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FOREIGN EXCHANGE MARKETS IN SOUTH-EAST ASIA 1990-2004: AN EMPIRICAL ANALYSIS OF SPILLOVERS DURING CRISIS AND NON-CRISIS PERIODS

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Abstract

The East Asian crisis of 1997 sparked an extensive literature in an effort to explain the causes and spread of heightened foreign exchange (FX) market pressures in the region. In this paper we model FX movements and calculate spillover effects covering the extended period between 1990 and 2004. Using Markov switching vector autoregressions, we find substantial evidence that FX correlations vary across crisis and non-crisis states, a result that bears implications for international portfolio diversification and reserve pooling. Contagion effects are also present during crises. Finally, we gauge the ability of stock market indices to forecast time-varying transition probabilities and discover positive results.

JEL Classification: F3

Keywords: East Asia, Currency Crisis

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Introduction

A 1999 IMF factsheet on the Fund's response to the Asian crisis of 1997 states that "[...] the IMF, along with everyone else, did not foresee the scale of the financial contagion that followed the events in Thailand".[2] A key event was the devaluation of the Thai baht in July 1997. Even though Thailand was running a current account deficit of almost 8% of GDP and, hence, was susceptible to an exchange rate correction, other countries in the region, that were subsequently affected by speculative attacks in the foreign exchange market, were not experiencing equivalently large external imbalances at the time. The region's rapid real GDP growth rates in the early 1990s had earned the countries the title 'Asian Tigers'. With a reputation for fiscal prudence and reasonably low inflation rates it seemed that little threatened continued economic advance.

With the liberalization of capital accounts new foreign money was channelled into economies usually through the banking system. However, a combination of asymmetric information and moral hazard problems led to excessive borrowing (e.g. Mishkin, 1999, Corsetti *et al*., 1998). An underestimation of the risks both by bank managers and international investors meant that several firms were burdened with substantial amounts of foreign currency short-term debt. This constituted a serious problem, as most firms' earnings were in local currency, an imbalance that seriously exposed them to the risk of devaluation.

So, uniquely in the recent history of crises, the source of the Asian crisis was not some serious macroeconomic imbalance but rather the inability of the private sector to allocate funds to the most productive uses through the appropriate assessment of risks. In other words, the region's problem was structural in the sense that financial market

[2] Available at http://www.imf.org/external/np/exr/facts/asia.htm.

regulation, supervision and management were inadequate. Related speculative pressures in the FX markets eventually led the south-east Asian governments to abolish the pegs (at least temporarily) and, as a result, the region's currencies depreciated sharply. The real effects in the region were painful, as economic growth was adversely affected.

Since the Asian crisis, a substantial amount of research has examined the mechanisms through which it was dispersed amongst countries in the region. This paper covers similar ground, but uses recently devised econometric tools. It also exploits a more complete set of data running up until 2004. This allows comparisons to be made between crises and non-crisis periods. More specifically, the paper addresses a number of research questions.

First, is the relationship between currencies as measured by exchange rates different from that between wider FX market pressure indicators? If so, this suggests that different countries may respond to spillover effects in different ways with some allowing the exchange rate to take the strain of adjustment and others opting for rising interest rates and/or reserve decumulation. Second, does the relationship (the extent and nature of the spillovers) differ between crisis and non-crisis periods? This is an important question for the risk reduction of internationally diversified portfolios. If the relationship changes, then what might be sensible behaviour before a crisis may not be as sensible during (or after) it. Third, are contagion effects present is south-east Asian FX markets and, if yes, which countries are the sources and which the recipients? And finally, do stock markets anticipate crises in foreign exchange markets? Given that the Asian crisis was largely generated in the private sector where potential risks had accumulated, we test to see whether stock prices contain information about anticipated switches from tranquil to crisis states.

The paper is empirical. We do not seek to impose and test any particular model. However, the relationships we examine are informed by the relevant theory. A concluding section briefly discusses some of the policy implications of our findings.

Data and Variables

Monthly nominal bilateral exchange rates with the US dollar for Indonesia, Korea, Malaysia, the Philippines and Thailand are taken from *International Financial Statistics* published by the IMF. Figures 1, 2 and 3 capture the recent history of exchange rate movements in the East Asian FX markets, including the turbulence in 1997. The five countries in our sample (Indonesia, Korea, Malaysia, the Philippines and Thailand) had implemented a variety of exchange rate regimes over the sample period, but immediately before July 1997 they were all *de facto* fixing their currencies to the US dollar. When speculative pressures in the region arose, interest rates escalated and international reserves fell in an effort to defend the values of the local currencies. Eventually, the countries abolished their quasi-fixed exchange rate regimes and floated their currencies.[3]

We use the above-mentioned variables (nominal exchange rates, interest rates and international reserves) in the construction of a foreign exchange (FX) market pressure indicator (*fxmpi*). Our analysis is based on two 'crisis' measures: the percentage change

[3] According to Reinhart and Rogoff (2004) prior to the 1997 events all countries in the sample were running de facto pegs against the US dollar (except Malaysia, which was operating a de facto moving band around the US dollar). Post-crisis all currencies were freely floating (or falling). Eventually some reverted to managed floats (Philippines, Thailand) or established new pegs (Malaysia).

in the values of the nominal exchange rate (*dlxr*) and *fxmpi*.[4] Increases in the value of *fxmpi* signify more pressure (hence the negative sign for the reserves component of the indicator).

$$fxmpi_t = [\alpha * dlxr_t + \beta * dir_t - \gamma * dlres_t] * 100,$$

where *dir* is the change in the domestic interest rate and *dlres* is the change in the natural logarithm of international reserves minus gold (in dollars). The weights of the variables are determined as follows:

$$\alpha = \frac{\frac{1}{SD_{dlxr}}}{\frac{1}{SD_{dlxr}} + \frac{1}{SD_{dir}} + \frac{1}{SD_{dlres}}},$$

$$\beta = \frac{\frac{1}{SD_{dir}}}{\frac{1}{SD_{dlxr}} + \frac{1}{SD_{dir}} + \frac{1}{SD_{dlres}}}, \text{ and}$$

$$\gamma = \frac{\frac{1}{SD_{dlres}}}{\frac{1}{SD_{dlxr}} + \frac{1}{SD_{dir}} + \frac{1}{SD_{dlres}}},$$

where *SD* stands for standard deviation. The need to both measures arises from the fact that it is possible that nominal exchange rate movements do not reveal the extent of speculative pressures. These may be reflected by the use of other policy instruments (e.g. reserves, interest rates and capital controls). Hence, we can use *fxmpi* to assess the presence of speculative pressures and *dlxr* to determine how successful these have been.

[4] *fxmpi* has its roots in Girton and Roper (1977). The use of similar indices to capture pressures in the FX market is not unusual (e.g. Eichengreen *et al.*, 1996), even though there have also been criticisms (see Eika *et al.*, 1996 and Willett and Nitithanprapas, 2000).

We do not incorporate a measure of capital controls in our estimations because of the unreliability of data.

Table 1 provides descriptive statistics and correlations for the two crisis measures. Even though percent changes in exchange rates are highly correlated between countries in the sample, the same cannot be said about the wider pressure indicator. Figures 2a and 2b plot all series over time. The increased volatility in mid 1997 is evident everywhere.

Tranquil and Crisis Regimes

To model the time series we adopt a commonly used strategy for the analysis of structural change: a Markov regime switching model (Hamilton, 1989). This approach is appropriate, as the model assumes autoregressive processes in which the parameters depend on the realizations of an unobserved regime variable, which in turn is modelled as a Markov chain. The latter assumes that realizations of the state only depend on their (chronologically) previous realization. The regime variable is discrete and can only take two values: 0 if there is no crisis and the distribution has a low mean and 1 if there is a 'crisis' and the distribution has a high mean. In contrast to Hamilton (1989) we assume a heteroscedastic setting in which the variance changes across the two regimes.

The model can be written as

$$y_t - \mu(s_t) = \beta_1\left[y_{t-1} - \mu(s_{t-1})\right] + \ldots + \beta_\rho\left[y_{t-\rho} - \mu(s_{t-\rho})\right] + \varepsilon_t ,$$

where ρ denotes the order of the autoregression and μ is the regime-dependent mean conditional on the state variable, s_t. In this setting, we can estimate the matrix of transition probabilities (which contains the probabilities of remaining in one regime or of switching to another). In the case with two regimes we have four such probabilities: p_{11},

p_{12}, p_{21} and p_{22}, where, for example, p_{11} gives the probability of remaining in regime 1 and p_{12} gives the probability of switching from regime 1 to regime 2.[5]

Table 2a gives the results of the estimations of heteroscedastic Markov switching (intercept) models with two regimes and three autoregressive terms for *fxmpi*.[6] It can be seen that for Indonesia, Korea, Malaysia and the Philippines regime 1 is identified as the one with higher FX pressures (as captured by the higher mean). In contrast, for Thailand regime 1 is the low pressure regime. In all cases, regime 2 is more volatile (as captured by the higher standard error of the regression). Both regimes are quite persistent, although regime 2 less so than 1. Results for *dlxr* (Table 2b) are quite similar, although regimes are now less persistent. In addition, and consistent with the rest of the sample, regime 2 for Thailand is now a crisis regime. Malaysia's distributions of observations across the two regimes are the same. This could reflect Malaysia's use of capital controls.

