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Abstract

In this paper we adopt a non linear approach to examine the dynamics of the international reserves holdings by the emerging economies. To do so, we estimate the demand for international reserves with a panel smooth transition model, that loosens two restricting hypotheses, homogeneity and time-stability. We find evidence for the presence of a non linear behavior in the demand for international reserves, a result that is new to the literature. The coefficients are found to change smoothly, as a function of two threshold variables- out of seven candidates tested in total. Our specification accounts for the acceleration of foreign exchange reserves accumulation that the linear specifications fail to explain.

Key Words : International Reserves, Precautionary Demand, Mercantilist, Global Imbalances, Panel Smooth Threshold Regression Models.

J.E.L Classification: C23, E58 F31, F41.

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1 Introduction

It is important to understand the determinants of the demand for international reserves by the emerging countries because their recent sharp accumulation has distorted global balances. The supply of official savings from emerging economies has more than offset the effect of the American current account deficit and led to a fall in global interest rates (Bernanke, 2005). Obviously the financial crisis has changed the picture. The surge in fiscal deficits to restore growth in major developed countries will probably put an upward pressure on long term interest rate. In this context, the pace of accumulation (or desaccumulation) of reserves will influence the pattern of the new global monetary equilibrium in the aftermath of the financial crisis.

And yet, despite an abundant literature that originates in Heller (1966), the different empirical works on international reserves holdings fail to explain the following: global reserves have increased from 1 trillion US dollar in 1990 to 6 trillion in 2008, two third of this growth was driven by the emerging countries where reserves have grown by more than 20% a year from 2003.

In this paper, we investigate the determinants of the demand for international reserves with a panel smooth transition model (PSTR[1]) that has the great advantage to allow parameters to vary across countries and time. In sum we loosen two restricting assumptions of the existing empirical works that may be responsible for their shortfall. To do so, we investigate the general specification proposed by Aizenman and Lee (2007) who used a linear homogeneous strategy to explain the demand for international reserves. We construct the regression variables rigorously as they did and estimate the model on 20 emerging countries during the 1980-2004 period.

The PSTR specification loosens homogeneity and time-stability hypotheses and allows the parameters to change smoothly as a function of a threshold variable. In the empirical part, we consider seven "candidates" for the threshold variable, four of which to test the standard distinction between *mercantilist* and *precautionary* concerns (Aizenman and Lee, 2007). The mercantilist concerns focuses on hoarding reserves to defend export competitiveness while the precautionary literature considers the international reserves holdings as a way to hedge against balance of payment instability. In addition we include three threshold variables to test the indirect influence of the macroeconomic

[1]For other application of the PSTR specification, see Fouquau, Hurlin and Rabaud (2008), Bessec and Fouquau (2008).

conditions in the United States (US henceforth). This hypothesis stems from the central role played by the US dollar in the current international monetary system.

We find evidence for the presence of a non linear behavior in the demand for international reserves, a result that is new to this literature. Additional major results are the following: non-linearity is best rejected when the deviation of the real exchange rate to its purchasing power parity value is used as a threshold variable. This deviation is used as a proxy of the country's international price competitiveness, a key variable of the export-led growth model that most emerging countries have adopted in the aftermath of the Asian crisis. In turn, we find that the degree of capital account liberalization is not a proper variable to account for non-linearity. In sum, we find that the acceleration of international reserves accumulation in the merging countries stems from their adoption of export-led growth strategies rather than from capital account liberalization.Our results thus support the mercantilist rather than precautionary motives, contrary to Aizenman and Lee (2007). Moreover our results highlight the influence of the US macroeconomic context, a fact that complements the mercantilist view. The elasticity of most determinants of the international reserves holdings increases along the deterioration of the US balance of payment and the subsequent slide of the US dollar. Our results suggest that the recent surge in international reserves in the emerging countries is a corollary of major US macroeconomic imbalances. It contrasts sharply with the lead followed by Obstfled, Shambaugh and Taylor (2008) who explain the recent surge in emerging economies by precautionary motives to protect their economy against double drain defined as followed: "a combination of internal drains (runs from bank deposits to currency) and external drains (flight to foreign currency or banks)". In sum their view suggests a proactive management of the foreign exchange reserves along adequacy ratio. In turn our results support a passive accumulation by central banks in the emerging economies, subject to the variation of an exogenous variable, i.e. the US macroeconomic conditions.

Next session presents the linear specification that we use to introduce the standard model, section 3 introduces the PSTR specification and section 4 explains the linearity and specification tests. In section 5 we present the data and specification that we investigate and session 6 provides the results of the estimation. Section 7 concludes.

2 Linear specification of international reserves demand

The issue of the determinants of the demand for international reserves has been abundantly debated in the literature and yet there is no consensus on the question. They can be grouped into two broad categories, the *mercantilist* and the *precautionary* motives (Aizenman and Lee, 2006). Along the first argument, the countries hoard international reserves to limit the appreciation of their currencies and maintain exports competitiveness (Dooley, Folkerts-Landau and Garber, 2003). In turn, the mercantilist view focuses on international reserves hoarding to get an insurance against unstable balance-of-payment (Bird and Rajan, 2003).

We investigate the relationship of Aizenman and Lee (2007) who used a linear homogeneous strategy to explain the demand for international reserves. Later we will loosen these restricting hypotheses, homogeneity and time-stability, and explain our motivations to provide a non-linear specification. Aizenman and Lee (2007) compared the importance of precautionary versus mercantilist motives in a single specification[2] :

$$\begin{aligned} Res_{it} = \beta_0 &+ \beta_1 Pop_{it} + \beta_2 Open_{it} + \beta_3 ER\ Volat_{it} \\ &+ \beta_4 EXGrowth_{it} + \beta_5 PL.\ Dev_{it} + \beta_6 KAcc_{it} \\ &+ \beta_7 TOT_{it} + \beta_8 CrisisDum + \epsilon_{it} \end{aligned} \tag{1}$$

for $i = 1, \ldots, N$ and $t = 1, \ldots, T$, where N and T design the cross-section and the time dimensions of the panel. In Eq (1), foreign reserves holdings motivated by mercantilist concerns are positively correlated with higher export growth rate (EX Growth). In addition, if a country holds reserves to manipulate its real exchange rate, the reserves are positively correlated to the deviation of the real exchange rate to its PPP value (PL Deviation[3]). More precisely, a country with a depreciated real exchange rate hoards reserves to move its real exchange rate away from the PPP value. On the contrary, a country with an over-appreciated exchange rate accumulates reserve to limit the appreciation.

On the other hand, reserves holdings motivated by precautionary concerns are positively correlated with the degree of capital account liberalization (K

[2]All variables are in log except Export growth.

[3]Defined as the fitted value from the regression of the national price levels to the relative income- the PPP-based real per-capita income relative to the United States. We refer the readers to Aizenman and Lee (2007) for more details on the computation of this variable.

Acc) and dummies that capture two important balance-of-payment crises, the Mexican and Asian crises. The inclusion of dummies test wether emerging countries have built-up reserves in reaction to the past crises and get protected against future crises.

