Can governments sleep more soundly when holding international reserves? A banking and financial vulnerabilities perspective

Audrey Sallenave, Jean-Pierre Allegret, Tolga Omay

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Authors

Audrey Sallenave, University of Toulon and Var, LEAD Toulon, Provence-Alpes-Côte d'Azur, FR
audrey.sallenave@univ-tln.fr

Corresponding author:
Jean-Pierre Allegret, GREDEG, CNRS, University Côte d'Azur Sophia Antipolis, Région Sud, FR
jean-pierre.allegret@gredeg.cnrs.fr.
Campus Azur, GREDEG, 250 rue Albert Einstein 06 CS 10269 - F 06905 SOPHIA ANTIPOLIS Cedex FRANCE

Tolga Omay, Atilim Universitesi, Economics, Ankara, TR
tolga.omay@atilim.edu.tr.

Abstract: We use a sample of 40 developing and emerging countries over the period 1995-2015 to assess the effectiveness of international reserve holding as a crisis mitigator. We test the relevance of the reserve accumulation decreasing returns assumption by estimating the most recent version of the PSTR model. We find that increasing stocks of international reserves allows domestic authorities to mitigate the negative impacts of financial and banking vulnerabilities on GDP growth rates leading to reject the decreasing returns assumption. This evidence is robust to sensitivity checks.

Keywords: Banking vulnerabilities; Financial vulnerabilities; External shocks; Emerging and developing countries; Panel Smooth Transition Regression model; Reserves accumulation

JEL codes: E52; E58; F30; F41

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I. Introduction

Financial globalization is characterized by three movements concerning more specifically emerging and developing countries (hereafter EMDEs): a significant sensitivity to shocks and crises (Laeven and Valencia, 2018); the predominance of intermediate exchange rates regimes in an "extended Bretton Woods II" (Ilzetzki et al., 2022) and a dramatic increase in the holding of foreign exchange reserves fueling intense debates on the effectiveness of reserves to cope with global financial instability.

Crisis prevention perspective models suggest that the probability of sudden stop or rollover risk for external public debt is a decreasing function of reserve holding (Jeanne and Rancière, 2011; Bianchi et al., 2018). Higher international reserve holdings reduce the likelihood of external crises (Gourinchas and Obstfeld, 2012; Catão and Milesi-Ferretti, 2014). Crisis mitigation literature suggests reserve holding reduces the negative effect of currency mismatches on output (Jeanne, 2007), exerts a positive influence on both real GDP growth during the crisis and post-crisis growth (Dominguez et al., 2012; Bussière et al., 2015), and allows to decrease output volatility in countries with higher level financial openness (Aizenman and Hutchison, 2012).

Our paper is related to international reserve holding as a crisis mitigator. We focus our attention on the hypothesis put forward in the literature according to which the accumulation of foreign exchange reserves follows diminishing returns: beyond a threshold, it becomes ineffective in responding to international shocks. Berkmen et al. (2012) stress that during the global financial crisis, higher foreign reserve holdings led to smaller growth revisions but that the relationship becomes statistically insignificant for countries with very high reserves. Alberola et al. (2016) show that reserve accumulation becomes increasingly less effective in reducing capital outflows. However, this hypothesis is debated in the literature. For instance, X (2018 and 2019) use different threshold models and conclude that reserve holding improves the resilience of domestic economies to external shocks.

Accepting or rejecting the hypothesis of diminishing returns in the holding of reserves has important implications for the policy of accumulation of foreign exchange reserves in EMEDs. Indeed, if the accumulation of reserves is on a path of diminishing returns, then the inefficiencies linked to the holding of reserves become more and more significant as the amount of reserves increases. Conversely, if this assumption is rejected, the gains in terms of lower production losses may outweigh the costs associated with inefficiencies.

This paper contributes to this debate by extending the literature in two main directions. First, we use the innovative PSTR model proposed by González et al. (2017). An important added value is to better consider the heterogeneity between the individuals composing the panel. We also add a novelty to the traditional linearity test by considering recent nonlinear and asymmetric panel unit root tests as a complement to the standard linearity tests. To the best of our knowledge, this is the first time that an alternative to the standard linearity tests has been proposed in a panel smooth transition regression framework. Second, we consider a large set of global factors and vulnerability variables for a sample of EMDEs spanning twenty years. As we focus on financial and banking vulnerabilities, our benchmark indicator of reserve holdings is total reserves minus gold in percentage of M2. This ratio is a good proxy to assess the extent to which liquid domestic liabilities of the banking system are backed by foreign exchange reserves (Obstfeld et al., 2010).

Our main result does not support the diminishing returns assumption. Specifically, we find that increasing stocks of international reserves allows domestic authorities to mitigate the negative impacts of financial and banking vulnerabilities on GDP growth rates and reduce the vulnerability to global shocks. Importantly, our results are robust to an array of sensitivity checks.

The rest of the paper is organized as follows. Section 2 describes the data and outlines our estimation methodology, section 3 reports and comments on our results. The concluding section stresses the main policy implications of these findings.

II. Methodology and data

Sample and data description

Our sample includes 40 EMDEs over the period 1995Q1-2015Q4. They amount to 86% of EMDEs' reserves. [2] Two subsamples distinguish countries according to their *de facto* exchange rate regimes -fixed and floating- using Ilzetzki *et al.* (2019) revised classification. The third subsample includes non-OECD countries to take account the level of economic and financial development.

Our benchmark model includes eight indicators of financial vulnerability influencing economic performance during financial crises.[3] Five indicators are related to the financial channel highlighted in the literature on the Asian and the Global financial crises. The current account balance as a percentage of GDP (*ca*) is used as a proxy to measure the extent to which countries are sensitive to episodes of sudden stops to capital flows as external deficits lead to dependence on net capital inflows. The international claims of BIS-reporting banks on the percentage of borrower GDP (*bis inter*) allows us to account for the critical role of banking flows in international capital movements. International claims include the cross-border claims in any currency and local claims of foreign affiliates denominated in nonlocal currencies. To better isolate external vulnerabilities and the role of international reserves our estimates exclude local claims in local currencies. These flows have had a major influence on the expansion of domestic credit in many emerging and developing countries (Feldkircher, 2014). An extensive literature suggests that global factors matter when analyzing the behavior of international capital flows.

[2] See appendix A for the list of selected countries.
[3] See appendix B for a description of the data. See Supplementary material (Tables 1-2) for summary statistics.

We approximate these global factors by considering three indicators related to the financial channel. First, as U.S. financial conditions have a worldwide influence (Rey, 2013), we include in our model the U.S. financial stress index (*fsi*) constructed by Cardarelli et al. (2008). The FSI is a composite indicator encompassing the main characteristics of financial stress events. Bloom et al. (2018) stress that positive uncertainty shocks generate sharp macroeconomic fluctuations. Because of the impact of uncertainty shocks on international capital flows, we use the U.S. economic policy uncertainty index (*Uncertainty*) in our estimates.[4] Our third indicator is the global emerging market bond index (*embig*) which measures yield spreads (over safe or risk-free assets which bear minimal credit risk) on emerging market countries' debt instruments. Our choice is motivated by the large body of work which suggests that emerging bond spreads respond significantly to global financial risk (Akıncı, 2013).

Three indicators are related to banking system vulnerability. To proxy for liability dollarization, we consider the ratio of foreign liabilities in the domestic financial sector relative to money stocks (currency mismatch, *currency*) (Levy Yeyati et al., 2010). An extensive literature suggests that the higher the domestic liability dollarization, the higher the output loss in the aftermath of an exchange rate depreciation (Cavallo and Izquierdo, 2009). To capture the exposure of banks to wholesale funding, we consider the ratio of bank credit to bank deposits (*credit deposit*). Higher leverage implies an increase in non-core liabilities (including the wholesale market) relative to core liabilities (retail deposits) worsening bank vulnerability to financial stress (Hahm et al., 2013). Our last indicator is the ratio of private sector credit-to-GDP gap as measure of the build-up of excessive credit is approximated by the credit-to-GDP gap measures. The credit-to-GDP gap (*credit gap*) is defined as the difference between the credit-to-GDP ratio and its long-run trend, using a one-sided Hodrick-Prescott filter as in Drehmann (2013).

[4] The worldwide influence of U.S. business cycles is the reason why we include the U.S. index. The correlation between the U.S. economic policy uncertainty index and the world index is 0.8. For details, see Baker et al. (2016).

Econometric methodology

Panel Smooth Transition Regression model

We consider the following PSTR model (González et al., 2017):

$$y_{it} = \mu_i + \beta_0' X_{it} + \beta_1' X_{it} g(q_{it}; \gamma, c) + \varepsilon_{it} \quad (1)$$

where $i = 1, \dots, N$, $t = 1, \dots, T$. N and T denote the panel's cross-sectional and time-dimension respectively. Y_{it} is the dependent variable (*gdp growth*), μ_i is country fixed effects, X_{it} is a *k*-dimensional vector of the time varying exogenous variables, Q_{it} is the threshold variable and the error ε_{it} is assumed to be *i.i.d* $(0,\sigma_\varepsilon^2)$. The threshold parameter is given by c. To account for a possible smooth and gradual transition between regimes, we follow Granger and Terasvirta (1993) who consider the following logistic transition function:

$$g(q_{it}; \gamma, c) = [1 + exp\ (-\gamma \prod_{j=1}^{m} (q_{it} - c_j)]^{-1} \quad (2)$$

where $c = (c_1, \dots, c_m)'$ denotes a *m*-dimensional vector of location parameters and γ determines the smoothness of the transition function from one regime to another.[5] The value of *m* affects the regime-switching behavior. For *m* = 1, the PSTR model implies that the two extreme regimes are associated with high and low values of the transition variable. *For* m = 2, the PSTR model becomes a three-regime threshold model where the intermediate regime follows a different pattern, while the two other extreme share the same dynamics. According to the results of linearity tests (see below), we set the value of *m* to be 1, i.e. a two regimes PSTR model. This implies a monotonic change in the coefficient β_0 to $\beta_0 + \beta_1$ as the transition function q_{it} increases. The marginal effect (slope parameters) satisfies:

$$\frac{\partial y_{it}}{\partial x_{it}} = \beta_{it} = \beta_0 + \beta_1\ g(q_{it}; \gamma, c), \text{ with by convention } \beta_0 \le \beta_{it} \le \beta_0 + \beta_1.$$

[5]Between the two extreme cases, i.e. *m* > 1 and $\gamma \to \infty$, the number of identical regimes remains 2 but the function switches between zero and 1 at $c_1, \dots, c_m$.

The first regime (β_0) -the *low forex regime*- corresponds to the states where foreign exchange reserves are below the threshold c. The second regime ($\beta_0 + \beta_1$) -the *high forex regime*- corresponds to the states where foreign exchange reserves are above the threshold c.

Nonlinearity test: a new approach

It is critical to pay particular attention to the specification procedure testing for linearity against the nonlinearity (i-e PSTR alternative). Simulating a panel in which the errors are homoskedastic leads to the conclusion that the standard LM test is hugely oversized whatever the value of *N*. In contrast, heteroskedasticity robust version of the LM test tends to be undersized for each combination of *N* and *T*. Using bootstrapping of the LM statistic[6] Becker and Osborn (2010) show that results are not efficient[7] if the errors are heteroskedastic.

To accommodate this issue, we implement the wild cluster (WC) and the wild cluster bootstrap (WCB) (Cameron et al., 2008). The results (**Table 1**) conclude in favor of heterogeneity for each sample and suggest that the estimated model with one transition is appropriate.[8]

Table 1 Homogeneity test (1995Q1-2015Q4): *resm2* as transition variable

m=1	WB (*p*-value)	WCB (*p*-value)
Full sample	216.9 (0.00)	6.142 (0.00)
Float sample	113.1 (0.00)	2.955 (0.00)
Peg sample	129.8 (0.00)	3.324 (0.00)
Non-oecd sample	260.7 (0.00)	7.30 (0.00)

These tests account for overall linearity, not individual nonlinearity of the model, *i.e.* nonlinearity of each of the variables of the model. Individual nonlinearity is beyond the scope of the standard WC and WCB test. Checking the individual nonlinearity is important in order to reinforce the robustness of our previous results. To this aim, we implement the

[6] In bootstrapping the LM statistic, Gonzalez et al. (2017) made use of the warp-speed method proposed by Giacomini et al. (2013).

[7] The LM statistic remains oversized.

[8] Results for the other transition variables (*resdebt* and *resgdp*) are available upon request. We find also one transition i-e $m = 1$.