Visual inspection of the crisis regime probabilities using both measures (not reported) shows that for most countries the period from mid 1997 to early 1998 was characterized by speculative pressures and falls into the category of a crisis regime. Of course, the apparent 'synchronicity' of the incidence of crises may reflect regional inter-dependence arising from trade links, a common unobserved shock, or contagion (defined as a change in the 'real' transmission mechanism following a country-specific shock).

In this paper, we do not try to determine the exact classification of the spillovers although we do test several related hypotheses. First, we examine the contemporaneous correlations between the pressure indicators across regimes. This has important

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[5] The model of Hamilton assumes that the transition probabilities are constant. This has the implication that exogenous variables cannot affect the probability of switching from one regime to another. Diebold (1994), Filardo (1994) and Filardo and Gordon (1998) extend the model to time-varying transition probabilities. We use a variation of Filardo and Gordon (1998) later in the paper.

[6] Setting a different lag length than the reported of three months does not affect the results substantially.

implications for portfolio management. The possibility that the correlations may change sign and/or magnitude in different states of the world could affect the risk characteristics of a portfolio comprising holdings in the different markets. In order to carry out this exercise we need to extend the methodology to a Markov switching vector autoregression (see Kolzig, 1997). Examining the FX market in the context of a system of interrelated economies has the advantage that we are allowing the market in question to be affected by recent movements in other markets as well as by recent movements in the market itself. Hence we can calculate and compare the (regime-dependent) correlations.

Second, we construct the multivariate version of the Forbes and Rigobon (2002) contagion test, as proposed by Dungey *et al*. (2005). This allows us to examine the effects of each country's FX market on the rest of the countries in the sample, while controlling for the effect of heteroscedasticity.[7]

Finally, we extend the Markov switching setting to one that allows the transition probabilities to vary over time. This permits us to investigate the predictive information contained in an exogenous variable. We select a one-month lag of each country's stock market index as the exogenous variable to examine whether movements in stock markets *lead* movements in FX markets.

Regime-dependent Correlations

Turning to the VAR version of the fixed transition probability model, the system can now be written as

[7] One needs to be careful with the use of the term contagion, as it been associated with numerous definitions in the literature, which can be interpreted loosely or strictly. Our approach does not include fundamentals given the monthly frequency of our data and the absence of agreement in the literature on what would constitute a universally accepted set of fundamentals. Hence, we resort to a looser definition of contagion, namely 'a significant change in the transmission mechanism of shocks during a crisis'.

$$y_t = \mu(s_t) + \sum_{j=1}^{\rho} B_j \left[y_{t-j} - \mu(s_{t-j}) \right] + \varepsilon_t ,$$

where *y* is a vector of dependent variables and *B* denotes a matrix of estimated parameters with rows equal to *j* and columns equal to the number of variables in *y*. Estimation of this model assuming two regimes and an autoregressive order $\rho = 1$ (consistent with the Schwarz criterion) gives the results reported in table 3. It is evident that, for both measures, regime 1 is classified as a tranquil regime with a low mean and variance, whereas regime 2 is classified as a crisis regime with a high mean (indicating devaluations/pressures in FX) and increased volatility. The tranquil regime continues to be highly persistent implying that switching to a crisis regime is associated with a relatively low probability. Switching back from a crisis regime to a tranquil one is, on the other hand, associated with a higher probability, even though crisis regimes are also fairly persistent.

Figure 3 plots the (smoothed) probabilities of being in crisis across the two measures. Following the turbulence of the second half of 1997 the FX pressures overall subsided. However, the second graph shows that exchange rate depreciation continued for several years after 1997 without being accompanied by higher interest rates or a loss of reserves.

Table 4 shows the estimated correlations for the five countries across the two regimes. It can be seen that, for both measures, correlations change from one regime to the other. It is interesting to note that with the *fxmpi* it is not only the magnitude that changes but also, in several instances, the sign as well. For example, Thailand's correlations with the rest of the countries in the sample change sign across the two regimes. Using *dlxr* it is mainly the magnitude that changes.

However, an investor with no sophisticated information about the prevailing state of the world at each observation would potentially base his/her fund allocation strategy on non-regime dependent (constant) correlations like those reported in Tables 1c and 1d. Even though the differences between the constant correlations and the crisis ones are less pronounced, it is still possible for the constant correlations to convey misleading information. For example, Thailand's *fxmpi* correlation with Korea is -2.6% increasing to 3.5% during crises. The implication is that an investor with assets in Thailand and Korea, who may have allocated funds based on the small negative correlation between the two countries, will find that the benefits from such diversification are reduced during times of crisis, as the devaluation probability and associated default risks increase simultaneously in both countries in times of FX turbulence. Even so, in most cases the signs of the contemporaneous correlations are retained and differences in magnitude are not dramatic, a fact that limits the usefulness of the extra information contained in regime-dependent correlations. The same conclusion can be reached from an analysis of exchange rate correlations.

Contagion

We now turn to the issue of contagion. Forbes and Rigobon (2002) have shown that an increase in correlations in a crisis state does not necessarily represent contagion. Even without a change in the real transmission mechanism (our definition of contagion) the increased volatility in one market will result in higher correlation with another market in a crisis state. Forbes and Rigobon (2002) construct a correlation coefficient that controls for the effects of heteroscedasticity. Dungey *et al*. (2005) have extended the test in a multivariate setting. For country 1

$$\frac{\omega_{1,t}}{\sigma_{nc,1}} = \phi'_1 \Lambda + \chi'_1 \left(\Lambda \otimes \delta_t\right) + \nu_{1,t}\,,$$

where $\omega_{1,t}$ contains the stacked values of *fxmpi* or *dlxr* for country 1 (the observations that correspond to the tranquil periods stacked on top of the observations that correspond to the crisis periods), σ_{nc} denotes the (non time-varying) standard deviation of the non-crisis observations, ϕ and χ are vectors of estimated coefficients, Λ is a matrix containing scaled, stacked observations of *fxmpi* or *dlxr* for the rest of the countries, i.e. $\left[\frac{\omega_{2,t}}{\sigma_{nc,2}},\ldots,\frac{\omega_{n-1,t}}{\sigma_{nc,n-1}}\right]$, and δ_t is a stacked dummy variable taking the value 0 if the system is in a tranquil state and 1 if it is in a crisis state.

The system of equations is estimated with the seemingly unrelated regression (SUR) method. The estimates contained in χ capture contagion effects (if any) so that we can examine the direction and magnitude of spillovers arising from a particular country during a crisis. Table 5 presents results for *fxmpi* and *dlxr*. Focusing on the FX market pressure indicator it turns out that Korea, Malaysia and the Philippines seem to 'export' their FX pressures to Indonesia and Thailand, both of which appear to be victims of contagion during the sample period. Thailand on the other hand, which was the first country to devalue in 1997, only seems to affect Korea. These results suggest that contagion may be present but may be more constrained than is sometimes assumed. Focusing on exchange rate changes, there is no clear direction of contagion effects.

Indonesia affects and is affected by Thailand. It also affects the Philippines, which in turn affects Thailand and Korea. Korea affects Malaysia.

Clearly, the results between *fxmpi* and *dlxr* are strikingly different, which highlights the different types of information that the two measures convey: *fxmpi* is a wider measure and can indicate a crisis even in the absence of an actual devaluation, whereas *dlxr* only indicates a crisis when there is a substantial loss in the value of the currency (in terms of $US) but can miss speculative pressures where the use of reserves and the interest rate has been successful.

The Informational Content of Stock Prices

Up to this point, we have assumed constant (time-invariant) transition probabilities, as in Hamilton (1989) and Krolzig (1997). However, this structure does not allow us to consider the role of additional variables in forecasting transition probabilities. Hence, we extend the framework to include time-varying transition probabilities, as in Filardo and Gordon (1998).[8] Gibbs sampling techniques are used to estimate parameters of the unobserved state variable.[9] The matrix of time-varying transition probabilities is

$$P(S_t = s_t \mid S_{t-1} = s_{t-1}, z_t) = \begin{bmatrix} p_{11}(z_t)\, p_{12}(z_t) \\ p_{21}(z_t)\, p_{22}(z_t) \end{bmatrix},$$

The above expression simply tells us that the probability that the unobserved state variable assumes a specific value (that can only be 0 or 1) depends on the previous value of the state variable and an exogenous time series, z_t.

[8] Cerra and Saxena (2002) use a time-varying setting to test contagion effects for Indonesia during the 1997 crisis.
[9] For a discussion of Gibbs sampling see Casella and George (1992). For details of implementation of the estimations please contact the corresponding author. The Gauss code is available on Martin Ellison’s webpage at http://www2.warwick.ac.uk/fac/soc/economics/staff/faculty/ellison/.

