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The Regime Changing Behavior of Exchange Rates and Stock Market Prices of Selected Emerging Countries: An application of the Markov Switching Vector Autoregressive model (MS-VAR)

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ABSTRACT

This article aims to analyze the dynamic relationship between stock market returns and exchange rate movements for emerging countries (Brazil, Argentina, Mexico and India), from January 2005 to December 2021, using Markov Switching Vector Autoregressive model, with regime change. The impact of exchange rate movements on stock returns is not statistically significant in all emerging countries. This reveals that fluctuations in US dollar exchange rates do not have a strong influence on the dynamics of stock market returns during normal and turbulent periods. On the other hand, the impacts of stock returns on exchange rate movements are significant only for the Brazilian and Mexican markets.

INTRODUCTION

The relationship between stock prices and exchange rate movements not only affects portfolio decisions, but also changes in economic policies and the valuation performance of investments. Currency depreciation improves the competitiveness of local companies, resulting in increased exports as well as future cash flow performance. In general, emerging markets import more than they export and a currency devaluation has a negative impact, ie significantly increasing the cost of raw materials and reducing the competitiveness of companies. Thus, companies' stock prices will increase (decrease) in response to increases (decreases) in expected cash flows.

Several empirical studies analyze dynamic links between stock prices and exchange rate movements. Kanas (2005) in his study explores the question of the links of the volatility regime between the Mexican exchange market and six emerging equity markets, namely, the markets of Mexico, Brazil, Argentina, Hong Kong, Hungary and Thailand, applying the Markov Switching Vector Autoregressive (MS-VAR) model. The author found evidence of regime dependency between the Mexican foreign exchange market and each of these stock markets. Ismail & Isa (2009) employ the two-regime multivariate MS-VAR model to capture regime switching behavior in both the mean and variance of the Malaysian stock market. The authors address that, as the stock price index decreases, exchange rates depreciate and when the stock price index increases, exchange rate appreciation results.

Hwang (1999) tests the relationship between the Canadian dollar and stock prices on the Toronto Stock Exchange comprising the period 1973 to 1996. Using the Engle-Granger cointegration test, the author found no long-run relationship between exchange rates and the Toronto stock market. In the short run, the empirical evaluation showed that the exchange rate had a positive effect on stock prices. Chow *et al.* (1997) employed regression analysis to examine the relationship between exchange rates and stock prices for the US. The authors concluded that there is a statistically significant positive relationship between exchange rates and stock prices. In the opposite case, Tsagkanos & Siriopoulos (2013) identified through the cointegration method a significant negative relationship between the variables when analysing the long-run relationship between exchange rates and stock prices for the US and the European Union (EU), comprising the period 2008 to 2012.

Adjasi *et al.* (2011) employed the VAR model as well as impulse-response analysis to examine the relationship between stock prices and exchange rate movements for a sample of data from the seven African countries (South Africa, Egypt, Tunisia, Nigeria, Ghana, Kenya and Mauritius) over the period 1992-2005. The authors, based on the empirical results, found no long-term relationship between stock markets and exchange rates for all countries except Tunisia. Chkili & Nguyen (2014) using the MS-VAR model, analysed the dynamic relationship between exchange rates and stock market prices for BRICS countries (Brazil, Russia, India, China and South Africa) over the period 1997-2013. The authors showed empirical evidence of two distinct regimes in stock markets, i.e. that the responses of stock market volatility to shocks in exchange markets were significant in all countries except South Africa.

Chkili *et al.* (2011) applied the Markov-Switching EGARCH model to investigate the dynamic relationships between exchange rates and stock market returns in four emerging countries (Hong Kong, Singapore, Malaysia

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and Mexico) during normal and turbulent periods. The authors found evidence of regime-dependent linkages and asymmetric responses of stock market volatility to shocks affecting the exchange market. Diamandis & Drakos (2011) examined the long-run and short-run dynamics between equity and foreign exchange markets for four Latin American countries (Argentina, Brazil, Chile and Mexico), as well as their interactions with US equity markets. These authors identified that the two markets in these economies are positively related to the US equity market.

