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Exchange Rate Flexibility across Financial Crises

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EXCHANGE RATE FLEXIBILITY ACROSS FINANCIAL CRISES

NON-TECHNICAL SUMMARY

Most currencies in the world are more or less linked to the dollar or the euro, even if very few of them have strictly fixed exchange rates. Up to now, the use of the euro as an anchor currency has been confined to Europe, its immediate vicinity and some African countries, leaving the rest of the world to the US dollar influence. The long-lasting prevalence of the US dollar as an anchor currency has however been more and more challenged for several years and some evolution has begun to take shape, especially since the start of the present financial crisis. Many countries have loosened the link of their currency to the US dollar in the global financial crisis that started in July 2007, a fact that may be explained by relying on the literature on contagion across markets.

Spillovers from advanced financial markets to currencies in emerging countries stem from the same causes documented in the literature on contagion, such as the drying–up of investors' liquidity, the rise in risk aversion, and the updating of their risk assessments. Consequently, interdependencies across currencies are likely to be exacerbated during crisis periods.

In this paper, we try to address these issues by answering the following questions: (i) Have exchange rate policies been modified in the sense of a greater flexibility since the start of the financial turmoil in July 2007? (ii) Is this evolution in line with what happened during previous crises? More generally, we aim at investigating the linkages between currency markets in emerging countries and financial market strains in the global economy. We expect that the co-movements between these two types of markets are exacerbated in episodes of financial turmoil.

To check these hypotheses more precisely, we start by measuring the exchange rate policies by their degree of flexibility, which itself is proxied by the volatility of the exchange rates for a sample of emerging countries. Then, we study the relationships between currency flexibility and various proxies for stress on global financial markets. We introduce the possibility of non-linearities by running smooth transition regressions (STR) over a sample of 21 emerging countries from January 1994 to September 2009. The results confirm that exchange rate flexibility does increase more than proportionally with the global financial stress, for most countries in the sample. We also evidence regional contagion effects spreading from one emerging currency to other currencies in the neighboring area.

ABSTRACT

This paper studies the impact of global financial turmoil on the exchange rate policies in emerging countries. Many emerging countries have loosened the link of their currencies to the US dollar since the bursting of the subprime crisis in July 2007. Spillovers from advanced financial markets to currencies in emerging countries stem from the same causes documented in the literature on contagion, such as the drying–up of investors' liquidity, the rise in risk aversion, and the updating of their risk assessments. Consequently, interdependencies across currencies are likely to be exacerbated during crisis periods. To test this hypothesis, we assess the exchange rate policies by their degree of flexibility, itself proxied by the exchange rate volatility, and investigate their relationship to a global financial stress indicator, measured by the volatility on global markets. We introduce the possibility of non-linearities by running smooth transition regressions (STR) over a sample of 21 emerging countries from January 1994 to September 2009. The results confirm that exchange rate flexibility does increase more than proportionally with the global financial stress, for most countries in the sample. We also evidence regional contagion effects spreading from one emerging currency to other currencies in the neighboring area.

JEL Classification: F31, G15, C22.
Key Words: Financial crises, dollar pegs, contagion effects, nonlinearity.

FLEXIBILITE DES TAUX DE CHANGE AU COURS DES CRISES FINANCIERES

RESUME NON TECHNIQUE

La plupart des devises dans le monde sont plus ou moins étroitement ancrées au dollar ou à l'euro, même si très peu d'entre elles reposent sur un système de taux de change fixe. Le choix de l'euro comme monnaie d'ancrage reste actuellement confiné aux pays européens de proximité immédiate et à certains pays d'Afrique, le dollar conservant ainsi une large part de son leadership dans le reste du monde. Pourtant, dans un grand nombre de cas, l'ancrage au dollar a été rompu depuis la crise financière qui a démarré en juillet 2007.

L'assèchement de la liquidité et la réévaluation du risque de la part des investisseurs se sont traduits par des tensions se manifestant d'abord sur les marchés financiers des pays industrialisés ; elles ont ensuite atteint les devises des pays émergents suivant un phénomène de contagion bien décrit dans la littérature. Cette contagion expliquerait la similitude observée dans les évolutions d'un certain nombre de devises émergentes.

Dans cet article, nous cherchons à répondre aux questions suivantes : (i) les politiques de change ont-elles été modifiées dans le sens d'une plus grande flexibilité des devises depuis le début de la crise financière de juillet 2007 ? (ii) Cette évolution est-elle semblable aux phénomènes constatés lors des crises précédentes ? De façon plus générale, nous étudions les liens entre les marchés des changes des pays émergents et les tensions sur les marchés financiers des économies développées, en analysant si les co-mouvements entre ces deux types de marchés sont plus forts durant les périodes de crise financière.

Afin de tester ces hypothèses, nous mesurons les politiques de change par leur degré de flexibilité, lui même approximé par la volatilité des taux de change pour un ensemble de pays émergents. Nous étudions ensuite les relations entre la flexibilité des taux de change et diverses mesures de tension sur les marchés financiers mondiaux. Nous testons en particulier l'existence de non linéarités en estimant des modèles à changement de régime (STR) sur un échantillon de 21 pays émergents sur la période allant de janvier 1994 à septembre 2009. Les résultats obtenus confirment que la flexibilité des taux de change augmente plus que proportionnellement avec le degré de tension sur les marchés financiers pour la plupart des pays de notre échantillon. Nous mettons également en évidence des effets de contagion régionale entre les marchés des changes des pays appartenant à une même zone géographique.

RESUME COURT

Cet article étudie l'impact de la crise financière mondiale sur les politiques de change dans les pays émergents. Un grand nombre de pays émergents ont relâché leur lien avec le dollar depuis le début de la crise financière de juillet 2007. L'assèchement de la liquidité et la réévaluation du risque de la part des investisseurs se sont traduits par des tensions se manifestant d'abord sur les marchés financiers des pays industrialisés ; elles ont ensuite atteint les devises des pays émergents suivant un phénomène de contagion bien décrit dans la littérature. Cette contagion expliquerait la similitude observée dans l'évolution d'un certain nombre de devises émergentes. Afin de tester cette hypothèse, nous mesurons les politiques de change par leur degré de flexibilité, lui même approximé par la volatilité des taux de change pour un ensemble de pays émergents, et étudions leur lien avec divers indicateurs de tension sur les marchés financiers mondiaux. Nous testons en particulier l'existence de non linéarités en estimant des modèles à changement de régime (STR) sur un échantillon de 21 pays émergents sur la période allant de janvier 1994 à septembre 2009. Les résultats obtenus confirment que la flexibilité des taux de change augmente plus que proportionnellement avec le degré de tension sur les marchés financiers pour la plupart des pays de notre échantillon. Nous mettons également en évidence des effets de contagion régionale entre les marchés des changes des pays appartenant à une même zone géographique.

Classification JEL : F31, G15, C22.
Mots-clefs : crises financières, ancrage au dollar, effets de contagion, non-linéarité.

EXCHANGE RATE FLEXIBILITY ACROSS FINANCIAL CRISES[♦]

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INTRODUCTION

Most currencies in the world are more or less linked to the dollar (USD) or the euro (EUR), even if very few of them have strictly fixed exchange rates. This phenomenon has been well-documented, especially since the pioneer papers by Reinhart (2000) and Calvo and Reinhart (2002). Up to now, the use of the EUR as an anchor currency has been confined to Europe, its immediate vicinity and some African countries (ECB, 2008). This leaves the rest of the world to the USD influence, especially Central and South America, emerging and less developed Asia, and the Middle-East. The broadness of this area makes the issue very important to the world economy. The long-lasting prevalence of the USD as an anchor currency,[1] which follows on from the Bretton Woods period, may seem puzzling, since countries are now free to set their own arrangements. Various reasons have been extensively discussed in the economic literature, such as externality gains from existing networks (Aglietta and Deusy-Fournier, 1995; Hartman, 1998; Goldberg and Tille, 2008); the high liquidity of the US financial markets (Longstaff, 2004; Forbes, 2008); emerging countries' anxiety to protect their export-led economy (Dooley *et al.* , 2003) or the US huge external deficit which mirrors the expansion of US forex reserves in emerging countries (Eichengreen, 2004; Gourinchas and Rey, 2007).

Nevertheless, the key role of the USD in the international monetary system has been more and more challenged for several years and some evolution has begun to take shape, especially since the start of the present financial crisis. Many countries have loosened the link of their currency to the USD in the global financial crisis that started in July 2007, either because they have been pushed into this strategy by market pressures, or for tactical reasons. Looking back

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[1] See Bénassy-Quéré et al. (2006) among others.

at the main global crises, we find that ruptures of pegs have been often concentrated in those episodes. Rationales for this may be found in the literature on contagion across markets.

Contagion effects involved in currency crises have been closely scrutinized, especially in the aftermath of the 1997 Asian crisis (Masson, 1998; Corsetti, Pesenti and Roubini, 1999; Kaminsky and Reinhart, 2000). They have also been extensively documented in the economic literature, as they are key factors to understand financial crises (for a survey, see Allen and Gale, 2000; Pericoli and Sbracia, 2003). Actually, most channels of contagion described in this literature can be applied to the transmission of a crisis in advanced financial markets spreading out to emerging currency markets. Firstly, contagion can stem from a drying-up of investors' liquidity. After a sharp price fall in a major market, investors have to cope with a reduction of wealth and tend to withdraw their funds from other risky assets. As they all do it simultaneously, this results in firesale prices spreading the crisis over (Schinasi and Smith 2001; Goldstein and Pauzner, 2004; Caramazza *et al*., 2004). Banks' liabilities overlapping across countries, convergence trading (Kyle and Xiong, 2001; Xiong, 2001), margin calls (Calvo, 1999), risk management tools such as value-at-risk (Persaud, 2000), and marked to market valuations (Adrian and Shin, 2008), all contribute to tightening liquidity constraints in case of crisis and to spark capital repatriation from emerging markets as well as a decline in bank loans. Secondly, a crisis can act as a "wake-up call", as investors tend to revise their judgments and preferences after its burst, especially on assets issued by countries of the same region. They suddenly see other financial assets as more risky than before, which can set off a "flight to quality" (Caballero and Krishnamurthy, 2005, 2007). As well, their risk appetite is likely to drop (Kumar and Persaud, 2002), which is confirmed by empirical studies (Coudert and Gex, 2008). Thirdly, the rise in uncertainty during a crisis paves the way to herding behavior (for a survey, see Bickchandani and Sharma, 2000). This may be due to asymmetric information (Kodres and Pritsker, 2002), or to the compensation plans of portfolio managers (Chakravorti and Lall, 2004).