Emirmahmutoglu and Omay's (EO) (2014) nonlinear test. It assumes nonlinearity against the alternative of linearity and combines the nonlinear time series framework in Sollis (2009) and the nonlinear panel unit root in Ucar and Omay (UO) (2009)[9] to propose a unit root test for heterogeneous panels against the alternative of symmetric/asymmetric ESTAR nonlinearity. Sollis's (2009) test is extended to nonlinear asymmetric heterogeneous panels as follows:

$$\Delta y_{it} = G_{it}(\gamma_{1i}, y_{i,t-1})\{S_{it}(\gamma_{2i}, y_{i,t-1})\rho_{1i} + (1 - S_{it}(\gamma_{2i}, y_{i,t-1}))\rho_{2i}\}y_{i,t-1} + \varepsilon_{it}, \quad (3)$$

$$G_{it}(\gamma_{1i}, y_{i,t-1}) = 1 - exp(-\gamma_{1i} y_{i,t-1}^2)\gamma_{1i} \geq 0 \ \forall\, i \quad (4)$$

$$S_{it}(\gamma_{2i}, y_{i,t-1}) = [1 + exp(-\gamma_{2i} y_{i,t-1})]^{-1}\gamma_{2i} \geq 0 \ \forall\, i \quad (5)$$

where $\varepsilon_{it} \sim iid(0, \sigma_i^2)$. If $\gamma_{1i} > 0$ and $\gamma_{2i} \to \infty$ the size of the deviation is large for the state variable $(y_{i,t-1})$ and an ESTAR transition occurs between the central regime and the outer regime model with γ_{1i} determining the speed of the transition. If the deviation is in the negative direction of the state variable, the outer regime is $\Delta y_{it} = \rho_{i2} y_{i,t-1} + \varepsilon_{it}$ and if the deviation is in the positive direction the outer regime is $\Delta y_{it} = \rho_{i1} y_{i,t-1} + \varepsilon_{it}$, where the transition functions take the respective extreme values of 0 and 1 for these two cases. If $\rho_{i1} \neq \rho_{i2} \ \forall \ i$, the autoregressive adjustment is asymmetric. Note that (3) nests UO's (2009) panel symmetric ESTAR specification test if $\rho_{1i} = \rho_{2i} = \rho_i$ for all i. Because of the extreme assumption $\gamma_{2i} \to \infty$ the logistic function reduces to a simple step function and behaves like the TAR model. Asymmetry can occur also for small and moderate values of γ_{2i}. Under the other extreme value for $\gamma_{2i} (i.e., \gamma_{2i} \to 0)$, irrespective of the values of ρ_{1i} and ρ_{2i}, the composite function $G_{it}(\gamma_{1i}, y_{i,t-1})\{S_{it}(\gamma_{2i}, y_{i,t-1})\rho_{1i} + (1 - S_{it}(\gamma_{2i}, y_{i,t-1}))\rho_{2i}\}$ becomes symmetric due to the fact that $S_{it}(\gamma_{2i}, y_{i,t-1}) \to 0.5 \ \forall\, t$ and $\forall\, i$. This feature can be used to test whether series has symmetric or asymmetric dynamics.

[9] Available upon request.

In the case where the errors in (3) are serially correlated, we can extend (3) to allow for higher order dynamics:

$$\Delta y_{it} = G_{it}(\gamma_{1i}, y_{i,t-1})\left\{S_{it}(\gamma_{2i}, y_{i,t-1})\rho_{1i} + \left(1 - S_{it}(\gamma_{2i}, y_{i,t-1})\right)\rho_{2i}\right\} y_{i,t-1} + \sum_{j=1}^{p_i} \delta_{ij}\Delta y_{i,t-j} + \varepsilon_{it} \qquad (6)$$

The unit root hypothesis can be tested against the alternative hypothesis of globally stationary symmetric or asymmetric ESTAR nonlinearity with a unit root central regime by testing $H_0: \gamma_{1i} = 0$ in (3). However, there are unidentified parameters under this null such as γ_{2i}, ρ_{1i} and ρ_{2i}. Following the same procedure as employed in the Kapetanios-Shin-Shell (KSS) test, this problem can be handled by deriving an auxiliary model using a Taylor approximation. However, to solve the unidentified parameters problem the composite function must contain two different transition functions. Therefore, a Taylor approximation both around $\gamma_{1i} = 0$ and $\gamma_{2i} = 0$ should be employed. We follow Sollis (2009) and derive the auxiliary equation in two steps within the panel context. Replacing $G_{it}(\gamma_{1i}, y_{i,t-1})$ in (3) with a first order Taylor expansion around $\gamma_{1i} = 0$ gives:

$$\Delta y_{it} = \rho_{1i}\gamma_{1i}y_{i,t-1}^3 S_{it}(\gamma_{2i}, y_{i,t-1}) + \rho_{2i}\gamma_{1i}y_{i,t-1}^3\left(1 - S_{it}(\gamma_{2i}, y_{i,t-1})\right) + \varepsilon_{it} \qquad (7)$$

Replacing $S_{it}(\gamma_{2i}, y_{i,t-1})$ in (11) with a first order Taylor expansion around $\gamma_{2i} = 0$ gives:

$$\Delta y_{it} = a(\rho_{2i}^* - \rho_{1i}^*)\gamma_{1i}\gamma_{2i}y_{i,t-1}^4 + \rho_{2i}^*\gamma_{1i}y_{i,t-1}^3 + \varepsilon_{it} \qquad (8)$$

where $a = 1/4$. Rearranging the coefficients as $\phi_{1i} = \rho_{2i}^*\gamma_{1i}$ and $\phi_{2i} = a(\rho_{2i}^* - \rho_{1i}^*)\gamma_{1i}\gamma_{2i}$ we obtain the following auxiliary equation:

$$\Delta y_{it} = \phi_{1i}y_{i,t-1}^3 + \phi_{2i}y_{i,t-1}^4 + \varepsilon_{it} \qquad (9)$$

Equation (9) is extended and the augmented version is obtained as:

$$\Delta y_{it} = \phi_{1i}y_{i,t-1}^3 + \phi_{2i}y_{i,t-1}^4 + \sum_{j=1}^{p_i} \delta_{ij}\Delta y_{i,t-j} + \varepsilon_{it} \qquad (10)$$

The null hypothesis $H_0: \gamma_{1i} = 0 \ \forall \ i$ becomes $H_0: \phi_{1i} = \phi_{2i} = 0 \ \forall \ i$ in the auxiliary model. The proposed test statistic is computed by taking the average of the individual $F_{i,AE}$ statistics. Thus,

$$\bar{F}_{AE} = N^{-1} \sum_{i=1}^{N} F_{i,AE}. \tag{11}$$

Sollis (2009) states that individual $F_{i,AE}$ have a non-standard $F-$distribution. The panel $\bar{F}_{AE}$ test statistic also has a non-standard distribution and exact critical values of $\bar{F}_{AE}$ can be computed via stochastic simulation for different values of N and T. If the unit root hypothesis ($\phi_{1i} = \phi_{2i} = 0 \ \forall \ i$) is rejected, then the null hypothesis of symmetric ESTAR nonlinearity can be tested against the alternative of asymmetric ESTAR nonlinearity by testing $H_0: \phi_{2i} = 0 \ \forall \ i$ against $H_1: \phi_{2i} \neq 0$ in (10). Under the symmetric null hypothesis, Sollis (2009) suggests using the individual $t-$statistics ($t_{i,AE}^{as}$) with standard $t-$distribution. In the panel framework, we compute $\bar{t}_{AE}^{as}$ taking the average of the individual statistics which have a standard distribution. The limiting distribution of these test statistics is valid under the assumption of i.i.d. disturbances. However, if the disturbances are not independent, the limit distributions of the test statistics proposed here are no longer valid and are unknown in the presence of cross correlations among the cross-section units. We use the sieve bootstrap methodology proposed by Chang (2004) to obtain the empirical distributions of $\bar{F}_{AE}$ and $\bar{t}_{AE}^{as}$ test statistics.[10]

The results[11] (**Table 2**) clearly reject the null of linear stationarity.

We can see that the $\bar{t}_{AE}^{as}$ statistic rejects the null hypothesis against the alternative of stationary symmetric or asymmetric exponential smooth transition autoregressive (ESTAR) nonlinearity. Overall, the results of these nonlinear/asymmetric panel unit roots provide strong support for a nonlinear and asymmetric transition variable (*resm2*) in each of our subsamples.[12]

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[10] For details, see Supplementary material A.

[11] We also preformed UO's (2009) test. Results are available upon request.

[12] The results for the remaining variables are available upon request.

Table 2 Nonlinear/asymmetric Panel unit root test with linearity tests in Alternative hypothesis

	Emirmahmutoglu and Omay (2014)	
	Intercept $\bar{t}_{AE}^{as}$	intercept/trend $\bar{t}_{AE}^{as}$
Full	5.685 (0.001)	5.893 (0.000)
Float	6.456 (0.000)	6.613 (0.000)
Peg	4.788 (0.009)	5.174 (0.051)
Non_oecd	4.788 (0.009)	5.263 (0.021)

Note: p-values are in parentheses.

These findings are in line with the previous linearity test and show clearly that a nonlinear framework is the most appropriate. The two tests support each other. The extra information provided by the EO (2014) test is that the series are stationary and nonlinear and that they can enter the model as the level of the series. It provides us extra information about the structure of nonlinearity, which confirms the use of m = 1 or LSTR transition. LSTR is asymmetric and ESTR is symmetric nonlinearity.

III. Results

Baseline results

Results with *resm2* as transition variable are organized in two main parts. The first (**Table 3**) refers to the estimates for the full sample. The second presents the estimates for our subsamples (floating exchange rate regime, **Table 4**; non-OECD countries, **Table 5**; peg exchange rate regime, **Table 6)**. In all tables, the penultimate row provides the threshold values for our variable of interest. The threshold values fall into a narrow band ranging from 26% (for the peg sub-sample) to 32% (for the non-OECD countries). The distribution of our observations is not skewed towards either one side or the other of the thresholds (See the last row of **Tables 3-6**): 54% of the observations are above the threshold value for the full sample, amounting to 46%, 64%, and 48% for the float, peg, and non-OECD subsamples respectively.

In the first regime (**Tables 3-6** column 1), we show that our vulnerability indicators exhibit results consistent with our *a priori* expectations. A decrease in the current account deficit as a percentage of GDP exerts a negative impact on real GDP growth. Similarly, real GDP growth responds negatively to an increase in the level of the currency mismatch. This result highlights the exposure of high currency mismatch countries to sizable currency depreciations and implies a significant negative balance sheet effect on the domestic economy.

Table 3 Full sample 1995Q1-2015Q4[13]

	resm2			
	1	**2**	**3**	**4**
	(β_0)	(β_0+β_1)	(β_0)	(β_0+β_1)
Ca	-0.22***	0.80**	-0.41***	0.73**
Bis inter	-0.130**	0.022**	-0.13**	0.072**
Currency	-18*	-8.3**	-26**	-17**
Credit deposit	-5.5**	-0.55**	-12**	-3.5**
Credit gap	-0.062***	-0.025*	-0.29**	-0.16*
Uncertainty	-0.015**	-0.0026*	-0.0084**	-0.0086*
Fsi	-0.44*	-0.49**		
Gsfci			-0.9**	-0.57**
Embig	-0.0031**	-0.0023*	-0.0031*	-0.001*
Nb of transitions	1		1	
Smooth parameter γ	0.12		0.48	
Threshold	29		30	
Obs > Threshold	54%		50.9%	

Table 5 shows that the non-OECD countries subsample appears particularly sensitive to currency mismatch vulnerability insofar as their financial systems tend to be less robust to sudden domestic currency depreciations. An increase in the credit-to-GDP gap has a negative influence on real GDP growth (**Tables 3-6**). This result is consistent with the literature on early warning of financial crisis.

Table 4 Float sample 1995Q1-2015Q4

	resm2

[13] For Tables in the rest of the paper, (*): significant at the 10% level; (**): significant at the 5% level and (***): significant at the 1% level. Regime 2 denotes the coefficients of each variable above the threshold parameter.

	1	2	3	4
	(β_0)	(β_0+β_1)	(β_0)	(β_0+β_1)
Ca	-0.41**	1.40***	-0.17**	1.10***
Bis inter	-0.33**	-0.170***	-0.28**	-0.140***
Currency	-3.4**	9**	-9.2**	4.5*
Credit deposit	-6.3**	2.4**	-7.5**	6.9**
Credit gap	-0.40**	-0.22***	-0.11**	-0.052*
Uncertainty	-0.034***	-0.0051**	-0.032**	0.00
Fsi	-0.41*	-0.12**		
Gsfci			-0.44**	-0.21**
Embig	-0.0060*	-0.0027*	-0.0078*	-0.0028**
Nb of transitions	1		1	
Smooth parameter γ	0.40		0.12	
Threshold	31		31	
Obs > Threshold	45.5%		45.5%	

A second important result confirms the dilemma hypothesis (Rey, 2013): an increase in vulnerability is damaging to real GDP growth even in countries with floating exchange rates (**Table 4**). Finally, a rise in our common factors -*i.e. uncertainty*, *fsi*, and *embig*- tend to be associated to a slowdown in real GDP growth (except for *uncertainty* in the peg sub-sample).