The inclusion of Population is a scaling variable measure to capture the size effect on international reserves holdings. Reserve holding is positively correlated with the country's population because they increase with the size of international transactions. In addition, reserves accumulation is positively correlated with the ratio of imports to GDP (Open) to account for the classic argument according to which international reserves are held in proportion of a number of months of imports so that they may substitute to exports receipts in case of a current account crisis (Heller, 1966, Frenkel, 1974). Greater flexibility in the exchange rate (ER Volat) is negatively correlated with reserves holdings because it reduces the need for reserves. Last the terms of trade (TOT) are positively correlated to reserves if countries absorb their fluctuations through reserves holdings.

In this paper, we keep Aizenman and Lee (2007)'s specification and add the log of the ratio of short-term external debt to GDP (Debt) as an additional variable to Eq (1). Indeed the growth of capital markets and the accrued liberalization of capital accounts have generated more balance-of-payment instability (Bird and Rajan, 2003). Countries with a large stock of short-term debt and an open capital account, accumulate international reserves to smooth the adjustment process in case of *sudden stops* episodes. In sum, countries accumulate international reserves to get extra liquidity in the event of a crisis that isolates them from the international capital markets (Aizenman and Lee 2007) and triggers a domestic capital flight (De Beaufort, Winjholds and Kapteyn, 2001, Obstfeld, Shambaugh and Taylor, 2008). These last determinants have received considerable attention after 1999 when Pablo Guidotti and Alan Greenspan proposed to incorporate the short-term foriegn-currency debt to determine the adequate ratio of international reserves (Greenspan, 1999). The estimated model is given by Eq (2):

$$\begin{aligned} Res_{it} = \beta_0 &+ \beta_1 Pop_{it} + \beta_2 Open_{it} + \beta_3 Debt_{it} + \beta_4 EXGrowth_{it} \\ &+ \beta_5 PLDev_{it} + \beta_6 KAcc_{it} + \beta_7 TOT_{it} + \epsilon_{it} \end{aligned} \quad (2)$$

In addition, we have dropped the exchange rate volatility because it is time-constant[4] and its impact is accounted for in the country-specific fixed effects

[4]ER Volatility is a standard deviation of the monthly percentage change in the exchange

that we will insert in the estimation. Last Eq (2) excludes the crisis dummies because they introduce the idea of non-linearity. However we use a more general methodology to account for these effects or more sophisticated ones. Indeed, according to Aizenman and Lee (2007)'s results, to remove the dummies does not change the significance and value of the other estimators (see Aizenman and Lee, 2007, Estimation IV in Table 2, p. 24).

We use eq (2) as a benchmark to check that the coefficients are consistent with literature and so that in case we find non-linearity, this is not due to a different sample[5]. Table 3 that reports the estimation's results of the linear specification confirms the consistence of our sample. Indeed the sign of all coefficients is the same as in Aizenman and Lee (2007)[6]. As in hte literature we find that debt does not explain international reserves. This result is common in linear estimations (Jeanne and Rancière, 2006) and is probably due to the decrease in the ratio of external debt in most countries during the period while the reserves holdings were increasing sharply. We will check in the estimation part that this variable has a non-linear effect on the international reserves.

Eq (2) has two major drawbacks. It assumes homogeneous and time-constant coefficients across the N countries of the panel, i.e. $\beta_{i,t} = \beta, i = 1, ...N$. It is indeed highly restricting and unrealistic to assume that, for instance, all countries accumulate the same amount of international reserves in proportion to their external debt while each country may have a different risk aversion. Moreover, the rapid accumulation of international reserves in the last decade suggests that the weight of estimators may have changed during the period.

Generally, heterogeneity and time variability issues cannot be dealt with at the same time. For instance, it is possible to consider a heterogeneous panel model by assuming that the parameters β_{it} are randomly distributed (for a presentation of random coefficients models, see Hsiao and Pesaran, 2004). It implies that heterogeneity is the consequence of unspecified structural factors. In other words it is impossible to understand the factors of

rate against the dollar while the country-specific effects

[5]We use similar data and a slightly longer samplethan Aizenman and Lee (2007). They are introduced in section 5.

[6]Contrary to Aizenman and Lee (2007) we expect the sign of PL dev to be positive only but our interpretation is the same. It is because we keep unchanged the sign of the residuals in the regression described in not 2 while they transform the serie by taking its absolute value.

heterogeneity.

On the contrary, we assume that there are different factors that can explain the variability of the coefficients. For example, the degree of capital account liberalization may change the elasticity between international reserves and the ratio of external debt to GDP. If reserve holdings are driven by precautionary concerns, the elasticity between short term debt and international reserves should increase with the degree of capital openness, because the more countries are open, the more vulnerable to sudden stop. We will verify this particular result related to the external debt in Section 4. This idea clearly matches the definition of a threshold regression model: "threshold regression models specify that individual observations can be divided into classes based on the value of an observable variable" (Hansen, 1999, page 346).

Our solution to circumvent these issues consists in introducing threshold effects in a linear panel model. In this context, we use a Panel Smooth Threshold Regression (PSTR) model proposed by Gonzalez et al. (2005). The following section will introduce the specification that we investigate in this paper.

3 Threshold Effects in International Reserves Holdings

In this section we present the PSTR specification to explain the demand for international reserves[7]:

$$Res_{it} = \alpha_i + \beta_0 X_{it} + \beta_1 \ X_{it} \ g(q_{it}; \gamma, c) + \epsilon_{it} \tag{3}$$

for $i = 1, \ldots, N$ and $t = 1, \ldots, T$, where N and T design the cross-section and the time dimensions of the panel, to simplify the equation (3) $X_{it} = [pop_{it}, open_{it}, debt_{it}, growth_{it}, Pldev_{it}, KAcc_{it}, Tot_{it},]$ is the vector of explicative variables i^{th} country at time t. The residual ϵ_{it} is assumed to be $i.i.d.\,(0, \sigma_{\varepsilon}^2)$. To explain simply the mechanism of transition, let us consider first a brutal transition (PTR model) as in Hansen (1999). In this case, the

[7]For other application of the PSTR specification, see Fouquau, Hurlin and Rabaud (2008), Bessec and Fouquau (2008).

function $g(.)$ equals an indicator function:

$$g(q_{it}; c) = \begin{cases} 1 & \text{if } q_{it} \geq c \\ 0 & \text{otherwise} \end{cases} \tag{4}$$

In this model, the transition mechanism between extreme regimes is very simple: at each date, if the threshold variable q_{it} (example. the export growth) observed for a given country is smaller than a given value, called the location parameter c, the international reserves demand of the country is defined by a particular model (or regime); this regime is different if the growth of the exportations is larger than this location parameter. More precisely, the coefficient of PL. Deviation is equal to β_0 if export growth is smaller than c and to $\beta_0 + \beta_1$ if export growth is larger. In our application, the coefficient β_0 associated with slow or negative export growth is expected to be null or small and positive, whereas $\beta_0 + \beta_1$ prevailing in large exporter countries should be positive and higher. Indeed, the large exporter countries associated with high export growth are likely to manipulate their real exchange rate to support their export-led growth strategy. In this paper, we consider seven "candidates" for the threshold variable in order to test three different hypotheses: the precautionary versus the mercantilist motives as well as the US international position an explanation of the threshold effect.

However in the Eq (4) and (3) the PTR model imposes that the relationship can be divided into a (small) finite number of classes. Usually the number of regimes is set to a maximum of 4, for computational aspects.