Two additional strands of reasons may also explain the ruptures of pegs under global financial strains. Firstly, there is a policy issue at stake for emerging countries' governments that may choose to update their exchange rate policy in time of crises. Admittedly, they are likely to be pushed to do so by market pressures. Nevertheless, governments can also go for greater flexibility in their exchange rate policy in order to boost their competitiveness and sustain their ailing exports. This may be a policy response to the decrease in their foreign exchange receipts. They can also be led to this choice by following their neighbors' strategies, which is utterly rationale. This kind of effect could have been at stake in the 1997 Asian crises. Even if most countries had no choice but to let their currencies depreciate under the fire of speculative attacks, it could also have been a rational strategy for them.. This argument is particularly relevant in the case of Asian countries. As they tend to trade more and more between themselves, it could be rationale for them to consider a common currency. This common currency has been the dollar for several decades, leading McKinnon (2000) to talk of an "Asian Dollar Standard". But the situation could change, especially because the trade links of these countries have loosened with the United States in parallel to their increasing integration (Kwack, 2004).

A second strand of reasons stems from the fact that some currencies are seen as safe-havens during crises. This is the case for the yen and the Swiss franc (Ranaldo and Söderlind, 2007), but also probably for the USD in the immediate aftermath of the bankruptcy of Lehman Brothers in late 2008 (McCauley and McGuire, 2009). More fundamentally, these movements stem from the carry-trade strategies developed during the tranquil periods which build huge long-positions on risky currencies, whereas accumulating short-positions on low-interest currencies such as the yen and the Swiss franc (Lustig et al., 2007; Burnside et al., 2008). These carry trades suddenly unwind during crises (Kohler, 2010), sparking violent depreciation in high-interest currencies such as those of emerging countries.

In this paper, we try to address these issues by answering the following questions: (i) Have exchange rate policies been modified in the sense of a greater flexibility since the start of the financial turmoil in July 2007? (ii) Is this evolution in line with what happened during previous crises? All the rationales mentioned above point to a positive answer to these questions. More generally, we aim at investigating the linkages between currency markets in emerging countries and financial market strains in the global economy. We expect that the co-movements between these two types of markets are exacerbated in episodes of financial turmoil.

To check these hypotheses more precisely, we start by measuring the exchange rate policies by their degree of flexibility, which itself is proxied by the volatility of the exchange rates for a sample of emerging countries. In this respect, we follow the spirit of the works done by Reinhart and Rogoff (2004) and Ilzetzki *et al*. (2008). Then, we study the relationships between currency flexibility and various proxies for stress on global financial markets. This boils down to testing the volatility spillovers from advanced financial markets to emerging currency markets. The transmission of volatility may be a normal phenomenon in globalized markets, but can also take on abnormal turns during episodes of financial stress, which is a typical symptom of "contagion". Contagion effects can be evidenced empirically by different methods (for a survey see Dungey *et al*., 2004), although it is difficult to disentangle the precise channels at stake. Forbes and Rigobon (2002) insist on the rupture in the usual interdependence mechanisms between markets during a crisis. These disrupted links can be captured by different ways and most of them involve acknowledging nonlinearities in the transmission channels. Favero and Giavazzi (2000) introduce dummy variables for outliers in a VAR model. Eichengreen, Rose and Wyplosz (1995, 1996) also rely on dummy variables linked to the pressures on the exchange market. Some works have focused on co-movements when asset returns are extreme (Bae *et al*., 2003; Hartman *et al*., 2004).

In parallel, some studies have been devoted to the transmission of stress of advanced countries to emerging markets. In their review of the literature, Dungey *et al*. (2004) consider advanced countries financial stance as a "common factor" affecting emerging countries in most models, not as a factor of contagion in itself. Diebold and Yilmaz (2008) use a variance decomposition in a VAR model containing 19 equity markets to assess the spillovers across countries. Balakrishnam *et al*. (2009) construct an indicator of the financial stress put on emerging countries by combining measures on several markets. They find that this indicator co-moves with the financial stress in the advanced countries and that the degree of co-movements varies across countries according to their financial linkages, although vulnerability factors also play a role.

Here, we want to assess volatility spillovers by testing for possible nonlinearities. Indeed, strains in global financial markets are likely to affect exchange rates in emerging markets more badly when they reached high degrees. We verify that hypothesis by running smooth transition regressions (STR) and testing for nonlinearities over a sample of 21 emerging countries during the period from January 1994 to September 2009. We represent stress on financial markets by different indicators. One popular candidate for this role is the VIX, the CBOE Volatility Index, which stands for the implied volatility of the S&P 500 index. We also consider other indicators, based on the realized volatility of different market indexes, as well as indicators standing for emerging markets as a whole.

The rest of the paper is organized as follows. Section 1 presents the data and compares exchange rate and financial market volatilities around crisis episodes. Relying on the estimation of STR models, Section 2 assesses the relationships between global financial stress and emerging currency volatility. Section 3 is devoted to the study of regional contagion effects within the emerging countries by testing whether the intensity of such effects differs across crisis and non-crisis periods. Section 4 concludes.

1. DATA FOR ASSESSING CURRENCY FLEXIBILITY AND GLOBAL FINANCIAL STRESS

1.1. Exchange rates

The sample period spans from January 1994 to September 2009, on a monthly periodicity. It includes 21 currencies of emerging countries; in Latin America: those of Argentina (ARS), Brazil (BRL), Chile (CLP), Colombia (COP), Mexico (MXN), Peru (PEN), Uruguay (UYU), Venezuela (VEB); in Asia: those of China (CNY), Indonesia (IDR), India (INR), Korea (KRW), Malaysia (MYR), Philippines (PHP), Singapore (SGD), Thailand (THB); in the Middle East: those of Israel (ILS), Kuwait (KWD), Morocco (MAD). We also add the Russian ruble (RUB) and the South African rand (ZAR).

This set of currencies matches the main emerging countries in the traditional dollar zones of influence, which are Latin America, Asia and the Middle East. We have deliberately left out emerging Europe and North Africa, as the link of their currencies to the euro could have disturbed the interpretation of the results. Consequently, all the currencies in the sample were more or less linked to the USD over the period under review, at least for some time (for a complete description of the exchange rates regimes of these countries, see Ilzetzki *et al.*, 2008). This justifies our calculations on exchange rates against USD. The later are taken from Bloomberg. We alternatively consider real exchange rates to account for exchange rate regimes aimed at stabilizing real exchange rates, such as crawling pegs and some managed floats. Indeed, most Latin American countries were experiencing a crawling peg sometime or another in the sample. It was the case for Bolivia, Brazil, Colombia, Mexico, Peru, Uruguay and Venezuela. Other countries were having managed floats aimed at stabilizing their real exchange rate, such as Russia, Israel and India. Real exchange rates are calculated by deflating the exchange rate by the consumer price index (CPI), extracted from the IMF's International Financial Statistics database.

1.2. Indicators for global financial stress

Financial stress is represented by different indicators gauging the volatility of financial markets; all series being extracted from Bloomberg. (i) First, we consider the VIX, which is the most popular gauge for financial strains; it measures the implied volatility of the S&P500 index options for the next 30 days, calculated by the Chicago Board Options Exchange (CBOE) (see Whaley, 2008; Becker *et al*., 2009). All other indicators are realized volatility that we calculate as squared returns. (ii) We consider the world MSCI (denoted as MSCI_W), which is the stock index calculated by Morgan Stanley Capital International made up of 1500 stocks in the developed countries. (iii) Financial strains on emerging markets are captured by the same type of stock index but for emerging countries (denoted as MSCI_EM), and by the emerging markets bond index calculated by JP. Morgan (EMBI). (iv) As most of the sample countries are commodity producers, we also consider two commodity indices: the CRB, calculated by the Commodity Research Bureau, and the S&P GSCI, the commodity index published by Standard and Poors' and Goldman Sachs. We consider the two indices, since their weighing of commodities is quite different, the weight on oil being very high for the S&P GSCI and lower for the CRB.

On the whole, we consider the volatility of six financial market indicators:

- two for the developed stock markets: the VIX and the MSCI_W,
- two for the emerging markets: the MSCI_EM and the EMBI,
- two for commodity markets: the CRB and the S&P GSCI.

1.3. Method for measuring the degree of currency flexibility

We measure currency flexibility through the volatility of the exchange rates. This choice is justified by a number of empirical works that have been carried out to identify exchange rate regimes (Reinhart, 2000; Calvo and Reinhart, 2002; Levy-Yeyati and Sturzenegger, 2003, 2005; Reinhart and Rogoff, 2004; Ilzetzki *et al*., 2008). All these studies have relied on exchange rate volatility to identify the flexibility of exchange rates. More precisely, the older studies considered three variables: exchange rate changes, changes in forex reserves and interest rates (Reinhart, 2000; Calvo and Reinhart, 2000). Then, Levy-Yeyati and

Sturzenegger (2003, 2005) only used the first two ones, leaving out the interest rate. The most recent research has only focused on the changes in exchange rates, which suggests that the information given by the other variables may be redundant (Reinhart and Rogoff, 2004; Ilzetzki *et al*., 2008). That is why we consider here that the exchange rate volatility is a good gauge for flexibility.

We measure the volatility of exchange rates $\left(\sigma_t^2\right)$ against USD (nominal or real) by two ways: the squared monthly returns of exchange rates (in logarithms) and through the estimation of a GARCH model (the mean equation including only a constant term). We only retain the squared returns in all the following results for several reasons: (i) results are very close for the two measures of volatility; (ii) they are more straightforward to interpret; (iii) they do not require any prior calculations of parameters, which may increase the uncertainty on the coefficients estimated in regressions. The same calculations are used to calculate the volatility of other financial markets.[2] In the next section, volatility figures are annualized and expressed in percentages.

1.4. Exchange rate flexibility during the crisis periods

We now take a look at the volatility data in order to check their evolution around several crisis episodes. Figure A1 in the Appendix displays the evolutions in volatility of the nominal exchange rate against the USD for the considered countries over the sample period. Unsurprisingly, these volatilities are characterized by sharp peaks, especially when currencies' pegs are suddenly broken. Periods of increased volatilities can also be spotted in the aftermath of main crisis episodes.