Rjoub (2012) empirically analyzes the dynamic relationship between Turkish stock price and exchange rates, and also considers US stock prices as a world market, in the long run and short run, in the period from 2001 to 2009, applying the methods of cointegration, Granger causality and impulse response. The cointegration result reveals that the long-run relationship is maintained and Granger causality shows that they are bidirectional relationships between the exchange rate and Turkish stock prices. Sosa *et al.* (2018) studied the dynamics of the link between stock market returns and exchange rate changes for the Latin American Integrated Market (MILA) countries based on the MS-VAR model. The authors indicated that stock markets have more impact on the exchange rate than the exchange rate in the stock markets of the countries analyzed.

The remainder of this paper is organized as follows: Section 2 introduces the Markov Switching Vector Autoregressive model (MS-VAR). Section 3 presents the empirical results and analysis and Section 4 the conclusion.

METHODOLOGY

According to Hamilton (1989), a time series variable can be modelled by a p-order autoregressive Markov change (MS-AR) with regime shifts in mean and variance, expressed according to equation 1.

$$y_t = \mu(S_t) + \left[\sum_{i=1}^{p} \phi_i (y_{t-i} - \mu(S_{t-i})\right] + \sigma(S_t)\varepsilon_t \quad (1)$$

where are the autoregressive coefficients, and are the mean and standard deviation, respectively, depending on the regime at time t, represents the stock market returns of selected emerging countries. The MS-AR model allows detecting possible regime changes in stock market returns, as well as examining the influence of crises on stock market volatility.

The main objective is to investigate the relationship between equity and US exchange markets in emerging countries in a regime change environment. Therefore, the MS-VAR model developed by Krolzig (1997) is suitable for the present study. This model is a generalization of the MS-AR model of Hamilton (1989). Thus, the MS-VAR model can be written according to equations 2 and 3.

$$r_t = \alpha_1 + \sum_{k=1}^{l} \alpha_{2,j}(S_t) r_{t-k} + \sum_{k=1}^{l} \alpha_{3,j}(S_t) e_{t-k} + v(S_t) u_{r,t} \quad (2)$$

$$e_t = \beta_1 + \sum_{k=1}^{l} \beta_{2,j}(S_t) e_{t-k} + \sum_{k=1}^{l} \beta_{3,j}(S_t) r_{t-k} + v(S_t) u_{e,t} \quad (3)$$

Where r_t and represent the stock market and exchange rate returns respectively for each country, μ_t is the variance $v(S_t)$ depending on the regime that follows a Markov process defined by P_{ij} transition probabilities between the states as follows:

$$P_{ij} = P[S_t = j \mid S_{t-1} = i] \quad \text{with} \quad \sum_{j=1}^{2} P_{ij} = 1 \quad , \text{ where } i,j \in \{1,2\}$$

Where

$$\begin{Bmatrix} P_{11} = P[S_t = 1 \mid S_{t-1} = 1] \\ P_{12} = 1 - P_{11} = P[S_t = 1 \mid S_{t-1} = 2] \\ P_{22} = P[S_t = 2 \mid S_{t-1} = 2] \\ P_{21} = 1 - P_{22} = P[S_t = 2 \mid S_{t-1} = 1] \end{Bmatrix}$$

The transition probabilities provide an expected duration which is the time it takes for the system to remain in a given regime. Thus, the expected duration is specified as:

$$E(D) = \frac{1}{1 - P_{ij}}$$

where i= 1, 2 and j= 1, 2...

The MS-VAR model is sufficient to capture the potential for regime shifts in the processes generating equity returns and exchange rates, as financial markets have experienced several periods of major instabilities and long swings in the last two decades.

