + \Phi_k \mathbb{E}[Y_{t+h-1}|s_t = j, X_{t-1}, Z_{j,t}])\end{aligned}$$

6. Step 5 is repeated for each possible value pair (X_{t-1}, V_t) based on our sample. We compute the mean of the IRFs resulting from different starting values.

3.3.5 Median Impulse Responses

A problem arises when we aim to represent the median impulse responses. Although for each identified structural model, the identified net capital inflows shock is orthogonal to other structural shocks, the median responses are likely to come from different structural models as the median is computed pointwise for each horizon. Thus, there is no guarantee that the median IRFs are the responses to orthogonal shocks. Fry and Pagan (2011) propose the

[7] Hence, $\tilde{V}_t = V_t + [0, 1, 0, 0]'$.

so-called *median target* (MT) method to address this issue. The idea is to find a single structural model with orthogonal shocks whose IRFs are close to the median IRFs.[8] As it turns out, the IRFs of the model selected by the MT method almost coincide with the median IRFs in our application. This indicates that correlation of the shocks associated with the median IRFs is not an issue. Thus, we choose to present the median IRFs.

We follow the sign restriction literature and use 16th and 84th quantile to assess significance of the impulse responses.

[8]The criterion for finding the closest IRFs is given by minimizing the sum of squared errors, where the errors are computed as the deviation of some model's IRFs to the median IRFs divided by the their standard deviation (see Fry and Pagan, 2011).

4 Results

This section discusses the results from the Markov Switching estimation procedure. Firstly, to justify the labeling of the two regimes as sudden stop and "normal" regime, we discuss the estimated regime switching probabilities and compare them to the sudden stop periods given in Calvo et al. (2006a). Furthermore, the impulse responses to a regime switch are analyzed to verify that they exhibit the pattern which is believed to characterize sudden stops. We identify a sudden stop regime which generates impulse responses consistent with the definition of sudden stops and which corresponds to similar periods as sudden stop periods according to the literature. Secondly, we discuss the conditional impulse response functions in order to analyze the effect of the identified net capital inflows shock on the variables if we stay in a given regime. The conclusion is that the identified shock has a negative effect on the GDP growth rate only if it is large and occurred during a sudden stop regime. Thirdly, the unconditional impulse responses are discussed to provide information on the expected responses of the variables to the identified shock if we allow for regime switches after impact. The results highlight the importance of regime switches as they have an effect on the significance of the impulse responses. Finally, after assessing the robustness of our results, we conduct a counterfactual analysis for historical sudden stop events using the Markov switching VAR approach.

4.1 Characterization of Regimes

Calvo et al. (2006a) provide dates on systemic and non-systemic sudden stop episodes for the years 1980 to 2004. The former are labeled 3S and define periods of a sudden stop that coincide with an increase of emerging markets bond spreads. The latter are defined as periods of capital inflow collapse. We combine the dates on non-systemic and 3S sudden stops to be closest to the empirical implementation of sudden stops followed in this paper. The MSVAR estimation yields sudden stop periods comparable to Calvo et al. (2006a). Furthermore, we compute impulse responses to a regime switch and can show that CAP/GDP decreases, which meets the definition of sudden stops. Hence, the MSVAR enables to identify sudden stop regimes without having to impose anything on the data or on the estimation method. This is an advantage over the approach currently followed by the literature that labels drops of CAP/GDP that exceed two standard deviations below the mean as a sudden stop.

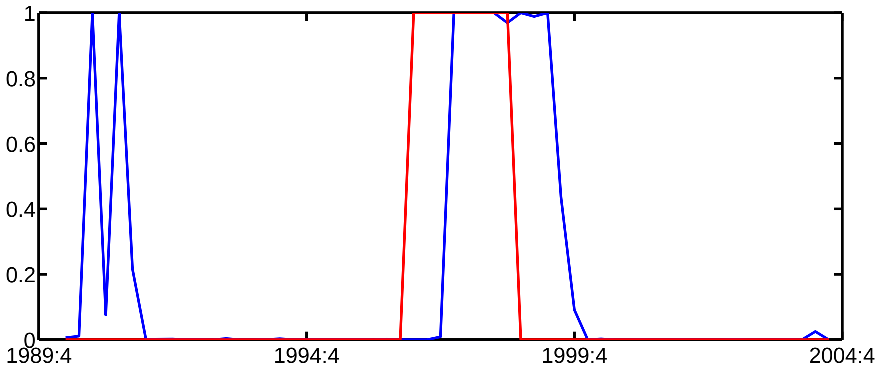


Figure 3: Indonesia: Comparison of MSVAR regime 1 (blue) to sudden stop dates of Calvo et al. (2006a) (red)

The probability of being in regime 1 coincides with the sudden stop dates in Calvo et al. (2006a) for most periods and both countries. For Indonesia, figure 3 provides a comparison of the estimated regime 1 based on the MSVAR to these dates. Although our sample continues to 2011 Q2, we restrict the discussion of regime probabilities on the periods up to 2004 Q4 for the reason of comparability with Calvo et al. (2006a). The Asian crisis around 1998 is picked up by both approaches.[9] However, only the MSVAR approach identifies two sudden stop periods at the beginning of the sample. For Mexico, the comparison of the probability of being in regime 1 with the sudden stop regimes given in Calvo et al. (2006a) is depicted in figure 4. We can see that this regime coincides quite often with sudden stop regimes identified by these authors. A closer look reveals that both approaches are very similar up to the end of 1989. There is only a short drop in the probability of being in regime 1 in the years 1983 and 1984 while Calvo et al. (2006a) label these years as a sudden stop period.[10] The peso crisis around 1995 is picked up by both measures. While the MSVAR approach reveals high probabilities for regime 1 in the years 1989/1999, Calvo et al. (2006a) find a sudden stop regime around 2001. However, the latter period is the only sudden stop regime where the output decline is almost zero while it is above 3.75% for all other periods identified by these authors.

[9] While we use quarterly data, Calvo et al. (2006a) only provide annual dates of peak, trough and recovery associated with sudden stop episodes. This may explain small differences in the dating of sudden stops.

[10] However, Calvo et al. (2006a) also find two subsequent sudden stops in the 80ies, the first reaching its trough in 1983, which is in line with the regime probabilities from the MSVAR.

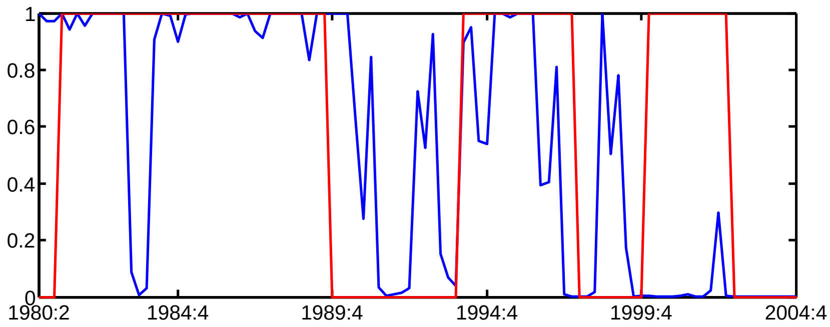


Figure 4: Mexico: Comparison of MSVAR regime 1 (blue) to sudden stop dates of Calvo et al. (2006a) (red)

In addition to the regime probabilities being close to the sudden stop episodes identified by the literature, we find that the impulse responses to a regime switch are consistent with the definition of sudden stops. The conditional IRFs indicate that the hypothetical exercise of starting in regime 2 and switching once and for all to regime 1 leads to significantly lower net capital inflows in percentage of GDP (-1 percentage point for Mexico, -1.6 percentage points for Indonesia). The response of the terms of trade to this regime switch is not significant for Mexico and significant only in the short run for Indonesia. Hence, we are confident that the regime switch characterizes (CAP/GDP) shocks and not terms of trade shocks.