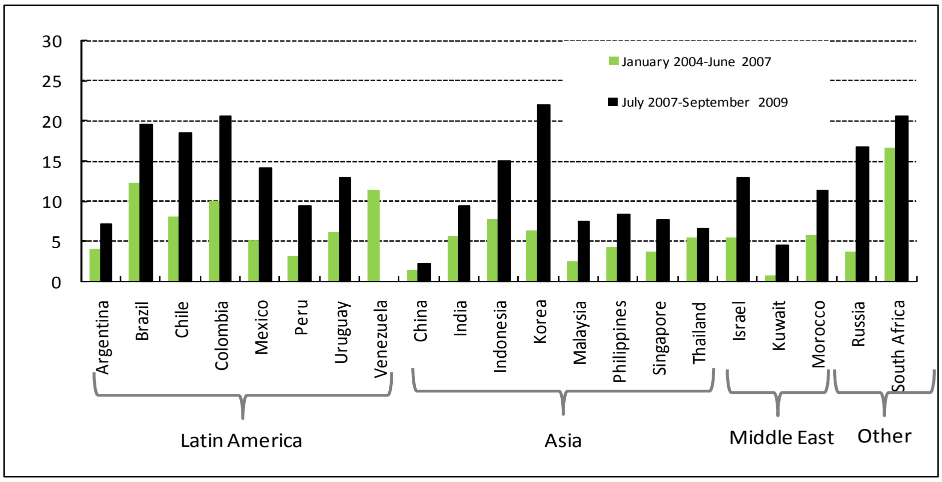
Firstly, we check that major turmoils in advanced financial markets give rise to more exchange rate flexibility in emerging countries.[3] To do that, we compare the currency volatility before and after the subprime crisis that burst in July 2007 (Figure 1). We take a large window both (i) before the crisis—January 2004-June 2007—as this period is often considered as a tranquil episode on financial markets, characterized by low volatility and low spreads, and (ii) after it—July 2007-September 2009—as when we wrote the paper, the crisis was not over. Results show that this crisis did trigger a surge in currency volatility for all countries but one (Venezuela). Indeed, most countries have loosened the link of their currencies to the USD after the crisis, especially Brazil, Chile, Korea, Mexico and Russia. Note that the depreciation that hit some of these currencies at the start of the crisis, subsequently reversed to an appreciation in a number of cases (such as Brazil); so the surge in volatility does not necessarily mean depreciation. Venezuela managed to keep its hard peg to

[2] Note that all our series of volatility are stationary, as indicated by the results of standard unit root tests (available upon request to the authors).

[3] Our aim in this section is not to identify all crises, but just to provide some stylized facts. For instance, we do not study the LTCM or the Dot-com crises, which were very near the Asian and Argentinean crises, respectively.

the USD throughout the crisis, thanks to its tight capital controls. China also tightened its currency peg to the USD, fearing that a depreciation of the dollar would yield losses in its huge forex reserves as well as a loss in its export competitiveness.

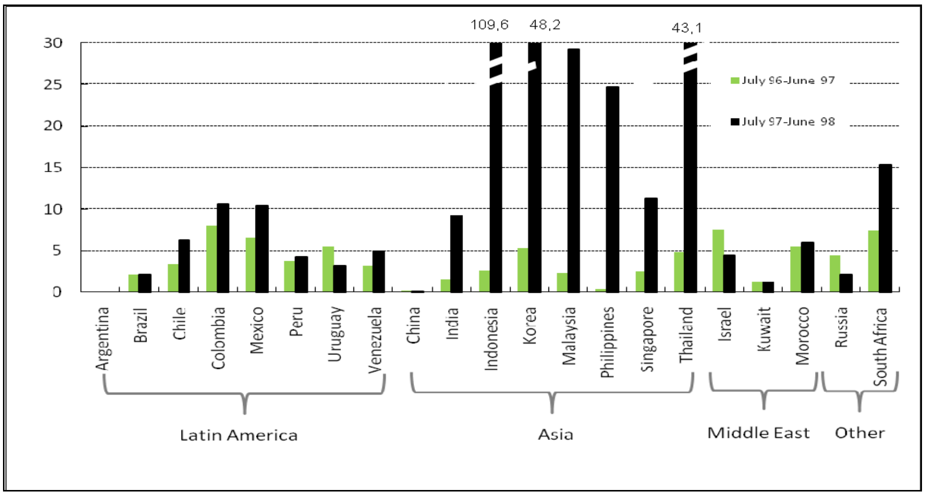
Figure 1. Exchange rate volatility around the subprime crisis, annualized in %



Source: Authors' calculations, based on Bloomberg data.

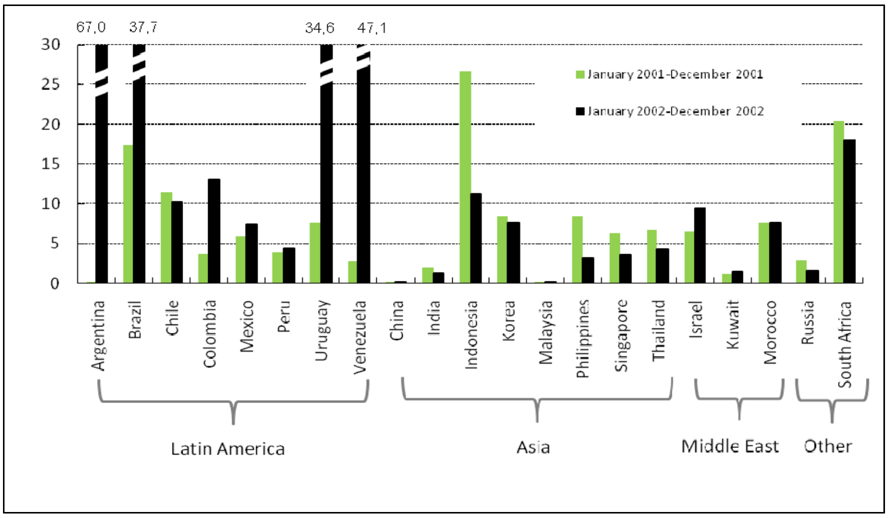
Secondly, we consider the effects of two major currency crises that occurred over the period: the 1997 Asian and the 2002 Argentinean crises. We select these particular episodes, because each of them brought about strains on world financial markets across the board. Volatilities are calculated with a one-year window before and after the crisis (Figures 2 and 3). The Asian crisis brought about a surge in currency flexibility mainly in South-Asia (Indonesia, Korea, Malaysia, Philippines, Singapore, Thailand), although some subdued spillovers were also felt as far as Latin America (Colombia, Chile, Mexico, Peru). The collapse of Argentina's currency board in 2002 also resulted in an increase in exchange rate volatility, mainly confined to the neighboring countries (Brazil, Colombia, Uruguay, Venezuela).

Figure 2. Exchange rate volatility around the Asian crisis, annualized in %



Source: Authors' calculations, based on Bloomberg data.

Figure 3. Exchange rate volatility around the Argentinean crisis, annualized in %



Source: Authors' calculations, based on Bloomberg data.

On the whole, these figures illustrate that major crises generate large volatility spillovers. Firstly, the subprime crisis has spread over to all countries considered in our sample (but one).

This confirms results by studies analyzing aggregate financial stress indices (Balakrishnan *et al.*, 2009) and volatility spillover index (Diebold and Yilmaz, 2008). Increased linkages among global financial markets and greater mobility of capital are certainly at stake in this worldwide dimension of the crisis. Secondly, currency crises in emerging markets, such as the Asian and the Argentinean crises, triggered more regional contagion than global effects, even if they threatened the whole financial system. Fewer countries were involved, although for those that were hit, the exchange rate volatility soared more sharply than in the present crisis.[4]

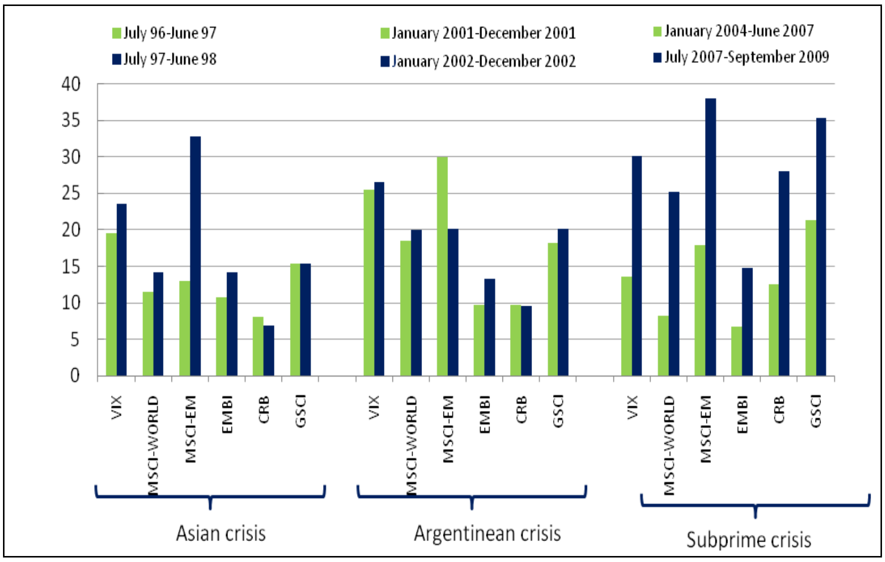
These preliminary results lead us to consider two types of effects that crises may yield on emerging countries' currencies: (i) the impact of the global financial crises, born in advanced countries (Section 2); (ii) the regional contagion due to currency crises in other emerging countries (Section 3).

1.5. Financial market volatility during the crises

We now take a look at the volatility of our indicators of global financial markets, which will act as proxies for global financial stress (Figure A2 in the Appendix). Unsurprisingly, the volatility sharply increased at the end of the period, following the subprime crisis. Figure 4 compares volatility around the same crisis episodes as previously. The subprime crisis triggered a surge in volatility for all our indicators across the board, in developed and emerging markets as well as for commodity indices. The Asian crisis also brought about a rise in volatility on all markets, except for commodities, its impact being particularly strong on emerging stock markets. The effect of the Argentinean crisis on global markets was more subdued, although it did trigger a rise in emerging market bond spreads.