Data

In the present study, the information was obtained from the monthly closing price data on stock market indices and US dollar exchange rates through the websites Yahoo Finance and Exchange-rates, respectively of emerging countries including Brazil, Argentina, Mexico and India. The period of analysis is from January 2005 to December 2021. This period was selected to incorporate the periods of significant crises (subprime crisis and COVID-19 pandemic). The period considered for this study will give an understanding of the dynamic relationship between stock market returns and change in exchange rates of the selected countries.

RESULTS AND ANALYSIS

Descriptive Statistics

Panels A and B in Table 1 provide descriptive statistics for stock returns and changes in exchange rate series. The statistics presented in Panel A report that the stock market in Argentina over the period had the highest average return, while the stock market in Mexico had the lowest average return. With respect to the volatility levels indicated by the standard deviation, the stock market in Argentina was the most volatile, followed by Brazil, India and Mexico. The kurtosis value is high for all the return series. This shows non-normality, i.e. indicating leptokurtic distribution. Therefore, using Jarque-Bera (1987) statistical test rejected the hypothesis of normal

distribution, and found that the stock returns were not normal. The Ljung-Box statistics (LB*2) to test for autocorrelation in the returns series rejected the null hypothesis and showed evidence of serial correlation in all the returns series. Panel B of Table 1 shows that the averages in the exchange rate changes for all the emerging country markets analysed were positive, verifying devaluation against the US dollar. During the period, on average, Argentina had the highest appreciation of the US dollar and the most volatile, while the Indian rupee was the least volatile. The Jarque-Bera (1987) test showed that the changes in the exchange rate were different from a normal distribution. It is observed that the average stock market has higher levels of returns relative to the foreign exchange markets.

Table 1: Descriptive Statistics

Countries	Mean	Std. Dev.	Skewness	Kurtosis	JB	LB*2
Panel A: Stock returns						
Brazil	0.0084	0.0689	-1.0281	7.2539	181.38	0.0000
Argentina	0.0188	0.1102	-1.0083	7.2711	181.26	0.0000
Mexico	0.0068	0.0484	-0.7088	5.1003	52.17	0.0000
India	0.0103	0.0648	-0.7704	6.5600	121.64	0.0000
Panel B: Exchange rate changes						
Brazil	0.0038	0.0380	0.9704	5.7481	91.96	0.0000
Argentina	0.0177	0.0488	3.4740	20.3170	2828.75	0.0000
Mexico	0.0034	0.0359	1.3211	8.1462	271.90	0.0000
India	0.0027	0.0226	0.2894	4.6000	23.40	0.0000

Source: Prepared by the author

Table 2 presents the unit root and stationarity tests for the data series using Augmented Dickey & Fuller (ADF,1979), Phillips & Perron (PP, 1988) and KPSS (1992). Looking at the table, the ADF and PP tests showed evidence of unit root at the levels of all the series. Similarly, the KPSS test rejected the null hypothesis of stationarity at levels of all series, suggesting that the series were non stationary. Therefore, in first differences, the ADF, PP and KPSS tests showed that the series are stationary. Thus, all three tests indicated that the stock market index and exchange rate series are non-stationary in levels, but stationary in first differences at a 5% significance level. This implies that the series are integrated of order 1, i.e. I (1) and appropriate for further analysis.

Table 2: Unit root and stationary tests

Countries	ADF- testLevel	First Diff.	PP – test Level	First Diff.	KPSS – test Level	First Diff.
Panel A: Stock prices						
Brazil	-2.5822	-12.0041**	-2.6715	-11.9837**	0.1909	0.0869**
Argentina	-2.2865	-13.9584**	-2.2865	-14.0417**	0.3049	0.0566**
Mexico	-2.5742	-13.1119**	-2.6687	-13.1751**	0.3121	0.0445**
India	-3.3659	-13.1474**	-3.6684	-13.1819**	0.0509	0.0479**
Panel B: Exchange rate changes						
Brazil	-2.2389	-9.8293**	-2.2154	-9.7047**	0.3398	0.0511**
Argentina	-0.6885	-13.8535**	-0.6099	-13.8971**	0.4160	0.0328**
Mexico	-3.1186	-13.5523**	-3.0876	-14.0157**	0.2756	0.0474**
India	-2.5631	-12.5776**	-2.6814	-12.5507**	0.1367	0.0571**