The unconditional IRFs to a regime switch, which allow for further changes in the regime, provide a description of the expected impact of a regime switch. These responses are plotted in figure 5. There is a significant drop of (CAP/GDP) for both countries. There is no significant impact on the terms of trade except for the short run in Indonesia. This corresponds to the definition of sudden stops in the literature. Finally, the response of the GDP growth rate as well as the logarithm of GDP is significantly negative for both countries. Therefore, sudden stops characterized by regime switches have a significant negative impact on output growth and level. The response of the risk premium is not significant. Hence, no impulse responses are provided.

Henceforth, we label the regime 1 of both countries as sudden stop regime because the probabilities are consistent with the dates in Calvo et al. (2006a) and the impulse responses to regime switches are as we would expect from a sudden stop.[11]

[11] The probabilities of regime 1 for the whole sample are provided in the appendix and can be found in figure 14 for Mexico and figure 15 for Indonesia.

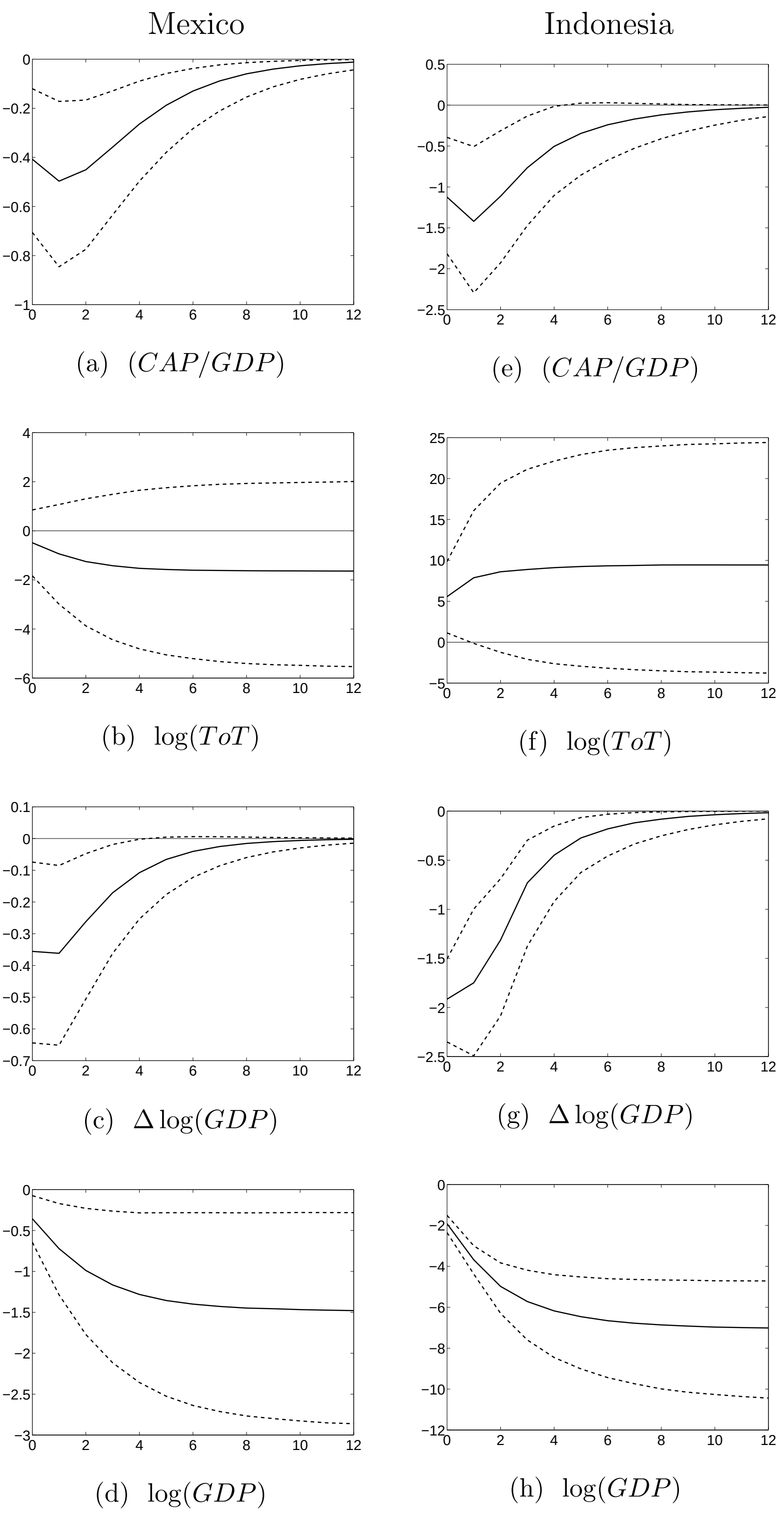
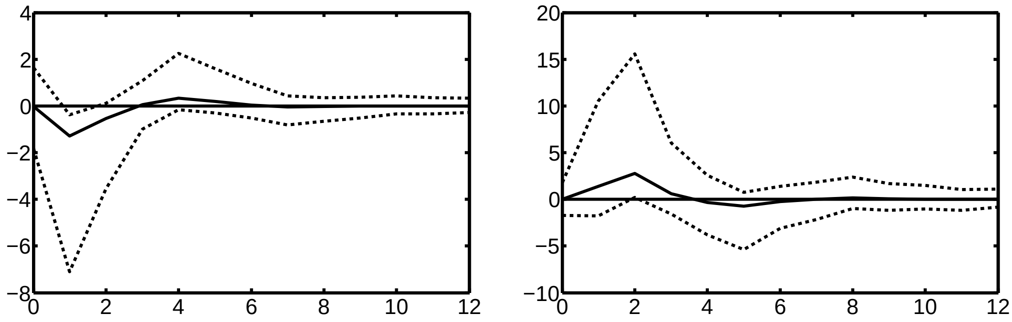


Figure 5: Impulse responses to a switch to the sudden stop regime

Indonesia



(a) $\Delta \log GDP$ (b) ΔRP

Figure 6: Conditional impulse response to net capital inflows shock.

4.2 Net Capital Inflows to GDP Shock

In this section, we discuss different impulse response functions. First, the two regimes are analyzed based on conditional impulse responses. Secondly, the impulse responses based on the whole model and thus allowing for regime switches are analyzed. The conditional impulse response of the GDP growth rate to a large shock is significantly negative for both countries for sudden stop periods only. Allowing for switches to sudden stops after we started off in a "normal" regime yields significantly negative responses for Indonesia. For Mexico, allowing for switches to the "normal" regime after we started off in a sudden stop regime yields responses that do not differ significantly from zero.

4.2.1 Conditional Impulse Responses

The impulse responses of CAP/GDP and terms of trade to the identified net capital inflows shock are significantly negative in both regimes. This is due to the implemented sign restrictions. Furthermore, for the sudden stop regime, the response of the Indonesian GDP growth rate is significantly negative one quarter after impact while the change in risk premium increases significantly two quarters after impact (figure 6). The impulse responses of the change in risk premium and GDP growth do not differ significantly from zero for both regimes of Mexico and for the "normal" regime of Indonesia. The comparison of impulse responses across the regimes is provided in the appendix (figure 17 for Mexico and 16 for Indonesia).

Sudden stops are not just related to the sign of the shock but also to the size. Hence, we analyze the impulse responses accordingly. We compute the impulse responses of GDP growth and log(GDP) to the identified shock for four groups. The definition of the groups depends on the size of the response of the net capital inflows to GDP ratio (CAP/GDP) on impact. The smallest response of CAP/GDP up to the first quartile of all responses is the first group (Q1-min). The second group (Q2-Q1) covers all responses that lie between the median and first quartile of all responses of CAP/GDP on impact. The third group (Q3-Q2) covers the responses between the third quartile and the median. Finally, the last group (max-Q3) covers the most negative response of CAP/GDP to the third quartile.