In this empirical exercise we examine the ability of (lagged) stock market movements to explain changes in regime, in particular the movement from a tranquil to a crisis period. The choice of a stock market index as a 'leading indicator' is based on the informational value that stock prices contain about the future. Stocks are valued on the basis of discounted future cash flows. Under normal circumstances, an expected ordinary devaluation (i.e. not one that is associated with a slowdown or recession) could have beneficial effects for an export-orientated firm without foreign currency obligations. However, in the case of south-east Asia, following the liberalization of the capital account, several firms were burdened with foreign currency debt when the primary sources of revenues were in local currency (see Mishkin, 1999). Hence, any evidence of a looming devaluation would potentially lead to the selling of stocks, especially by international investors. We use the one-month lag of the stock market index to reduce the potential problem of two-way causation.

Table 6 reports the estimated parameters for the FX market pressure equation $[1-\phi(L)](y_t-\alpha_0-\alpha_1 s_t)+\eta_t$, where y_t is either of our two pressure measures and $\phi(L)$ is a polynomial in the lag operator of order 3. It also reports the parameters of the transition probability equation $S_t^* = \gamma_0+\gamma_z z_t+\gamma_s s_t+\varepsilon_t$, where S_t^* is a latent variable and z_t is the lagged stock market index (in natural logarithms). To obtain estimation results for these equations one needs to have informed priors for parameters α_0, α_1, γ_0, γ_z and γ_s.[10]

[10]Note that the estimations are carried out for three of the countries in the dataset, as we have been unable to obtain a full series for the stock market indices of Indonesia and Thailand.

The results provide some support for the hypothesis that the information contained in movements of the stock market can be used to forecast the transition probabilities of a FX pressure model. The estimated coefficient γ_z is on most occasions negative, which confirms that increases in the stock index are associated with a higher probability of remaining in a non-crisis state. Equivalently, decreases in the value of the stock market index are associated with a higher probability of switching to a crisis state. Parameters γ_0 and γ_s capture the asymmetry in the durations between tranquil and crisis periods. More specifically, non-crisis periods last longer than crisis periods. Parameters ϕ_1, ϕ_2 and ϕ_3 describe the dynamics of the autoregression and parameters α_0 and α_1 correspond to the FX market pressure equation reported above. It can be seen that the mean rates of change for the tranquil and crisis states are negative and positive, respectively (recall that a positive rate of change indicates higher FX pressure). The estimated variance is also reported for each country.

Despite the encouraging results achieved, the model tends to identify fewer crises than their actual frequency. Of course, there is no official definition of what constitutes a crisis, so we resort to constructing an *ad hoc* measure to facilitate comparisons. We assign a value of 1, and hence indicate a crisis, if an observation is greater than the average of the series (*fxmpi* or *dlxr*) plus 1.5 times the standard deviation of the series. Figure 4 compares the 'actual' chronology of crises with the model's assigned 'smoothed' probabilities of crises. The model with *fxmpi* does relatively well in identifying some but not all crisis incidents. The model with *dlxr* picks up most of the crises.

Concluding Remarks

In this paper, we have used recent advances in econometric techniques to answer questions about the interrelationships between south-east Asian foreign exchange markets during the period 1990-2004. South east Asia is particularly interesting given the opportunity to examine a number of countries that are frequently and somewhat loosely classified together, as well as the transition sequence from periods that may be characterised as non-crisis to crisis and back to non- crisis.

We discover different results depending on whether we use correlations between nominal exchange rates or between a broader indicator of foreign exchange market pressure that incorporates changes in interest rates and reserves. We also find that the relationships differ as between crisis and non-crisis periods. We further examine whether the increased correlations for some countries during crises represent contagion. Finally, we investigate whether movements in stock market prices anticipate crises in terms of changes in transition probabilities.

Although the paper is empirical, it is informed by relevant theory and our results are not counter-theoretical. Moreover, they have potentially important policy implications. The observed change in correlations we discover as between non-crisis and crisis periods suggests that some types of diversification that may be risk-reducing during a non-crisis period may not be risk-reducing during a crisis. It also suggests that reserve pooling arrangements that depend on negative correlations amongst participants may be ill-informed if non-crisis periods are used to identify correlations that are, in reality, contingent on whether crises exist. However, the differences between simple regime-independent correlations (which are most likely to be observed by agents) and crisis state correlations are smaller than differences between crisis and non-crisis regime correlations. Still, controlling for shifts in the states of the world provides useful information to economic agents. Moreover, our findings suggest that policy initiatives to mitigate contagion may need to have a more limited focus than is sometimes assumed. We find some evidence of contagion, which does not appear to be as widespread as it is often assumed. Finally, we find that stock market indices have some explaining power of FX regime switches.

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Table 1a: Descriptive statistics *fxmpi*.

	***fxmpi*_IND**	***fxmpi*_KOR**	***fxmpi*_MAL**	***fxmpi*_PHI**	***fxmpi*_THA**
Mean	0.926	0.872	0.79	1.271	0.601
Median	0.841	0.727	0.595	0.305	0.697
Maximum	38.069	8.141	27.597	41.194	13.328
Minimum	-12.581	-6.346	-18.019	-16.39	-8.076
Std. Dev.	5.081	2.258	3.96	6.798	2.357
Skewness	2.281	0.218	1.272	1.946	0.351
Kurtosis	19.518	4.291	16.483	13.242	9.428
Jarque-Bera	2190	13	1404	895	311
Observations	179	179	179	179	179

Table 1b: Descriptive statistics *dlxr*

	***dlxr*_IND**	***dlxr*_KOR**	***dlxr*_MAL**	***dlxr*_PHI**	***dlxr*_THA**
Mean	0.913	0.240	0.19	0.512	0.234
Median	0.358	0.088	0.0	0.144	-0.025
Maximum	67.722	36.95	15.679	13.775	17.237
Minimum	-26.884	-8.856	-14.1	-7.126	-15.377
Std. Dev.	7.861	3.579	2.4	2.331	3.063
Skewness	3.824	6.241	1.15	1.497	1.609
Kurtosis	34.622	64.704	23.33	10.774	18.345
Jarque-Bera	7894	29559	3122	517	1833
Observations	179	179	179	179	179

Table 1c: Correlations *fxmpi*

	***fxmpi*_IND**	***fxmpi*_KOR**	***fxmpi*_MAL**	***fxmpi*_PHI**	***fxmpi*_THA**
MPI_IND	1				
MPI_KOR	0.117	1			
MPI_MAL	-0.012	0.057	1		
MPI_PHI	-0.042	-0.023	0.135	1	
MPI_THA	0.193	-0.026	-0.069	0.020	1

Table 1d: Correlations *dlxr*

	***dlxr*_IND**	***dlxr*_KOR**	***dlxr*_MAL**	***dlxr*_PHI**	***dlxr*_THA**
***dlxr*_IND**	1				
***dlxr*_KOR**	0.479	1			
***dlxr*_MAL**	0.618	0.441	1		
***dlxr*_PHI**	0.545	0.432	0.584	1	
***dlxr*_THA**	0.623	0.607	0.718	0.655	1

Table 2a: MSIH(2)-AR(3) results for *fxmpi*

	IND	KOR	MAL	PHI	THA
Mean (regression 1)	0.6548 (0.1639)	0.4949 (0.1376)	0.4310 (0.1771)	0.4674 (0.3090)	0.7504 (0.1484)
Mean (regression 2)	2.5872 (1.354)	0.6120 (0.2689)	0.8311 (1.0186)	2.6101 (1.3535)	-0.0423 (0.8815)
SE (regression 1)	1.9511	0.84107	1.6194	2.9063	1.3478
SE (regression 2)	10.109	2.6033	6.8225	10.227	4.6150
Observations (regression 1)	137.5	65.4	124.6	113.0	145.6
Observations (regression 2)	38.5	110.6	51.4	63.0	30.4
p_{11}	0.9463	1	0.9405	0.9811	0.9655
p_{12}	0.0537	0	0.0595	0.0189	0.0345
p_{21}	0.1935	0.0089	0.1463	0.0482	0.1697
p_{22}	0.8065	0.9910	0.8537	0.9518	0.8303

Notes: Results are presented for a heteroscedastic Markov switching specification with two regimes and three autoregressive terms. The dependent variable is a foreign exchange market pressure indicator, which has been constructed for Indonesia, Korea, Malaysia, the Philippines and Thailand.