As common in the literature on threshold panel data, we circumvent this issue in considering a logistic transition function (LPSTR model) which allows the existence of an infinite number of regimes :

$$g(q_{it}; \gamma, c) = \frac{1}{1 + \exp\left[-\gamma(q_{it} - c)\right]} \quad , \gamma > 0 \tag{5}$$

where c denotes a location parameter and parameter γ determines the slope of the transition function. In the two cases, the transition function $g(.)$ is a continuous function bounded between 0 to 1. Figure depicts this transition function for various values of the slope parameter γ.

The logistic function in (5) has a S-shape (Figure 1). It represents a smooth transition from an inferior regime (with low export growth) to a superior one (where the coefficient increases) with an infinite number of intermediate regimes in between. The γ parameter determines the smoothness i.e. the speed of the transition from one regime to the other one. When the γ parameter tends to infinity, the transition function $g(q_{it}; \gamma, c)$ tends to the indicator function (equation 4) and thus the LPSTR model corresponds to the PTR model. In contrast, when γ tends to zero, the transition function $g(q_{it}; \gamma, c)$ is constant and the model reduces to the standard linear model with individual effects (the so-called "within" model).

The PSTR model has the great advantage to allow parameters to vary across time and countries given the threshold variable. More precisely, the coefficient is defined as a weighted average of the parameters β_0 and β_1:

$$e_{it} = \frac{\delta Res_{it}}{\delta X_{it}} = \beta_0 + \beta_1 \; g(q_{it}; \gamma, c) \tag{6}$$

Consequently, this specification allows for an evaluation of the influence of variables X_{it} on the demand for international reserves according to the level of q_{it}. There is a caveat the reader should be aware of: the coefficient in a PSTR model can be different from the estimated parameters defined in the extreme regimes, i.e. the parameters β_0 and $\beta_0+\beta_1$, as illustrated by equation (6). It is preferable to interpret the sign of these parameters, which indicates (i) an increase or a decrease in the estimator depending on the value of the threshold variable (e.g. export growth) and (ii) the varying coefficient in the time and individual dimensions given by equation (6).

The PSTR model can be generalized to $r + 1$ extreme regimes as follows:

$$Res_{it} = \alpha_i + \beta_0 X_{it} + \sum_{j=1}^{r} \beta_j X_{it} \; g_j(q_{it}; \gamma_j, c_j) + \epsilon_{it} \tag{7}$$

where the r transition functions $g_j(q_{it}; \gamma_j, c_j)$ depend on the slope parameters γ_j and on location parameters c_j. In this generalization, if the threshold variable q_{it} is different from S_{it}, the coefficient for the i^{th} country at time t is defined by the weighted average of the $r + 1$ parameters β_j associated to the $r + 1$ extreme regimes:

$$e_{it} = \frac{\delta Res_{it}}{\delta X_{it}} = \beta_0 + \sum_{j=1}^{r} \beta_j \; g_j(q_{it}; \gamma_j, c_j) \tag{8}$$

In total, this specification takes into account the estimators heterogeneity and time-instability. This is because we allow the estimator to depend on exogenous variables, i.e. the threshold variable. To our knowledge, this econometric procedure is novel in its application to international reserves determinants studies. Next session introduces the linearity test and the sequential procedure to identify the number of regimes.

4 Estimation and specification tests

The estimation of the PSTR model consists of several stages. In the first step, a linearity test is applied and the threshold specification with one transition function is estimated. Then, if the linear specification is rejected, the optimal number of transition functions is determined by conducting tests of no remaining non-linearity. Regardless of the choice of the transition function, the estimation of the parameters of the PSTR model requires eliminating the individual effects α_i by removing individual-specific means and then applying non linear least squares to the transformed model (see Gonzàlez et al., 2005 or Colletaz and Hurlin, 2006 for more details).

Following the procedure of Gonzàlez et al. (2005), testing the linearity in a PSTR model (equation 3) can be done by testing $H_0 : \gamma = 0$ or $H_0 : \beta_0 = \beta_1$. In both cases, the test is non standard since the PSTR model contains unidentified nuisance parameters under H_0 (Davies, 1987). This issue is well known in the literature devoted to time series threshold models. A possible solution is to replace the transition function $g(q_{it}; \gamma, c)$ by its first-order Taylor expansion around $\gamma = 0$ and to test an equivalent hypothesis in an auxiliary regression. We then obtain:

$$Res_{it} = \alpha_i + \theta_0 \ X_{it} + \theta_1 \ X_{it} \ q_{it} + \epsilon^*_{it} \tag{9}$$

In these auxiliary regressions, parameters θ_1 and θ_2 are proportional to the slope parameter γ of the transition function. Thus, testing the linearity against the PSTR simply consists in testing $H_0 : \theta_1 = 0$ in (9) for a logistic function. If SSR_0 denotes the panel sum of squared residuals under H_0, i.e. in the linear panel model with individual effects and SSR_1 the panel sum of squared residuals under H_1, i.e. in the transformed PSTR model with two regimes, the corresponding LM statistic is then defined by:

$$LM_F = (SSR_0 - SSR_1) / \left[SSR_0 / (TN - N - 1) \right] \tag{10}$$

Under the null hypothesis, the F-statistic has an approximate $F(1, TN - N - 1)$ distribution. The logic is similar when it comes to testing the number of transition functions in the model or equivalently the number of extreme regimes. The idea is as follows: we use a sequential approach by testing the null hypothesis of no remaining nonlinearity in the transition function.

For instance let us assume that we have rejected the linearity hypothesis. The second step is then to test whether there is one transition function (H_0 :

$r = 1$) or whether there are at least two transition functions ($H_0 : \; r = 2$). Recall that a model with $r = 2$ is defined as:

$$Res_{it} = \alpha_i + \beta_0 X_{it} + \beta_1 \; X_{it} \; g_1(q_{it}; \gamma_1, c_1) + \beta_2 \, X_{it} \, g_2(q_{it}; \gamma_2, c_2) + \epsilon_{it} \quad (11)$$

The testing procedure consists in replacing the second transition function by its first-order Taylor expansion around $\gamma_2 = 0$ and testing linear constraints on the parameters. If we use the first-order Taylor approximation of $g_2(q_{it}; \gamma_2, c_2)$, the model becomes:

$$Res_{it} = \alpha_i + \beta_0 X_{it} + \beta_1 \; X_{it} \; g_1(q_{it}; \gamma_1, c_1) + \theta_1 \; X_{it} \; q_{it} + \epsilon^*_{it} \quad (12)$$

and the test of no remaining nonlinearity is simply defined by $H_0 : \theta_1 = 0$. Let us denote SSR_0 the panel sum of squared residuals under H_0, i.e. in a PSTR model with one transition function. Let us denote SSR_1 the sum of squared residuals of the transformed model (equation 12). As in the previous examples, the F-statistic LM_f can be calculated in the same way by adjusting the number of degrees of freedom. The testing procedure is then as follows. Given a PSTR model with $r = r^*$, we test the null $H_0 : r = r^*$ against $H_1 : r = r^* + 1$. If H_0 is not rejected the procedure ends. Otherwise, the null hypothesis $H_0 : r = r^* + 1$ is tested against $H_1 : r = r^* + 2$. The testing procedure continues until the first acceptance of H_0. Given the sequential aspect of this testing procedure, at each step of the procedure the significance level must be reduced by a constant factor $0 < \rho < 1$ in order to avoid excessively large models. We assume $\rho = 0.5$ as suggested by Gonzàlez et al. (2005).