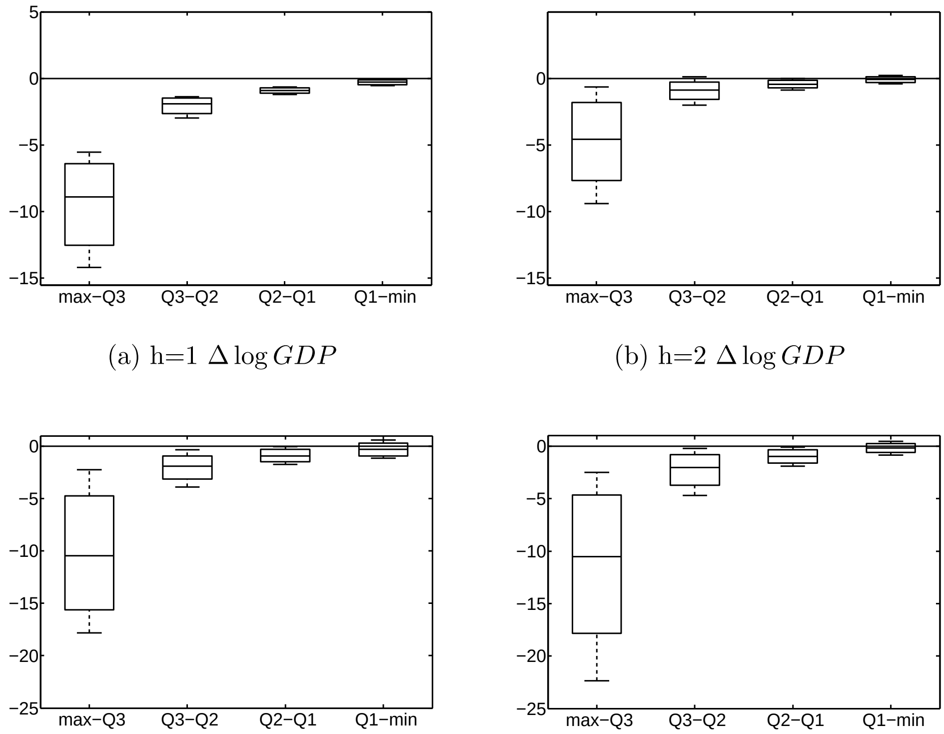
In the sudden stop regime, the response of GDP growth of both countries is significantly[12] negative for large negative responses of CAP/GDP to the identified shock. Hence, as proposed by the current literature, the size of the shock matters. For shocks that lead to a large negative response of CAP/GDP (max-Q3), GDP growth declines for a few quarters after impact. Our results show that considering a regime switching framework is important. In the "normal" regime, the responses are not significantly negative. For Indonesia, the responses of GDP growth are significant one and two quarters after impact for the group covering the largest shocks (max-Q3). In fact, one period after impact, the response is significantly negative for all but the smallest shock group. All other impulse responses of GDP growth are not significantly different from zero. Boxplots[13] are provided for the significant impulse responses in figure 7.

For Mexico, the responses of GDP growth are significantly negative only for the most negative responses of CAP/GDP for three to six quarters after impact in the sudden stop regime. We provide the impulse response only for three quarters after impact in the sudden stop regime in figure 8 as the responses for four to six quarters after impact are similar. Furthermore, the response of GDP growth to a large negative response of CAP/GDP is small, but significantly positive in the "normal" regime. Figure 8 shows the plot of this significant positive response in the "normal" regime two quarters after impact. The response of $log(GDP)$ is significant only for Indonesia for one, two and four quarters after impact. Again, we find that the larger the shocks, the more negative the response. These responses are also provided in figure 7.

[12]As common in the sign restriction literature, we rely again on the interval between 1/6 and 5/6 to assess significance.

[13]The box covers the interquartile range, while adding the whiskers covers 2/3 of the impulse responses.

Indonesia



(a) h=1 $\Delta \log GDP$

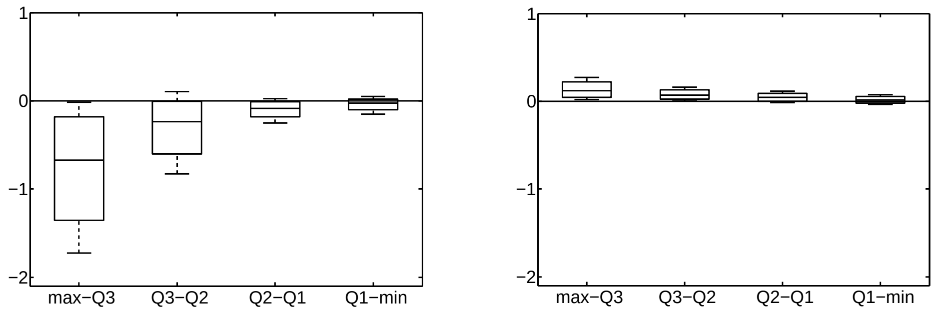
(b) h=2 $\Delta \log GDP$

(c) h=1 $\log(GDP)$

(d) h=4 $\log(GDP)$

Figure 7: Boxplot of impulse responses (conditional) of sudden stop regime dependent on size of shock. x-axis is the response of CAP/GDP, ordered by size on impact (h=0), to the identified shock. y-axis is the response of $\Delta \log GDP$ or $\log(GDP)$ for a specific horizon (h).

Mexico



(a) h=3 $\Delta \log GDP$ (SS)

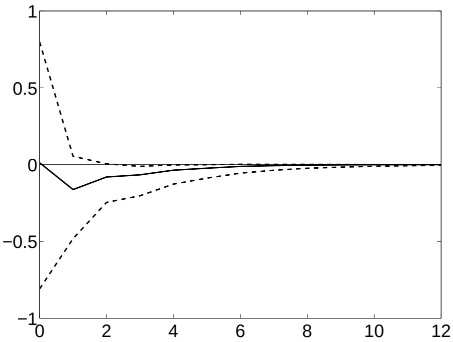
(b) h=2 $\Delta \log GDP$ (N)

Figure 8: Boxplot of impulse responses (conditional) of sudden stop regime (SS) and "normal" regime (N) dependent on size of shock. x-axis is the response of CAP/GDP, ordered by size on impact (h=0), to the identified shock. y-axis is the response of $\Delta \log GDP$ for a specific horizon (h).

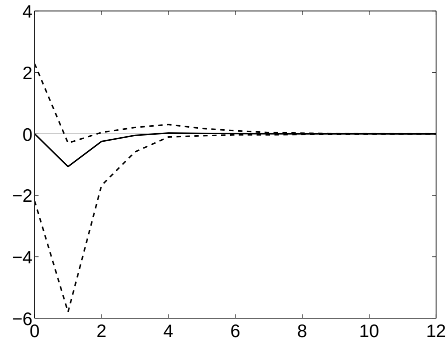
4.2.2 Unconditional Impulse Responses

On impact we are either in the "normal" or the sudden stop regime. After impact, we allow for regime changes. An overview of the impulse responses are provided in the appendix in figure 18 for Indonesia and figure 19 for Mexico. The responses of terms of trade and net capital inflows to GDP ratio are significantly negative by construction. For Mexico, neither the response of the change in the risk premium nor the GDP growth response does significantly differ from zero. For Indonesia, the impulse response of the change in the risk premium is positive two quarters after impact if the shock occurred in the sudden stop regime. The response of GDP growth is now negative whether the economy is in a sudden stop regime or in the "normal" regime on impact. Hence, the allowance of regime switches drives the response of GDP growth to the identified net capital inflows shocks significantly into the negative numbers (figure 9). This finding is confirmed when analyzing the impulse responses of GDP growth and GDP with respect to the size of the response of CAP/GDP. The response of GDP growth to the identified shock is significantly negative for larger responses of CAP/GDP (max-Q3, Q3-Q2) one quarter after impact, whether we start in the sudden stop regime (SS) or the "normal" regime (N). Furthermore, the accumulated impulse response is also significantly negative for large responses of CAP/GDP, irrespective of the regime. However, the size of the response still differs across the regimes. If the economy is in a sudden stop regime when the shock occurs, the negative