[4] We have performed a comparison test to check if the results are significantly different between the two sub-samples—before and after the turmoil—for each considered crisis (detailed results available upon request to the authors). For the subprime crisis, the difference is significant for all countries, except China, Thailand and Venezuela. Regarding Argentinean and Asian crises, volatility series before and after the crisis are significantly different for most South American and East Asian countries.

Figure 4. Volatility of global financial markets indicators around three crisis episodes. Note: all variables are annualized volatility in % of the corresponding market indices, except for the VIX, which is taken in level.



Source: Authors' calculations, based on Bloomberg data

2. RELATIONSHIP BETWEEN CURRENCY FLEXIBILITY AND GLOBAL FINANCIAL STRESS

As illustrated in the previous section, the relationship between the global financial stress and the degree of exchange rate flexibility is expected to be positive. However, one may wonder about the time variation of the intensity of this link and, more generally, about the linearity of this relationship. Indeed, our aim is to investigate whether the link between exchange rate flexibility and global financial stress is higher during crisis episodes. In other words, we examine if a high degree of stress in global financial markets is likely to have a proportionally higher impact on the exchange rate flexibility than a weak degree. This non-linear impact is due to the fact that financial market strains are able to spark investors' "flight to quality" and/or a deliberate softening of exchange rate policies in emerging countries, only when they reach a certain level, whereas their impact is much weaker in normal times.

2.1. Methodology

To assess this potential nonlinear relationship, we rely on the smooth transition regressions framework. In these models, two regimes characterized the dynamics of the exchange rate flexibility—low and high volatility—, the transition from one regime to the other being smooth. As recalled by Baele (2003) among others, such regime-switching models are preferable to the use of dummy variables to investigate the impact of some particular events.

Indeed, the dates used for dummy variables may be uncertain since such events may have been long anticipated, or may need time to become effective. Regime-switching models do not have these drawbacks since series are allowed to switch endogenously from one regime to the other, depending on the value of an (observable) transition variable. It is, therefore, not imposed *a priori*.

Since we are interested in the bivariate link between the volatility of the exchange rate and the stress on the global financial markets, we consider here a simple specification in which only one explanatory variable is retained, this variable being identical to the transition variable proxying the stress on financial markets.[5] Let σ_t^2 be the degree of exchange rate flexibility measured as the volatility of the exchange rate, the later being proxied by the squared returns of the considered exchange rate series. The smooth transition regression (STR) model of order *p* that we consider is given by:

$$\sigma_t^2 = \alpha_{10} + \sum_{j=1}^{p} \alpha_{1j} \sigma_{t-j}^2 + \beta_1 s_t + \left(\alpha_{20} + \sum_{j=1}^{p} \alpha_{2j} \sigma_{t-j}^2 + \beta_2 s_t \right) g(s_t; \gamma, c) + \varepsilon_t \quad (1)$$

where ε_t is $iid(0, \sigma_\varepsilon^2)$, s_t is the transition variable and $g(s_t; \gamma, c)$ is the transition function which by convention is bounded by zero and one. $\gamma > 0$ denotes the speed of transition from one regime to the other, and c is the threshold parameter.

In order to catch possible real effects, we also run Equation (1) in real terms:

$$\sigma_{Rt}^2 = \alpha'_{10} + \sum_{j=1}^{p} \alpha'_{1j} \sigma_{Rt-j}^2 + \beta'_1 s_t + \left(\alpha'_{20} + \sum_{j=1}^{p} \alpha'_{2j} \sigma_{Rt-j}^2 + \beta'_2 s_t \right) g(s_t; \gamma', c') + \varepsilon_{Rt} \quad (1')$$

where σ_{Rt}^2 stands for the volatility of real exchange rates. This formulation accounts for crawling pegs and managed floats aimed at stabilizing real exchange rates. It also allows us to correct for high inflation periods in some countries and for the heterogeneity in the inflation rates in the sample.

In this model, the economy can be in two states, representing two degrees of exchange rate flexibility: low and high volatility. The transition between these two regimes is smooth, so there exists a continuum of states between extreme regimes. Two transition functions are commonly considered (Teräsvirta and Anderson, 1992):

- $g(s_t; \gamma, c) = (1 + \exp(-\gamma(s_t - c)))^{-1}$: logistic STR model (LSTR)

[5] As noticed, we consider here a simple bivariate framework since our main objective is to put forward the existence of nonlinearities in the links between the exchange rate volatility and the global financial stress. Of course, if the main objective is to rely on the exchange rate crisis literature, this analysis can be extended to a multivariate case to account for various control variables.

- $g(s_t;\gamma,c) = 1-\exp\left(-\gamma(s_t-c)^2\right)$: exponential STR model (ESTR)

In the LSTR specification, the economy evolves between two regimes characterized by different dynamics, the transition from one regime to the other being smooth. This specification accounts for asymmetric realizations, in the sense that the two regimes are associated with small and large values of the transition variable relative to the threshold value. Turning to the ESTR specification, the two regimes have similar structures—meaning that increases and reductions of the transition variable have similar dynamics[6]—but the middle grounds are characterized by different dynamics. In both cases—LSTR and ESTR—when γ goes to zero, the STR process reduces to a linear model. When γ tends to infinity, the LSTR model becomes a two-regime threshold model with abrupt transition (Tong, 1990). This is not the case for the ESTR model which also becomes linear when the speed of transition goes to infinity. To recover the threshold model as a special case of the ESTR specification, we follow Jansen and Teräsvirta (1996) by writing the ESTR model such as:

$$g(s_t;\gamma,c) = \left(1+\exp\left(-\gamma(s_t-c_1)(s_t-c_2)\right)\right)^{-1} \qquad (2)$$

with $c_1 \le c_2$ and $c=(c_1,c_2)'$. When γ goes to infinity and if $c_1 \ne c_2$, we have: $g(s_t;\gamma,c)=1$ for $s_t < c_1$ and $s_t > c_2$, and $g(s_t;\gamma,c)=0$ for $c_1 \le s_t \le c_2$. In this case, the ESTR model with Equation (2) as the transition function allows recovering a three-regime threshold model with abrupt transition as a special case—the two extreme regimes being similar.

To specify the STR model, we follow the methodology proposed by Teräsvirta (1994) consisting of three steps:

- *Specification of the linear model*. This step consists in specifying the linear autoregressive part of the model (i.e. determining *p* in Equations (1) and (1')) and selecting the transition variable. To this end, we use the Schwarz information criterion.[7]
- *Test of linearity and choice of the transition variable*. We test for the null hypothesis of linearity against the STR alternative by running the following auxiliary regression (Luukkonen *et al*., 1988):

  $$\sigma_t^2 = \theta'_0 z_t + \sum_{j=1}^{3} \theta'_j \tilde{z}_t s_t^j + \eta_t \qquad (3)$$

  where $z_t = (1,\tilde{z}_t)'$, $\tilde{z}_t$ being the vector containing the explanatory variable and the lagged values of σ_t^2. Testing the null of linearity (γ = 0) is then equivalent to a test of:

  $H_0 : \theta'_1 = \theta'_2 = \theta'_3 = 0$

[6] The two regimes are associated with small and large absolute values of the transition function: the transition function is U-shaped and symmetric around *c*, meaning that local dynamics are the same for high and low values of the considered series.

[7] Note that, for robustness checks, we have also used the Akaike information criterion, which globally led to similar results.

in Equation (3).

We carry out this test for all potential transition variables, i.e. for our six measures of global financial stress: the VIX and the MSCI_W for the developed markets, the MSCI_EM and the EMBI for the emerging countries, and the two commodity indexes: the CRB and the S&P GSCI. If the null of linearity is rejected for more than one potential transition variable, we then select the transition variable as the variable with the strongest test rejection (i.e. the smallest *p*-value).

- *Choice between LSTR and ESTR specification*. Once linearity has been rejected, we choose between the LSTR and ESTR specifications by implementing the following test sequence on Equation (3) (Teräsvirta, 1994):[8]

$$H_{04}: \theta'_3 = 0$$

$$H_{03}: \theta'_2 = 0 \big| \theta'_3 = 0$$

$$H_{02}: \theta'_1 = 0 \big| \theta'_2 = \theta'_3 = 0$$

The rejection of H_{04} leads to the choice of the LSTR specification. If H_{04} is accepted and H_{03} is rejected, the ESTR model is selected. Finally, not rejecting H_{04} and H_{03}, but rejecting H_{02} leads to the LSTR specification.

Once the choice of the nonlinear specification has been made, we estimate the STR model and apply various misspecification tests: test of no residual autocorrelation (Teräsvirta, 1998), LM-test of no remaining nonlinearity (Eitrheim and Teräsvirta, 1996), and ARCH-LM test (Engle, 1982).

2.2. Results

As STR processes involve the estimation of many coefficients, for the sake of brevity, we only report the coefficients of our variables of interest, which are the proxies for financial market volatility (s_t), in both the linear and nonlinear regimes and their t-statistics.[9,10] Table 1 concerns nominal exchange rates series and displays the results of linearity tests for each country, together with the estimation of STR models (Equation (1)) and the retained transition variable, corresponding to the variable with the strongest linearity test rejection.

[8] See also Escribano and Jorda (1998) who have proposed a selection procedure to choose between a logistic and an exponential specification.

[9] Teräsvirta and Anderson (1992) themselves admitted that it is difficult to interpret all the individual coefficients of STR processes.

[10] Complete results are available upon request to the authors.

Five key findings stand out from Table 1. First, the null hypothesis of linearity is widely rejected, as this is the case for 20 out of the 21 countries (first column, Table 1). Moreover, for most of these 20 countries, the retained specification is the LSTR one. This is an interesting result, putting forward that the low and high volatility regimes are indeed characterized by different dynamics.

Second, the relationship between the degree of exchange rate flexibility and the global financial stress is positive in the nonlinear regime for a majority of countries (Column 4, Table 1). It is significantly positive for 10 out of 20 countries. In other words, the exchange rate flexibility tends to increase more than proportionally with global financial volatility: countries whose currencies are anchored to the USD tend to relax their peg in cases of increasing uncertainty on financial markets. There are nevertheless some exceptions; particularly some countries such as Malaysia or Venezuela that protect their foreign exchange market by tight exchange rate controls. Turning to the relationship between the exchange rate flexibility and the global financial stress in the linear regime (Column 3, Table 1), it should be noted that it is significantly positive for two countries, namely Peru and Israel. For Israel, the global financial volatility variable is more significant in the nonlinear regime than in the linear part, while it is only significant in the low-volatility regime for Peru. For the latter, there exists a positive link between the Peruvian sol volatility and the commodity index volatility which looses it significance during episodes of important financial stress. Regarding Mexico, the only country for which the null hypothesis of linearity is not rejected, the relationship is positive for all the global financial stress variables except the VIX, but is never significant.