Tables 3-6 column 2 present the results for the high reserves holding regime. If the assumption of diminishing returns from the accumulation of foreign exchange reserves is relevant, we must observe either lack of an effect on the sensitivity of real GDP growth to the vulnerability indicators, or even a deterioration in macroeconomic resilience.

Table 5 Non OECD sample 1995Q1-2015Q4

	resm2			
	1	**2**	**3**	**4**
	(β_0)	$(\beta_0+\beta_1)$	(β_0)	$(\beta_0+\beta_1)$
Ca	-0.12**	0.65*	-0.11**	0.56**
Bis inter	-0.051**	0.035**	-0.052**	0.023**
Currency	-11*	8.2**	-10**	7.3*
Credit deposit	-1.6**	-0.33**	-2.6**	-0.058**
Credit gap	-0.067***	0.15*	-0.051**	0.064*
Uncertainty	-0.001 ***	-0.016**	-0.0031***	-0.009**
Fsi	-0.16***	-0.14**		
Gsfci			-0.29***	-0.16***
Embig	-0.0018*	-0.0013**	-0.002*	-0.0015**
Nb of transitions	1		1	
Smooth parameter γ	0.7		0.34	
Threshold (Forex)	32		33	
Obs > Threshold	47.6%		45.4%	

Table 6 Peg sample 1995Q1-2015Q4

	resm2			
	1	**2**	**3**	**4**
	(β_0)	$(\beta_0+\beta_1)$	(β_0)	$(\beta_0+\beta_1)$
Ca	-0.54***	-0.37***	-0.67***	-0.50**
Bis inter	-0.073***	-0.040**	-0.069**	-0.042**
Currency	-5.3**	-4.8**	-10**	-8.7**
Credit deposit	-2.1***	0.073***	-4.5***	-2**
Credit gap	-0.27*	-0.094*	-0.19**	-0.089**
Uncertainty	0.0091***	-0.0130**	0.012**	-0.019*
Fsi	-0.24**	-0.091**		
Gsfci			-0.31**	-0.068**
Embig	-0.00027*	-0.0011*	-0.002*	-0.0041*
Nb of transitions	1		1	
Smooth parameter γ	0.42		0.28	
Threshold	26		27	
Obs > Threshold	64.1%		60.9%	

Our main finding contradicts the assumption of diminishing returns since the values of the β coefficients ($\beta_0 + \beta_1$) are lower in the second regime than their values in the first regime when we consider the country specific variables. As a result, increasing the stock of international reserves allows domestic authorities to mitigate the negative impacts of financial and banking vulnerabilities. For our common factors variables, our results support the effectiveness of reserve holdings in the high regime, but to a lesser extent in the peg subsample.

Robustness tests

We conduct three robustness tests of our main empirical findings. First, we consider two alternative threshold variables. Second, we replace the *fsi* by the Goldman Sachs financial conditions index and add two variables related to real external shocks. Third, we examine whether our baseline results are sensitive to the most severe crisis period i.e. the global financial crisis (2008Q1-2010Q4).

Is the baseline model robust to alternative threshold variables?

We consider two alternative threshold variables used in the literature on reserve accumulation (Bussière et al., 2015). First, the foreign exchange reserves in percentage of GDP (*resgdp*) that allows to control for country size. Second, the foreign exchange reserves in percentage of external short-term debt (*resdebt*) in line with the Greenspan-Guidotti rule that requires foreign exchange reserves to cover the stock of short-term debt.[14] As external short-term debt data are available only at a yearly basis, we use a linear interpolation method to transform them into quarterly data.[15]

[14] See Supplementary material for tests with alternative threshold variables. Results of weak cross-sectional dependence test (Tables 5-6) reject the null hypothesis of no cross-sectional dependence. Results of homogeneity test and non-remaining heterogeneity test (Tables 7-8-9-10) reject the linearity. The number of thresholds is established to 1. Results of UO (2009) and EO (2014) are available in (Tables11-12). Conclusions are similar for the *resm2* variable.

[15] Data are unavailable for Czech Republic, Estonia, Israel, and Sri Lanka.

Tables 7-10 report the results for *resgdp* (columns 1-2) and *resdebt* (columns 3-4). The results provide robust evidence that international reserves accumulation is effective to mitigate financial and banking vulnerabilities. They do not support the diminishing returns assumption. First, as for the baseline model, the threshold values range in a narrow band in our different sub-samples. In addition, the distribution around each threshold does not exhibit a significant skew.

Table 7 Full sample 1995Q1-2015Q4

	resgdp		***resdebt***	
	1	**2**	**3**	**4**
	(β_0)	($\beta_0+\beta_1$)	(β_0)	($\beta_0+\beta_1$)
Ca	-1.4**	0.2**	-2.8**	0.32***
Bis inter	-0.13***	0.014**	-0.26**	-0.20**
Currency	-1.1**	-0.3**	-33**	-18*
Credit deposit	-4.9***	5.9**	-13**	-4.6**
Credit gap	-0.30**	-0.071**	-0.57*	-0.24**
Uncertainty	-0.017**	-0.0077*	0.041*	0.014**
Fsi	-0.0085**	-0.310**	-0.21**	-0.06*
Gsfci				
Embig	-0.002*	-0.0051*	-0.007*	-0.0023*
Nb of transitions	1		1	
Smooth parameter γ	0.42		0.5	
Threshold	14		130	
Obs > Threshold	48.5%		39.3%	

Second, the signs of our explanatory variables in the first regime (columns 1 and 2) remain consistent with those expected by the economic intuitions: an increasing vulnerability exerts a negative influence on GDP growth.

Third, results on the second regime (Columns 3 and 4 for *resgdp* and *resdebt* respectively) confirm that the accumulation of reserves beyond a specific threshold allows the authorities to mitigate output losses due to vulnerabilities.

Table 8 Float sample 1995Q1-2015Q4

	resgdp		*resdebt*	
	1	**2**	**3**	**4**
	(β_0)	($\beta_0+\beta_1$)	(β_0)	($\beta_0+\beta_1$)
Ca	-0.53**	0.57**	-0.89**	0.83**
Bis inter	-0.11**	-0.02**	-0.94**	-0.51***
Currency	-2.3**	-0.14**	-23**	-12**
Credit deposit	-12**	13*	-25***	18***
Credit gap	-0.19***	-0.067**	-0.49**	-0.23**
Uncertainty	-0.07***	-0.01**	-0.04**	-0.0013*
Fsi	-0.08**	-0.03**	-0.072**	-0.40*
Gsfci				
Embig	-0.006***	-0.0067***	-0.0025**	-0.0033**
Nb of transitions	1		1	
Smooth parameter γ	2.2		0.1	
Threshold	16		120	
Obs > Threshold	46.6%		44%	

Table 9 Non OECD sample 1995Q1-2015Q4

	resgdp		*resdebt*	
	1	**2**	**3**	**4**
	(β_0)	($\beta_0+\beta_1$)	(β_0)	($\beta_0+\beta_1$)
Ca	-2.3*	0.11*	-1.6**	-0.08*
Bis inter	-0.13**	0.051**	-0.06**	-0.019**
Currency	-1.4**	2.3**	-8.1**	-0.048***
Credit deposit	-4.7*	-3.3**	-6.8*	-2.2**
Credit gap	-0.65***	-0.21***	-0.62**	-0.29**
Uncertainty	-0.006**	-0.004**	-0.046**	-0.016**
Fsi	-0.18	-0.13	-0.38**	-0.14**
Gsfci				
Embig	-0.004***	-0.003***	-0.009*	-0.0033*
Nb of transitions	1		1	
Smooth parameter γ	0.23		0.5	
Threshold (Forex)	12		140	
Obs > Threshold	61.15%		41.5%	

Table 10 Peg sample 1995Q1-2015Q4

	resgdp		***resdebt***	
	1	**2**	**3**	**4**
	(β_0)	($\beta_0+\beta_1$)	(β_0)	($\beta_0+\beta_1$)
Ca	-1.10**	0.94**	-0.9**	0.92**
Bis inter	-0.150**	-0.10**	-1.2**	-0.68***
Currency	-1.5**	-1.0**	-18**	-15**
Credit deposit	-14**	13**	-13**	5.2***
Credit gap	-0.340*	-0.140**	-0.43**	-0.25*
Uncertainty	-0.0034**	-0.006**	0.0014*	0.0011*
Fsi	-0.22**	-0.02**	-0.57**	-0.31**
Gsfci				
Embig	-0.0048*	0.005*	0.017*	0.001*
Nb of transitions	1		1	
Smooth parameter γ	0.66		0.32	
Threshold	13		150	
Obs > Threshold	45.8%		33.6%	

Are the results robust to the inclusion of real external factors and alternative financial conditions indicators?

We investigate to what extent our baseline results change if we include real external shocks and a new financial stress indicator.

We add two real variables. First, to proxy for the international trade, the index of global real economic activity in industrial commodity markets (*Kilian*) (Kilian, 2009) is preferred to the G7 activity index which is too restrictive to account for the growing weight in the world economy of emerging economies, while the G20 index can pose endogeneity problems. The expected signs for the β coefficients are positive: an increase in the *kilian* index is associated to an acceleration in real GDP growth.

Second, in line with the literature emphasizing terms of trade fluctuations as a driver of economic growth (Fernández et al., 2017), we add a terms of trade (*tot*) variable to consider price variations in imported commodities. Since an increase in the *tot* index acts as a windfall income gain, we expect positive β coefficients.

Then we introduce the Goldman Sachs financial conditions index for the United States (*gsfci*).[16] As the *fsi* variable used in our baseline model is highly correlated with this index, especially after 2007Q4, we exclude it from this extended specification. As a preliminary test, we introduce the *gsfci* instead of *fsi* but without *kilian* and *tot* variables. **Tables 3-10** above, columns 3-4, show that results do not significantly change.

As the introduction of *tot* and *kilian* do not qualitatively change the results regarding the country-specific variables, we focus our attention on the common shocks variables.[17] **Tables 11-14** (columns 1-2) present the results with *resm2* as threshold variable. The model with *gsfci* (columns 3-4) does not change the main results. The results are qualitatively unchanged when we estimate the extended specification with *resgdp* (columns 5-6) or *resdebt* (columns 7-8) as threshold variables. For the common factors variables (*i.e. uncertainty*, *fsi* (*gsfci*) and *embig*), our results are broadly in line with the benchmark model (columns 1-2), even after controlling the effect of the new financial conditions index (*gsfci*, columns 3-4). Alternative threshold variables (columns 5-8) confirm this finding.

The new specification with *kilian* and *tot* confirms our results about the effectiveness of the accumulation of foreign exchange reserves, including in regime 2. For *tot*, our results suggest that reserve holding is effective ($\beta_0 < \beta_0 + \beta_1$).

[16] For details, see Hatzius and Stehn (2018).
[17] All results are available in the Supplementary material (Tables 13-16).

Table 11 Full sample 1995Q1-2015Q4_tot_kilian

	resm2				***resgdp***		***resdebt***	
	1	2	3	4	5	6	7	8
	(β_0)	(β_0+β_1)	(β_0)	(β_0+β_1)	(β_0)	(β_0+β_1)	(β_0)	(β_0+β_1)
Uncertainty	-0.015***	-0.0033***	-0.0063***	-0.0035***	-0.0058***	-0.005***	-0.007	-0.006
Fsi	-0.94**	-0.80**			-0.051**	-0.038**	-0.054	-0.033
Gsfci			-0.23***	-0.11***				
Embig	-0.016***	-0.007***	-0.0017**	-0.0006*	-0.08***	-0.008**	0.00	-0.0017
Kilian	0.005*	0.034**	0.0046*	-0.0240*	0.0016*	0.032*	0.045	0.027
Tot	0.25**	0.096*	0.02**	0.043**	0.047**	0.068**	0.054	0.062

Table 12 Float sample 1995Q1-2015Q4_tot_kilian

	resm2				***resgdp***		***resdebt***	
	1	2	3	4	5	6	7	8
	(β_0)	(β_0+β_1)	(β_0)	(β_0+β_1)	(β_0)	(β_0+β_1)	(β_0)	(β_0+β_1)
Uncertainty	-0.03**	-0.0001**	-0.028**	-0.0054**	-0.0064**	-0.0025**	0.00[ns]	0.001*
Fsi	-0.16**	-0.011**			-0.23***	-0.150***	-0.24**	-0.1**
Gsfci			-1.30*	-0.62**				
Embig	-0.012***	-0.0054**	-0.009*	-0.0054*	-0.0033*	-0.0034**	-0.002**	-0.0003**
Kilian	0.041***	0.048**	0.041**	0.044**	0.0063**	0.0270**	0.001**	0.032**
Tot	0.023**	0.075*	0.025*	0.092*	0.015*	0.1*	0.04*	0.081*