*Note: ** 5% level of significance, Source: Prepared by the author*

Regime shifts in emerging country stock markets

To verify whether stock market returns have regime change behaviour, we proceeded to test the null hypothesis of no regime change (i.e. the dynamics of stock returns are best reproduced by a linear autoregressive model) against the alternative hypothesis of regime change which corresponds to an MS-AR model. The likelihood ratio (LR) test developed by Garcia & Perron (1996) is used to make the choice of the appropriate model. Therefore, the test is determined through equation 4.

$$LR = 2x\left[\ln L_{MS-AR} - \ln L_{AR}\right] \quad (4)$$

where is the log-likelihood of the models. The best fitting model is selected based on the critical values of Davies (1987). Table 3 indicates that the LR test statistics are significant in all cases at the 1% level. These results reject the null hypothesis of no regime change for the selected emerging country stock markets, which means that the time-varying behaviour of these markets is best described by the non-linear MS-AR model using the Akaike test (AIC, 1973). Similar results for other emerging markets were the work developed by Chkili *et al.* (2011) and Chkili & Nguyen (2014).

Table 4 represents the estimated MS-AR models for emerging country stock markets. An analysis of the standard deviations shows that they are statistically significant for all markets and their values indicate the existence of two regimes: Regime 1(low volatility) and

Table 3: LR test statistics and AIC

Countries	LnL(AR)	LnL(MS-AR)	LR	AIC (AR)	AIC (MS-AR)
Brazil	247.93	263.60	31.34***	-2.5121	-2.6318
Argentina	153.85	169.12	30.54***	-1.5472	-1.6610
Mexico	314.73	323.80	18.14***	-3.1973	-3.2493
India	373.03	394.90	43.74***	-3.7952	-3.9784

*Notes: *** denote the null hypothesis of no regime shift is rejected at the 1% significance level*

regime 2 (high volatility). For all stock markets, the standard deviation (volatility) of regime 2 is higher than the volatility of regime 1. Among emerging country stock markets, Argentina and Brazil have the highest level of volatility in regime 2. On the other hand, Mexico presents the lowest level of volatility in both regimes. It is observed, that the probability of being in regime 2 is lower than the probability of remaining in regime 1, independent of the markets. The probability of being in a regime of low volatility ranges from 0.9704 (Mexico) to 0.9852 (Brazil), while the probability of being in a regime of high volatility is between 0.5226 (Brazil) and 0.9578 (Mexico). The magnitude of the probabilities (P_{11} and P_{22}) highlights the fact that the low volatility regime is more persistent than the high volatility regime, i.e. the stock market in emerging countries stays longer in regime 1 than in regime 2. The average duration of the high volatility regime is 19.75 months in Mexico and 2.50 months in Brazil. As for the average duration of the low volatility regime is 63.33 months in Brazil, followed by 59.33 months in Argentina, 41.50 months in India and 38.33 months in Mexico.