Third, the variable which governs the regime change reflects mainly the volatility on developed financial markets (8 cases in 20) and that of the commodity prices (6 cases in 20); fewer currencies react to the volatility on the emerging financial markets (6 in 20) (Column 5, Table 1). Unsurprisingly, the currencies of commodity-producers, such as Argentina, Brazil, Peru, Thailand, South Africa, are more exposed when the commodity indexes become more volatile. This can be related to the fact that currencies of commodity-exporters generally depend on the commodity-terms of trade (Coudert, Couharde and Mignon, 2008). The transition variable is mainly the CRB index (5 cases in 6), as it puts more weight on non-fuel commodities, which are exported by those countries.

Table 1. Linearity tests and estimation of STR models, relationship between exchange rate flexibility and financial stress

	1	2	3	4	5	6	7	8
Country	Model	Number of lags	Linear Coefficient on st β1	Nonlinear coefficient on st β2	Transition variable st	Speed of adjustment γ	Threshold c1	c2
ARS	ESTR	3	-0.02	42.44	CRB	64.32	3.32	498.46
			(-0.04)	(2.96)				
BRL	LSTR	3	-29.20	29.56	CRB	231.03	3.61	
			(-0.89)	(0.90)				
CLP	LSTR	3	0.17	21.32	VIX	7.22	45.48	
			(1.38)	(1.81)				
COP	ESTR	1	-10.72	11.14	VIX	97.29	35.79	55.26
			(-5.01)	(5.18)				
MXN	Linear							
PEN	LSTR	1	0.081	-0.015	CRB	25.29	137.22	
			(3.47)	(0)				
UYU	ESTR	2	-0.02	0.18	MSCI_EM	36.96	60.61	1532.46
			(-0.80)	(1.63)				
VEB	LSTR	4	-18.82	18.70	CRB	229.81	6.33	
			(-0.67)	(0.69)				
CNY	LSTR	2	-0.03	0.03	VIX	38.32	21.09	
			(-2.30)	(1.96)				
IDR	LSTR	6	-49.23	49.25	EMBI	109.1	0.55	
			(-0.26)	(0.26)				
INR	ESTR	3	-1.72	1.75	VIX	428.45	27.11	39.66
			(-2.03)	(2.06)				
KRW	LSTR	3	-2.06	1.59	EMBI	1082.4	5.29	
			(-0.38)	(0.29)				
MYR	LSTR	6	0.020	0.001	MSCI_EM	18.08	73.87	
			(0.41)	(0.03)				
PHP	LSTR	1	1.11	-1.10	MSCI_W	116.64	2.35	
			(0.25)	(-0.25)				
SGD	ESTR	3	-0.09	0.10	MSCI_EM	33.43	161.78	262.95
			(-0.84)	(0.93)				
THB	LSTR	3	-0.78	0.75	SP GSCI	105.39	10.13	
			(-0.28)	(0.27)				
ILS	LSTR	4	0.30	1.87	VIX	1385.91	39.54	
			(2.11)	(3.15)				
KWD	LSTR	7	0.00	0.14	MSCI_W	203.93	75.84	
			(-1.21)	(6.78)				
MAD	LSTR	5	-0.37	0.28	EMBI	0.27	14.64	
			(0.00)	(5.08)				
RUB	LSTR	5	-0.01	26.51	MSCI_W	6.55	112.55	
			(-0.03)	(11.40)				
ZAR	LSTR	1	-0.10	0.83	CRB	21.19	98.13	
			(-0.52)	(3.69)				

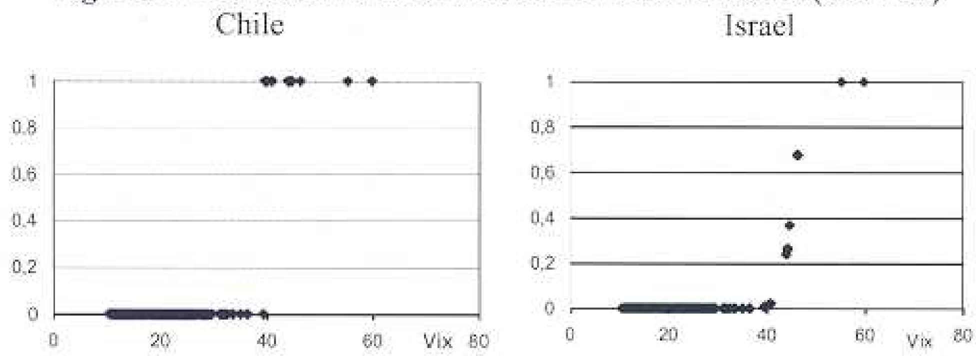
Note: (i) The currencies are called by their Bloomberg codes, corresponding to the following countries : Argentina (ARS), Brazil (BRL), Chile (CLP), Colombia (COP), Mexico (MXN), Peru (PEN), Uruguay (UYU), Venezuela (VEB), China (CNY), India (INR), Indonesia (IDR), Korea (KRW), Malaysia (MYR), Philippines (PHP), Singapore (SGD), Thailand (THB), Israel (ILS), Kuwait (KWD), Morocco (MAD), Russia (RUB), South Africa (ZAR). MSCI_W is a stock market index of developed countries, MSCI_EM is the same for emerging countries; EMBI, the emerging bond global composite index; CRB and SP GSCI are commodity indexes. Values in brackets are the t-statistics of the estimated coefficients. The number of lags is the order *p* of the autoregressive part in the STR model. (ii) The transition variable is the volatility of the considered index (except for the VIX, which is directly the VIX index). (iii) We estimate the equation: $\sigma_t^2 = \alpha_{10} + \sum_{j=1}^{p} \alpha_{1j}\sigma_{t-j}^2 + \beta_1 s_t + \left(\alpha_{20} + \sum_{j=1}^{p} \alpha_{2j}\sigma_{t-j}^2 + \beta_2 s_t\right) g(s_t;\gamma,c) + \varepsilon_t$ over the period January 1994-September 2009.

A closer look at the detailed results allows us to somewhat qualify these findings. Indeed, results reported in Table 1 are relating to the transition variable for which the rejection of the null hypothesis of linearity is the strongest although for some countries, the null of linearity is rejected for more than one transition variable. In those cases, we find that (i) the countries which are sensitive to the international volatility measured by the VIX, such as India, also react when this volatility is proxied by the MSCI_W; (ii) some of the countries whose transition variable is the international volatility also react to the volatility on emerging markets, this is the case for Russia; (iii) for Israel, the null of linearity is also rejected when the CRB and the SPGSCI act as the transition variable, evidencing some impact of the commodity prices on this country's currency. This interesting result shows that the volatility of commodity prices is able to affect not only the currencies of commodity-exporters but also those of highly dependent countries.

Fourth, the speed of adjustment is quite high in most countries (Column 6, Table 1). This means that the exchange rate flexibility rapidly switches from one regime to the other, according to the level of global financial stress. A closer look at the results shows that the speeds of transition are the highest in the wealthiest countries in the sample, namely Korea, Israel and Kuwait. Indeed, a wealthy country is expected to react more rapidly to a high volatility episode, and thus to correct it more quickly,[11] suggesting that the transition from the high volatility regime to the linear one tends to be rapid. Similarly, such countries are more exposed to the international volatility, be it proxied by the volatility on the international stock markets or on commodity markets, explaining that the change from the low to the high volatility regime may be rapid. Figure 5 illustrates these results by plotting the transition function versus the retained transition variable for Israel and Chile. It is shown that the transition between the two regimes is quite smooth for Chile, whereas it is clearly abrupt for Israel.

[11] Indeed, one may expect that wealthiest countries have more means than poorest ones to react to disequilibria, and are thus able to correct them more quickly.

Figure 5. Transition function versus transition variable (the VIX)



Fifth, the threshold values vary according to both the transition variable and the countries (Column 7, Table 1). To see that, let us examine for instance how often these thresholds are broken in the case of the VIX index, whose levels are the most familiar, as closely watched by market observers. Some currencies like the Indian rupee began to react more strongly as soon as the VIX overcomes the threshold of 27, which generally occurs just after the burst of a major crisis, such as the 1997 Asian crisis, the 1998 LTCM crisis, the Argentinean crisis in 2002, and the subprime crisis (see Figure A2 in Appendix). For other countries such as Chile and Israel, the regime switches only when the VIX overcomes a threshold around 40, as represented on the transition functions above in Figure 5. This situation occurs much more rarely, as it was the case in the sample only in the aftermath of the LTCM crisis in late 1998 and after the bankruptcy of Lehman Brothers in October 2008.

The results for the estimation of Equation (1'), where nominal exchange rates have been replaced by real series are displayed in Table A1 in the Appendix. Results are very close, as real exchange rate volatility also depends on global financial stress nonlinearly, for all countries but one (Brazil). The relationship between the two variables is significantly higher in the nonlinear regime for 9 countries. The fact that results in nominal and real terms are globally close is not surprising given that the real exchange rate volatility is mainly driven by the nominal one, as prices are less volatile than exchange rates. There exists however some differences for a few number of countries, particularly for those whose currencies are pegged to the USD, and therefore exhibit little nominal flexibility (Kuwait, Colombia...).

Table A2 in the Appendix displays the results for misspecification tests. To avoid too many tables, we only report the results for the most interesting models, i.e. models in which the relationship between exchange rate flexibility and global financial stress is significant and has the expected sign. The residuals have globally the good properties for Argentina, Chile, China, India, Korea, South Africa and Singapore in nominal terms, and for the other countries in real terms, with the exception of Peru.