Table 13 Non OECD sample 1995Q1-2015Q4_tot_kilian

	resm2				***resgdp***		***resdebt***	
	1	2	3	4	5	6	7	8
	(β_0)	($\beta_0+\beta_1$)	(β_0)	($\beta_0+\beta_1$)	(β_0)	($\beta_0+\beta_1$)	(β_0)	($\beta_0+\beta_1$)
uncertainty	-0.011***	-0.016**	-0.016**	-0.0097**	-0.01	-0.005	-0.004**	-0.005**
Fsi	-0.073***	-0.15**			-0.13	-0.12	-0.01*	-0.01*
Gsfci			-0.32**	-0.43**				
Embig	-0.0035*	-0.0017**	-0.0054*	-0.0049**	-0.003	0.00ns	-0.0023**	-0.001*
Kilian	-0.014*	0.023**	-0.013**	0.023**	0.006	0.028	0.024**	0.034**
Tot	0.066**	0.013**	0.019**	0.084**	0.079	0.06	0.0058**	0.012**

Table 14 Peg sample 1995Q1-2015Q4_tot_kilian

	resm2				***resgdp***		***resdebt***	
	1	2	3	4	5	6	7	8
	(β_0)	($\beta_0+\beta_1$)	(β_0)	($\beta_0+\beta_1$)	(β_0)	($\beta_0+\beta_1$)	(β_0)	($\beta_0+\beta_1$)
uncertainty	-0.0027*	-0.012*	-0.0073*	-0.0016*	-0.006*	-0.008*	-0.028*	-0.009*
Fsi	-0.18*	-0.088**			-0.04**	-0.02**	0.0061*	-0.002*
Gsfci			-0.26**	-0.032**				
Embig	-0.0017***	-0.0004*	-0.0034**	-0.0005**	-0.005***	-0.001*	-0.0057***	-0.0023**
Kilian	-0.001***	0.02**	-0.008*	0.015**	0.00074	0.025**	-0.038***	0.0027***
Tot	0.055*	-0.025**	0.02***	0.08**	0.05*	0.093**	0.1**	0.12**

Regarding the *kilian* variable, the negative sign of the coefficients for regime 1 are counterintuitive for the peg and non-OECD subsamples. However, the second regime suggests that holding reserves above a certain threshold is effective for dealing with variations in global real economic activity. All the coefficients are positive and higher than those observed in regime 1. Our results using alternative specifications broadly support the benchmark findings.

Lessons from the global financial crisis

The 2008-2010 subperiod offers a natural experiment to assess the robustness of our results. Not only the period experienced the largest contraction in GDP growth over the period studied, but also it exhibited a dramatic deterioration in our vulnerability variables. The small number of observations leads us to consider only our initial set of variables. During financial crisis episodes, common factors tend to co-move leading to higher correlations between some of our explanatory variables.[18] To avoid biased estimates, we test our baseline model using four alternative specifications. As subsamples results do not change our main findings, we focus here on the full sample (**Tables 15**).[19] provide the β coefficients estimates and show that reserves accumulation tends to soften the negative influence of financial and banking vulnerabilities on real GDP growth. Thus, holding reserves is effective to protect domestic economies against international financial shocks. Taking into account the *gsfci* variable in the model (columns 7-8 and 11-12) does not change our main findings. The results for the explanatory variables common to all the countries suggest that holding reserves above a critical threshold improves the economy's response to their increase. The main exception is *uncertainty* variable. Recall that this variable experienced a significant jump at the start of the crisis followed by a rapid decline. These fluctuations over the estimation period may be disturbing our results to some extent.

[18] Table 4 in Supplementary material.
[19] See Supplementary material for the subsamples, Tables 17-19.

Table 15 Full sample 2008Q1-2010Q4

	Specification 1		Specification 2		Specification 3				Specification 4			
	1	2	3	4	5	6	7	8	9	10	11	12
	(β_0)	($\beta_0+\beta_1$)	(β_0)	($\beta_0+\beta_1$)	(β_0)	($\beta_0+\beta_1$)	(β_0)	($\beta_0+\beta_1$)	(β_0)	($\beta_0+\beta_1$)	(β_0)	($\beta_0+\beta_1$)
Ca	-0.40***	-0.12**	-0.23**	-0.08***	-0.44***	-0.23**	-0.36***	0.12**	-0.27*	-0.049*	-0.063**	**-0.0045***
Bis inter	-0.018***	0.036**							-0.048*	-0.065*	-0.007*	**-0.0016***
Currency			-0.41**	-0.2**	-8**	-4.4***	-10**	-9.3**				
Credit deposit	-7.8***	-4.6**	-7.2**	-2.4**	-2.7**	-0.35**	-5.6**	-1.1***	-5.5***	0.56**	-4.4***	**-0.015****
Credit gap	-0.93**	-0.64**	-0.33**	-0.33*	-0.45*	-0.37**	-0.27**	-0.14**	-0.25***	-0.19*	-0.19***	**-0.15***
Uncertainty	0.076***	0.064***	0.042*	0.046**	-0.031***	-0.034*	-0.017***	-0.013*	-0.009***	-0.02*	-0.062**	**-0.026****
Fsi					-0.28**	0.01***			0.07	-0.40**		
Gsfci							-1.3***	-0.48***			-0.97**	**-0.25****
Embig	-0.032***	-0.030**	-0.023***	-0.015**								
Nb of transitions	1		1		1		1		1		1	
Smooth paramete γ	0.24		0.59		0.85		0.51		0.25		0.75	
Threshold (resm2)	32		31		30		31		30		34	
Obs > Threshold	50%		52.9%		57.5%		52.9%		57.5%		43.7%	

Regarding the specific vulnerability, our conclusions on the effectiveness of holding foreign exchange reserves are largely confirmed. The coefficients of the common variables highlight two main changes. First, the use of *resgdp* or *resdebt* as threshold variables show a lower effectiveness of reserve holding regarding *embig*. Second, our results suggest an improvement in the efficiency of reserves in the face of changes in *uncertainty*. Alternative threshold variables do not qualitatively change the main findings.[20]

IV. Conclusion

This paper contributes to the literature on the effectiveness of holding foreign exchange reserves to address the banking and financial vulnerabilities that characterize many EMDEs. In the aftermath of the global financial crisis, an extensive literature supports such effectiveness from both crisis prevention and crisis mitigation perspective. However, as stressed a long time ago, reserve holding is not a free lunch. Specifically, monetary authorities must face sterilization costs and bear a non-optimal use of domestic saving. More recently, international institutions and academic studies drawn attention on the presence of worldwide negative externalities and advanced that reserve accumulation exhibits diminishing returns.

However, the majority of EMDEs have rebuilt or continued to increase their reserve stocks after 2009. Some of them have announced their intention to hoard reserves for precautionary reasons, to ensure better access to global financial markets in times of crisis and to avoid excessive exchange rate volatility) (Prasad, 2014: 71-73). But since holding reserves is not a free lunch, does it pay to adopt such a strategy?

Our paper provides some answers to this question by focusing on the diminishing returns assumption. In order to better capture the threshold effect in the GDP growth rate-forex nexus, we estimate a PSTR model. Considering a large panel of EMDEs over the period 1995-2015, our main results lead us to qualify diminishing returns assumption. Specifically, we show that

[20] See Supplementary material (Tables 20-23 for *resgdp* and 24-27 for *resdebt*).

holding reserves is effective even in the case of the high holding regime in responding to domestic vulnerabilities and global shocks. These results are robust to alternative specifications. Such findings are highly relevant to investigate the behavior of EMDEs in the current global financial environment. Even if many EMDEs has increased their resilience to global shocks by improving their fundamental and economic framework, their vulnerabilities become highly critical in an environment marked by protracted uncertainty and a dramatic increase in financial interconnectedness. The EMDEs remain extremely sensitive to perturbation affecting the global financial cycle. In addition, better fundamentals are a necessary but not sufficient condition to improve resilience to external shocks as investors do not discriminate among EMDEs at very short-term. Yet, short-term instability can have persistent impacts.

In the absence of diminishing returns, the accumulation of foreign exchange reserves in EMDEs remains a profitable strategy for two main reasons. On the one hand, production losses due to financial crises are not only high, but also long-lasting. On the other hand, it is fundamental to keep in mind that EMDEs have few reliable alternatives to quickly mobilize liquidity in the event of financial crises. Indeed, despite the progress made, the Global Financial Safety Net remains incomplete, highly politicized and continues to suffer from the "stigma effect" regarding the credits granted by the International Monetary Fund.

From an economic policy perspective, our approach does not seek to determine whether the current level of reserves is adequate or not as the IMF seeks to do. The determination of such a level remains based on assumptions specific to groups of countries and, probably, changing over time. Its relevance has yet to be tested in the context of a systemic financial crisis. But fundamentally, our approach allows us to conclude that holding reserves pays off for EMDEs.

Finally, as an important literature shows that reserve accumulation is complementary to macroprudential instruments (Carstens, 2019), a way to reduce the costs related to reserve holding is to articulate this behavior -and not only the effectiveness of foreign exchange interventions in the IMF integrated policy framework (IMF, 2020).

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VI. Appendices

A. Country sample

Full sample: Argentina, Belarus, Bolivia, Brazil, Bulgaria, Chile, China, Colombia, Costa Rica, Croatia, Czech Republic, Ecuador, Estonia, Georgia, Guatemala, Hungary, India, Indonesia, Israel, Jamaica, Latvia, Lithuania, Macedonia, Malaysia, Mexico, Morocco, Paraguay, Peru, Philippines, Poland, Romania, Russia, Serbia, South Africa, South Korea, Sri Lanka, Thailand, Turkey, Ukraine, and Uruguay.

Countries with peg exchange rate regimes: Argentina, Belarus, Bolivia, Bulgaria, China, Costa Rica, Croatia, Ecuador, Estonia, Georgia, Guatemala, India, Jamaica, Latvia, Lithuania, Macedonia, Peru, Russia, Sri Lanka, and Ukraine.

Using the coarse classification, fixed exchange rate regimes include No separate legal tender, Pre-announced peg or currency board arrangement, Pre-announced horizontal band that is narrower than or equal to +/-2%, De facto peg, Pre-announced crawling peg, Pre-announced crawling band that is narrower than or equal to +/-2%, De factor crawling peg, and De facto crawling band that is narrower than or equal to +/-2%.

Countries with float exchange rate regimes: Brazil, Chile, Colombia, Czech Republic, Hungary, Indonesia, Israel, Malaysia, Mexico, Paraguay, Peru, Philippines, Poland, Romania, Serbia, South Africa, South Korea, Thailand, Turkey, and Uruguay.

Using the coarse classification, float exchange rate regimes include Pre-announced crawling band that is wider than or equal to +/-2%, De facto crawling band that is narrower than or equal to +/-5%, Moving band that is narrower than or equal to +/-2%, Managed floating, and Freely floating.

Non-OECD countries: Argentina, Belarus, Bolivia, Brazil, Bulgaria, China, Colombia, Costa Rica, Croatia, Ecuador, Georgia, Guatemala, India, Indonesia, Jamaica, Lithuania, Macedonia, Malaysia, Morocco, Paraguay, Peru, Philippines, Romania, Russia, Serbia, South Africa, Sri Lanka, Thailand, Ukraine, and Uruguay.