Table 2b: MSIH(2)-AR(3) results for *dlxr*

	IND	KOR	MAL	PHI	THA
Mean (regression 1)	0.2738 (0.0342)	0.0495 (0.1014)	0.1280 (4.0660)	-0.0035 (0.0688)	-0.1152 (0.0669)
Mean (regression 2)	1.3227 (1.2033)	1.6585 (2.1383)	0.1280 (4.0660)	0.6837 (0.3334)	1.5112 (1.2203)
SE (regression 1)	0.17942	1.1660	2.3295	0.50134	0.73633
SE (regression 2)	11.197	8.7569	2.3295	2.9652	6.5375
Observations (regression 1)	89.3	157.7	88	88.3	145.2
Observations (regression 2)	86.7	18.3	88	87.7	30.8
p_{11}	0.9292	0.9657	0.7472	0.8733	0.9333
p_{12}	0.0708	0.0343	0.2528	0.1267	0.0667
p_{21}	0.0636	0.2920	0.2528	0.1310	0.3172
p_{22}	0.9364	0.7080	0.7472	0.8690	0.6828

Notes: Results are presented for a heteroscedastic Markov switching specification with two regimes and three autoregressive terms. The dependent variable is the percent change in the nominal exchange rate for Indonesia, Korea, Malaysia, the Philippines and Thailand.

Table 3a: MSIH(2)-VAR(1) results for *fxmpi*

	IND	KOR	MAL	PHI	THA
Mean R1	0.597619	0.503195	0.489161	0.712728	0.573284
Mean R2	1.960138	0.641517	1.771888	0.939300	0.696158
Stan. Err. R1	3.101309	1.702228	2.308724	3.607553	1.563642
Stan. Err. R2	8.424579	3.172912	6.822248	10.728820	3.633208
Obs. In R1			129.2		
Obs. In R2			43.8		
p_{11}			0.9635		
p_{12}			0.0365		
p_{21}			0.1128		
p_{22}			0.8872		

Notes: Results are presented for a heteroscedastic Markov switching vector autoregression of order 1 with two regimes. The dependent variable is a foreign exchange market pressure indicator, which has been constructed for Indonesia, Korea, Malaysia, the Philippines and Thailand.

Table 3b: MSIH(2)-VAR(1) results for *dlxr*

	IND	KOR	MAL	PHI	THA
Mean R1	0.320101	-0.007432	-0.087561	0.140583	-0.021424
Mean R2	1.755504	0.749433	1.143743	0.892240	0.867608
Stan. Err. R1	1.836415	1.314356	0.629406	1.559233	0.934443
Stan. Err. R2	17.274242	7.378275	5.211998	3.966274	6.599764
Obs. In R1			141.2		
Obs. In R2			31.8		
p_{11}			0.9411		
p_{12}			0.0589		
p_{21}			0.2683		
p_{22}			0.7317		

Notes: Results are presented for a heteroscedastic Markov switching vector autoregression of order 1 with two regimes. The dependent variable is the percent change of the nominal exchange rate for Indonesia, Korea, Malaysia, the Philippines and Thailand.

Table 4a: Correlations in tranquil and crisis regimes *fxmpi*

	***fxmpi*_IND**	***fxmpi*_KOR**	***fxmpi*_MAL**	***fxmpi*_PHI**	***fxmpi*_THA**
***fxmpi*_IND**	1	0.1854	-0.0974	-0.1058	0.2809
***fxmpi*_KOR**	0.0416	1	0.1999	-0.1314	0.0350
***fxmpi*_MAL**	0.0767	-0.0771	1	0.1797	-0.1883
***fxmpi*_PHI**	0.0837	0.0895	0.1890	1	-0.0020
***fxmpi*_THA**	-0.0116	-0.0267	0.0383	0.0855	1

Notes: Contemporaneous correlations in regime 1 (tranquil) are reported below the diagonal and contemporaneous correlations in regime 2 (crisis) are reported above the main diagonal.

Table 4b: Correlations in tranquil and crisis regimes *dlxr*

	***fxmpi*_IND**	***fxmpi*_KOR**	***fxmpi*_MAL**	***fxmpi*_PHI**	***fxmpi*_THA**
***fxmpi*_IND**	1	0.3796	0.6450	0.7283	0.5870
***fxmpi*_KOR**	0.2524	1	0.3602	0.4701	0.5557
***fxmpi*_MAL**	-0.0005	0.0221	1	0.7886	0.7034
***fxmpi*_PHI**	0.1907	0.2685	0.0217	1	0.8423
***fxmpi*_THA**	0.5004	0.5796	0.0780	0.2670	1

Notes: Contemporaneous correlations in regime 1 (tranquil) are reported below the diagonal and contemporaneous correlations in regime 2 (crisis) are reported above the main diagonal.

Table 5a: Multivariate contagion test *fxmpi*

	***fxmpi*_IND**	***fxmpi*_KOR**	***fxmpi*_MAL**	***fxmpi*_PHI**	***fxmpi*_THA**
Constant	0.10 (0.09)	0.44* (0.10)	0.12 (0.13)	0.15 (0.12)	0.34* (0.11)
Delta coef.	0.35 (0.24)	0.45** (0.21)	0.28 (0.33)	0.62** (0.30)	-0.78* (0.30)
ϕ_{IND}		0.04 (0.10)	0.06 (0.12)	0.02 (0.11)	0.23* (0.10)
ϕ_{KOR}	0.06 (0.06)		0.15 (0.09)	-0.16** (0.08)	-0.05 (0.08)
ϕ_{MAL}	0.01 (0.06)	0.11*** (0.06)		0.25* (0.07)	-0.04 (0.07)
ϕ_{PHI}	-0.02 (0.06)	-0.14*** (0.07)	0.29* (0.08)		0.11 (0.07)
ϕ_{THA}	0.30* (0.06)	-0.03 (0.07)	-0.01 (0.08)	0.10 (0.08)	
χ_{IND}		0.09 (0.13)	-0.36 (0.23)	-0.13 (0.17)	1.13* (0.19)
χ_{KOR}	0.21* (0.02)		0. 06 (0.05)	0.02 (0.04)	-0.29* (0.04)
χ_{MAL}	0.13* (0.04)	0.03 (0.05)		0.05 (0.04)	-0.19* (0.05)
χ_{IPHI}	-0.18* (0.03)	0.04 (0.04)	-0.05 (0.04)		0.17* (0.04)
χ_{THA}	-0.01 (0.01)	0.03 (0.01)*	-0.01 (0.01)	0.01 (0.01)	

Notes: Method of estimation: seemingly unrelated regressions. Standard errors are reported in parentheses. * indicates significance at the 1% level, ** indicate significance at the 5% level and *** indicate significance at the 10% level.

Table 5b: Multivariate contagion test *dlxr*

	***fxmpi*_IND**	***fxmpi*_KOR**	***fxmpi*_MAL**	***fxmpi*_PHI**	***fxmpi*_THA**
Constant	0.13 (0.23)	0.05 (0.17)	-0.15 (0.17)	0.27 (0.20)	-0.12 (0.12)
Delta coef.	-0.93 (0.58)	0.34 (0.42)	0.43 (0.44)	0.88*** (0.46)	-0.62** (0.30)
ϕ_{IND}		-0.12 (0.20)	-0.14 (0.21)	0.60** (0.23)	0.28** (0.13)
ϕ_{KOR}	0.07 (0.28)		-0.28 (0.21)	0.14 (0.24)	0.56*** (0.12)
ϕ_{MAL}	0.20 (0.22)	-0.10 (0.16)		0.25 (0.19)	0.23** (0.11)
ϕ_{PHI}	0.25** (0.10)	0.04 (0.07)	0.14*** (0.07)		0.15*** (0.05)
ϕ_{THA}	0.39 (0.29)	0.84* (0.19)	0.37 (0.24)	0.39 (0.27)	
χ_{IND}		0.34 (0.21)	0.42 (0.21)	-0.42*** (0.24)	-0.33** (0.14)
χ_{KOR}	0.34 (0.30)		0.11*** (0.23)	-0.20 (0.26)	-0.16 (0.13)
χ_{MAL}	0.30 (0.24)	-0.08 (0.18)		-0.10 (0.21)	0.09 (0.13)
χ_{IPHI}	0.27 (0.20)	-0.28*** (0.15)	0.12 (0.15)		0.32*** (0.09)
χ_{THA}	-0.57*** (0.32)	-0.07 (0.22)	0.30 (0.26)	0.14 (0.29)	

Notes: Method of estimation: seemingly unrelated regressions. Standard errors are reported in parentheses. * indicates significance at the 1% level, ** indicate significance at the 5% level and *** indicate significance at the 10% level.