Next session presents data and the results of linearity and specification tests.

5 Data and specification results

The estimation is based on a unbalanced panel of 20 emerging countries[8] during the 1980-2004 period. The sources of the data are the World Development Indicators (WDI) and Penn World. We constructed the regression variables rigorously as Aizenman and Lee (2007) except for the index of capital account openness constructed by Edwards (2005). Instead we use the publicly

[8]The primary sample included 24 emerging countries to be consistent with the estimation of Aizenman and Lee (2007). However we dropped 4 countries for a lack of data. They are: Argentina, Brazil, Chile, Colombia, Hungary, Indonesia, Malaysia, Mexico, Pakistan, Peru, Philippines, Poland, South Africa, Thailand, Venezuela, Algeria, China, Egypt, India, and Morocco.

and longer spanned index proposed by Lane and Milesi-Ferreti (2006). The definitions of the data are reproduced in the appendix. We added the log of short-term external debt to GDP ratio (WDI database) as an additional explanatory variable to their model.

The last step but not least before estimating a PSTR model is to identify the threshold variables in order to capture model's non-linearity. Recall that PSTR specification of the demand for international reserves is the following:

$$Res_{it} = \alpha_i + \beta_0 X_{it} + \beta_1 \ X_{it} \ g(q_{it}; \gamma, c) + \epsilon_{it} \tag{13}$$

We consider seven "candidates" for the threshold variable q_{it}. The first group of variables includes domestic variables, the second, US macroeconomic variables. This is to test whether the central banks in the emerging countries are influenced by the domestic macroeconomic context and/or the US context when they decide to accumulate international reserves.

In the domestic variables, we test which variable may influence the central bank decision by keeping the standard distinction between mercantilist and precautionary concerns. That is, we examine the influence of export growth and price level deviation (PL. dev) on the one hand, and capital account liberalization and debt on the other hand It is important to note that we will focus on the effect of the threshold variable on four determinants, i.e. capital account, debt, export growth and the PL. deviation. The threshold effect is expected to be null or marginal on the control variables, i.e. population, openness and terms of trade.

In model I, we will test the influence of PL. dev as a threshold variable. This is the most complex transition mechanism. Precisely, we will assess the influence of the exchange rate misalignment (the distance to PPP value) on mercantilist behavior. We expect the countries with highly over-appreciated exchange rate to compensate export growth by holding more reserves than countries close to their PPP value (the elasticity between reserves and export growth should increase). This is because, according to the mercantilist view, the central bank with over-appreciated exchange rate intervene on the exchange rate market to slow down their currency appreciation. The contrary holds for countries with under-appreciated exchange rate: we expect the countries with under-appreciated exchange rate to accumulate less reserves when the exchange rate is far from the PPP value (the elasticity between reserves and export growth should decrease). This is because countries with under-appreciated exchange rate wish to keep it away from the PPP value by hoarding international reserves. In sum, if the mercantilist view holds, we should find three regimes with a sharp transition as in a PTR model *à la* Hansen (1999). Indeed when PL. Dev is negative (below the PPP value) and small, the elasticity between reserves and export growth is small (first regime). It increases along with PL. dev (second regime). When PL. dev gets positive value (i.e. the exchange rate is over-appreciated) countries compensate even more export growth by hoarding reserves.

In model II, we will test the influence of export growth as a threshold variable. It is expected to influence the elasticity between international reserves and PL. dev. As a matter of fact, the largest exporter countries are the most likely to follow an export-led growth strategy. According to the mercantilist view, large exporters intervene on the foreign exchange (forex) market to limit the appreciation of their currency and defend their export competitiveness. Therefore the elasticity between international reserves and PL. dev should increase along the export growth.

In model III, we will test the influence of the degree of capital account openness as a threshold variable. In particular, we will measure its impact on the proportion of international reserves accumulated to hedge the external debt against external shocks. The more open the capital account, the more countries are vulnerable to capital flight episodes. Therefore according to the precautionary literature, liberalized countries should accumulate more reserves in proportion of their external debt than closed countries (the elasticity between international reserves and debt should increase along capital account). In addition we expect the threshold variable to influence its own elasticity (the elasticity between international reserves and capital account should increase along capital account).

In model IV that includes debt as a threshold variable, we test differently a similar idea. We measure the influence of the level of the external debt on the elasticity between international reserves and capital account. According to the precautionary view, largely indebted countries are expected to be more sensitive to their vulnerability to capital flight episodes (the elasticity between international reserves and capital account should increase along debt). In addition largely indebted countries should build up international reserves with their export receipts (the elasticity between international reserves and export should increase along debt).

In model V to VII, we test the influence of the macroeconomic conditions in the United States (US henceforth) as a threshold variable. Three variables capture the international position of the US and are used to test the same common idea. It stems from the central role played by the US dollar in the current international monetary system. As it has been observed, the accumulation of reserves by the emerging countries has recently offset the American deficit and limited the depreciation of the US dollar. We can check if it was done along sheer mercantilist concerns, namely to defend the peg. To do so, we examine the effect of the US macro variables on the elasticity between international reserves and export growth. For example, in model V, that includes the current account position of the United States, we expect that the larger the US current account deficit, the more the central banks in emerging countries accumulate international reserves to limit their currency appreciation (i.e. the US dollar depreciation) and maintain their competitiveness.

The US macroeconomic context may also influence the elasticity between international reserves and debt. The worse the international position of the United States, i.e., the more they absorb international savings to finance their deficits, the less the emerging countries can borrow money on the international capital market. Therefore the elasticity between international reserves and debt should decrease along with the deterioration of the US international position. We test alternatively the current account balance (as a proportion of GDP), the savings (as a proportion of GDP) and the US real interest rate to capture the international position of the US[9]. The choice of the savings rate is justified by the textbook relationship between national savings and current account balance. The relationship between the real interest rate and the current account balance is understood in a model linking the money market and the exchange rate market[10]. The international position of the United States deteriorates when the current account balance deteriorates (US macro 1 decreases), the savings rate rate (US macro 2) decreases and the real interest rate (US macro 3) decreases. Last it is the right place to mention that these threshold variables do not depend on individuals ($q_{it} = q_t$). This allows to take into account only non-linearity and time-instability but not heterogeneity across the countries.

[9]In the literature, the US real interest rate is usually introduced to measure the effect of opportunity costs of holding international reserves. However it would not be relevant to interpret this threshold variable as an opportunity cost because a threshold effect has only indirect effects on the coefficient of the explanatory variables. Basically, the opportunity cost has no expected effect on the elasticity between international reserves and export growth, K account or debt.

[10]See for example Krugmman and Obstfeld, International Economics, Ed 11th, 2008.

For each model, the first step is to test the linear specification of international reserve holdings against a specification with threshold effects. If the linearity hypothesis is rejected, the second step will determine the number of transition functions required to capture non-linearity. The results of these tests are reported in Table 2. For each specification, the LM statistics for the linearity tests (H_0: $r = 0$ versus H_1: $r = 1$) and for the no remaining non-linearity tests (H_0: $r = a$ versus H_1: $r = a + 1$) are computed (see section 3 for a detailed explanation of the specification tests). The values of the statistics are reported up to the first non rejection of H_0.