B. Data and Sources

Name of the data	Definition	Sources
Currency	Foreign liabilities in the domestic financial sector (line 26C) / Money stocks (line 14+line 24)	IMF-International Financial Statistics (IFS)
Ca	Current account / GDP	IMF-IFS
Bis inter	International claims of BIS-reporting banks over borrowers' GDP	BIS International banking statistics (Immediate counterparty basis, 4O: All excluding 4C banks, excl. domestic positions (= 4R + 4Q +4V)), Consolidated data IMF-IFS
Credit deposit	Claims on Private Sector (line 22D) / (Transf. Dep. Included in Broad Money (line 24) + Other Dep. Included in Broad Money (line 25))	IMF-IFS
Credit gap	Credit-to-GDP ratio cycle component	IMF-IFS
Uncertainty	U.S. economic policy uncertainty index	http://www.policyuncertainty.com/index.html
Fsi	U.S. financial stress index	IMF
Embig	Global emerging market bond index.	Macrobond
Gsfci	US financial conditions index	Goldman Sachs
Kilian	Index of global real economic activity in industrial commodity markets	Kilian
Tot	Net exports	IMF
Resm2	Foreign exchange reserves minus gold / Monetary aggregate M2	IMF-IFS
Debt	External short-term debt	IMF Assessing Reserve Adequacy
Gdp growth	GDP Volume Percentage Change, Change Y/Y	IMF-IFS

Supplementary material

A. Sieve bootstrap algorithm methodology

This supplementary material presents the sieve bootstrap approach to overcome the assumption of dependence among cross-sectional units. To obtain an empirical distribution of the $\bar{F}_{AE}$ test statistic we use the following sieve bootstrap algorithm:

i. We run the following regression using ordinary least squares (OLS) for each individual and determine the lag orders via the information criteria by starting with p_{max} and applying a top-down strategy:

$$\Delta y_{it} = \phi_{1i} y_{i,t-1}^{3} + \phi_{2i} y_{i,t-1}^{4} + \sum_{j=1}^{p_i} \delta_{ij} \Delta y_{i,t-j} + \varepsilon_{it} \quad (1)$$

ii. Following Basawa et al. (1991), the null $\varphi_{1i} = \varphi_{2i} = 0$ is imposed to generate the bootstrap samples of residuals. Thus, we estimate the errors as:

$$\hat{\varepsilon}_{it} = \Delta y_{it} - \sum_{j=1}^{p_i} \hat{\delta}_{ij} \Delta y_{i,t-j} \quad (2)$$

iii. Following Stine (1987), the residuals must be centered via the formulation:

$$\tilde{\varepsilon}_t = \hat{\varepsilon}_t - (T - p - 2)^{-1} \sum_{t=p+2}^{T} \hat{\varepsilon}_t \quad (3)$$

where $\hat{\varepsilon}_t = (\hat{\varepsilon}_{1t}, \hat{\varepsilon}_{2t}, \dots, \hat{\varepsilon}_{Nt})'$ and $p = max(p_i)$.

iv. We develop the $N \times T[\tilde{\varepsilon}_{it}]$ matrix based on these residuals. We randomly select one full column at a time from the matrix to preserve the cross-covariance structure of the errors. We denote the bootstrap residuals $\tilde{\varepsilon}_{it}^{*}$, where $t = 1,2, \dots, T^{*}$ and $T^{*} = 2T$.

v. We generate Δy_{it}^{*} from the regression recursively as

$$\Delta y_{it}^{*} = \sum_{j=1}^{p_i} \hat{\delta}_{ij} \Delta y_{i,t-1}^{*} + \tilde{\varepsilon}_{it}^{*} \quad (4)$$

where $\hat{\delta}_{ij}$ are the estimates obtained from step (ii) and $\Delta y_{i,t-p_i}^{*} = 0$ for $p_i = 1,2, \dots, p_{max}$. Notice that we generate the $T + M$ values of Δy_{it}^{*} and discard the first Mvalues to ensure stationarity.

vi. We generate nonstationary bootstrap samples from the partial sums:

$$y_{it}^{*} = \sum_{j=1}^{t} \Delta y_{ij}^{*} \quad (5)$$

vii. Using bootstrap samples, we compute the bootstrap statistic $\bar{F}_{AE}^{*}$ by running the regression

$$\Delta y_{it}^* = \phi_{1i} y_{i,t-1}^{*3} + \phi_{2i} y_{i,t-1}^{*4} + \sum_{j=1}^{p_i} \delta_{ij} \Delta y_{i,t-j}^* + v_{it} \quad (6)$$

viii. We repeat steps (iv) to (vii) numerous times to find the bootstrap distribution of $\bar{F}_{AE,}^*$ and specify the bootstrap critical values by selecting the appropriate percentiles of the sample distributions.

Again, if the unit root hypothesis($\varphi_{1i} = \varphi_{2i} = 0 \; \forall \; i$) is rejected, we can obtain an empirical distribution of the $\bar{t}_{AE}^{as}$ test statistic using the following sieve bootstrap algorithm:

i. Under the null $\phi_{2i} = 0$, we estimate the following exponential smooth transition model for each individual using the genetic algorithm optimization method and obtain the coefficients estimates ($\hat{\gamma}_{1i}$ and $\hat{\rho}_i$) and the fitted residuals ($\hat{\varepsilon}_{it}$).

$$\Delta y_{it} = G_{it}(\gamma_{1i}, y_{i,t-1}) \rho_i y_{i,t-1} + \varepsilon_{it} \quad (7)$$

ii. We estimate the regression by OLS and determine the lag orders via information criteria by starting with p_{max} and applying a top-down strategy.

$$\hat{\varepsilon}_{it} = \sum_{j=1}^{p_i} \beta_{ij} \hat{\varepsilon}_{i,t-j} + u_{it} \quad (8)$$

Then we obtain the coefficients estimates ($\hat{\beta}_{ij}$) and the fitted residuals ($\hat{u}_{it}$).

iii. Following Stine (1987), the residuals ($\hat{u}_{it}$) have to be centered via the formulation:

$$\tilde{u}_t = \hat{u}_t - (T - p - 2)^{-1} \sum_{t=p+2}^{T} \hat{u}_t \quad (9)$$

where $\hat{u}_t = (\hat{u}_{1t}, \hat{u}_{2t}, \dots, \hat{u}_{Nt})'$ and $p = max(p_i)$.

iv. We develop the $N \times T[\tilde{u}_{it}]$ matrix from these residuals. We randomly select a full column at a time from this matrix to preserve the cross-covariance structure of the errors. We denote the bootstrap residuals with $\tilde{u}_{it}^*$, where $t = 1,2, \dots, T^*$ and $T^* = 2T$.

v. We generate stationary nonlinear bootstrap samples (Δy_{it}^*) from the regression recursively and simultaneously as:

$$\hat{\varepsilon}_{it}^* = \sum_{j=1}^{p_i} \hat{\beta}_{ij} \hat{\varepsilon}_{i,t-j}^* + \tilde{u}_{it}^* \quad (10)$$

$$\Delta y_{it}^* = G_{it}(\hat{\gamma}_{1i}, y_{i,t-1}^*) \hat{\rho}_i y_{i,t-1}^* + \hat{\varepsilon}_{it}^* \quad (11)$$

vi. Using bootstrap samples, the bootstrap statistic $\bar{t}^{*as}_{AE}$ is computed by running the regression:

$$\Delta y_{it}^* = \phi_{1i} y_{i,t-1}^{*3} + \phi_{2i} y_{i,t-1}^{*4} + \sum_{j=1}^{p_i} \delta_{ij} \Delta y_{i,t-j}^* + v_{it} \quad (12)$$

vii. We repeat steps (iv) to (vi) numerous times to find the bootstrap distribution of $\bar{t}^{*as}_{AE}$, and specify the bootstrap critical values by selecting the appropriate percentiles of the sample distributions.

B. Tables

Table 1 Descriptive statistics, 1995-2015

Full sample

	Mean	Median	std	Min	Max
Growth	3.829	4.299	4.449	-20.11	23.8
Resm2	34.02	30.52	18.04	1.289	147
Embig	525.5	423.7	286.2	161.6	1388
Ca	-2.231	-2.345	5.218	-23.9	16.53
Currency	0.4702	0.3551	0.4861	0.009887	4.844
Credit_depot	1.047	0.9751	0.4287	0.1083	4.845
Bis_inter	16.86	11.27	17.05	0.2495	125.5
Fsi	-0.3514	-1.109	3.715	-4.642	18.12
Credit_gap	0.6795	0.4881	7.565	-31.87	28.21
Tot	100.5	100.4	4.535	76.46	119.3
Kilian	5.817	0.856	27.87	-48.1	66.01
Uncertainty	110	100.7	37.92	52.09	235.1
Resgdp	15.62	13.73	9.279	0.6065	52.98
Gsfci	99.84	99.67	0.9151	98.21	103.5
Resdebt	174.8	121.6	185.9	4.868	1719

Float sample

	Mean	Median	std	Min	Max
Growth	3.706	4.206	3.771	-17.93	16.59
Resm2	34.07	29.87	17.86	1.289	118.5
Embig	525.5	423.7	286.3	161.6	1388
Ca	-1.268	-1.693	4.51	-21.05	16.53
Currency	0.5583	0.4026	0.5808	0.02296	4.844
Credit_depot	1.034	0.9963	0.3917	0.2638	3.385
Bis_inter	16.94	14.14	10.97	3.902	83.76
Fsi	-0.3514	-1.109	3.715	-4.642	18.12
Credit_gap	0.9104	0.3819	7.871	-31.87	28.21
Tot	99.98	100.1	3.707	87.59	113.3
Kilian	5.817	0.856	27.87	-48.1	66.01
Uncertainty	110	100.7	37.93	52.09	235.1
Resgdp	17.11	15.62	9.353	0.6065	52.98
Gsfci	99.84	99.67	0.9152	98.21	103.5
Resdebt	154	127.5	93.03	4.868	527.4

Non-OECD sample

	Mean	Median	std	Min	Max
Growth	3.809	4.401	4.492	-20.11	23.8
Resm2	35.68	31.27	19.06	1.289	147
Embig	525.5	423.7	286.2	161.6	1388
Ca	-2.105	-2.367	5.468	-23.9	16.53
Currency	0.4382	0.3093	0.5102	0.009887	4.844
Credit_depot	1.028	0.9517	0.4365	0.1083	4.845
Bis_inter	14.78	10.17	13.99	1.12	106.3
Fsi	-0.3514	-1.109	3.715	-4.642	18.12
Credit_gap	0.9942	0.5803	6.89	-31.87	28.21
Tot	100.3	100.2	4.718	76.46	119.3
Kilian	5.817	0.856	27.87	-48.1	66.01
Uncertainty	110	100.7	37.93	52.09	235.1
Resgdp	15.56	13.05	9.911	0.6065	52.98
Gsfci	99.84	99.67	0.9151	98.21	103.5
Resdebt	191.1	130.9	202.1	4.868	1719

Peg sample

	Mean	Median	std	Min	Max
Growth	3.95	4.415	5.029	-20.11	23.8
Resm2	33.98	31.24	18.23	1.625	147
Embig	525.5	423.7	286.3	161.6	1388
Ca	-3.181	-3.175	5.676	-23.9	16.26
Currency	0.3671	0.2762	0.3143	0.009887	1.864
Credit_depot	1.06	0.9478	0.4623	0.1083	4.845
Bis_inter	16.78	8.884	21.37	0.2495	125.5
Fsi	-0.3514	-1.109	3.715	-4.642	18.12
Credit_gap	0.45	0.6346	7.245	-31.23	27.78
Tot	101.1	100.9	5.173	76.46	119.3
Kilian	5.817	0.856	27.87	-48.1	66.01
Uncertainty	110	100.7	37.93	52.09	235.1
Resgdp	14.15	12.26	8.968	0.832	47.25
Gsfci	99.84	99.67	0.9152	98.21	103.5
Resdebt	195.3	111.8	243.4	10.45	1719

Table 2 Descriptive statistics, 2008-2010

Full sample

	Mean	Median	std	Min	Max
Growth	2.319	3.576	5.741	-19.59	16.24
Resm2	37.17	32.03	17.88	5.935	92.22
Embig	392.9	316.4	147.9	281.4	709.8
Ca	-2.524	-2.109	6.751	-23.46	16.53
Currency	0.4337	0.3969	0.3291	0.01038	1.598
Credit_depot	1.144	1.007	0.4683	0.53	2.573
Bis_inter	23.66	13.15	25.63	1.728	117.4
Fsi	4.511	2.986	6.782	-4.284	18.12
Credit_gap	4.959	4.774	7.245	-17.75	27.78
Tot	137.6	133.5	31.33	92	187.4
Kilian	19.79	17.72	10.09	2.063	51.84
Uncertainty	100.9	100.6	1.15	99.56	103.5
Resgdp	219	134.2	261.4	24.19	1719
Gsfci					
Resdebt					

Float sample

	Mean	Median	std	Min	Max
Growth	2.944	3.791	4.564	-14.38	15.03
Resm2	36.28	30.89	19.52	10.34	92.22
Embig	392.9	316.4	148	281.4	709.8
Ca	-1.061	-1.484	5.693	-21.05	16.53
Currency	0.433	0.3951	0.2783	0.06047	1.461
Credit_depot	1.067	1.012	0.3674	0.53	2.02
Bis_inter	19.21	14.72	15.95	3.902	83.76
Fsi	4.511	2.986	6.789	-4.284	18.12
Credit_gap	4.747	5.943	7.225	-17.75	20.68
Tot	137.6	133.5	31.36	92	187.4
Kilian	20	17.8	10.14	8.202	51.84
Uncertainty	100.9	100.6	1.151	99.56	103.5
Resgdp	179.4	155.8	99.47	60.12	490.2
Gsfci					
Resdebt					