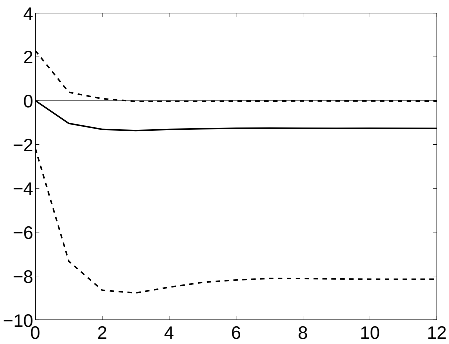
Indonesia



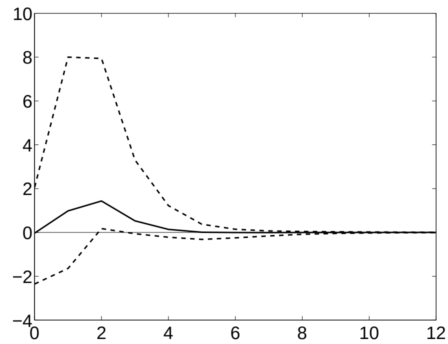
(a) $\Delta \log GDP$ (N)



(b) $\Delta \log GDP$ (SS)



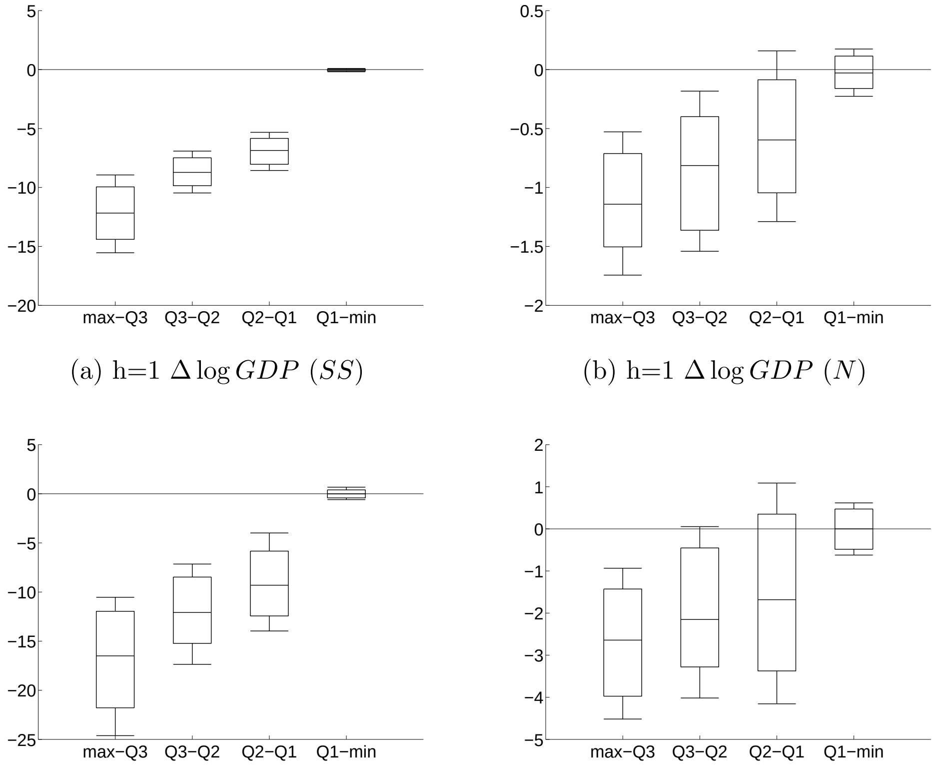
(c) $\log GDP$ (SS)



(d) ΔRP (SS)

Figure 9: Unconditional impulse responses to net capital inflows shock for both regimes.

Indonesia



(a) h=1 $\Delta \log GDP$ (SS)

(b) h=1 $\Delta \log GDP$ (N)

(c) h=4 $\log(GDP)$ (SS)

(d) h=4 $\log(GDP)$ (N)

Figure 10: Boxplot of impulse responses (unconditional) of sudden stop regime (SS) and "normal" regime (N) dependent on size of shock. x-axis is the response of CAP/GDP, ordered by size on impact (h=0), to the identified shock. y-axis is the response of $\Delta \log GDP$ or $\log(GDP)$ for a specific horizon (h).

response is much more pronounced as can be inferred from figure 10.

4.3 Robustness

An important result of our estimation is that regime switches have a negative impact on GDP growth. In order to check the robustness of this result, we estimate an episode VAR (EVAR) and a Panel EVAR. The EVAR provides a simple and useful framework for the analysis of macroeconomic responses to exogenous shocks or events that occurred in certain episodes. Following the procedure applied in Burnside et al. (2004), the EVAR consists of a VAR model including a lag polynomial of an exogenous dummy variable as explanatory variable. Thus, the model takes the form

$$\begin{aligned} &\Phi(L)X_t = c + A(L)D_t + Z_t, \\ &\text{with } X_t = [\Delta \log ToT_t, (CAP/GDP)_t, \Delta \log GDP_t, \Delta RP_t]', \end{aligned} \tag{4.1}$$

in which $\Phi(L) = (I - \Phi_1 L - \Phi_2 L^2 - \ldots - \Phi_p L^p)$ and $A(L) = (A_0 + A_1 L + A_2 L^2 + \ldots + A_q L^q)$ are lag polynomials and where X_t denotes a vector of macroeconomic variables, Z_t is a vector of shocks that are uncorrelated over time and D_t is the exogenous sudden stop dummy, which equals one in sudden stop episodes and zero otherwise. The dummy is constructed following the description in section 2.

Constructing the dummy yields only a few sudden stop periods. Hence, separate estimations of the EVAR for the different countries rely on a small number of sudden stop observations. The Panel EVAR approach mitigates this problem. Technically, (4.1) is jointly estimated for Indonesia and Mexico:

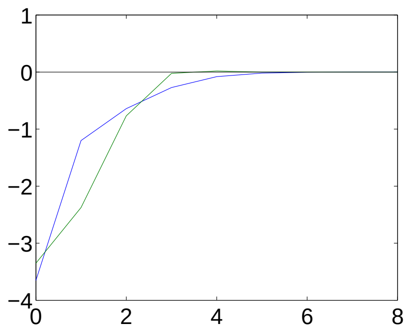
$$\Phi^j(L)X_t^j = C^j + A^j(L)D_t^j + Z_t^j, \tag{4.2}$$

where j denotes the country. Most of the parameters are country-specific in order to avoid unnecessary restrictions. However, to increase the number of sudden stop observations for the estimation of the lag polynomial on the sudden stop dummy, only the coefficients in $A^j(L)$ which give the response of GDP to a sudden stop shock are restricted to differ by a multiplicative factor across countries.[14] Thus, the Panel EVAR framework allows for different dynamics across countries in non-sudden stop periods while increasing the number of available sudden stop observations.

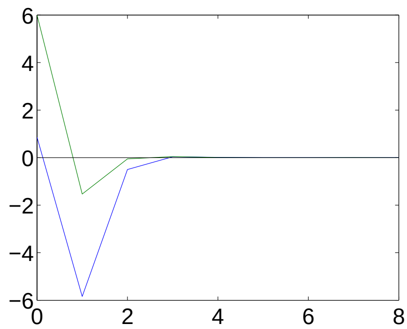
[14] As an example, consider the vectors of coefficients for the contemporaneous and lagged sudden stop dummy. If GDP is the third variable in X_t, then the coefficient vectors are $[a_{01}^j, a_{02}^j, a_{03}\psi^j, a_{04}^j]$ and $[a_{11}^j, a_{12}^j, a_{13}\psi^j, a_{14}^j]$, where ψ^j is the country specific multiplicative factor which is normalized to 1 for one of the countries.

The model is estimated using maximum likelihood estimation and the parameter restrictions on the coefficients are tested using a likelihood ratio test. The null hypothesis of the restrictions cannot be rejected. The lag length is chosen relying on the BIC information criterion testing models up to four lags in the VAR and also allowing up to four lags of the exogenous sudden stop dummy in addition to the contemporaneous sudden stop dummy. The correlogram of the residuals from the resulting VAR is checked to conform to white noise residuals.