Table 4: Estimation results for the MS-AR model

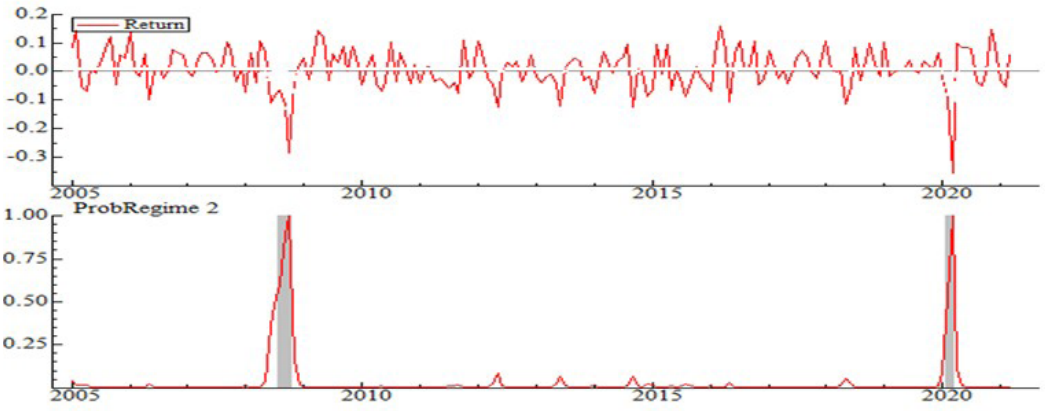
Parameters	Brazil	Argentina	Mexico	India
μ(1)	0.0122 (0.0043)***	0.0230 (0.0068)***	0.0042 (0.0029)*	0.0132 (0.0041)***
μ(2)	-0.1896 (0.0876)**	-0.0164 (0.0542)	0.0097 (0.0084)	-0.0026 (0.0257)
AR-1(1)	0.1386 (0.0762)**	-0.0245 (0.0867)	-0.1154 (0.1050)	-0.0574 (0.0847)
AR-1(2)	-0.1821 (0.2036)	0.0209 (0.1886)	0.1294 (0.1179)	0.0218 (0.1774)
σ(1)	0.0571 (0.0031)***	0.0862 (0.0060)***	0.0311 (0.0027)***	0.0465 (0.0041)***
σ(2)	0.1211 (0.0536)**	0.2131 (0.0470)***	0.0643 (0.0072)***	0.1147 (0.0228)***
ϱ_{11}	0.9852	0.9769	0.9704	0.9782
ϱ_{22}	0.5226	0.8195	0.9578	0.8926
$E(D_1)$	63.33	59.33	38.33	41.50
$E(D_2)$	2.50	8.00	19.75	9.00
LogL	264.38	169.11	328.05	275.42

*Notes: ***, **, * denote statistical significance at the 1%, 5%, 10%, respectively. Standard errors are in parentheses.*
Source: Prepared by the author based on the research

Figure 1 shows the behaviour of stock market returns and the smoothed and predicted probability in regime 2 (high volatility) for four countries under consideration. The smoothed probability of being in the high volatility regime reveals periods of high volatility to all markets. These periods were: 2007-2008 (US subprime crisis) and 2020 (COVID-19 pandemic).

September 2008 saw the beginning of a significant drop in the markets caused by the subprime crisis triggered by the bankruptcy of one of the US investment banks, Lehman Brothers, triggering a crisis in the international stock markets. At the beginning of January 2020, there was a negative impact on the stock market due to the coronavirus, generating strong turbulence in the world markets and the isolation policies to contain the advance of the pandemic (COVID-19), reflecting in the economy the effects of the paralysis of various economic activities. In the Mexican market from 2005 to 2007 there