3. REGIONAL CONTAGION

We now investigate the potential contagion effects stemming from the other emerging currency markets. More specifically, we test for regional contagion as we consider that a country is more likely to be submitted to contagion effects coming from its own neighbors than from the rest of the world. This hypothesis may be supported by different types of reasons: (i) countries may want to stabilize their exchange rates against their trade partners, often their neighbors, which incites them to change their exchange rate policy simultaneously; (ii) market pressures may be rising simultaneously in a given region because investors are prone to suddenly update their beliefs and preferences on a whole region in case of a problem somewhere.

3.1. Bringing in the indicator of regional contagion

In this framework, we relate each country *i* to its geographical zone G_i (G_i = Latin America, Asia, Middle East) and construct a contagion indicator, denoted $\overline{\sigma}_{it}^2$, which is equal to the average exchange rate volatilities among the other countries *j* of G_i (with $j \neq i$).[12]

$$\overline{\sigma}_{it}^2 = \sum_{j \in G_i, j \neq i} \sigma_{jt}^2 \qquad (4)$$

We follow the same methodology as in Section 2, paying a special attention to possible nonlinear effects. Consequently, we estimate the following specification:

$$\sigma_{it}^2 = \alpha_{i10} + \sum_{j=1}^{p_i} \alpha_{i1j} \sigma_{it-j}^2 + \beta_{i1} s_t + \delta_{i1} \overline{\sigma}_{it}^2 + \left(\alpha_{i20} + \sum_{j=1}^{p_i} \alpha_{i2j} \sigma_{it-j}^2 + \beta_{i2} s_t + \delta_{i2} \overline{\sigma}_{it}^2 \right) g_i(x_t; \gamma_i, c_i) + \varepsilon_{it} \qquad (5)$$

Two types of transition variables x_t are considered: a proxy of the global financial stress s_t (as in Section 2), and the regional contagion indicator $\overline{\sigma}_{it}^2$. Our aim here is to investigate whether the intensity of contagion changes over time and, more specifically, whether its dynamics differs across crisis and non-crisis episodes.

3.2. Results

The summarized results relating to the estimation of Equation (5) are reported in Table 2, which gives the estimated coefficients of the proxy for contagion $\overline{\sigma}_{it}^2$ in both the linear and

[12] Two countries, namely Russia and South Africa, do not belong to the three considered geographical zones. For these two countries, the contagion indicator is defined by the average exchange rate volatility of all the other countries of our sample (except Russia (resp. South Africa) for South Africa (resp. Russia)).

the nonlinear regimes.[13]

First, the null hypothesis of linearity is rejected for all countries but one (Column 1, Table 2). Moreover, the two regimes are governed by different dynamics since the LSTR specification is generally retained as for Section 2.

Second, the results show that contagion across countries is more important in high volatility regimes (Columns 3 and 4, Table 2). (i) In a majority of countries (11 in 21), the coefficient on the contagion indicator is significantly positive in the nonlinear regime, it is even higher than that in the linear one (except for one country). (ii) There is no contagion in the linear regime, except in six countries (Uruguay, Indonesia, Philippines, Singapore, Thailand, and Kuwait). Out of these six countries, there are only two (Indonesia and the Philippines) for which the contagion effect is significant in the linear regime and not in the nonlinear one; for the four others, the coefficient of our contagion variable is higher in the nonlinear regime than in the linear one. These results confirm the nonlinear effects of contagion, which significantly increase in period of turmoil, as evidenced by Forbes and Rigobon (2002). In other words, during tranquil periods, the volatility of the exchange rate in a given country is linearly affected by that of the neighboring countries, whereas linkages among currency markets do increase during crisis periods.

[13] As for Section 3, complete results are available upon request to the authors.

Table 2. Linearity tests and estimation of STR models, contagion effects

	1	2	3	4	5	6	7	8
			Linear	Nonlinear	Transition variable	Speed of adjustment	Threshold	
Country	Model	Number of lags	$\overline{\sigma}_{it}^2$	$\overline{\sigma}_{it}^2$	st	γ	c_1	c_2
ARS	LSTR	3	0.36 (0.37)	-0.25 (-0.24)	$\overline{\sigma}_{it}^2$ (a)	470.53	109.61	
BRL	LSTR	2	-0.16 (-0.33)	0.60 (0.65)	MSCI_EM	32.30	20.79	
CLP	LSTR	3	0.00 (-0.48)	3.63 (2.92)	VIX	2.56	47.67	
COP	LSTR	3	0.00 (0.00)	0.04 (0.46)	SPGSCI	135.43	141.89	
MXN	Linear							
PEN	LSTR	1	0.00 (-0.86)	0.06 (7.28)	VIX	3568.81	23.89	
UYU	LSTR	4	0.03 (2.19)	0.98 (3.13)	MSCI_W	273.18	68.75	
VEB	LSTR	4	0.04 (0.06)	1.46 (1.21)	CRB	322.45	6.34	
CNY	LSTR	2	0 (-0.32)	0 (0.05)	MSCI_E	62704	66.37	
IDR	ESTR	2	6.29 (13.16)	-10.22 (-1.29)	EMBI	144.76	0.30	31.70
INR	ESTR	1	-1.36 (-0.38)	1.36 (0.38)	MSCI_W	10.21	100.91	175.11
KRW	LSTR	3	0.00 (0.00)	14.14 (12.92)	CRB	698.84	6.72	
MYR	LSTR	7	-0.22 (-1.04)	1.01 (3.63)	SPGSCI	14.06	15.33	
PHP	LSTR	2	0.71 (3.03)	-0.19 (-0.8)	SPGSCI	152.98	12.70	
SGD	LSTR	5	0.06 (7.67)	0.64 (2.18)	MSCI_W	8.08	47.23	
THB	LSTR	2	0.61 (4.46)	8.27 (7.50)	MSCI_W	1627.83	19.43	
ILS	LSTR	1	-0.10 (-0.65)	1.42 (2.80)	VIX	82.21	31.98	
KWD	LSTR	1	0.04 (1.93)	0.62 (11.19)	$\overline{\sigma}_{it}^2$ (a)	31.66	19.29	
MAD	LSTR	5	0.04 (0.43)	0.84 (1.78)	MSCI_W	20.89	78.07	
RUB	ESTR	2	*-19.79* (-2.26)	19.87 (2.27)	$\overline{\sigma}_{it}^2$ (a)	29.03	13.71	
ZAR	LSTR	1	-0.02 (-0.20)	-0.05 (-0.11)	EMBI	3.59	71.28	

Note: The following equation is estimated:

$$\sigma_{it}^2 = \alpha_{i10} + \sum_{j=1}^{p_i} \alpha_{i1j}\sigma_{it-j}^2 + \beta_{i1}s_t + \delta_{i1}\overline{\sigma}_{it}^2 + \left(\alpha_{i20} + \sum_{j=1}^{p_i} \alpha_{i2j}\sigma_{it-j}^2 + \beta_{i2}s_t + \delta_{i2}\overline{\sigma}_{it}^2\right) g_i\left(x_t;\gamma_i,c_i\right) + \varepsilon_{it}.$$

$\overline{\sigma}_{it}^2$ is the contagion indicator. Explanatory variable: (a): SPGSCI, (b): MSCI_EM. See note (i) of Table 1.

Third, in most of the cases, the transition variable reflects the volatility on international financial markets (Column 5, Table 2). This evidences the importance of global financial stress in advanced economies on the contagion process. For three countries (Argentina, Kuwait, and Russia), the contagion indicator itself acts as the transition variable, meaning that contagion tends to operate only above a given threshold.

Finally, as for Section 2, the transition speed is generally high, though varying across countries (Column 6, Table 2). In other words, the exchange rate volatility rapidly switches from one regime to the other, according either the level of global financial stress or the level of contagion; a finding that is consistent with the increasing integration process of world financial markets.

The summarized results from the estimation of Equation (5) for real exchange rate series are displayed in Table A3 in the Appendix. Here, real series may be more relevant than nominal ones when studying contagion since inflation effects are removed, a fact that may be important for our panel of countries which are characterized by very different inflation regimes. As before, the results are relatively close whether one considers series in nominal or in real terms. Indeed, for 13 out of 21 countries, the contagion process is significant in the nonlinear regime. The coefficient on contagion is also always higher than in the linear regime, except for only two countries (namely Indonesia and the Philippines) as in the nominal case. On the whole, our findings illustrate that the main driver of the real exchange rate volatility is the nominal one. Table A4[14] in the Appendix shows that real residual series display no autocorrelation at the first lag. In some cases, there is however some remaining nonlinearity, which generally disappears for some countries in nominal terms.

4. CONCLUSION

Many emerging countries have loosened the link of their currencies to the US dollar since the burst of the subprime crisis in July 2007, mainly because they had to face violent market pressures, as speculators bid down their currencies. The main relevant explanations may rely on contagion effects. For example, investors bearing heavy losses on advanced stock markets and lacking liquidity to meet their margin calls or their risk management requirements may engage in selling off all sorts of risky assets across the board, including their assets on emerging countries in local currencies. Crises are also the times when carry-trades unwind, as risk-aversion rises. Incidentally, the rationale to pegging to the dollar could also have been wiped off by neighboring countries giving up their peg.

Consequently, exchange rate policies in emerging countries are likely to be contingent on the situation of financial markets in advanced countries, spillovers being particularly strong in the aftermath of a crisis. To check for this hypothesis, we have tested the links between exchange rate policies and financial strains in advanced markets. To do that, we have measured

[14] As before, we only report results relating to the models for which the mean flexibility is significant and positive.

exchange rate policies by their degree of flexibility, which in turn is proxied by currency volatility; we have assessed the global financial stress by the volatility both on stock markets of advanced countries and on commodity markets. The results confirm that the flexibility of exchange rates tends to increase more than proportionally with the indicator of global financial strains. We have also evidenced nonlinearities in the contagion effects spreading from one emerging currency to its neighbors.

According to these results, spillovers from financial turmoil in advanced markets do result in the loosening of exchange rate policies in emerging countries. This has been manifest since the outset of the subprime crisis, although this does not exclude the possibility that other factors have been at work in the renewal of exchange rate arrangements. In this case, the situation may not be reversed by the return to normal. In particular, the role of the US dollar in the international monetary system has been more and more questioned for several years, while the US has kept on accumulating external debt, threatening the long-term value of its currency. This could also be another reason for countries to slacken their links to the US dollar.