The linearity tests clearly reject the null hypothesis of a linear relationship whichever threshold variable is included in the specification. This result is very important because it highlights the presence of a non linear behavior in the demand of international reserve for the first time to our knowledge. The strongest rejection of the null hypothesis of linearity is obtained with PL. deviation. With a view of selecting a particular model among the seven proposed, the "optimal" model would thus be model I. Indeed, as suggested by Gonzàlez et al. (2005), the "optimal" threshold variable corresponds to the variable which leads to the strongest rejection of the linearity hypothesis.

The novel idea of this paper was to test the indirect influence of the US macroeconomic conditions on the demand for international reserves by emerging economies. Our results confirm this hypothesis because the three US macro threshold variables do reject linearity with a LM statistics value between $20,3$ and $41,5$. We observe that according to the LM statistics, model II and III (export growth and capital account openness) reject linearity less than models V to VII (US macro variables). In sum, the US macroeconomic context is statistically better than the degree of capital liberalization and the export growth to account for non-linearity in the demand for international reserves.

The specification tests of no remaining non-linearity lead to the identification of an optimal number of transition functions. In most cases, only one transition function is necessary, excepted for export growth and debt which needs two and three functions respectively. In other words, a small number of extreme regimes is sufficient to capture non-linearity in the relationships. And the less extreme regimes, the less estimators to identify. In the meanwhile, recall that a smooth transition model, even with two extreme regimes ($r = 1$), can be viewed as a model with an infinite number of intermediate regimes. The coefficients are defined at each date and for each country as weighted averages of the values obtained in the two extreme regimes. The weights depend on the value of the transition function. So, even if $r = 1$, this model allows a "continuum"of coefficient values (or regimes), each one associated with a different value of the transition function $g(.)$ between 0 and 1.

In sum we obtain a parsimonious estimation that takes into account as exhaustively as possible non-linearity and/ or heterogeneity and time-instability. In the next session, we present and comment the estimations results.

6 Non-linear results of international reserves holdings

The coefficients are defined at each date and for each country as weighted averages of the values obtained in the two extreme regimes. Therefore, as mentioned in section II, the coefficients in a PSTR model can be different from the estimated parameters defined in the extreme regimes, i.e. the parameters β_0 and $\beta_0 + \beta_1$ in equation (6). So for each model we first interpret the sign of parameter β_1, which indicates an increase ($\beta_1 > 0$) or a decrease ($\beta_1 < 0$) in the estimator along the increase in the threshold variable. In a second step, we will plot the evolution of each estimator to properly interpret the variation of the coefficient along the threshold variable.

The effect of the threshold variable on four determinants, PL. deviation, export growth, capital account and debt is reported for each model in table 1. In models I, III, V to VII, we found one transition function only ($r = 1$) so we can easily interpret the effect just as explained previously. Table 1 does not report the results for models II and IV because $r = 2$ and $r = 3$ respectively. We need the graph to analyze the effects because with more than one transition, we do not know the shape of the transition function (it is no longer an S-shape function).

The results of model I confirm the economic mechanisms described in the previous section. On the one hand, the elasticity between international reserves and export growth increases along PL. dev. More precisely, the furthest the real exchange rate is from its PPP value, the more the central banks compensate the appreciation of their currency The graphical analysis will allow us to confirm or infirm the scenario with three regimes assumed in the previous section. Note that as expected PL. dev has no impact on the

Table 1: Impact of increase in the threshold variable on the coefficient

	Model I PL. dev	Model III K Account	Model V US macro 1	Model VI US macro 2	Model VII US macro 3
PL. dev	no effect	no effect	no effect	no effect	no effect
Export Growth	↗	↗	↘	↘	↘
K Account	no effect	↗	↘	↘	↘
Debt	no effect	↘	↗	↗	↗

other estimators.

In turn, model III does not support the precautionary hypothesis according to which, financially liberalized countries should accumulate more reserves in proportion of their external debt than financially closed countries. On the contrary, we find that the estimator of debt decreases, i.e. debt explains less international reserves. It is probably not due to the effect of capital account but to a time-effect. Indeed the ratio of external debt has decreased in most countries during the period, so does its elasticity. The result that debt does not explain international reserves is common in linear estimations (Jeanne and Rancière, 2006). However the elasticity between reserves and export growth increases along the openness of the capital account. The more financially open, the more countries tend to compensate growing trade and limit their currency appreciation by accumulating reserves.

In model V to VII, note that the three US variables have a similar effect as threshold variables. The expected effect of the US macroeconomic conditions on the estimators of export growth and debt is confirmed. Again the better the US international position, the less the central banks compensate the appreciation of their currency (the lower the elasticity between international reserves and export growth). The contrary holds in the elasticity between international reserves and debt. The better the international position of the United States (the higher US macro 1), the more the emerging countries borrow money on the international capital market, and so the more the debt explains international reserves. During the period obviously, the international position of the United States has deteriorated. So the same reasoning holds but the reader should interpret the table with a decreasing trend if she wants to understand the historical evolution.

In total, a first analysis of the sign of $\beta 1$ confirms the expected influence of the real exchange misalignment and of the US macroeconomic variables on the determinants of the demand for foreign exchange reserves. The graphical analysis will provide additional information on the patterns of the transition to propose simple extrapolations.

Figure 2 and 3 plot the value of the coefficients given the theoretical values[11] of the threshold variable in each model. We also refer the reader to table 3 and 4 that report the coefficients value in extreme regimes and in the benchmark linear model. Table 3 confirms the estimations robustness as in most cases, the value of the coefficient in the linear estimation is closed to the coefficient of the first regime's non-linear model.

In model I, the graphical analysis confirms the scenario with three regimes assumed in the previous section between international reserves and export growth. As a matter of fact, the smooth transition allows that the coefficient increases when the threshold variable is close and inferior to zero and accelerates thereafter. It means that the elasticity increases smoothly from $0,01$ to $0,9$ in an infinite number of intermediate regimes. At the threshold value, $c = 0,26$ the coefficient is $\frac{\beta_0+\beta_1}{2} = 0,45$. Economically, it means that countries with slightly under-appreciated (negative and close to 0) exchange rate have a higher coefficient than countries with highly under-depreciated (negative and far from 0) exchange rate. In sum, countries manipulate more their exchange rate when they have an under-appreciated exchange rate that is close to the PPP value than when it is already far from it. In turn, countries with slightly over-appreciated (positive and close to zero) exchange rate have a lower coefficient than countries with highly over-appreciated exchange rate. The same graph plots the individual value of the coefficient in 2003 for four countries, Brazil, China, Hungary and Morocco. Three countries were indeed under-appreciated and are found in the lower part of the function while Morocco has the only over-appreciated currency and is found on the upper-part of the function. Note that the Chinese currency, RMB has appreciated since the People Bank of China People granted a greater flexibility to the exchange rate regime in July 2005, a date that is not included in the sample. According to our results, China should have moved upward along the curve since 2005 implying a higher coefficient between reserves and export growth. It suggests that the surge in the accumulation of foreign exchange reserves in China stems from greater interventions on the forex market to compensate the growing trade.

[11]The theoretical value corresponds to the range between the min and max values of the threshold variable. In practice, there may not be points along the entire transition function. However we found in all estimations that there is no cluster of points and that they are well distributed along the function.