Table 6: Time-varying transition probabilities

	KOR		MAL		PHI	
	fxmpi	*dlxr*	*fxmpi*	*dlxr*	*fxmpi*	*dlxr*
γ_0	1.227	3.21	1.431	4.002	2.259	-1.839
	(0.323)	(0.676)	(0.325)	(0.557)	(0.164)	(0.84)
γ_z	-0.036	-0.254	-0.552	-0.624	-0.002	0.837
	(0.145)	(0.131)	(0.056)	(0.102)	(0.088)	(0.186)
γ_S	0.441	0.037	0.617	0.877	-0.514	-0.326
	(0.315)	(0.362)	(0.328)	(0.175)	(0.163)	(0.17)
α_0	-1.209	-24.435	-21.26	-10.711	-35.842	-8.792
	(4.249)	(2.567)	(5.617)	(0.747)	(3.393)	(0.811)
α_1	1.972	24.52	21.903	10.596	36.648	9.065
	(3.984)	(2.557)	(5.672)	(0.734)	(3.401)	(0.82)
ϕ_1	0.271	0.56	-0.056	0.028	0.125	0.605
	(0.155)	(0.1)	(0.12)	(0.077)	(0.078)	(0.085)
ϕ_2	-0.044	-0.222	0.31	-0.004	-0.031	-0.369
	(0.14)	(0.11)	(0.136)	(0.077)	(0.074)	(0.093)
ϕ_3	0.304	-0.055	0.108	-0.314	0.132	0.036
	(0.108)	(0.084)	(0.089)	(0.071)	(0.073)	(0.076)
σ^2	3.416	4.642	11.097	2.657	23.146	2.747