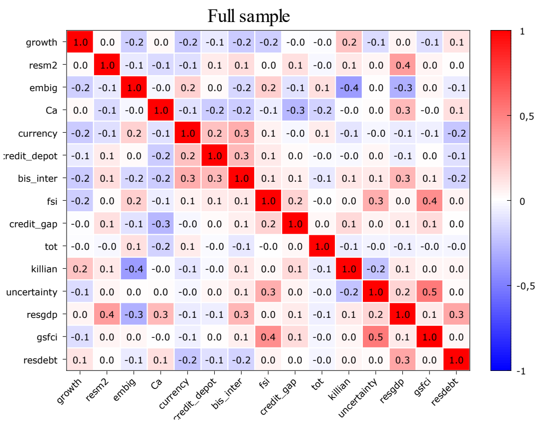
Non-OECD sample

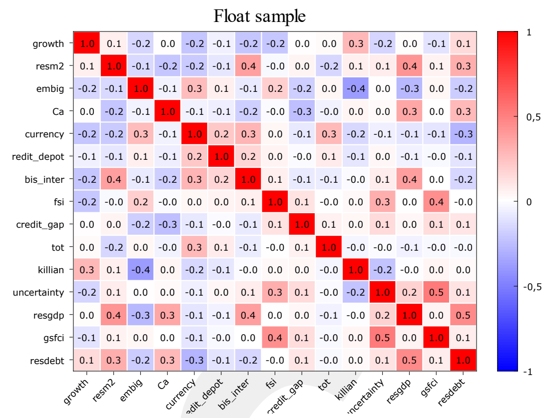
	Mean	Median	std	Min	Max
Growth	3.055	4.188	5.468	-19.59	16.24
Resm2	40.14	34.86	18.45	5.935	92.22
Embig	392.9	316.4	147.9	281.4	709.8
Ca	-2.718	-2.28	7.331	-23.46	16.53
Currency	0.3772	0.3459	0.2725	0.01038	1.05
Credit_depot	1.068	0.9524	0.4107	0.53	2.158
Bis_inter	18.61	10.16	18.97	1.728	94.59
Fsi	4.511	2.986	6.784	-4.284	18.12
Credit_gap	5	4.536	6.479	-15.58	26.47
Tot	137.6	133.5	31.34	92	187.4
Kilian	20.36	18.65	10.84	2.063	51.84
Uncertainty	100.9	100.6	1.15	99.56	103.5
Resgdp	248.8	171.1	283.5	25.13	1719
Gsfci					
Resdebt					

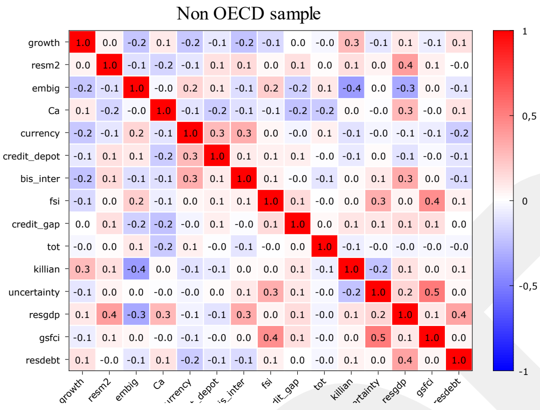
Peg sample

	Mean	Median	std	Min	Max
Growth	1.695	3.358	6.667	-19.59	16.24
Resm2	38.06	33.26	16.05	5.935	84.46
Embig	392.9	316.4	148	281.4	709.8
Ca	-3.987	-3.086	7.391	-23.46	11.86
Currency	0.4346	0.414	0.381	0.01038	1.598
Credit_depot	1.222	1.006	0.5408	0.5962	2.573
Bis_inter	28.11	11.1	31.97	1.728	117.4
Fsi	4.511	2.986	6.789	-4.284	18.12
Credit_gap	5.17	3.714	7.274	-15.58	27.78
Tot	137.6	133.5	31.36	92	187.4
Kilian	19.57	17.69	10.06	2.063	47.25
Uncertainty	100.9	100.6	1.151	99.56	103.5
Resgdp	256.4	100.8	347.8	24.19	1719
Gsfci					
Resdebt					

Table 3 Correlation matrix, 1995-2015







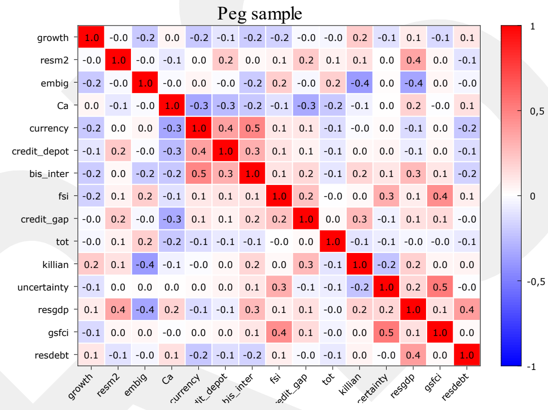
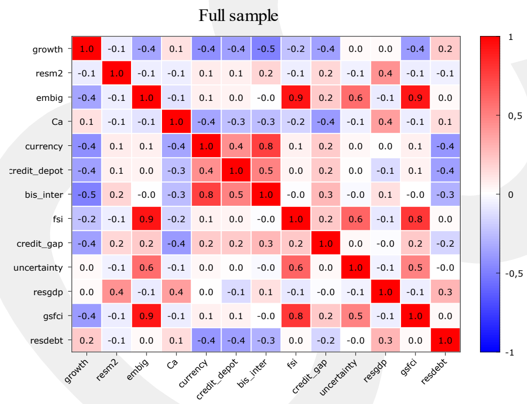
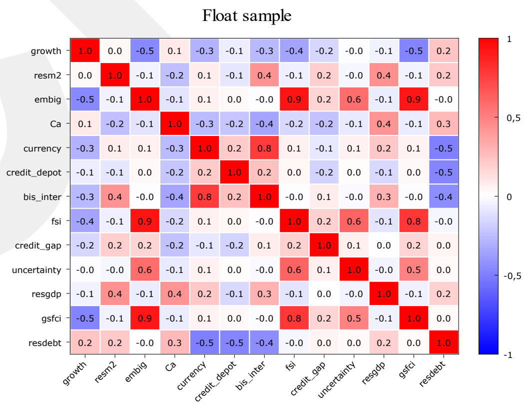
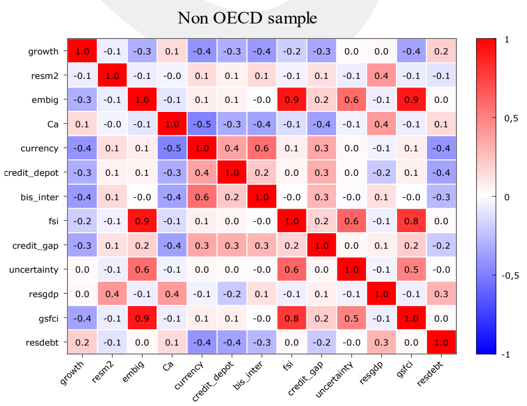


Table 4 Correlation matrix, 2008-2010







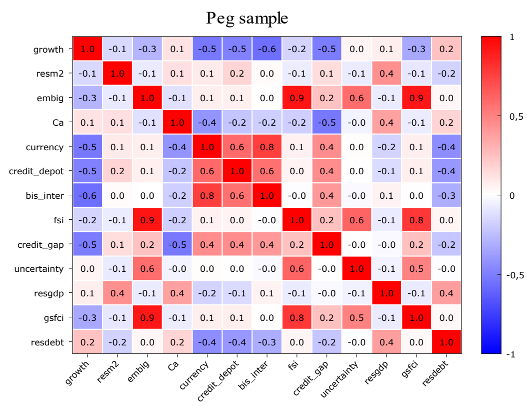


Table 5 Weak cross-sectional dependence test (threshold variable: *resgdp*)

	Pesaran (2015)
	CD-stat
Full	38.358 (0.00)
Float	1.143 (0.00)
Peg	11.137 (0.00)
Non-oecd	26.157 (0.00)

Note: Pesaran's (2015) cross-sectional independence test follows a standard normal distribution. Under the null hypothesis, the cross-section dependence (CD) tests for no dependence between cross section units.

Table 6 Weak cross-sectional dependence test (threshold variable: *resdebt*)

	Pesaran (2015)
	CD-stat
Full	32.595 (0.00)
Float	0.494 (0.00)
Peg	9.897 (0.00)
Non-oecd	25.751 (0.00)

Note: Pesaran's (2015) cross-sectional independence test follows a standard normal distribution. Under the null hypothesis, the cross-section dependence (CD) tests for no dependence between cross section units.

Table 7 Homogeneity test (1995Q1-2015Q4): (threshold variable: *resgdp*)

m=1	WB (p-value)	WCB (p-value)
Full sample	210.9 (0.00)	7.028 (0.00)
Float sample	131.9 (0.00)	4.319 (0.00)
Peg sample	108.3 (0.00)	3.238 (0.00)
Non-oecd sample	169.3 (0.00)	9.138 (0.00)

Note: The table presents the wild cluster and the wild cluster bootstrap of the LM-type homogeneity tests. Corresponding p-values are given.

Table 8 Non remaining heterogeneity (1995Q1-2015Q4): (threshold variable: *resdebt*)

	WB (p-value)	WCB (p-value)
Full sample	29.44 (0.44)	0.9811 (0.49)
Float sample	18.01 (0.944)	0.589 (0.959)
Peg sample	12.1 (0.999)	0.361 (0.999)
Non-oecd sample	18.8 (0.404)	1.015 (0.439)

Table 9 Homogeneity test (1995Q1-2015Q4): (threshold variable: *resdebt*)

m=1	WB (p-value)	WCB (p-value)
Full sample	132.1 (0.00)	4.351 (0.00)
Float sample	126.1 (0.00)	4.065 (0.00)
Peg sample	49.83 (0.01)	1.39 (0.00)
Non-oecd sample	128.2 (0.00)	4.19 (0.00)

Note: The table presents the wild cluster and the wild cluster bootstrap of the LM-type homogeneity tests. Corresponding p-values are given.

Table 10 Non remaining heterogeneity (1995Q1-2015Q4): (threshold variable resdebt)

	WB (p-value)	WCB (p-value)
Full sample	21 (0.859)	0.691 (0.889)
Float sample	13 (0.995)	0.419 (0.997)
Peg sample	43.8 (0.06)	1.22 (0.194)
Non-oecd sample	74.96 (6.17)	0.55 (0.973)

Table 11 Nonlinear/asymmetric Panel unit root test with linearity tests in Alternative hypothesis (threshold variable: *resgdp*)

	Ucar and Omay (2009)	Emirmahmutoglu and Omay (2014)

	Intercept $\bar{z}_{NL}$	intercept/trend $\bar{z}_{NL}$	Intercept $\bar{t}_{AE}^{as}$	intercept/trend $\bar{t}_{AE}^{as}$
Full	-1.806 (0.021)	-2.484 (0.000)	2.872 (0.287)	4.663 (0.205)
Float	--1.483 (0.338)	-2.339 (0.000)	2.762 (0.307)	5.216 (0.131)
Peg	-2.143 (0.004)	-2.617 (0.000)	2.926 (0.365)	4.095 (0.621)
Non_oecd	-1.865 (0.028)	-2.517 (0.000)	2.953 (0.308)	4.773 (0.194)

Note: p-values are in parentheses.

Table 12 Nonlinear/asymmetric Panel unit root test with linearity tests in Alternative hypothesis (threshold variable: *resdebt*)

	Ucar and Omay (2009)		Emirmahmutoglu and Omay (2014)	
	Intercept $\bar{z}_{NL}$	intercept/trend $\bar{z}_{NL}$	Intercept $\bar{t}_{AE}^{as}$	intercept/trend $\bar{t}_{AE}^{as}$
Full	-3.282 (0.000)	-4.293 (0.000)	7.708 (0.000)	12.037 (0.000)
Float	-3.032 (0.000)	-4.170 (0.000)	7.223 (0.000)	10.645 (0.000)
Peg	-3.518 (0.000)	-4.410 (0.000)	8.515 (0.000)	12.817 (0.000)
Non_oecd	-3.366 (0.000)	-4.356 (0.000)	8.596 (0.000)	13.351(0.000)

Note: p-values are in parentheses.

Table 13 Full sample 1995Q1-2015Q4_tot_kilian

	resm2				***resgdp***		***resdebt***	
	1	2	3	4	5	6	7	8
	(β_0)	(β_0+β_1)	(β_0)	(β_0+β_1)	(β_0)	(β_0+β_1)	(β_0)	(β_0+β_1)
Ca	-0.23**	0.063**	-0.20**	-0.078**	-0.31**	-0.150**	-0.15	0.35
Bis inter	-0.28*	-0.15**	-0.08*	-0.055**	-0.120**	-0.014**	-0.045	-0.027
Currency	-33**	-20**	-9.2**	-8.7*	-0.53**	-0.28**	-2	-0.14
Credit deposit	-19***	-5.4**	-3.2**	-0.28**	-2.1*	-3.6**	-2.6	-1.7
Credit gap	-0.42**	-0.20*	-0.082**	-0.057**	-0.28**	-0.069**	-0.43	-0.11
Uncertainty	-0.015***	-0.0033***	-0.0063***	-0.0035***	-0.0058***	-0.005***	-0.007	-0.006
Fsi	-0.94**	-0.80**			-0.051**	-0.038**	-0.054	-0.033
Gsfci			-0.23***	-0.11***				
Embig	-0.016***	-0.007***	-0.0017**	-0.0006*	-0.08***	-0.008**	0.00	-0.0017
Kilian	0.005*	0.034**	0.0046*	-0.0240*	0.0016*	0.032*	0.045	0.027
Tot	0.25**	0.096*	0.02**	0.043**	0.047**	0.068**	0.054	0.062
Nb of transitions	1		1		1		1	
Smooth parameter γ	0.25		0.34		0.76		0.32	
Threshold (Forex)	30		31		15		130	
Obs > Threshold	50.95%		47.94%		43.86%		39.34%	

Notes: (*): significant at the 10% level; (**): significant at the 5% level and (***): significant at the 1% level. Regime 2 denotes the coefficients of each variable above the threshold parameter.