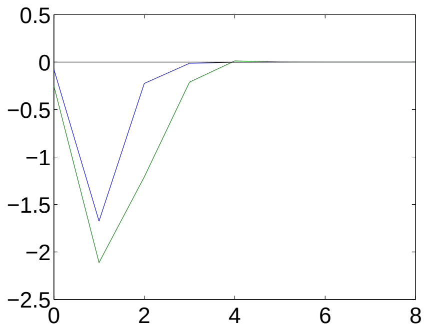
For Mexico, a VAR(1) model including the sudden stop dummy contemporaneously and with one lag minimizes the BIC. For Indonesia, we estimate a VAR(1) with the exogenous contemporaneous sudden stop dummy.



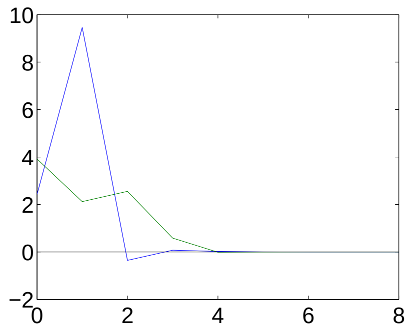
(a) CAP/GDP



(b) $\Delta \log$ (ToT)



(c) $\Delta \log$ (GDP)



(d) Δ RP

Figure 11: IRFs to sudden stop dummy in EVAR. Responses for Mexico in blue and for Indonesia in green.

The impulse responses of the VAR to the sudden stop dummy are depicted in figure 11. The responses of net capital inflows, GDP growth rate

($\Delta \log GDP$) and change in risk premium (ΔRP) is qualitatively similar across both countries. The net capital inflows to GDP ratio declines immediately in response to the sudden stop dummy. This negative response is given by the construction of the dummy. However, after about five quarters, the effect dies out. The decline in GDP growth is largest one quarter after shock impact. The risk premium increases after a sudden stop. Finally, the terms of trade decrease one quarter after impact for both countries.

	Sign. level	$\Delta \log ToT$	$\Delta \log GDP$	CAP/GDP	ΔRP
Indonesia	0.1		1^-; 2^-	0^-; 1^-; 2^-	2^+
Mexiko	0.1	1^-	1^-	0^- to 12^-	1^+
Indonesia	0.05		1^-; 2^-	0^-; 1^-	2^+
Mexiko	0.05		1^-	0^- to 4^-	

Table 1: Quarters with significant response to the sudden stop dummy. 0^+ (0^-) denotes a significantly positive (negative) response on impact, 1^+ (1^-) denotes a significantly positive (negative) response one quarter after impact and so forth. Empty cell means no significant response.

Except for terms of trade growth rate ($\Delta \log ToT$), all responses differ significantly from zero on impact or for at least one time period shortly after impact for both countries. Table 1 indicates the significance of the responses to a sudden stop for Indonesia and Mexico after different time horizons.[15] The response of net capital inflows is significantly negative on impact and for some more quarters. There is a significant drop of GDP growth with a lag of one or two quarters. The long run effect on GDP lies between approximately -2% and -3.7%. The change in risk premium is significant one or two quarters after impact.

For the Panel EVAR, we used the biggest lag length that was necessary for an individual country. Therefore, a VAR(1) with contemporaneous and lagged sudden stop dummy was estimated. The direct impact of a sudden stop on GDP is restricted to be equal up to a multiplicative constant across countries. The benefit is that, in contrast to the EVAR, we now have more sudden stop observations to determine the effect on output. As the results are comparable to the EVAR, impulse response functions are not reported, but available on request.

[15] Plots of the impulse responses with confidence interval are available on request.

Comparing the results to the impulse responses from the MSVAR, we can conclude that the responses are qualitatively similar. The shape of the responses of CAP/GDP and terms of trade is almost the same. However, these are given by construction of the sudden stop dummy. As for the MSVAR, we find a negative response of the GDP growth rate based on the EVAR and Panel EVAR. While the response is most negative on impact for the Markov switching VAR, it is most negative one quarter after impact for the EVAR and Panel EVAR. The increase in the change of the risk premium is much more pronounced compared to the MSVAR. We can conclude that the finding that GDP decreases in response to entering a sudden stop regime is robust.

4.4 Comparison to Observed Output Declines

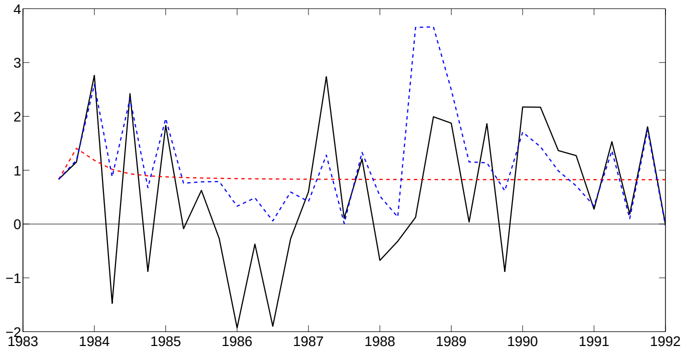
In this section, we compare the observed output decline in historical sudden stop periods with predicted counterfactuals from the MSVAR model. This comparison indicates what part of the observed decline can be attributed to the regime switch. The counterfactual is constructed assuming that there was no switch to the sudden stop regime. Thus, the counterfactual series differs from the observed series due to two reasons. First, it does not include the response to the regime switch as the regime is fixed at the "normal" state. This makes a difference because there is a significant response of GDP to a regime switch (as shown in section 4.1). Second, the counterfactual series features a different response to the structural shocks than the observed series because macroeconomic variables react differently to structural shocks depending on the regime (as shown in section 4.2).

Three historical sudden stop periods are analyzed: 1984 to 1990 in Mexico, 1994 to 1996 in Mexico, and 1997 to 1998 in Indonesia. These dates following from our MSVAR analysis closely match the sudden stop dates according to Calvo et al. (2006a). For each of these sudden stop events, we choose a date before the sudden stop and compute the counterfactual using the estimated historical structural shocks, but assuming that the regime stays in the "normal" state throughout. Moreover, a second counterfactual absent any shocks and regime switches is computed. The resulting GDP growth series are plotted in figure 12.

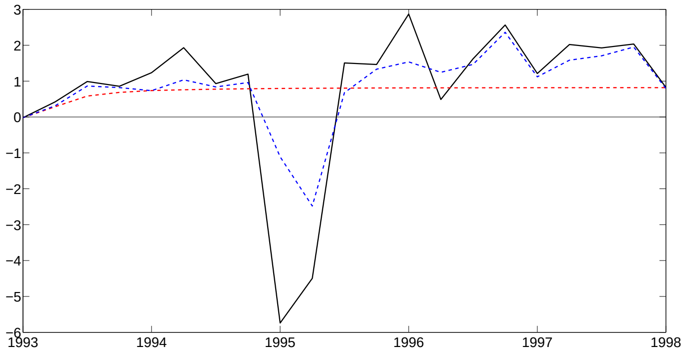
For the first sudden stop event in Mexico, GDP growth would have been higher on average if there had been no regime switch. In the beginning of 1992, one to two years after the sudden stop, the observed GDP level is 23% higher compared to the pre-crisis level in 1983 Q3. Absent regime switch, the GDP level would have been 46% higher than the pre-crisis level (see figure 13). Thus, there was a huge output loss due to the regime switch.

For the second sudden stop event in Mexico, the results show that GDP would have dropped because of negative shocks even if no regime switch occurred. However, the drop would have been mitigated. Overall, there is a small effect of the regime switch on the GDP level. In 1998 Q1, one year after the sudden stop, the observed GDP level is 17% higher and the counterfactual level lies 19% above the level in 1993 Q1 (see figure 13).