Brazil



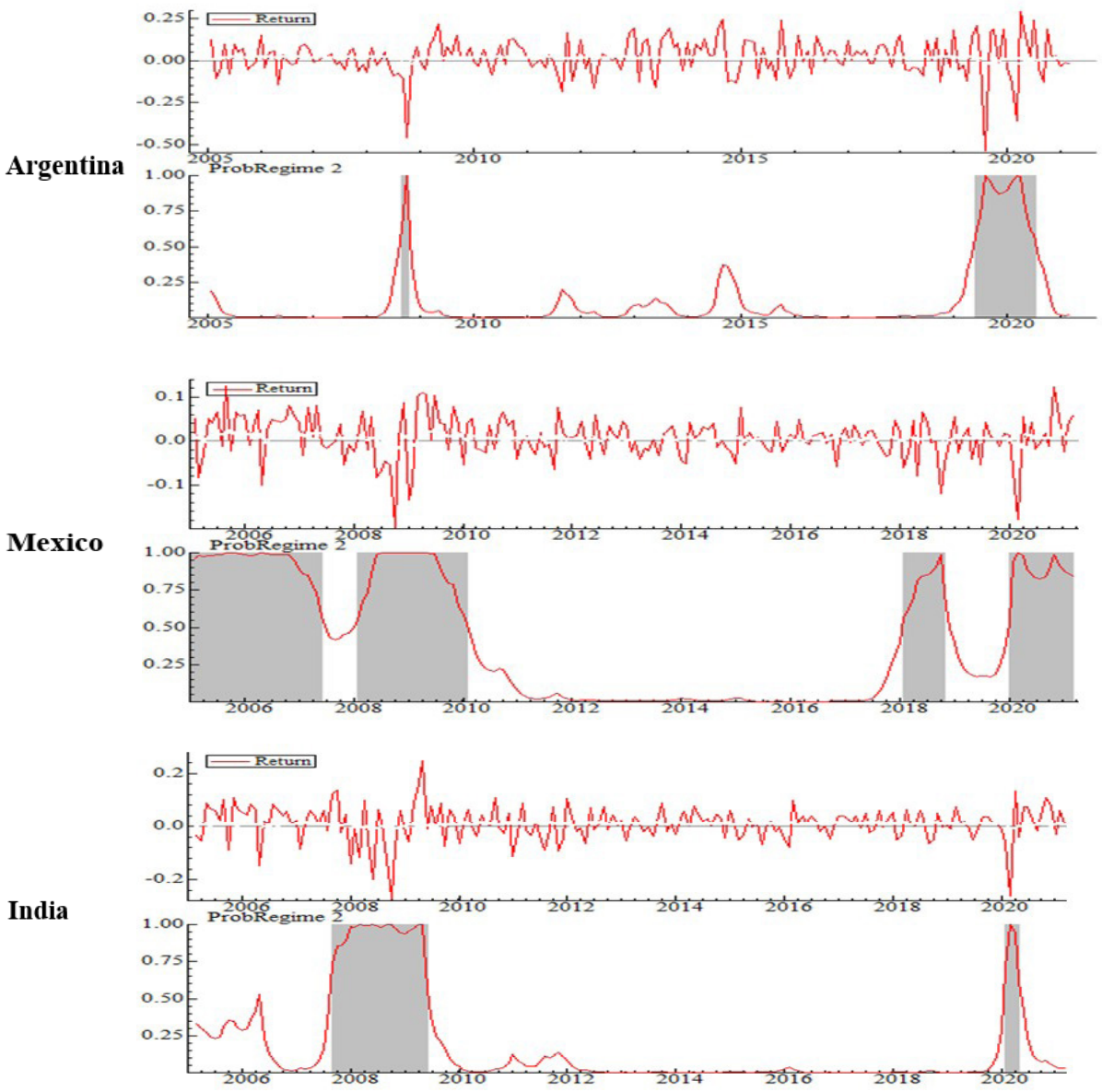


Figure 1: Stock market returns and soft probabilities of the high volatility regime

were oscillations of the high volatility regime, but in 2008 it entered this regime and remained until 2009. Subsequently, it showed a volatility peak in 2018, with a drop in stock market returns of around 15.63%. This is explained by the geopolitical and economic changes observed in the global and local environment, presenting a significant impact due to the change of government and the uncertainty generated by it.