In model II with export growth as a threshold variable, the transition functions are sharp. The coefficients of export growth, capital account and debt are impacted by the variation of export growth. Interestingly, the coefficient of export growth increases suddenly from $-0,01$ to $0,036$ when export growth gets higher than $-0,8\%$. The threshold value of $-0,8$ is small and close to 0 which may be interpreted as followed: as soon as export growth gets positive, countries accumulate more reserves to defend their competitiveness. In turn, the elasticity between reserves and capital account and debt decreases slightly from $0,8$ to $0,51$ and from 005 to -0,02 respectively when export growth crosses a higher threshold of 5%. The decrease in both coefficients suggests that central banks take less precautionary concerns into account in countries with an export-led growth strategy. Note that Brazil, China, Hungary and Morocco are all located on the second extreme regimes in 2003, as are all countries in our sample actually. The fact that transition is sharp suggests that higher export growth would not change the coefficients value. Therefore the acceleration of reserves holdings in the emerging countries can not be accounted for by an acceleration of export growth.

In model III with capital account as a threshold variable, the transition function is sharp. The elasticity between international reserves and export growth increases sharply from $-0,08$ to $0,016$ and the threshold value is $0,36$[12]. Note that this threshold value is very low and corresponds to financially close countries such as was China and Peru until 1989 and 1990 respectively. Since then, all countries in our sample are located on the higher regime, implying that their elasticity has been stable over the period. So capital openness cannot explain the increasing trend of reserves accumulation in the period. After the low statistics value of linearity test, it is a second evidence that rejects capital account as a proper variable to account for nonlinearity during the period. Again it tends to mitigate the importance of precautionary arguments.

In model IV, debt as a threshold variable has an effect only on its own coefficient. The higher the debt, the higher the coefficient but it tends to zero. We find again the same result as in linear estimations, that debt does not explain international reserves holdings.

Last, as mentioned above, the three US macroeconomic variables have a similar effect as threshold variables. The graphical analysis focuses on the

[12] $c = -1,01$ i.e the threshold is 0,36 because the variable is in log.

one that rejects best non-linearity, i.e. the saving rate. We will also briefly comment model VII because the smooth transition allows to extrapolate the coefficients evolution. Note tat the construction of the threshold variables does not allow to take into account heterogeneity between countries so the graph plots the value of the coefficients for four different years, 1980, 1991, 2000 and 2003 and not different countries as was the case above. In model VI, when the US saving rate drops below the threshold value $18,8\%$, the elasticities between international reserves and export growth and capital account increase. In turn, the elasticity between international reserves and debt decrease. Note that the saving rate stayed above the threshold value only until the beginning of the eighties. So during the majority of the period, the elasticities have kept the second regime's value. Model VI can not explain the acceleration in the foreign exchange reserves after the eighties. In turn the graphical analysis of model VII reveals that the elasticity between international reserves and capital account or export growth increases smoothly along the decrease in the US real interest rate. Elasticities have increased from 0,6 and 0,015 in 1991 to 0,85 and 0,025 in 2003 respectively. The sharp decrease in the US real interest rates from 2000 explains the acceleration of international reserves accumulation during the period.

In total, the position of the exchange rate relatively to its PPP value and the US real interest rate are particularly relevant to explain non-linearity in the demand for international reserves in the emerging countries. The variation of both variables trigger a smooth change in the pace and patterns of reserves holdings. It suggests that central banks in emerging countries accumulate foreign reserves primary to offset the variation the US$to defend a final objective of price competitiveness. Obviously it is because most of them have adopted an export-led growth strategy in the aftermath of the Asian crisis. It suggests that the management of foreign reserves is subject to an exogenous variable, i.e. the US dollar. It is different from the precautionary view which considers reserves holdings as a proactive way to protect the country against financial flows instability.

7 Conclusion

In this paper we adopted a non linear approach to examine the dynamics of the international reserves holdings by the emerging economies. To do so we estimated the demand for international reserves with a PSTR specification, that loosens two restricting hypotheses, homogeneity and time-stability. We found evidence for the presence of a non linear behavior in the demand for international reserves, a result that is new to this literature. After testing seven candidates for the threshold variable, we identified two threshold variables that may explain properly the acceleration of foreign exchange reserves accumulation described in the introduction. They are the misalignment of the real exchange rate and the level of the US real interest rate. In total, these results support the mercantilist view and mitigate the importance of precautionary concerns. As noted in the introduction, the US real interest rate is expected to increase in the aftermath of the crisis. Our results suggest that it should trigger a significative slow down of the international reserves accumulation.

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Data Appendix: Definitions of the regression variables

The sources of the data are the World Development Indicators (WDI) and Penn World.

- Reserves: international reserves holdings minus gold, measured in U.S. dollars.
- Res: ratio of reserves to the dollar value of nominal GDP, in percent.
- Population: log of population
- Openness: log of percent import share
- EX Growth: three-year moving average of the growth rate of real exports, lagged two years in the regression.
- Income: log of per-capita real GDP, PPP based.
- Relative Income: Income of each country relative to that of the United States.
- Price Level: national price levels (measured in U.S. dollars), obtained from the Penn World Table.
- PL. Deviation: residual from the regression of Price Level on Relative Income.
- K Account: Index of capital account liberalization, constructed by Lane and Milese-Ferretti (2006)[13]

[13] We did not use the index used in Aizenman and Lee (2007) because it is not publicly available. Instead we use the publicly and longer spanned index proposed by Lane and Milesi-Ferreti (2006).

- ToT: log of the net barter terms of trade index.

Regressions include country-specific constant terms. The primary sample include 20 emerging countries. They are: Argentina, Brazil, Chile, Colombia, Czech Republic, Hungary, Indonesia, Malaysia, Mexico, Pakistan, Peru, Philippines, Poland, Russia, South Africa, Thailand, Turkey, Venezuela, Algeria, China, Croatia, Egypt, India, and Morocco.

Source: Aizenman and Lee (2007), Data Appendix, p. 22.

Tables and figures

Table 2: LM_f Tests for Remaining Nonlinearity

Model	Model I	Model II	Model III	Model IV
Threshold Variable	Pl deviation	K account	Ex Growth	Debt
H0 : r = 0 vs H1 : r = 1	60.8 (0.00)	18.4 (0.01)	18.1 (0.01)	41.4 (0.00)
H0 : r = 1 vs H1 : r = 2	15.2 (0.04)	8.48 (0.30)	30.1 (0.00)	26.4 (0.00)
H0 : r = 2 vs H1 : r = 3	-	-	13.4 (0.06)	22.9 (0.06)
H0 : r = 3 vs H1 : r = 4	-	-	-	13.8 (0.05)
Model	Model V	Model VI	Model VII	
Threshold Variable	U.S Macro 1	U.S Macro 2	U.S Macro 3	
H0 : r = 0 vs H1 : r = 1	20.4 (0.00)	41.5 (0.00)	20.6 (0.00)	
H0 : r = 1 vs H1 : r = 2	15.2 (0.04)	12.0 (0.10)	12.2 (0.09)	
H0 : r = 2 vs H1 : r = 3	-	-	-	

Notes: US Macro 1 denotes . For each model (*i.e.* for each threshold variable), the testing procedure works as follows. First, test a linear model ($r = 0$) against a model with one threhosld ($r = 1$). If the null hypothesis is rejected, test the single threshold model against a double threshold model ($r = 2$). The procedure is continued until the hypothesis no additional threhold is not rejected. The corresponding LM_F statistic has an asymptotic $F[1, TN - N - (r + 1)]$ distribution under H_0. The corresponding p-values are reported in parentheses.