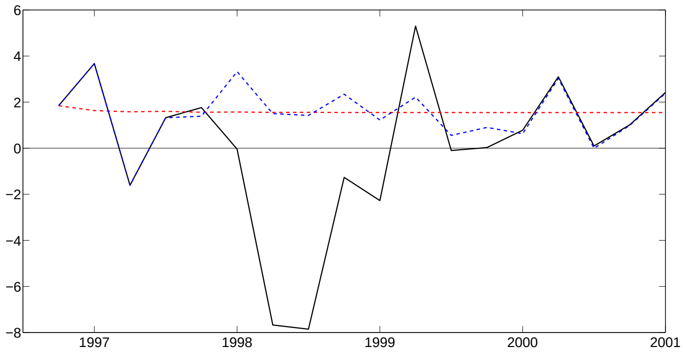
For Indonesia, the counterfactual series features much higher GDP growth than the observed series. Thus, bad structural shocks are not the reason for the output drop. Instead, it is the regime switch combined with the different response of macroeconomic variables in the sudden stop regime that led to the sharp decline in output. In 2001 Q1, two years after the sudden stop, the observed GDP level is still 2.5% below the level before the sudden stop (1996 Q4) whereas the counterfactual GDP has grown by more than 28%. Thus, there was a huge output loss due to the regime switch (see figure 13).



(a) Mexico, sudden stop period 1984 to 1990

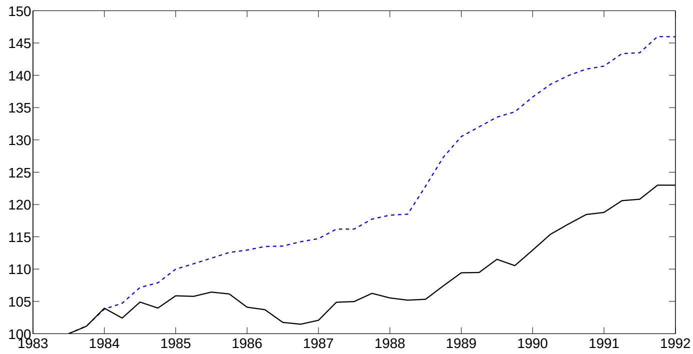


(b) Mexico, sudden stop period 1994 to 1996

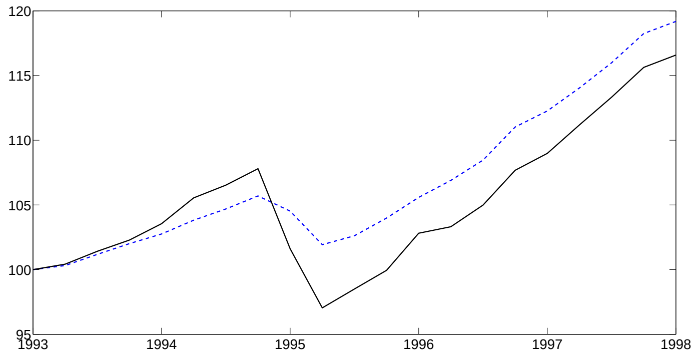


(c) Indonesia, sudden stop period 1997 to 1998

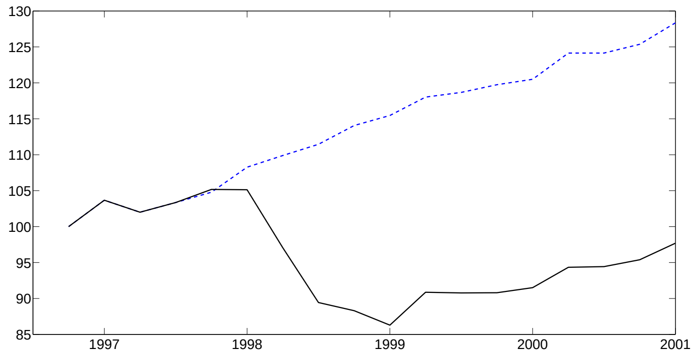
Figure 12: Comparison of observed GDP growth (black solid line) with counterfactual (blue dashed line) and counterfactual absent any shocks (red dashed line).



(a) Mexico, sudden stop period 1984 to 1990



(b) Mexico, sudden stop period 1994 to 1996



(c) Indonesia, sudden stop period 1997 to 1998

Figure 13: Comparison of observed GDP level (black solid line) with counterfactual (blue dashed line) normalized to a starting value of 100.

4.5 Summary of the Findings

Comparing the estimated regime 1 of the MSVAR with sudden stop dates of Calvo et al. (2006a) and computing impulse responses for a switch from regime 2 to regime 1 enables us to conclude that regime 1 is indeed a sudden stop regime. Based on the analysis of the conditional impulse responses, we argue that the behavior of GDP growth to the identified shock differs significantly across regimes. It reacts significantly negative in a sudden stop regime, while the response is not significantly negative in a "normal" regime. The unconditional impulse responses emphasize the importance of regime switches as these have an impact on the significance of the impulse responses. Allowing for switches to sudden stops after we started off in a "normal" regime yields significantly negative responses for Indonesia. The EVAR approach enables us to underline the robustness of the negative response of GDP growth to a regime switch. Finally, we compare the observed output drops during sudden stop periods to a counterfactual without regime switch. The findings indicate that the regime switch combined with regime-dependent responses of macroeconomic variables to the same structural shocks led to a massive decline in output. The level of GDP does not catch up once the regime shifts back to the "normal" state. Thus, the output level is lower in the long-run. Although bad structural shocks may explain part of the observed output drop in historical sudden stop periods, the most part seems to be due to the regime switch.

5 Conclusion

We propose the estimation of a Markov switching VAR to analyze the effects of switches between “normal” regimes and sudden stop regimes. Furthermore, we deviate from the existing empirical literature by using a sign restriction approach. This allows to analyze the responses in the VAR without the ad hoc specification of sudden stops as periods where capital inflows exceed two standard deviations below its mean. The combination of both approaches allows for rare shocks reflected by regime switches and a shock identification by sign restrictions that conforms to the definition of sudden stops. Our dataset consists of real GDP, the ratio of net capital inflows to GDP, the terms of trade and cross country differences in the overnight interest rates as a proxy for the risk premium. We collect this data for Mexico and Indonesia.

We are able to identify sudden stop periods that are consistent with sudden stop dates found in the literature. Furthermore, the response of the variables to a regime switch from the “normal” to the sudden stop regime meets the definition of sudden stops. This suggests that the VAR is well specified in order to analyze sudden stops. We find that the switch from the “normal” to the sudden stop regime has a significantly negative impact on both GDP growth and GDP level. Moreover, the results indicate that the response of GDP to a negative net capital inflows shock crucially depends on the regime and on the size of the initial drop in net capital inflows. For large shocks, the impulse responses are negative in sudden stop regimes for both countries when we do not allow for regime switches after impact. Finally, a comparison of the observed output decline in historical sudden stop events with predicted counterfactuals from the MSVAR model shows that the switch to the sudden stop regime combined with regime-dependent responses of macroeconomic variables to structural shocks led to massive declines in output in these periods, whereas bad structural shocks only had a rather small negative impact on output.

The negative response of GDP growth corresponds to the results in theoretical models by Neumeyer and Perri (2005), Jaimovich and Rebelo (2008) and Mendoza (2010). The latter develops a small open economy general equilibrium model with credit friction calibrated to fit the Mexican economy. He finds that the response to shocks is much more amplified in sudden stop states. This corresponds to our estimated impulse responses, whether we condition on staying in a regime or allow for regime switches. Moreover, in the model of Mendoza (2010), the risk premium increases if the collateral constraint binds, which is partially confirmed by our results. The response of the risk premium to the identified shock is positive, but it is only significant for Indonesia and not for Mexico.

Our empirical findings based on a Markov Switching approach yield insights for theoretical models. Regime switches capture structural breaks in the behavior of economic variables. The fact that we find significant responses to regime switches at sudden stop dates provides evidence for frictions becoming relevant during these events.

Future research could extend the analyses to other countries. Additionally to using data on other emerging economies that are believed to have been exposed to sudden stops, we could extend the analysis to some European countries which have been exposed to a massive drop in private capital inflows. This would allow us to examine whether and to what degree the current crisis is caused by sudden stops. Finally, the VAR setup allows for a thorough analysis of transmission mechanisms. Hence, future work could focus on the transmission channels of sudden stops.