Table 14 Float sample 1995Q1-2015Q4_tot_kilian

	resm2				***resgdp***		***resdebt***	
	1	2	3	4	5	6	7	8
	(β_0)	(β_0+β_1)	(β_0)	(β_0+β_1)	(β_0)	(β_0+β_1)	(β_0)	(β_0+β_1)
Ca	-0.62 **	1.00**	-0.43**	1.00*	-0.15**	0.89**	-0.02**	0.74**
Bis inter	-0.16 **	-0.10**	-0.14**	-0.094**	-0.017**	-0.035**	-0.1*	-0.09*
Currency	-11**	-9.3**	-6.7***	-3.4**	-0.92***	-0.72***	-1.6**	-0.14**
Credit deposit	-2.4**	3.2**	-1.3***	3.8**	-16**	1.7**	-1.5**	1.6**
Credit gap	-0.41**	-0.17**	-0.49**	-0.26**	-0.17***	-0.024**	-0.25**	-0.07**
Uncertainty	-0.03**	-0.0001**	-0.028**	-0.0054**	-0.0064**	-0.0025**	0.00^{ns}	0.001*
Fsi	-0.16**	-0.011**			-0.23***	-0.150***	-0.24**	-0.1**
Gsfci			-1.30*	-0.62**				

Embig	-0.012***	-0.0054**	-0.009*	-0.0054*	-0.0033*	-0.0034**	-0.002**	-0.0003**
Kilian	0.041***	0.048**	0.041**	0.044**	0.0063**	0.0270**	0.001**	0.032**
Tot	0.023**	0.075*	0.025*	0.092*	0.015*	0.1*	0.04*	0.081*
Nb of transitions	1		1		1		1	
Smooth parameter γ	0.59		0.59		1.90		0.16	
Threshold (Forex)	31		31		16		120	
Obs > Threshold	45.53%		45.53%		46.66%		44.04%	

Notes: (*): significant at the 10% level; (**): significant at the 5% level and (***): significant at the 1% level. Regime 2 denotes the coefficients of each variable above the threshold parameter.

Table 15 Non OECD sample 1995Q1-2015Q4_tot_kilian

	resm2				***resgdp***		***resdebt***	
	1	2	3	4	5	6	7	8
	(β_0)	(β_0+β_1)	(β_0)	(β_0+β_1)	(β_0)	(β_0+β_1)	(β_0)	(β_0+β_1)
Ca	-0.16**	0.51***	-0.12**	0.36**	-2.3	0.097	-0.66***	0.46**
Bis inter	-0.024***	0.005*	-0.029***	0.01*	-0.078	0.013	-0.03***	-0.07*
Currency	-10*	6.2*	-6.5**	3.4*	-1.8	2.4	-2.2**	1.6**
Credit deposit	-2.4***	1.5**	-2.1***	0.26*	-5	2.1	-4.2**	3.4**
Credit gap	-0.059***	0.15**	-0.042***	0.023**	-0.74	0.059	-0.220**	0.19*
Uncertainty	-0.011***	-0.016**	-0.016**	-0.0097**	-0.01	-0.005	-0.004**	-0.005**
Fsi	-0.073***	-0.15**			-0.13	-0.12	-0.01*	-0.01*
Gsfci			-0.32**	-0.43**				
Embig	-0.0035*	-0.0017**	-0.0054*	-0.0049**	-0.003	0.00	-0.0023**	-0.001*
Kilian	-0.014*	0.023**	-0.013**	0.023**	0.006	0.028	0.024**	0.034**
Tot	0.066**	0.013**	0.019**	0.084**	0.079	0.06	0.0058**	0.012**
Nb of transitions	1		1		1		1	
Smooth parameter γ	0.36		0.40		0.18		0.37	
Threshold (Forex)	34		35		11		140	
Obs > Threshold	43.41%		41.26%		59.76%		41.58%	

Notes: (*): significant at the 10% level; (**): significant at the 5% level and (***): significant at the 1% level. Regime 2 denotes the coefficients of each variable above the threshold parameter.

Table 16 Peg sample 1995Q1-2015Q4_tot_kilian

	resm2				***resgdp***		***resdebt***	
	1	2	3	4	5	6	7	8
	(β_0)	($\beta_0+\beta_1$)	(β_0)	($\beta_0+\beta_1$)	(β_0)	($\beta_0+\beta_1$)	(β_0)	($\beta_0+\beta_1$)
Ca	-0.60**	-0.33**	-0.68**	-0.48**	-0.51**	0.37**	-1.1**	0.037**
Bis inter	-0.060**	-0.043**	-0.071**	-0.049**	-0.06**	-0.02**	-0.048**	-0.011**
Currency	-4.7**	-0.23***	-5**	-0.012**	-1.8**	-1.6*	-2.7**	-0.66***
Credit deposit	-3.9**	-0.17*	-5.1**	-0.56***	-5.6**	3.6*	-1.4**	-0.033**
Credit gap	-0.26**	-0.090**	-0.24**	-0.073**	-0.25**	-0.13**	-0.420**	-0.18**
Uncertainty	-0.0027*	-0.012*	-0.0073*	-0.0016*	-0.006*	-0.008*	-0.028*	-0.009*
Fsi	-0.18*	-0.088**			-0.04**	-0.02**	0.0061*	-0.002*
Gsfci			-0.26**	-0.032**				
Embig	-0.0017***	-0.0004*	-0.0034**	-0.0005**	-0.005***	-0.001*	-0.0057***	-0.0023**
Kilian	-0.001***	0.02**	-0.008*	0.015**	0.00074ns	0.025**	-0.038***	0.0027***
Tot	0.055*	-0.025**	0.02***	0.08**	0.05*	0.093**	0.1**	0.12**
Nb of transitions	1		1		1		1	
Smooth parameter γ	0.37		0.29		1.20		0.03	
Threshold (Forex)	27		28		15		130	
Obs > Threshold	61.01%		58.45%		35.83%		37.79%	

Notes: (*): significant at the 10% level; (**): significant at the 5% level and (***): significant at the 1% level. Regime 2 denotes the coefficients of each variable above the threshold parameter.

Table 17 Float sample 2008Q1-2010Q4

Specification 1		Specification 2		Specification 3				Specification 4			
1	2	3	4	5	6	7	8	9	10	11	12
(β_0)	($\beta_0+\beta_1$)	(β_0)	($\beta_0+\beta_1$)	(β_0)	($\beta_0+\beta_1$)	(β_0)	($\beta_0+\beta_1$)	(β_0)	($\beta_0+\beta_1$)	(β_0)	($\beta_0+\beta_1$)

	1	2	3	4	5	6	7	8	9	10	11	12
Ca	-2.1*	-1.4***	-0.89***	-0.4*	-1.9***	-0.91***	-0.94**	-0.36**	-0.73**	-0.31***	-1.7**	-0.92**
Bis inter	-2.3**	-1.2**							-4***	-2***	-1.1**	-0.61**
Currency			-0.54**	-0.45*	-0.13**	-0.63**	-13*	-5.2*				
Credit deposit	-0.44*	-0.22**	-0.41**	-0.22**	-0.23**	-0.06**	-50*	-25*	-0.39**	-0.13*	-21*	-11*
Credit gap	-1.2**	-0.61**	-1.6**	-0.9**	-2.2*	-1.1**	-0.78**	-0.39**	-0.23**	-0.17**	-0.29**	-0.14**
Uncertainty	0.140**	0.090**	0.39**	0.22*	-0.44*	-0.22*	-0.047**	-0.014**	-0.39**	-0.19**	-0.034**	-0.0012*
Fsi					-2.3*	-1.6**			-0.89**	-0.80**		
Gsfci							-5.8**	-3.5**			-7.4**	-4.9**
Embig	-0.055**	-0.043*	-0.10	-0.07								
Nb of transitions	1		1		1		1		1		1	
Smooth parameter γ	0.11		0.74		0.44		0.01		0.57		0.02	
Threshold (resm2)	32		32		31		31		31		31	
Obs > Threshold	45.8%		45.8%		48.7%		48.7%		48.7%		48.7%	

Notes: (*): significant at the 10% level; (**): significant at the 5% level and (***): significant at the 1% level. Regime 2 denotes the coefficients of each variable above the threshold parameter.

Table 18 Non OECD sample 2008Q1-2010Q4

	Specification 1		Specification 2		Specification 3				Specification 4			
	1	2	3	4	5	6	7	8	9	10	11	12
	(β_0)	($\beta_0+\beta_1$)	(β_0)	($\beta_0+\beta_1$)	(β_0)	($\beta_0+\beta_1$)	(β_0)	($\beta_0+\beta_1$)	(β_0)	($\beta_0+\beta_1$)	(β_0)	($\beta_0+\beta_1$)
Ca	-0.14**	-0.092*	-0.240*	-0.11***	-0.10***	0.023***	-0.43**	0.14**	-0.13***	-0.061*	-2.7**	-1.3**
Bis inter	-0.073**	-0.025**							-0.056**	-0.021**	-2.7**	-1.5**

Currency			-2.3***	-1.3*	-8.7***	-6.1***	4.4*	1.6*				
Credit deposit	-3.8**	-3**	-1.6**	-3.4**	-4.2***	-2.2***	-5.1**	-3.9**	-2.5**	-2.3**	-29**	-13*
Credit gap	-0.20**	-0.11**	-0.14**	-0.041**	-0.28**	-0.24**	-0.44**	-0.35**	-0.20**	-0.044*	-3.8**	-1.8**
Uncertainty	0.03**	0.038**	0.032**	0.044**	-0.004*	-0.003**	-0.028**	-0.017**	-0.007*	-0.004*	-0.22**	-0.12**
Fsi					-0.24**	-0.48**			-0.3***	-0.22**		
Gsfci							-0.52***	-0.42***			-2.2**	-0.094***
Embig	-0.011*	-0.0018**	-0.009**	-0.001*								
Nb of transitions	1		1		1		1		1		1	
Smooth parameter γ	2.7		3.3		0.33		4.8		44		0.39	
Threshold (resm2)	35		36		34		37		35		33	
Obs > Threshold	49.1%		46.6%		51.6%		45%		49.1%		55.2%	

Notes: (*): significant at the 10% level; (**): significant at the 5% level and (***): significant at the 1% level. Regime 2 denotes the coefficients of each variable above the threshold parameter.

Table 19 Peg sample 2008Q1-2010Q4

	Specification 1		Specification 2		Specification 3				Specification 4			
	1	2	3	4	5	6	7	8	9	10	11	12
	(β_0)	($\beta_0+\beta_1$)	(β_0)	($\beta_0+\beta_1$)	(β_0)	($\beta_0+\beta_1$)	(β_0)	($\beta_0+\beta_1$)	(β_0)	($\beta_0+\beta_1$)	(β_0)	($\beta_0+\beta_1$)
Ca	-0.31***	-0.15**	-0.54**	-0.18*	-0.44**	-0.20**	-0.30***	-0.11**	-0.32***	-0.067**	-0.31**	-0.085**
Bis inter	-0.024**	-0.008**							-0.033	0.018***	-0.058**	-0.0041**
Currency			-2.8*	0.15*	-5.3**	-0.51**	-7.1**	-0.6*				

Credit deposit	-3.7**	-0.51**	-7.9**	-3.1**	-0.52*	-0.06*	-6.2**	-0.74**	-6**	-0.6**	-1.4**	-0.47**
Credit gap	-0.46**	-0.12*	-0.57*	-0.065*	-0.60*	-0.27***	-0.67*	-0.59***	-0.35*	-0.31***	-0.45**	-0.33*
Uncertainty	0.015**	0.028**	0.002**	0.017**	-0.047**	-0.006***	-0.018**	-0.0035*	-0.036***	-0.005***	-0.023**	-0.03**
Fsi					-0.21***	-0.19***			-0.21**	-0.13**		
Gsfci							-0.26**	-0.12*			-0.27**	-0.0023*
Embig	-0.0083**	-0.0032**	-0.0073*	-0.0054*								
Nb of transitions	1		1		1		1		1		1	
Smooth parameter γ	0.44		0.53		14		2.5		7.6		5.9	
Threshold (resm2)	31		31		31		31		30		29	
Obs > Threshold	56.2%		56.2%		56.2%		56.2%		61.2%		66.2%	

Notes: (*): significant at the 10% level; (**): significant at the 5% level and (***): significant at the 1% level. Regime 2 denotes the coefficients of each variable above the threshold parameter.