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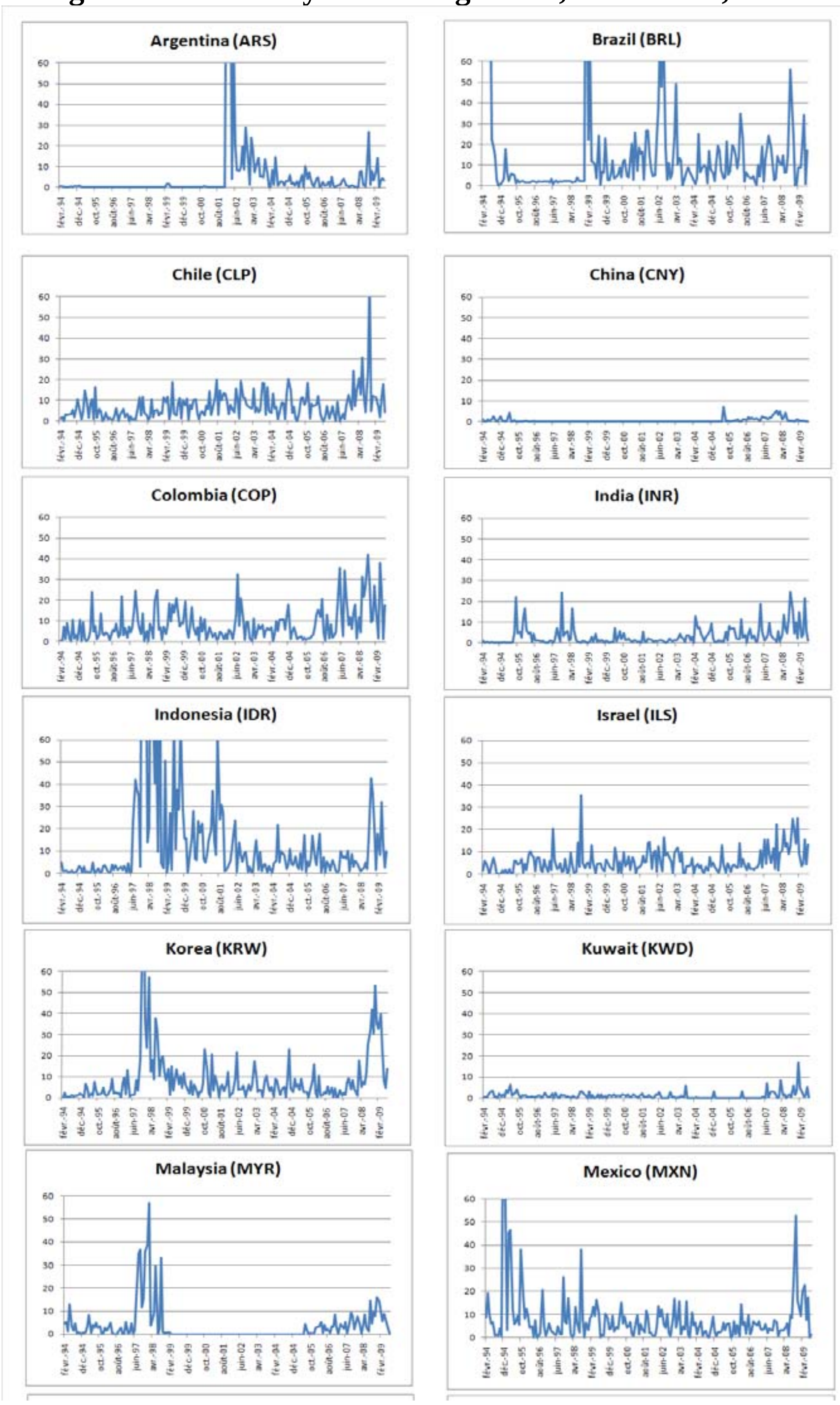
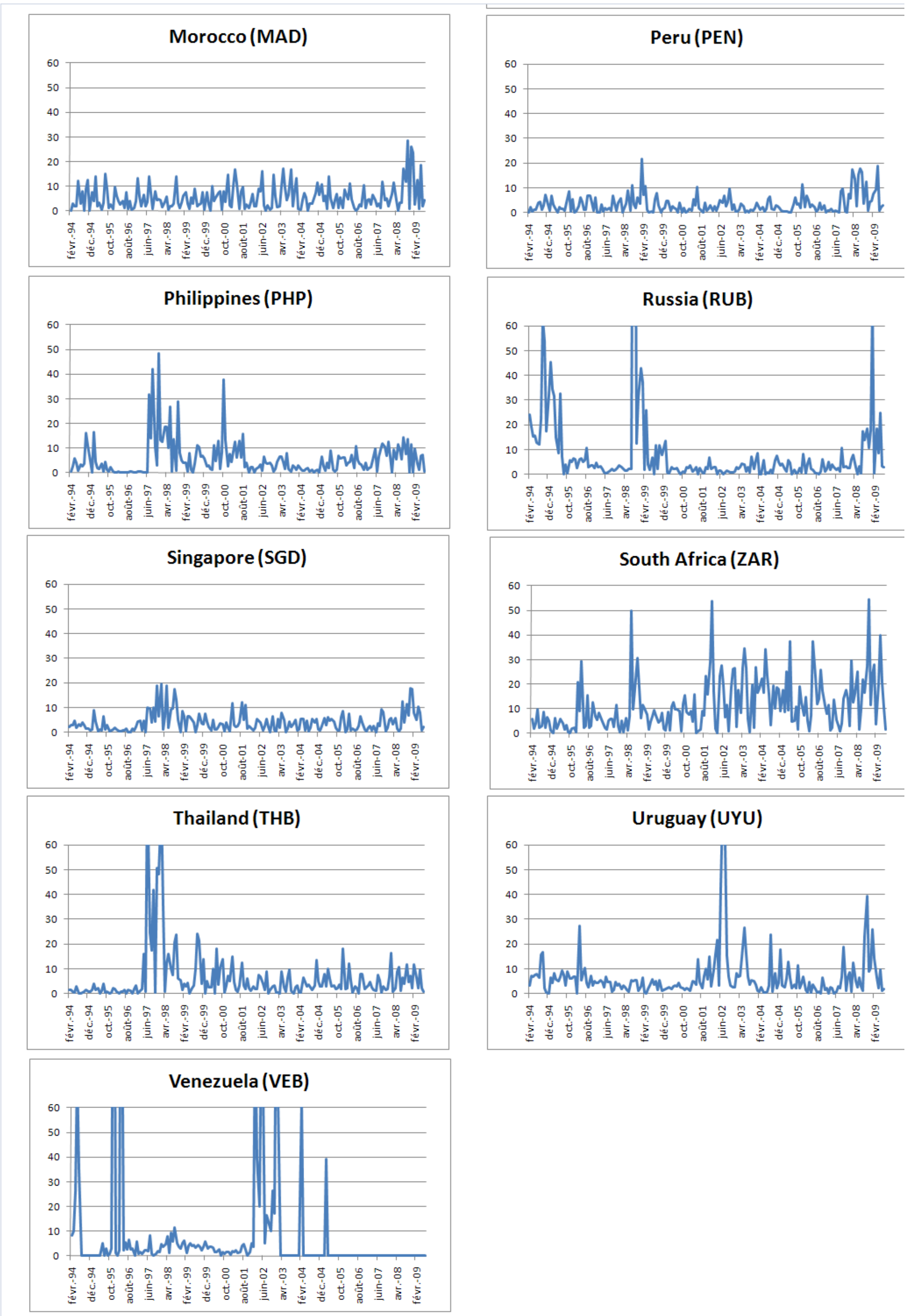
APPENDIX

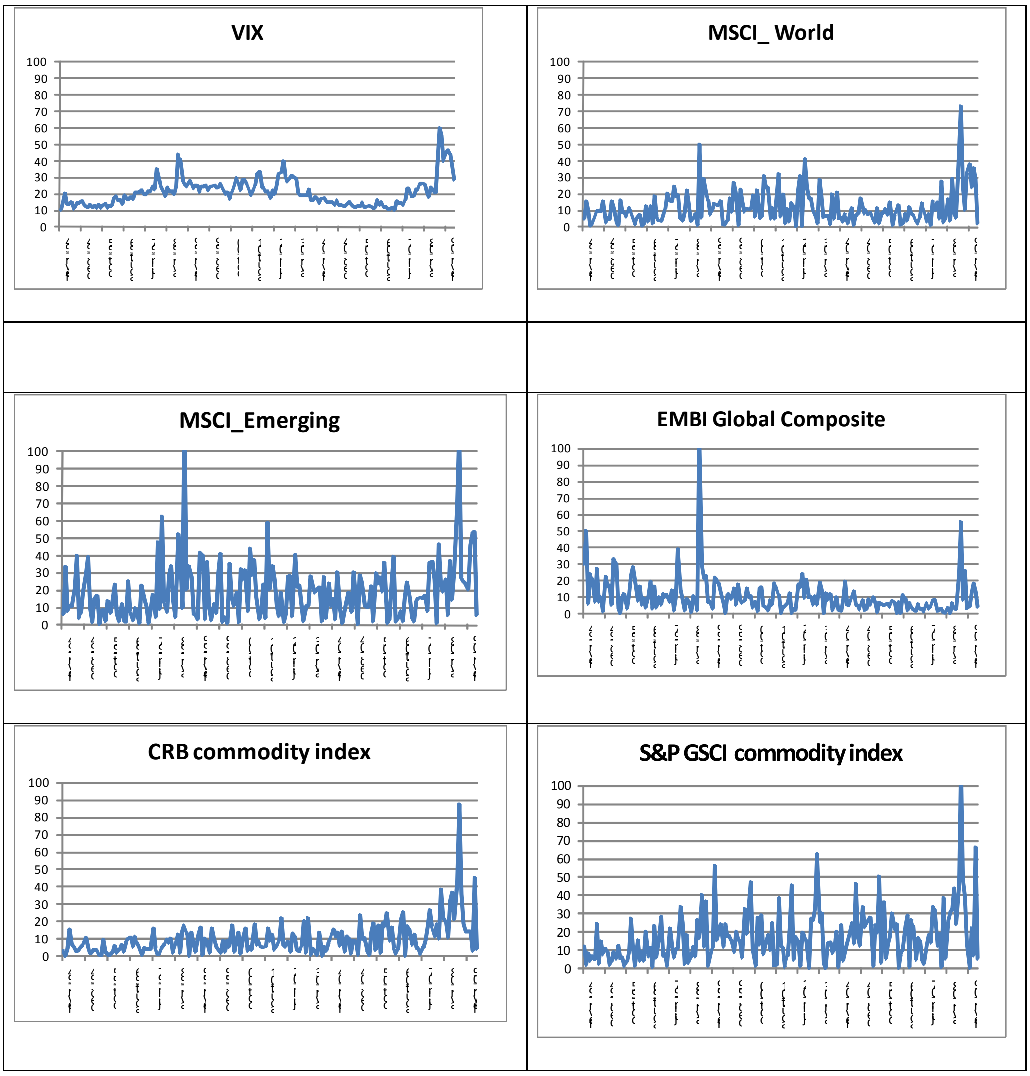
Figure A1. Volatility of exchange rates, annualized, in %





Note: Volatility figures are cut at a 60% threshold. Source: Authors calculations, based on Bloomberg data.