Table 3: Parameter estimates for the final PSTR

Specification	Linear Model		Model I		Model II	
Threshold Var.	none		Pl deviation		K account	
Parameter	β_0	β_1	β_0	β_1	β_0	β_1
Pop.	2.00	-	1.69	-0.39	1.68	0.2
	(7.59)		(6.12)	(-2.68)	(5.26)	(1.77)
Open	0.29	-	0.34	-0.07	0.72	-0.48
	(2.37)		(2.77)	(-0.25)	(1.97)	(-1.28)
Debt	-0.02	-	-0.03	-0.03	0.12	-0.15
	(-4.54)		(-6.31)	(-1.11)	(1.78)	(-2.22)
EX Growth	0.01	-	0.01	0.08	-0.07	0.09
	(3.95)		(2.12)	(4.23)	(-1.96)	(2.35)
Pl Deviation	0.49	-	-1.38	1.24	1.05	-0.61
	(1.88)		(-2.98)	(0.8)	(0.43)	(-0.24)
K account	0.61	-	0.67	0.19	-2.21	3.04
	(6.07)		(8.73)	(0.51)	(-3.66)	(5.02)
TOT	0.3	-	0.2	1.75	0.14	0.26
	(2.65)		(1.71)	(3.18)	(0.36)	(0.61)
Location parameter c	-		0.26		-1.01	
Slope parameter γ	-		18.1		23.7	
Schwartz Criterion	-		-1.42		-1.49	
Specification	Model V		Model VI		Model VII	
Threshold Var.	US Macro 1		US Macro 2		US Macro 3	
Parameter	β_0	β_1	β_0	β_1	β_0	β_1
Pop.	2.27	0	2.32	0.04	1.87	0.14
	(7.53)	(-0.06)	(7.16)	(0.79)	(6.45)	(1.43)
Open	0.19	0.44	0.15	0.1	0.22	0.29
	(1.59)	(2.26)	(1.18)	(0.5)	(1.76)	(0.8)
Debt	-0.03	0.05	-0.03	0.05	-0.04	0.08
	(-6.18)	(3)	(-6.25)	(3.63)	(-4.44)	(2.24)
EX Growth	0.01	-0.02	0.01	-0.03	0.03	-0.06
	(3.81)	(-1.66)	(4.03)	(-1.96)	(3.92)	(-1.93)
Pl Deviation	0.47	0.57	0.72	-0.17	0.85	-1.72
	(1.69)	(0.83)	(2.56)	(-0.24)	(2.14)	(-1.24)
K account	0.75	-0.71	0.84	-0.77	0.87	-1.35
	(8.81)	(-2.72)	(9.92)	(-2.32)	(6.72)	(-3.17)
TOT	0.32	-0.3	0.29	-0.26	0.5	-0.89
	(2.41)	(-1.65)	(1.99)	(-1.2)	(3.19)	(-2)
Location parameter c	-0.56		18.8		8.66	
Slope parameter γ	11.4		9.72		0.73	
Schwartz Criterion	-1.33		-1.37		-1.32	

Notes: The T-statistique in parentheses are corrected for heteroskedasticity. Linear model is estimated with individual fixed effetcs. For each transition function, the estimated location parameters c and the corresponding estimated slope parameter γ are reported. The PSTR parameters can not be directly interpreted as elasticities.

Table 4: Parameter estimates for the final PSTR

Specification	Model II			Model IV			
Threshold Var.	EX Growth			Debt			
Parameter	β_0	β_1	β_2	β_0	β_1	β_2	β_3
Pop.	2.05 (7.29)	-0.19 (-2.85)	0 (-0.21)	0.16 (0.2)	12330 (1.78)	0.01 (0.17)	-12320 (-1.78)
Open	0.03 (0.26)	0.7 (3.94)	0.37 (3.66)	-1.3 (-0.52)	16080 (0.76)	1.22 (2.93)	-16080 (-0.76)
Debt	-0.05 (-5.39)	0.04 (3.32)	0.03 (2.64)	-17.05 (-6.28)	35990 (4.25)	-0.51 (-1.67)	-35810 (-4.25)
EX Growth	0.03 (1.47)	-0.04 (-1.11)	-0.02 (-0.91)	0.16 (0.81)	-1180 (-0.68)	0 (0.06)	1180 (0.68)
Pl deviation	-0.45 (-1.15)	1.28 (1.98)	1.33 (3.03)	5.76 (0.84)	-33070 (-0.55)	0.98 (0.96)	33010 (0.55)
K account	0.8 (6.64)	-0.23 (-1.26)	-0.29 (-2.36)	4.31 (1.78)	-26460 (-1.26)	0.39 (1.21)	26420 (1.26)
TOT	0.39 (2.41)	0.18 (0.65)	-0.23 (-1.65)	-9.7 (-2.82)	112730 (3.64)	-0.59 (-1.02)	-112640 (-3.64)
Location parameter c		-0.81	5.17		0.60	2.44	0.60
Slope parameter γ		-6.19$\times 10^5$	8136		0.29	703	0.29
Schwartz Criterion		-1.26			-1.29		

Notes: The T-statistique in parentheses are corrected for heteroskedasticity. For each transition function, the estimated location parameters c and the corresponding estimated slope parameter γ are reported. The PSTR parameters can not be directly interpreted as elasticities.

Figure 1: Transition Function with c=0. Sensivity Analysis to the Slope Parameter γ