References

Agosin, M. R. and F. Huaita (2012). Overreaction in capital flows to emerging markets: Booms and sudden stops. *Journal of International Money and Finance 31*(5), 1140 – 1155.

Bordo, M. D., A. F. Cavallo, and C. M. Meissner (2010). Sudden stops: Determinants and output effects in the first era of globalization, 1880-1913. *Journal of Development Economics 91*(2), 227–241.

Burnside, C., M. Eichenbaum, and J. D. Fisher (2004). Fiscal shocks and their consequences. *Journal of Economic Theory 115*(1), 89 – 117.

Calvo, G. A. (1998). Capital Flows and Capital-Market Crises: The Simple Economics of Sudden Stops. *Journal of Applied Economics I*, 35–54.

Calvo, G. A., A. Izquierdo, and L.-F. Mejia (2004). On the Empirics of Sudden Stops: The Relevance of Balance-Sheet Effects. NBER Working Papers 10520, National Bureau of Economic Research, Inc.

Calvo, G. A., A. Izquierdo, and E. Talvi (2006a). Phoenix miracles in emerging markets: recovering without credit from systemic financial crises. BIS Working Papers 221, Bank for International Settlements.

Calvo, G. A., A. Izquierdo, and E. Talvi (2006b). Sudden Stops and Phoenix Miracles in Emerging Markets. *The American Economic Review 96*(2), pp. 405–410.

Chari, V. V., P. J. Kehoe, and E. R. McGrattan (2005). Sudden Stops and Output Drops. *American Economic Review 95*(2), 381–387.

Edwards, S. (2004). Financial Openness, Sudden Stops, and Current-Account Reversals. *American Economic Review 94*(2), 59–64.

Ehrmann, M., M. Ellison, and N. Valla (2003). Regime-dependent impulse response functions in a Markov-switching vector autoregression model. *Economics Letters 78*(3), 295–299.

Filardo, A. J. and S. F. Gordon (1998). Business cycle durations. *Journal of Econometrics 85*(1), 99–123.

Fry, R. and A. Pagan (2011). Sign Restrictions in Structural Vector Autoregressions: A Critical Review. *Journal of Economic Literature 49*(4), 938–60.

Hutchison, M. M. and I. Noy (2006). Sudden stops and the Mexican wave: Currency crises, capital flow reversals and output loss in emerging markets. *Journal of Development Economics 79*(1), 225 – 248.

IMF (2011). Global Financial Stability Report: Grappling with Crisis Legacies.

Jaimovich, N. and S. Rebelo (2008). News and Business Cycles in Open Economies. *Journal of Money, Credit and Banking 40*(8), 1699–1711.

Kehoe, T. J. and K. J. Ruhl (2009). Sudden stops, sectoral reallocations, and the real exchange rate. *Journal of Development Economics 89*(2), 235 – 249.

Koop, G., M. H. Pesaran, and S. M. Potter (1996). Impulse response analysis in nonlinear multivariate models. *Journal of Econometrics 74*(1), 119–147.

Krolzig, H. (2006). Impulse Response Analysis in Markov Switching Vector Autoregressive Models. In *Economics Department, University of Kent. Keynes Collage. https://editorialexpress.com/cgibin/conference/download. cgi.*

Mendoza, E. G. (2010). Sudden Stops, Financial Crises, and Leverage. *American Economic Review 100*(5), 1941–66.

Neumeyer, P. A. and F. Perri (2005). Business cycles in emerging economies: the role of interest rates. *Journal of Monetary Economics 52*(2), 345–380.

Rubio-Ramírez, J. F., D. Waggoner, and T. Zha (2005). Markov-switching structural vector autoregressions: theory and application. Working Paper 2005-27, Federal Reserve Bank of Atlanta.

Rubio-Ramírez, J. F., D. Waggoner, and T. Zha (2010). Structural Vector Autoregressions: Theory of Identification and Algorithms for Inference. *Review of Economic Studies 77*(2), 665–696.

A Appendix

A.1 Algorithm for identifying structural VAR models using sign restrictions

As the sign restriction approach is imposed on each regime individually, we neglect the state variable s_t in the following exposition. Consider a reduced form VAR model of order p:

$$X_t = \sum_{l=1}^{p} \Phi_l X_{t-l} + Z_t, \tag{A.1}$$

where X_t is the vector of endogenous variables and Z_t are the reduced form residuals.

The structural VAR model has the form:

$$X_t = A_0 X_t + \sum_{l=1}^{p} A_l X_{t-l} + V_t, \tag{A.2}$$

$$\Leftrightarrow X_t = \sum_{l=1}^{p} \Phi_l X_{t-l} + B_0 V_t, \tag{A.3}$$

with $\Phi_l = (I - A_0)^{-1} A_l$, $B_0 = (I - A_0)^{-1}$ and where V_t are the structural shocks.

Equations (A.1) and (A.3) imply the following relation between reduced form variables and structural shocks:

$$Z_t = B_0 V_t. \tag{A.4}$$

Normalizing the variance of the structural shocks to one, we get the relation:

$$\mathbb{E}_t Z_t Z_t' = B_0 B_0', \tag{A.5}$$

which is equation (3.2) once $Z_t Z_t'$ is replaced by the estimated covariance matrix of the VAR residuals $\hat{\Sigma}$.

We use the algorithm proposed by Rubio-Ramírez et al. (2010) to identify structural VAR models using sign restrictions. The procedure is as follows: Take any value of the unrestricted structural parameters A_0, A_1, …, A_p. Denote this values $\widetilde{A}_0$, $\widetilde{A}_1$, …, $\widetilde{A}_p$. Then, the algorithm repeats three steps.

(Step 1) An independent standard normal $n \times n$ matrix $\widetilde{H}$ is drawn, where n is the number of endogenous variables in the VAR. Let $\widetilde{H} = \widetilde{Q}\widetilde{R}$ be the QR decomposition of $\widetilde{H}$ with the diagonal of $\widetilde{R}$ normalized to be positive.

(Step 2) Let $P = \widetilde{Q}$ and generate impulse response functions from $\widetilde{A}_0 P$ and $\Phi(L)$.

(Step 3) If these responses satisfy the pre-specified sign restrictions, the draw is kept. Otherwise, the draw is rejected and the algorithm returns to the first step.

Starting out with a draw $\widetilde{A}_0$, $\widetilde{A}_1$, ..., $\widetilde{A}_p$ of unrestricted parameters, $\widetilde{A}_0 P$, $\widetilde{A}_1 P$, ..., $\widetilde{A}_p P$ is a draw of structural parameters that satisfy the sign restrictions.

As suggested in Rubio-Ramírez et al. (2010), we use the Cholesky decomposition of $\hat{\Sigma}$ and the estimated VAR coefficients $\hat{\Phi}(L)$ to obtain the starting values $\widetilde{A}_0$, $\widetilde{A}_1$, ..., $\widetilde{A}_p$. Then, steps 1 to 3 of the above algorithm are repeated 10'000 times. This procedure yields a set of rotational matrices P such that the impulse response functions of the structural models satisfy the sign restrictions.

A.2 Data

All data are taken from the OECD statistics database. The time series are transformed to get stationarity. Table 2 contains an overview. For GDP, the quarter-on-quarter growth rate of seasonally adjusted real GDP is used. The data are from the quarterly national accounts of the countries. Balance of payment data are used to construct the net capital inflows to GDP ratio, which is defined as the ratio of the change in the capital and financial account (nominal, seasonally adjusted) to GDP (nominal, seasonally adjusted).[16] The risk premium is approximated by the difference of the overnight (immediate) interest rates in the respective country and the United States. For stationarity reasons, we include the first difference of the risk premium in our models. Finally, the terms of trade are given by the ratio of the export deflator and the import deflator. The series is seasonally adjusted and the growth rate is taken to ensure stationarity.