Figure A2. Volatility of the indicators of global financial markets, annualized, in %



Source: Authors calculations, based on Bloomberg data.

Table A1. Linearity tests and estimation of STR models, relationship between exchange rate flexibility and financial stress, real exchange rates

	1	2	3	4	5	6	7	8
Country	Model	Number of lags	Linear coefficient on st β1	Non-linear coefficient on st β2	Transition variable st	Speed of adjustment γ	Threshold c1	 c2
ARS	ESTR	2	-31.43 (-1.72)	31.45 (1.73)	MSCI_W	102.45	12.92	13.25
BRL	Linear							
CLP	LSTR	1	0.22 (1.93)	22.45 (20.44)	VIX	16.19	45.33	
COP	ESTR	3	0.14 (2.09)	-0.03 (-0.29)	MSCI_W	20.94	0.74	79.26
MXN	LSTR	1	0.06 (0.09)	-0.17 (-0.27)	EMBI	2386.41	38.59	
PEN	ESTR	2	-1.72 (-2.45)	1.72 (2.45)	SPGSCI	12.42	138.46	138.46
UYU	LSTR	5	0.02 (0.24)	-0.04 (-0.44)	MSCI_W	368.59	68.91	
VEB	LSTR	4	0.35 (0.18)	-0.45 (-0.23)	EMBI	18926	24.36	
CNY	LSTR	4	0.00 (-0.29)	0.03 (1.96)	EMBI	53.89	63.52	
IDR	LSTR	1	8.15 (1.48)	-7.16 (-1.16)	VIX	4366	21.77	
INR	LSTR	1	0.01 (1.0)	0.70 (2.49)	SPGSCI	3.77	301.89	
KRW	LSTR	7	5.43 (1.08)	-5.20 (-1.04)	MSCI_W	4402.10	2.69	
MYR	LSTR	1	0.01 (0.26)	-0.005 (-0.09)	MSCI_E	10.40	81.93	
PHP	LSTR	3	-0.86 (-0.25)	0.89 (0.26)	MSCI_W	118.05	2.36	
SGD	ESTR	2	-0.22 (-4.22)	0.22 (4.35)	MSCI_E	71.77	189.94	751.97
THB	LSTR	3	-0.70 (-0.42)	0.67 (0.41)	SPGSCI	120.79	11.16	
ILS	LSTR	1	0.38 (2.79)	1.51 (3.56)	VIX	12.14	32.11	
KWD	ESTR	2	0.04 (0.59)	-0.04 (-0.59)	CRB	34.44	61.16	339.2
MAD	LSTR	3	-0.11 (-1.31)	0.16 (1.90)	CRB	35217.27	25.12	
RUB	LSTR	6	-0.04 (-0.37)	84.02 (3.65)	MSCI_W	76.07	81.07	
ZAR	LSTR	1	0.13 (0.66)	-0.15 (-0.74)	EMBI	190.0	59.42	

Note: This table reports the results of the estimation of Equation (1’). See notes (i) and (ii) of Table 1.

Table A2. Residual tests (relationship between exchange rate flexibility and financial stress), p-values

	No autocorrelation			
	Order 1	Order 4	No remaining nonlinearity	ARCH
		Nominal series		
ARG	0.29	0.85	0.83	1.00
CHL	0.94	0.48	0.07	0.49
COL	0.32	0.05	0.00	0.02
PER	0.00	0.00	0.00	1.00
CHN	0.57	0.40	0.59	1.00
IND	0.50	0.80	0.43	0.91
SGP	0.28	0.47	0.00	0.00
ISR	0.02	0.01	0.46	1.00
KUW	0.82	0.66	1.00	0.01
MOR	0.99	0.01	0.00	0.00
RUS	0.16	0.00	0.00	0.00
SAF	0.67	0.47	0.90	1.00
		Real series		
ARG	0.05	0.19	0.05	1.00
CHL	0.23	0.00	0.63	0.00
COL	0.92	0.22	0.17	1.00
PER	0.00	0.00	0.00	1.00
CHN	0.00	0.00	0.01	0.00
IND	0.61	0.40	0.37	0.95
SGP	0.25	0.09	0.04	0.01
ISR	0.81	0.15	0.46	0.25
MOR	0.01	0.00	0.00	0.22
RUS	0.42	0.14	0.00	0.20

Note: This table presents the results of residual tests (p-values). No autocorrelation refers to the test of no residual autocorrelation of order 1 and 4 described in Teräsvirta (1998). No remaining nonlinearity is the LM-test of no additive nonlinearity developed by Eitrheim and Teräsvirta (1996). ARCH is the ARCH-LM test of homoskedasticity against the alternative of conditional heteroskedasticity (Engle, 1982).

Table A3. Linearity tests and estimation of STR models, contagion effects, real exchange rates

Country	1	2	3	4	5	6	7	8
			Linear	Non linear	Transition variable	Speed of adjustment	Threshold	
Country	Model	Number of lags	$\overline{\sigma}_{it}^2$	$\overline{\sigma}_{it}^2$	st	γ	c1	c2
ARS	ESTR	1	-0.09	0.02	SPGSCI	19765	19.74	195.72
			(-0.35)	(0.07)				
BRL	Linear							
CLP	LSTR	3	0.01	3.19	VIX	3.05	45.79	
			(0.43)	(2.66)				
COP	LSTR	7	-0.02	0.87	VIX	796.33	31.57	
			(-0.62)	(5.24)				
MXN	Linear							
PEN	ESTR	2	-0.28	0.30	MSCI_W	1.31	84.11	357.33
			(-2.81)	(3.02)				
UYU	LSTR	6	0.05	0.58	MSCI_W	66.32	67.22	
			(1.59)	(2.17)				
VEB	LSTR	4	-0.29	0.82	VIX	176.26	16.89	
			(-0.37)	(0.88)				
CNY	LSTR	3	0.00	0.18	EMBI	256.07	60.45	
			(-0.41)	(2.27)				
IDR	LSTR	3	6.78	11.89	MSCI_W	16.16	29.93	
			(6.21)	(2.47)				
INR	LSTR	1	0.02	0.50	SPGSCI	3.90	299.63	
			(2.0)	(0.05)				
KRW	LSTR	2	0.19	2.55	CRB	571.65	6.50	
			(0.35)	(3.27)				
MYR	LSTR	6	0.25	0.46	CRB	61.34	4.05	
			(1.45)	(2.37)				
PHP	LSTR	2	0.61	0.14	EMBI	4.01	48.22	
			(2.93)	(0.39)				
SGD	LSTR	5	0.11	0.68	MSCI_W	7.68	54.86	
			(7.68)	(2.31)				
THB	LSTR	1	1.72	2.74	$\overline{\sigma}_{it}^2$ (b)	108.93	50.09	
			(3.49)	(4.12)				
ILS	LSTR	2	0.06	2.73	MSCI_W	1170.16	53.04	
			(0.45)	(2.84)				
KWD	ESTR	3	-1.24	1.25	$\overline{\sigma}_{it}^2$ (a)	609.35	7.85	13.55
			(-1.71)	(1.72)				
MAD	LSTR	2	-0.02	1.82	SPGSCI	1235.74	103.69	
			(-0.15)	(2.37)				
RUB	ESTR	2	-48.21	48.14	MSCI_D	15.57	81.0	362.15
			(-0.29)	(0.29)				
ZAR	LSTR	1	0.03	2.01	EMBI	174.90	59.39	
			(0.18)	(1.55)				

Note: See Table 2.

Table A4. Residual tests (contagion effects), p-values

	No autocorrelation			
	Order 1	Order 4	No remaining nonlinearity	ARCH
		Nominal series		
CHL	0.99	0.25	0.26	0.43
PER	0.02	0.08	0.00	0.15
URU	0.01	0.05	0.00	1.00
IDN	0.01	0.02	0.18	0.45
KOR	0.14	0.19	0.00	0.98
MLY	0.96	0.00	0.00	0.01
PHI	0.76	0.94	0.40	1.00
SGP	0.90	0.00	0.00	0.00
THA	0.25	0.06	0.93	1.00
EGY	0.03	0.15	0.00	1.00
ISR	0.01	0.09	0.26	1.00
KUW	0.27	0.70	0.58	0.01
MOR	0.66	0.00	0.21	0.00
RUS	0.46	0.19	1.00	1.00
		Real series		
CHL	0.75	0.23	0.32	0.01
COL	0.43	0.05	0.53	0.68
PER	0.69	0.01	0.74	0.00
URU	0.08	0.21	0.00	1.00
CHN	0.71	0.02	0.61	0.00
IDN	0.23	0.06	0.01	0.96
IND	0.65	0.44	0.39	0.97
KOR	0.82	0.97	0.00	0.00
MLY	0.40	0.00	0.00	0.40
PHI	0.17	0.01	0.57	1.00
SGP	0.21	0.22	0.01	0.87
THA	0.83	0.02	0.01	1.00
ISR	0.36	0.16	0.00	0.32
KUW	0.57	0.12	0.08	0.07
MOR	0.50	0.09	0.55	0.09
SAF	0.83	0.11	0.53	0.62

Note: This table presents the results of residual tests (p-values). No autocorrelation refers to the test of no residual autocorrelation of order 1 and 4 described in Teräsvirta (1998). No remaining nonlinearity is the LM-test of no additive nonlinearity developed by Eitrheim and Teräsvirta (1996). ARCH is the ARCH-LM test of homoskedasticity against the alternative of conditional heteroskedasticity (Engle, 1982).

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