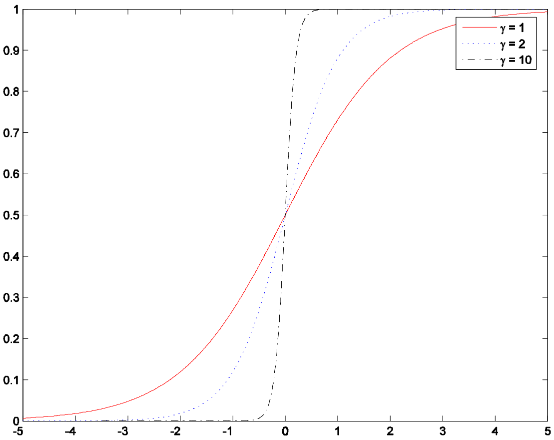
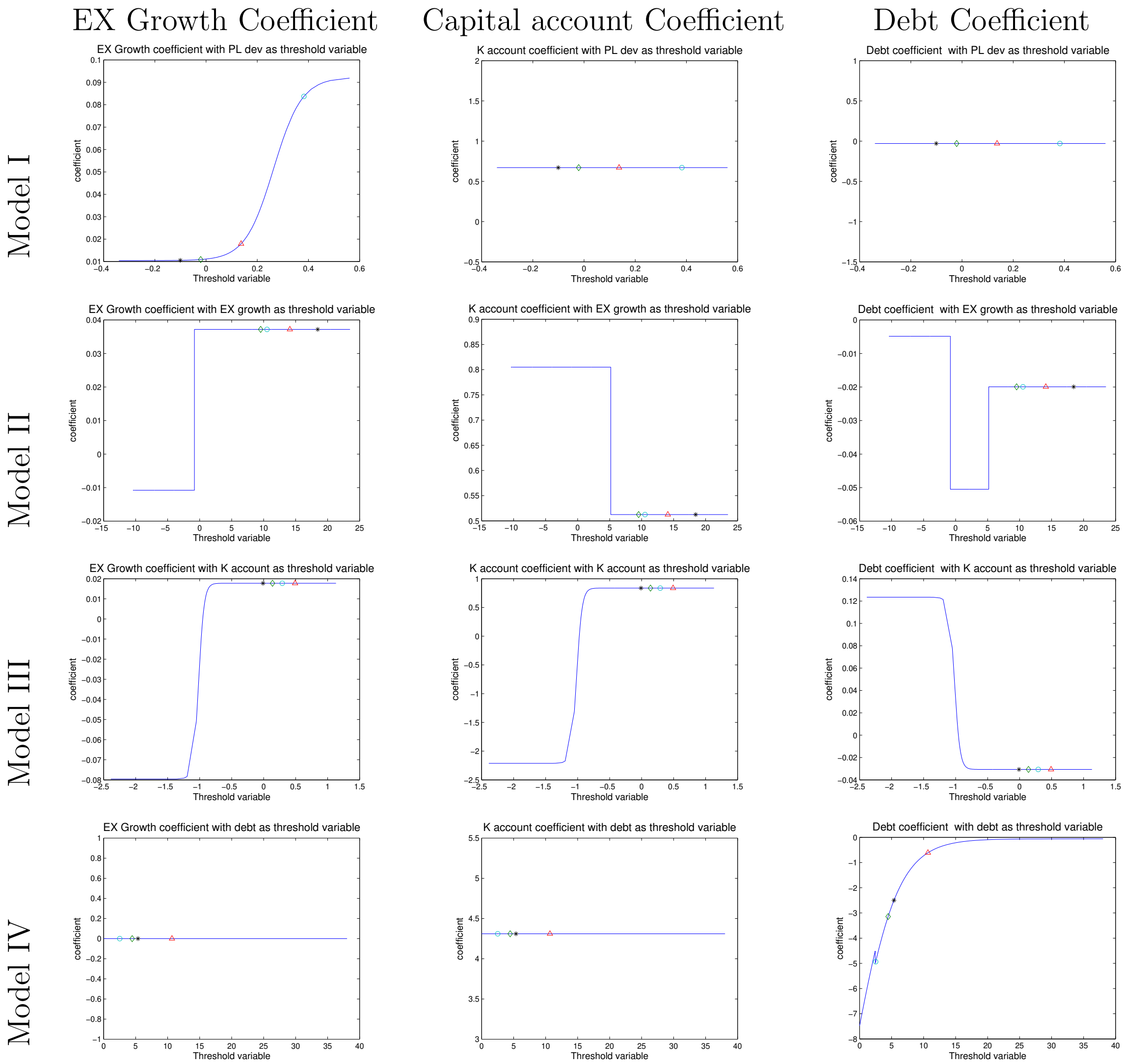
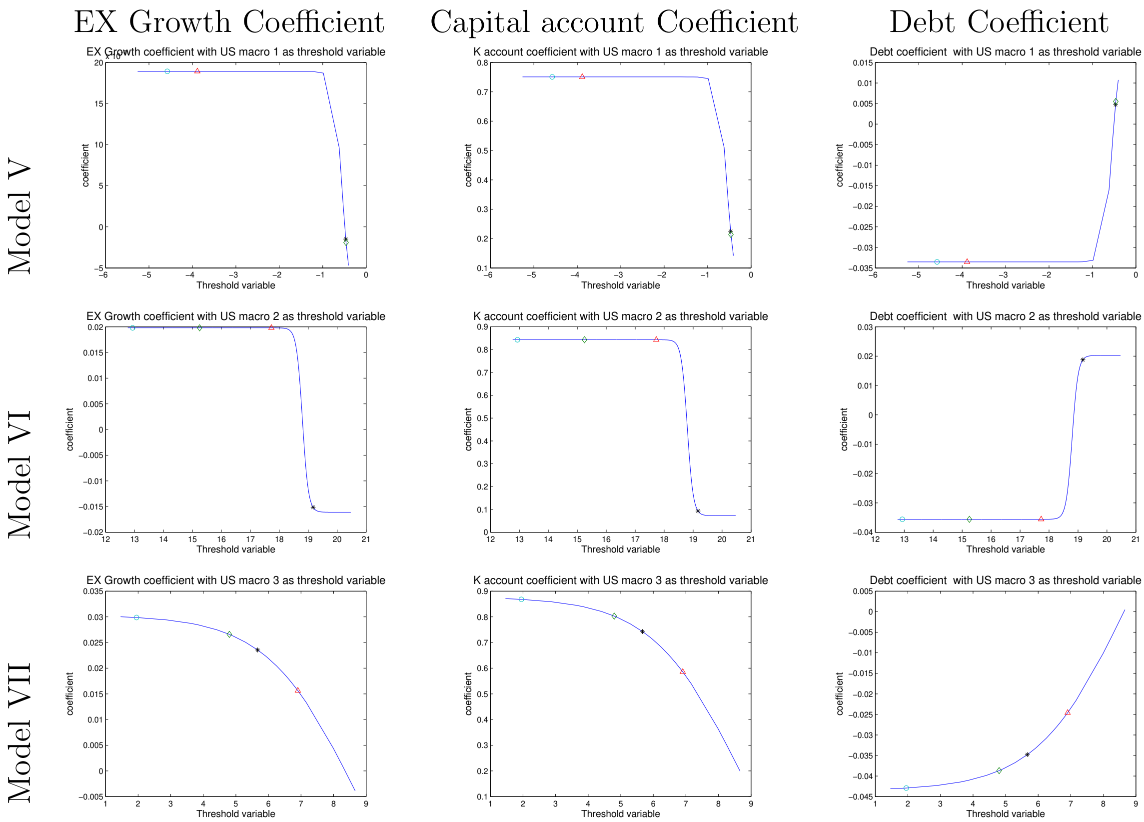


Figure 2: Estimated Coefficient of the PSTR specification



Notes : the missing graphs correspond to cases where the threshold variable has no significant effect on the coefficient at ten percent level. Model I: PL. Dev, Model II: Export Growth, Model III: K account, Model IV: Debt, Model VI and VII: US macro 2 (Savings), US macro 3 (RIR). In model I to IV $*$ denotes China in 2003, $\triangle$ Hungary in 2003, $\diamondsuit$ Brazil in 2003 and o Morocco in 2003. In model VI and VII $*$ denotes year 1980, $\triangle$ year 1991, $\diamondsuit$ year 2000 and o year 2003.

Figure 3: Estimated Coefficient of the PSTR specification



Notes : the missing graphs correspond to cases where the threshold variable has no significant effect on the coefficient at ten percent level. Model I: PL. Dev, Model II: Export Growth, Model III: K account, Model IV: Debt, Model VI and VII: US macro 2 (Savings), US macro 3 (RIR). In model I to IV $*$ denotes China in 2003, $\triangle$ Hungary in 2003, $\diamondsuit$ Brazil in 2003 and o Morocco in 2003. In model VI and VII $*$ denotes year 1980, $\triangle$ year 1991, $\diamondsuit$ year 2000 and o year 2003.