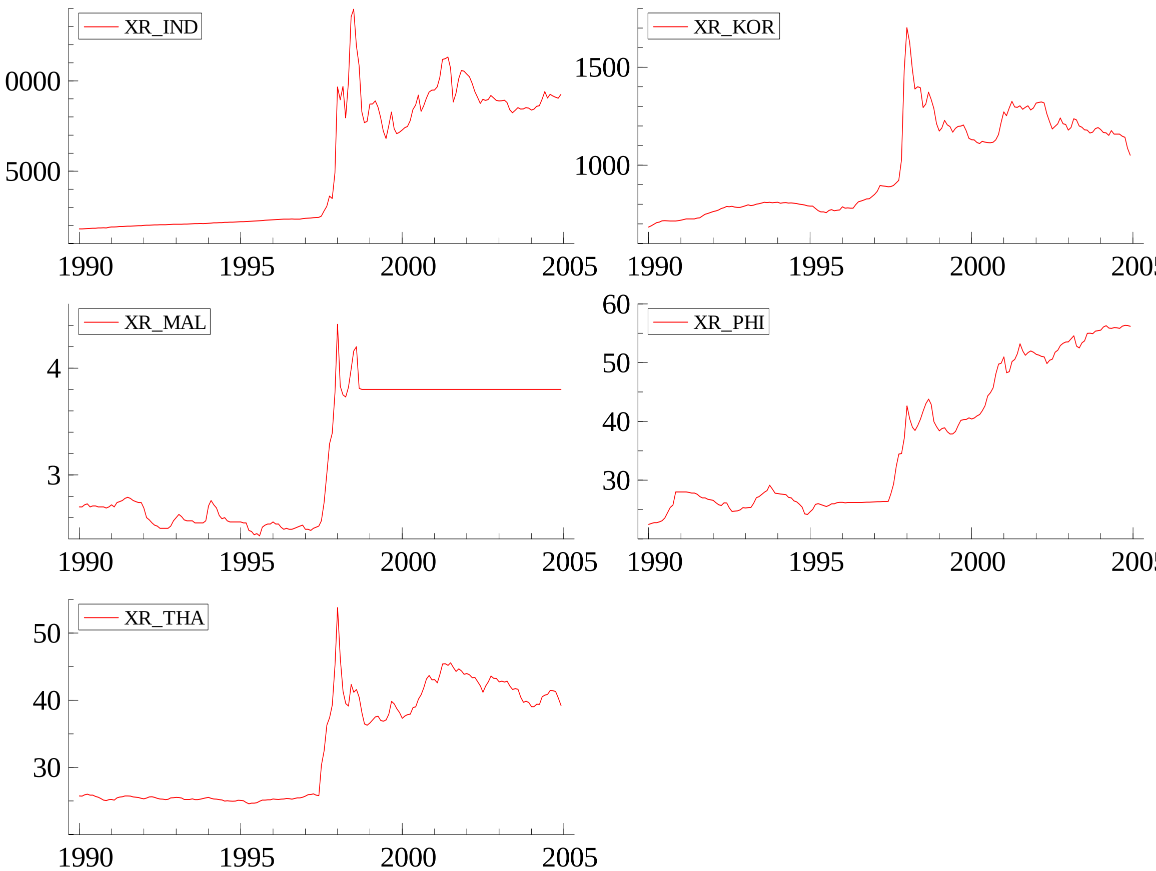


Figure 1a: Nominal exchange rates in East Asia

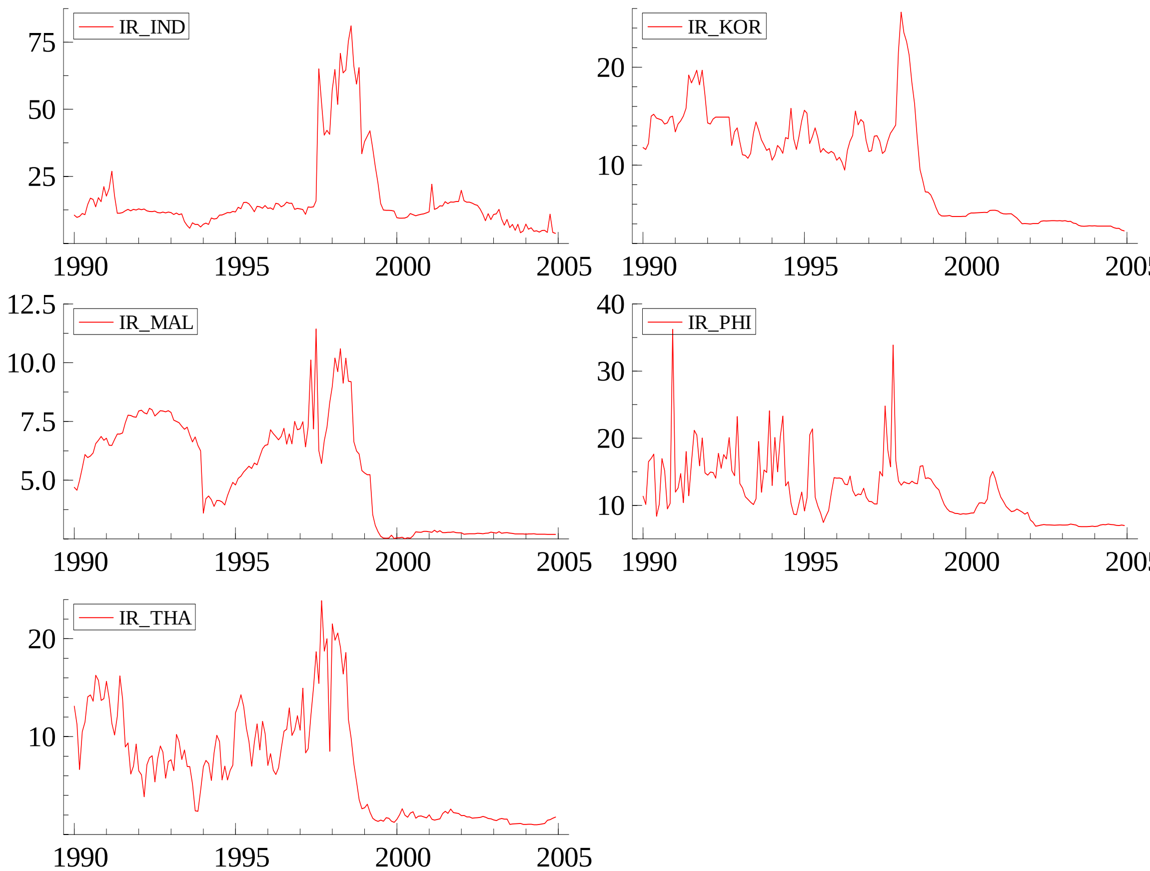


Figure 1b: Nominal interest rates in East Asia

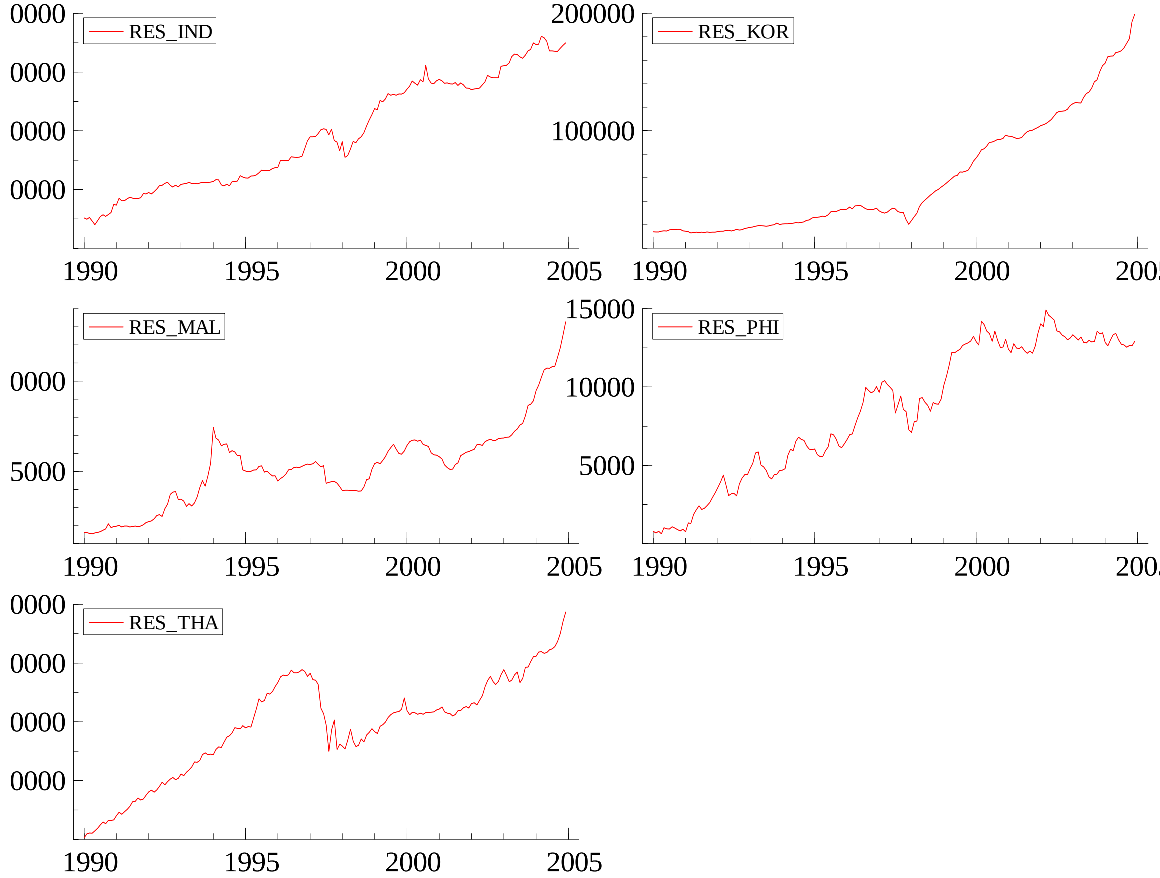


Figure 1c: International reserves in ($US) in East Asia

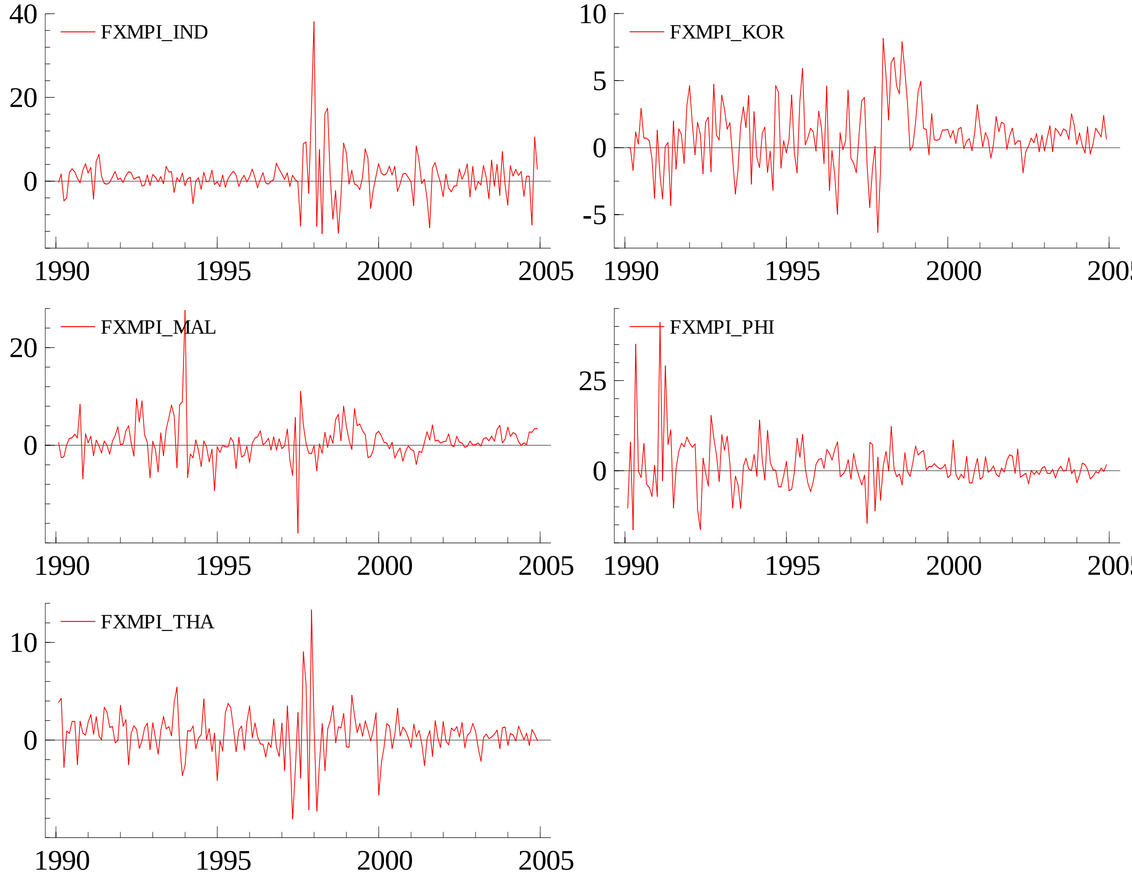


Figure 2a: Time series plots *fxmpi*

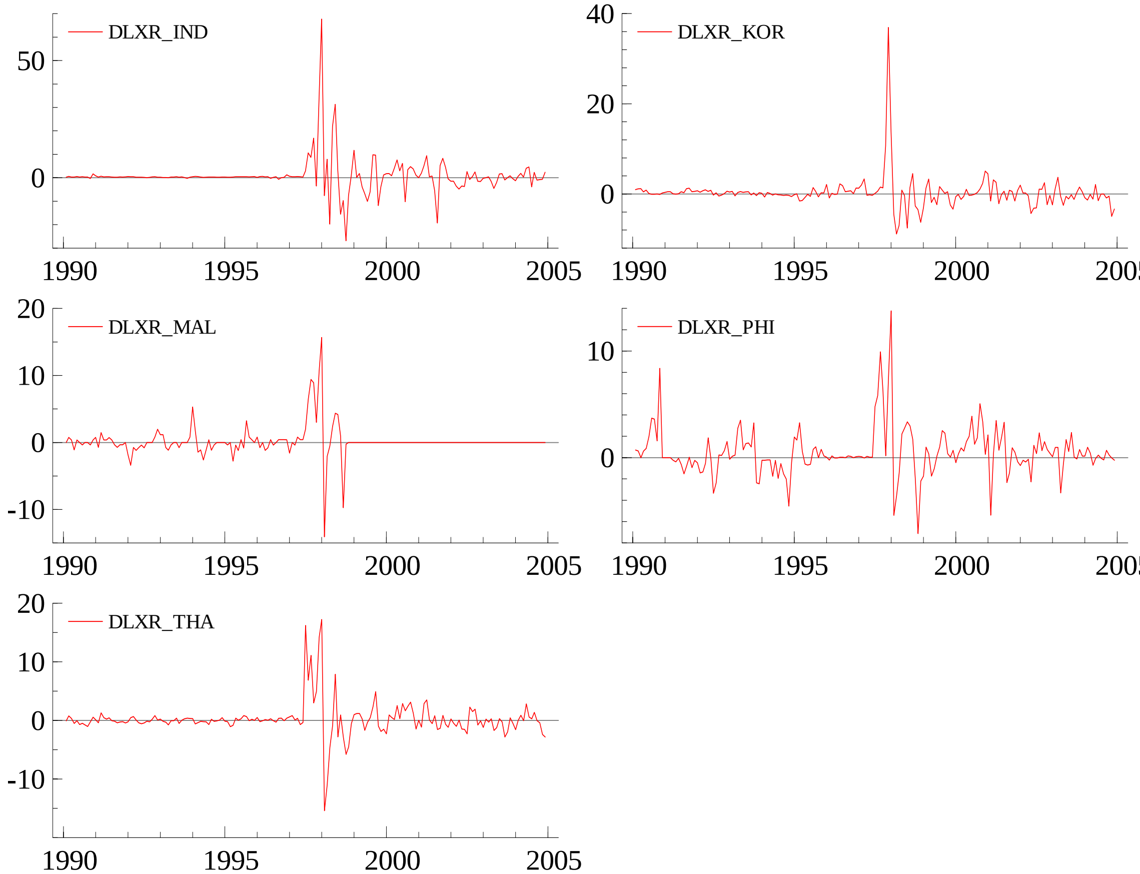
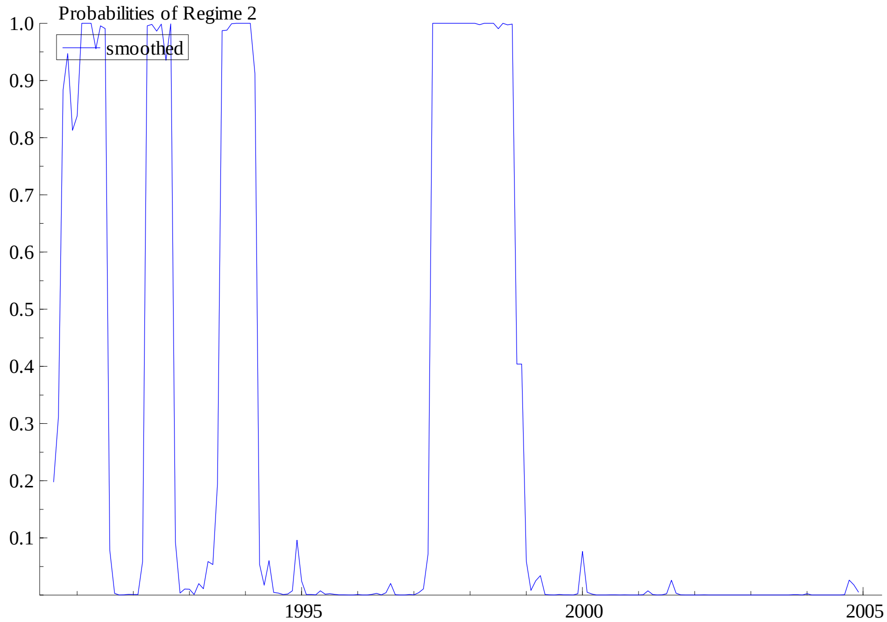