Table 20 Full sample 2008Q1-2010Q4 (threshold variable: res/gdp)

	Specification 1		Specification 2		Specification 3		Specification 4	
	(β_0)	($\beta_0+\beta_1$)	(β_0)	($\beta_0+\beta_1$)	(β_0)	($\beta_0+\beta_1$)	(β_0)	($\beta_0+\beta_1$)
Ca	-0.061**	-0.014**	-0.15**	-0.045**	-0.37**	-0.17**	-0.27**	-0.088**
Bis inter	-0.033**	-0.025**					-0.044*	-0.022**
Currency			-5.7***	-1.7***	-6**	-3.1***		
Credit deposit	-3.2***	-0.71**	-3.7**	-1.3**	-6.4**	-15*	-4.1***	0.77**
Credit gap	-0.19*	-0.22**	-0.25**	-0.22*	-0.4*	-0.22**	-0.25***	-0.160**
Uncertainty	-0.005**	-0.002*	0.0036*	0.027**	-0.07**	-0.01**	-0.006**	-0.016*
Fsi					-0.39**	-0.260***	-0.064**	-0.025**
Embig	-0.003***	-0.014**	-0.0039**	-0.0035*				
Nb of transitions	1		1		1		1	

Smooth parameter γ	0.95	0.66	0.53	6.72
Threshold (Forex/gdp)	19	18	18	17
Obs > Threshold	44.79%	48.75%	48.75%	53.12%

Notes: (*): significant at the 10% level; (**): significant at the 5% level and (***): significant at the 1% level. Regime 2 denotes the coefficients of each variable above the threshold parameter.

Table 21 Float sample 2008Q1-2010Q4 (threshold variable: resgdp)

	Specification 1		Specification 2		Specification 3		Specification 4	
	(β_0)	($\beta_0+\beta_1$)	(β_0)	($\beta_0+\beta_1$)	(β_0)	($\beta_0+\beta_1$)	(β_0)	($\beta_0+\beta_1$)
Ca	-0.035^{**}	0.031^{**}	-0.10^{***}	-0.033^{**}	-0.15^{**}	-0.093^{**}	-0.61^{***}	-0.37^{***}
Bis inter	-0.054^{**}	-0.049^{**}					-0.13^{**}	-0.11^{**}
Currency			-2.1^{**}	-1.2^{**}	-1.8^{**}	-0.24^{**}		
Credit deposit	-7^{***}	-3.8^{***}	-8.1^{***}	-5.3^{**}	-20^{*}	-16^{*}	-20^{**}	-18^{**}
Credit gap	-0.45^{***}	-0.340^{**}	-0.43^{**}	-0.41^{**}	-0.21^{**}	-0.091^{**}	-0.60^{**}	-0.25^{**}
Uncertainty	-0.032^{**}	-0.0073^{**}	-0.027^{**}	-0.013^{*}	-0.027^{*}	-0.003^{*}	-0.02^{*}	0.021^{*}
Fsi					-0.14^{**}	-0.018^{**}	-0.16^{**}	-0.093^{*}
Embig	-0.0085^{*}	-0.01^{ns}	-0.0076^{*}	-0.0082^{*}				
Nb of transitions	1		1		1		1	
Smooth parameter γ	0.53		0.56		0.22		0.21	
Threshold (Forex/gdp)	21		21		21		22	
Obs > Threshold	37.91%		37.91%		37.91%		35.41%	

Notes: (*): significant at the 10% level; (**): significant at the 5% level and (***): significant at the 1% level. Regime 2 denotes the coefficients of each variable above the threshold parameter.

Table 22 Non_OECD sample 2008Q1-2010Q4 (threshold variable: resgdp)

	Specification 1	Specification 2	Specification 3	Specification 4

	(β_0)	(β_0+β_1)	(β_0)	(β_0+β_1)	(β_0)	(β_0+β_1)	(β_0)	(β_0+β_1)
Ca	-0.14**	-0.061**	-0.21**	-0.078**	-0.15**	-0.073**	-0.17**	-0.035*
Bis Inter	-0.028**	-0.0085*					-0.037**	-0.014**
Currency			-2.6**	-2.5***	-2.7**	-1.8**		
Credit Deposit	-6.1**	-0.32**	-3.5**	-0.82**	-4**	-2.4**	-13**	2.3**
Credit Gap	-0.15**	-0.083**	-0.36**	-0.17**	-0.35**	-0.083**	-0.19**	-0.15**
Uncertainty	0.011**	0.028**	0.01*	0.03*	-0.023**	-0.0078*	-0.013**	0.021*
Fsi					-0.039*	-0.190**	-0.170**	-0.1**
Embig	-0.001*	-0.005**	-0.03**	-0.01**				
Nb Of Transitions	1		1		1		1	
Smooth Parameter Γ	0.95		17		1.4		21	
Threshold (Forex/Gdp)	21		26		21		20	
Obs > Threshold	40%		25.55%		40%		43.88%	

Notes: (*): significant at the 10% level; (**): significant at the 5% level and (***): significant at the 1% level. Regime 2 denotes the coefficients of each variable above the threshold parameter.

Table 23 Peg sample 2008Q1-2010Q4 (threshold variable: resgdp)

	Specification 1		Specification 2		Specification 3		Specification 4	
	(β_0)	(β_0+β_1)	(β_0)	(β_0+β_1)	(β_0)	(β_0+β_1)	(β_0)	(β_0+β_1)
Ca	-0.21***	-0.023**	-0.21**	-0.022**	-0.19***	-0.081**	-0.23***	-0.21**
Bis inter	-0.019**	-0.02**					-0.081***	-0.053**
Currency			-4.9**	-3.4**	-5.9**	-3**		
Credit deposit	-3.2***	-1.9***	-7.2*	-1.3**	-7.1*	-0.79***	-2.4**	-1.1**
Credit gap	-0.045**	-0.006*	-0.044**	-0.021**	-0.018**	-0.22**	-0.24**	-0.12**
Uncertainty	0.0074*	0.027**	0.008*	0.028**	-0.007**	-0.004*	-0.037**	-0.0098*
Fsi					-0.78**	-0.15**	-0.13**	-0.089**
Embig	-0.003**	-0.0004^{ns}	-0.008*	-0.01**				

Nb of transitions	1	1	1	1
Smooth parameter γ	0.98	0.86	4.6	0.62
Threshold (Forex/gdp)	21	21	22	15
Obs > Threshold	35.83%	35.83%	33.33%	62.91%

Notes: (*): significant at the 10% level; (**): significant at the 5% level and (***): significant at the 1% level. Regime 2 denotes the coefficients of each variable above the threshold parameter.

Table 24 Full sample 2008Q1-2010Q4 (threshold variable: resdebt)

	Specification 1		Specification 2		Specification 3		Specification 4	
	(β_0)	($\beta_0+\beta_1$)	(β_0)	($\beta_0+\beta_1$)	(β_0)	($\beta_0+\beta_1$)	(β_0)	($\beta_0+\beta_1$)
Ca	-0.35**	-0.15**	-0.054*	0.031*	-0.26**	-0.10**	-0.87**	-0.42**
Bis Inter	-0.32**	-0.29**					-0.15**	-0.069***
Currency			-8.9**	7**	29*	12*		
Credit Deposit	-13***	-7**	-6.3**	-3.6**	-3.2**	12*	-23**	-13**
Credit Gap	-0.2**	0.045**	-0.89**	-0.39**	-0.46**	-0.23**	-0.62**	-0.28*
Uncertainty	-0.11**	-0.024**	-0.15**	-0.045*	-0.140**	-0.029**	-0.1**	-0.012*
Fsi					-0.46**	0.051*	0.056**	-0.26**
Embig	0.043**	-0.011**	0.062**	0.02*				
Nb Of Transitions	1		1		1		1	
Smooth Parameter Γ	0.19		0.13		0.27		0.17	
Threshold (Forex/Short Term Debt)	140		150		150		140	
Obs > Threshold	42.91%		40.83%		40.83%		42.91%	

Notes: (*): significant at the 10% level; (**): significant at the 5% level and (***): significant at the 1% level. Regime 2 denotes the coefficients of each variable above the threshold parameter.

Table 25 Float sample 2008Q1-2010Q4 (threshold variable: resdebt)

	Specification 1		Specification 2		Specification 3		Specification 4	
	(β_0)	$(\beta_0+\beta_1)$	(β_0)	$(\beta_0+\beta_1)$	(β_0)	$(\beta_0+\beta_1)$	(β_0)	$(\beta_0+\beta_1)$
Ca	-0.18**	0.11**	-0.20**	0.25**	-0.091**	-0.017*	-0.018**	0.21*
Bis Inter	-0.35**	0.12*					-0.035**	-0.012**
Currency			-0.71***	7.8*	-7.5***	-6.2***		
Credit Deposit	-1.5**	-1.3**	-0.38***	-0.28**	-1.8**	-3.9**	-0.47**	4ns
Credit Gap	-0.15**	-0.049***	-0.15**	-0.081**	-0.24**	-0.18**	-0.18**	-0.028*
Uncertainty	0.0250ns	0.024*	-0.012**	-0.01*	-0.035***	-0.021***	-0.031***	-0.001**
Fsi					-0.23**	-0.16**	-0.19**	-0.14**
Embig	-0.005*	-0.017*	-0.045***	-0.015**				
Nb Of Transitions	1		1		1		1	
Smooth Parameter Γ	0.75		1.4		3.80		0.26	
Threshold (Forex/Short Term Debt)	140		140		140		140	
Obs > Threshold	45.83%		45.83%		45.83%		45.83%	

Notes: (*): significant at the 10% level; (**): significant at the 5% level and (***): significant at the 1% level. Regime 2 denotes the coefficients of each variable above the threshold parameter.

Table 26 Non-OECD sample 2008Q1-2010Q4 (threshold variable: resdebt)

	Specification 1		Specification 2		Specification 3		Specification 4	
	(β_0)	$(\beta_0+\beta_1)$	(β_0)	$(\beta_0+\beta_1)$	(β_0)	$(\beta_0+\beta_1)$	(β_0)	$(\beta_0+\beta_1)$
Ca	-0.12**	-0.062***	-0.24***	-0.10**	-0.22**	-0.078**	-1.3**	-0.61**
Bis Inter	-0.079**	-0.028**					-1.3***	-0.77**
Currency			-14*	-4.2*	-6.7***	-4.3***		
Credit Deposit	-4.8***	-1.4**	-3.2**	-0.14**	-2.4**	-0.69**	-22**	-12**
Credit Gap	-0.56**	-0.20**	-0.60**	-0.015**	-0.44**	-0.083*	-6.2***	-3**
Uncertainty	-0.048***	-0.0093*	-0.04***	-0.003*	-0.025**	-0.021**	-0.28***	-0.13***
Fsi					-0.42***	-0.34***	-1.4**	-0.43**
Embig	-0.0075**	-0.0068**	-0.009**	-0.002**				

Nb Of Transitions	1	1	1	1
Smooth Parameter Γ	0.87	0.10	0.12	0.31
Threshold (Forex/Short Term Debt)	180	190	160	180
Obs > Threshold	45.27%	43.33%	47.77%	45.27%

Notes: (*): significant at the 10% level; (**): significant at the 5% level and (***): significant at the 1% level. Regime 2 denotes the coefficients of each variable above the threshold parameter.

Table 27 Peg sample 2008Q1-2010Q4 (threshold variable: resdebt)

	Specification 1		Specification 2		Specification 3		Specification 4	
	(β_0)	($\beta_0+\beta_1$)	(β_0)	($\beta_0+\beta_1$)	(β_0)	($\beta_0+\beta_1$)	(β_0)	($\beta_0+\beta_1$)
Ca	-0.29***	-0.18***	-0.40***	-0.27**	-0.46***	-0.30**	-0.57***	-0.24**
Bis Inter	-0.33***	-0.18**					-0.35***	-0.19**
Currency			-9.3**	-6.2**	-8***	-6.7**		
Credit Deposit	-14*	-8.6**	-44***	-27***	-14***	-12**	-15***	-8.5**
Credit Gap	0.16*	-0.09**	-0.14**	-0.11**	-0.05**	-0.10**	0.067*	0.024*
Uncertainty	-0.029***	-0.012**	-0.017**	0.0056*	-0.06**	-0.05***	-0.035**	-0.030**
Fsi					-0.22***	-0.068**	-0.16***	-0.13**
Embig	0.025^{ns}	-0.0043*	-0.003*	-0.004*				
Nb Of Transitions	1		1		1		1	
Smooth Parameter Γ	0.64		0.62		0.17		0.58	
Threshold (Forex/Short Term Debt)	120		140		160		140	
Obs > Threshold	42.5%		40%		36.66%		40%	

Notes: (*): significant at the 10% level; (**): significant at the 5% level and (***): significant at the 1% level. Regime 2 denotes the coefficients of each variable above the threshold parameter.