Name	Source	Description	Transformation
GDP	OECD	Real GDP, seasonally adjusted.	Quarter-on-quarter growth rate
Net capital inflows to GDP ratio	OECD	Ratio of change in the capital and financial account to GDP. Both series used to construct the ratio are nominal and seasonally adjusted.	No transformation as the ratios are stationary.
Risk premium	OECD	Difference of the overnight (immediate) interest rates in the respective country and the United States. The overnight rates describes the official discount rates of central banks or call-money rates.	First difference
Terms of trade	OECD	Ratio of the export deflator to the import deflator, seasonally adjusted.	Quarter-on-quarter growth rate

Table 2: Description of the Data

[16] The Augmented Dickey Fuller (ADF) test and the Phillips Perron (PP) test indicate that this ratio is stationary for both Mexico and Indonesia.

A.3 Figures

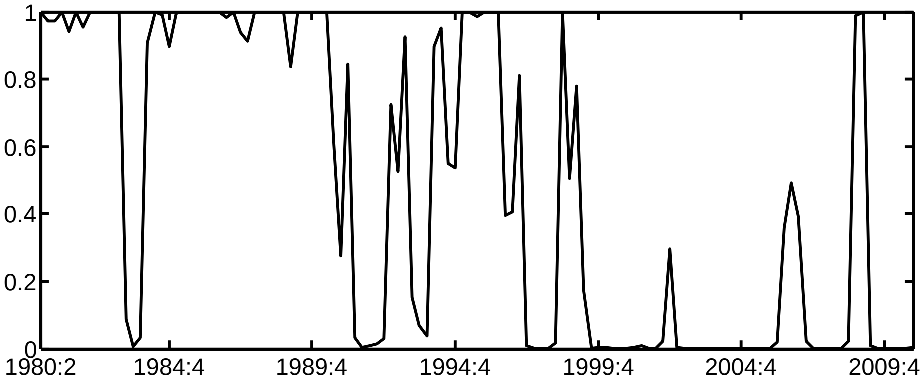


Figure 14: Sudden stop regime probabilities for Mexico

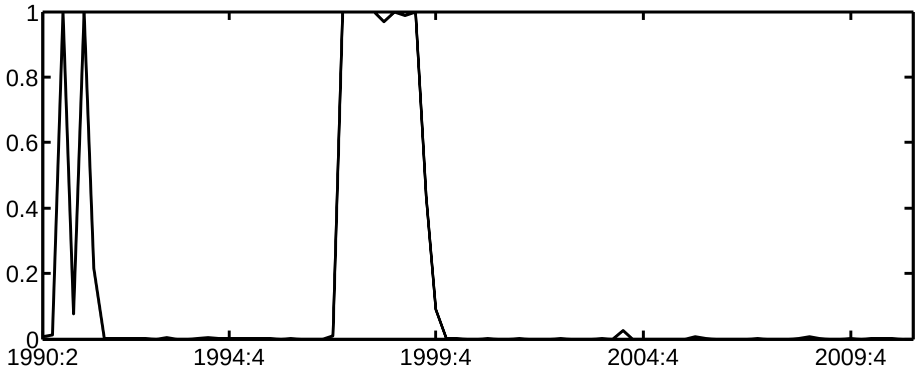
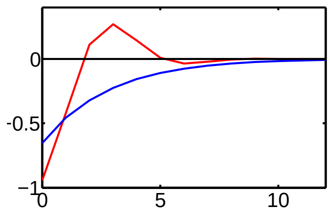
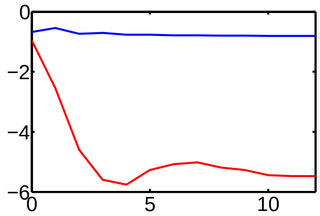


Figure 15: Sudden stop regime probabilities for Indonesia

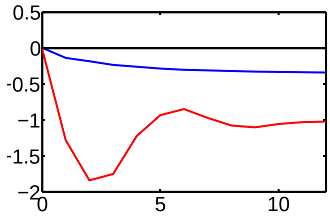
Indonesia



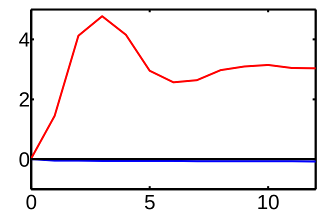
(a) CAP/GDP



(b) log (ToT)



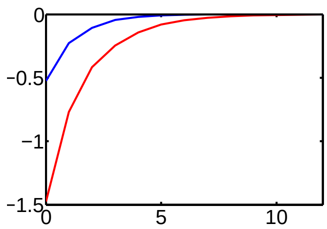
(c) log (GDP)



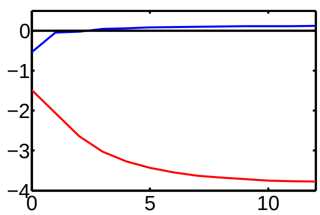
(d) RP

Figure 16: Conditional IRFs to a net capital inflows shock for Indonesia; IRF in sudden stop regime in red

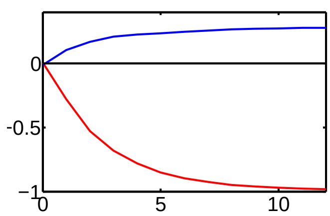
Mexico



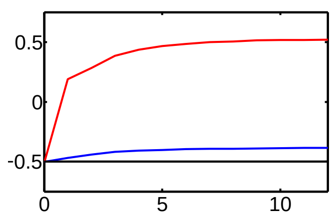
(a) CAP/GDP



(b) log (ToT)



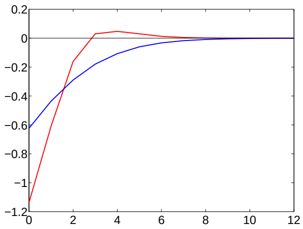
(c) log (GDP)



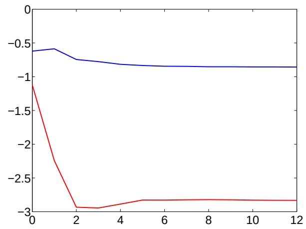
(d) RP

Figure 17: Conditional IRFs to a net capital inflows shock for Mexico; IRF in sudden stop regime in red

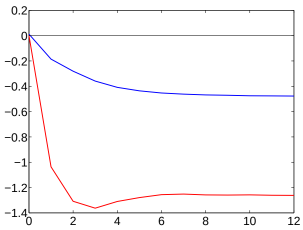
Indonesia



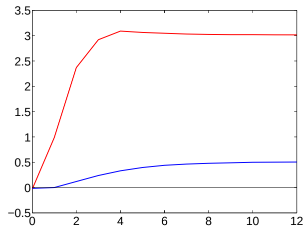
(a) CAP/GDP



(b) log (ToT)



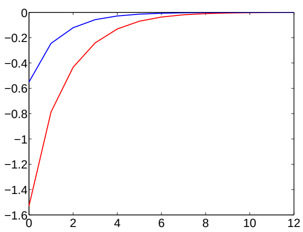
(c) log (GDP)



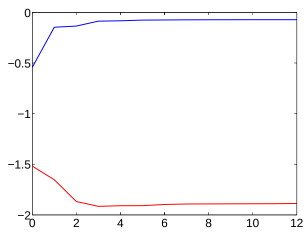
(d) RP

Figure 18: Unconditional IRFs to a net capital inflows shock for Indonesia; IRF in sudden stop regime in red

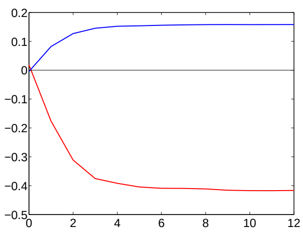
Mexico



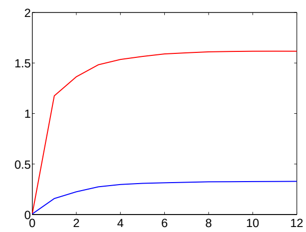
(a) CAP/GDP



(b) log (ToT)



(c) log (GDP)



(d) RP

Figure 19: Unconditional IRFs to a net capital inflows shock for Mexico; IRF in sudden stop regime in red