Figure 2b: Time series plot *dlxr*



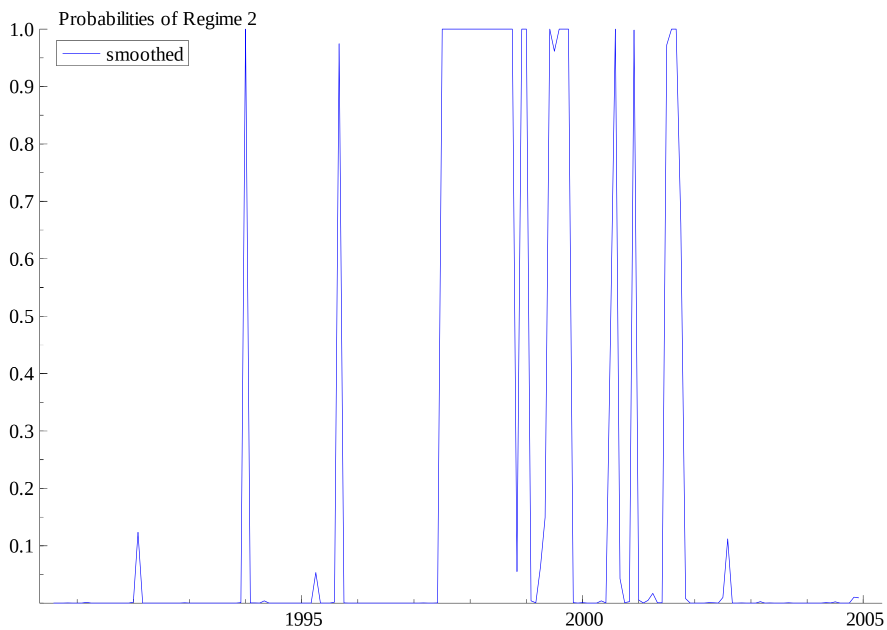


Figure 3: Regime 2 (crisis) probabilities for *fxmpi* (top) and *dlxr* (bottom)

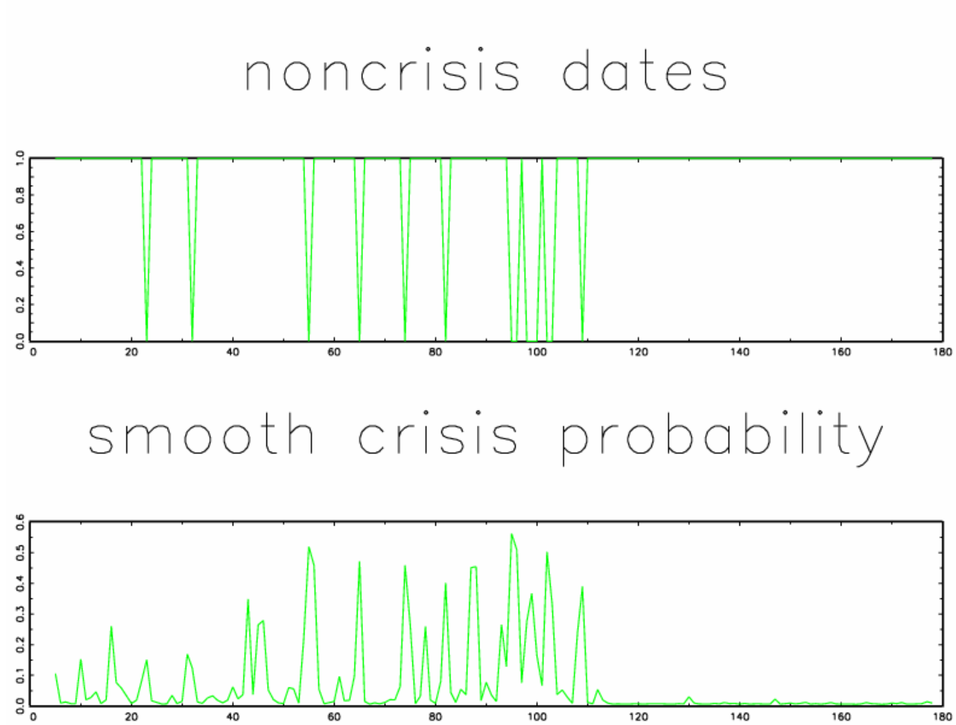


Figure 4a: ‘Actual’ and model chronologies for Korea using *fxmpi*

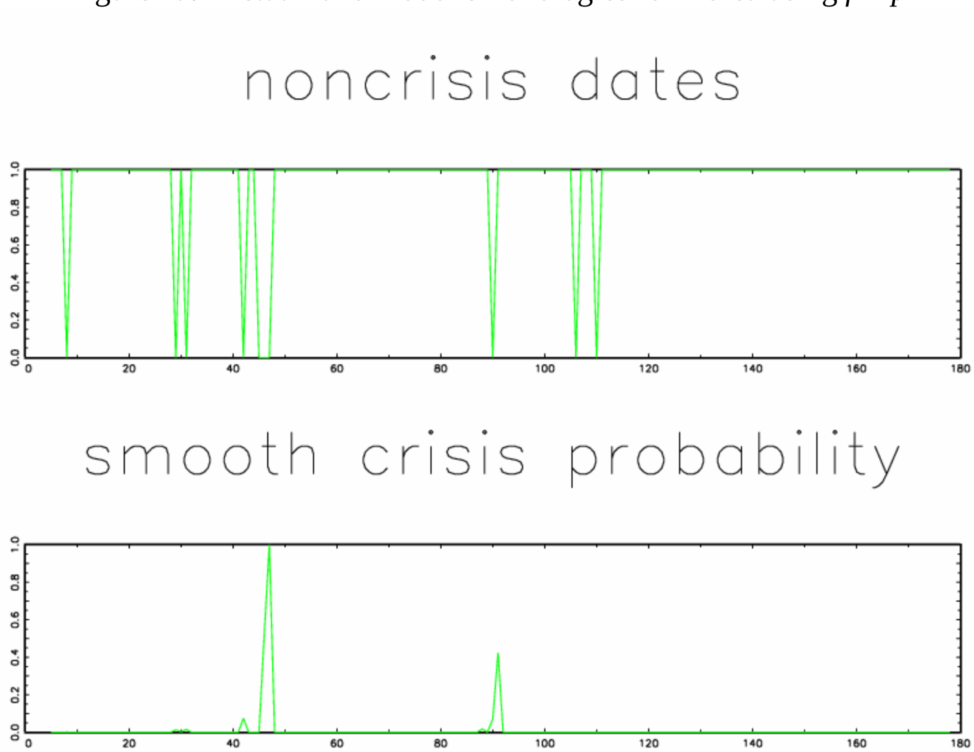


Figure 4b: ‘Actual’ and model chronologies for Malaysia using *fxmpi*

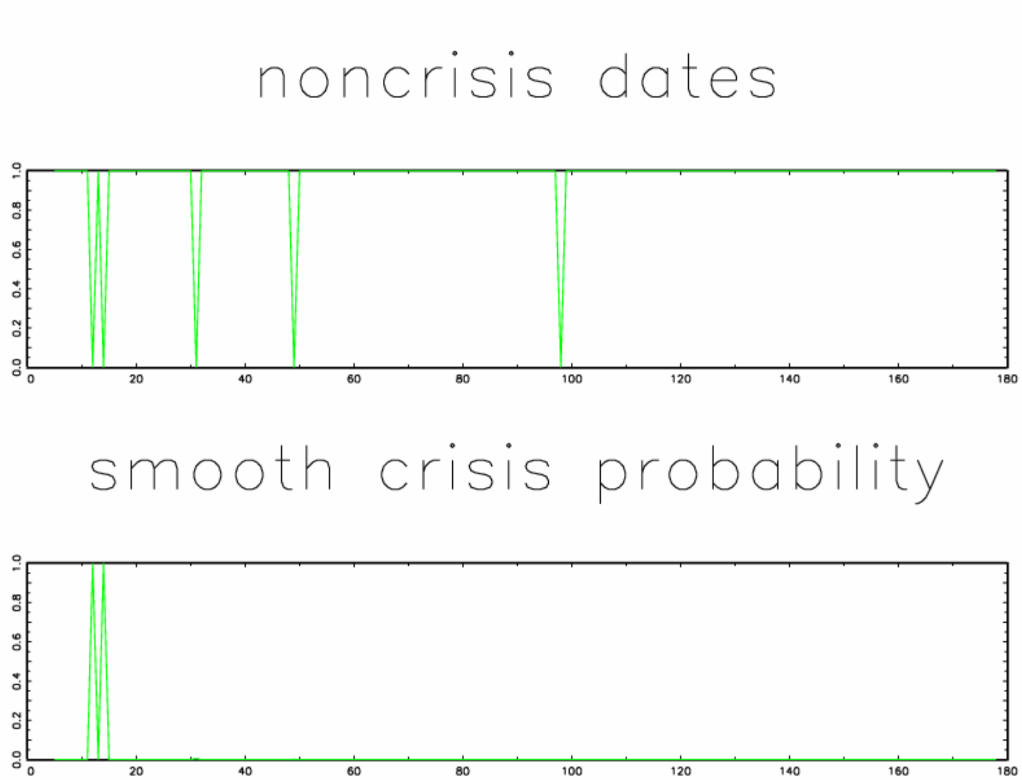


Figure 4c: ‘Actual’ and model chronologies for the Philippines using *fxmpi*

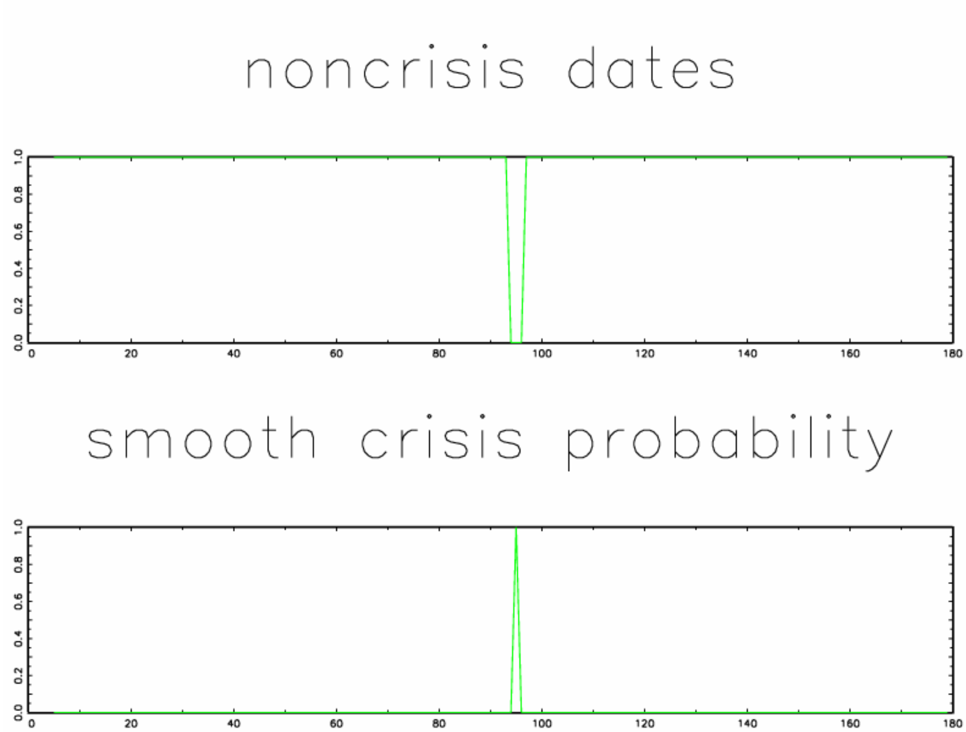


Figure 4d: ‘Actual’ and model chronologies for Korea using *dlxr*

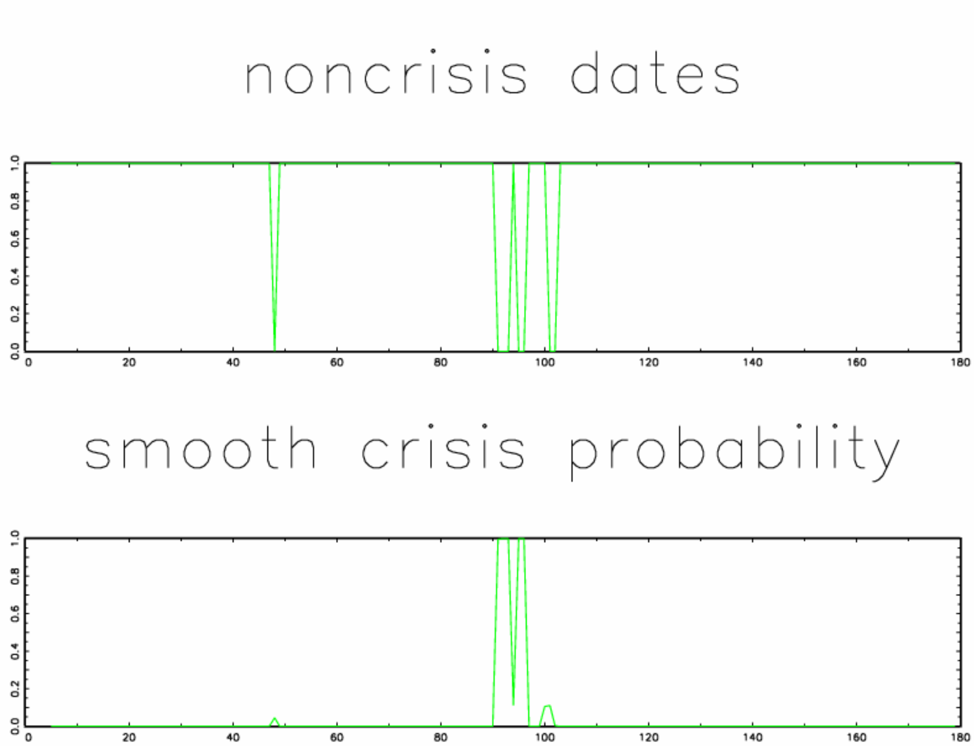


Figure 4e: ‘Actual’ and model chronologies for Malaysia using *dlxr*

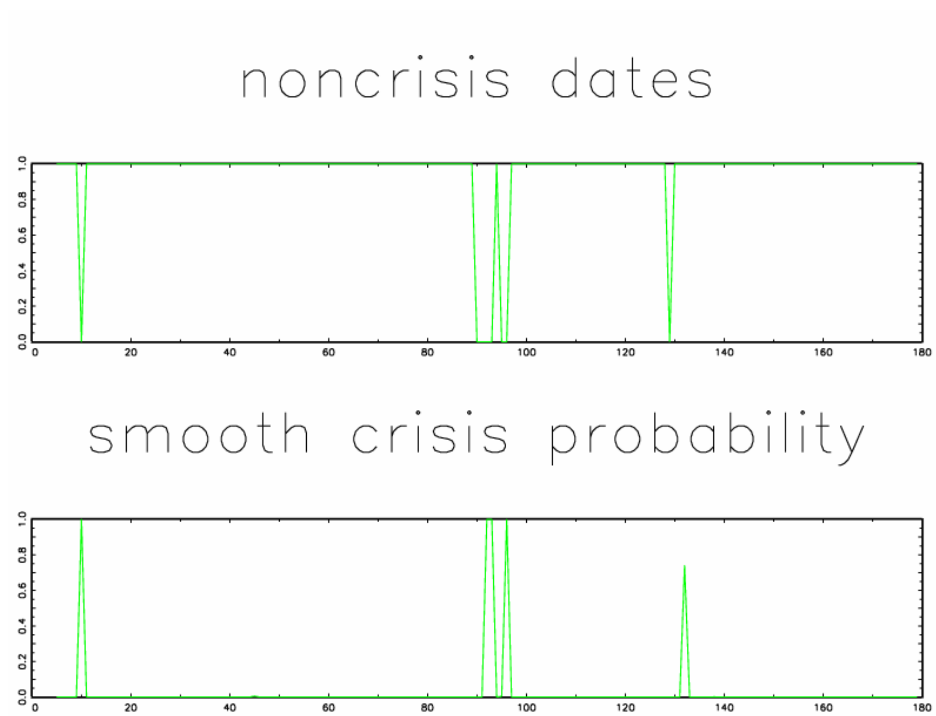


Figure 4f: ‘Actual’ and model chronologies for the Philippines using *dlxr*