Dynamic linkage between stock and exchange markets

To analyse the dynamic link between stock market returns and changes in exchange rates in the low and high volatility regimes of selected emerging countries using the MS-VAR model, it is necessary to perform the likelihood ratio (LR) tests, expressed according to equation 5.

$$LR = 2x\left[\ln L_{MS-VAR} - \ln L_{VAR}\right]. \quad (5)$$

The results presented in Table 5, and based on the AIC indices indicate that the LR test rejects the null hypothesis of no regime change in the link between stock markets and exchange rate in emerging countries. Thus, it can be concluded that the MS-VAR model is appropriate to verify the joint dynamic relationship of these markets under the influence of regime change.

Table 5: LR test statistics and AIC

Countries	LnL(VAR)	LnL(MS-VAR)	LR	AIC (VAR)	AIC (MS-VAR)
Brazil	662.08	672.51	20.86***	-6.7573	-6.7847
Argentina	470.13	634.26	328.26***	-4.7681	-6.3924
Mexico	717.46	743.49	52.06***	-7.3312	-7.5127
India	747.84	781.72	67.76***	7.6858	-7.9456

*Notes: *** denote the null hypothesis of no regime shift is rejected at the 1% significance level*

The estimates of the MS-VAR model with two regimes on the relationship between stock prices and exchange rate are presented in table 6. From the standard deviation of both markets, it can be seen that regime 1 (high volatility) was higher than regime 2 (low volatility) for all the emerging countries analysed in this study. The results in the table also show that the duration of the high volatility regime for the countries was between 4 and 8 months, while the average duration of the low volatility regime was between 15 and 34 months. This shows that the transition regime, indicated by and , respectively, suggesting that the low volatility regime was more persistent than the high volatility regime.

The estimated coefficients capturing the impact of

Table 6: MS-VAR model estimation

Parameters	Brazil	Argentina	Mexico	India
α_1	-0.036 (0.025)*	-0.005 (0.020)**	-0.048 (0.030)**	0.018 (0.005)***
α_2	0.014 (0.005)***	0.024 (0.009)***	0.013 (0.004)***	-0.178 (0.018)***
α_{21}	0.131 (0.087)*	-0.013 (0.071)	-0.039 (0.085)	-0.008 (0.090)
α_{22}	-0.130 (0.088)*	-0.094 (0.066)*	0.026 (0.084)	0.028 (0.079)
α_{31}	0.056 (0.172)	-0.053 (0.228)	-0.052 (0.112)	0.170 (0.233)
α_{32}	0.013 (0.156)	0.201 (0.177)	0.119 (0.109)	0.251 (0.240)
β_1	0.030 (0.014)	0.013 (0.012)	0.051 (0.026)	-0.002 (0.002)
β_2	0.001 (0.735)	0.002 (0.001)**	-0.002 (0.003)	0.017 (0.007)***
β_{21}	0.119 (0.090)*	0.528 (0.060)***	-0.113 (0.080)*	-0.044 (0.087)
β_{22}	-0.056 (0.080)	0.154 (0.021)***	-0.075 (0.074)	-0.155 (0.088)**
β_{31}	-0.155 (0.045)***	0.003 (0.007)	-0.028 (0.056)	0.017 (0.030)
β_{32}	0.003 (0.047)	-0.027 (0.006)*	0.048 (0.055)	0.015 (0.029)
Std. deviation – Stock returns				
σ_1	0.1056	0.1339	0.0745	0.0438
σ_2	0.0477	0.0944	0.0511	0.0139
Std. deviation – Exchange rate				
σ_1	0.0554	0.0904	0.0393	0.1027
σ_2	0.0236	0.0066	0.0247	0.0263
Probability				
ρ_{11}	0.7858	0.8705	0.7120	0.7522
ρ_{22}	0.9687	0.9379	0.9599	0.9199
Duration				
D_1	4.20	7.75	3.20	4.48
D_2	34.40	14.56	29.50	17.00
Log L	1414.1	1367.5	1406.2	1591.0

*Notes: ***, **, * denote statistical significance at the 1%, 5%, 10%, respectively. Standard errors are in parentheses.*
Source: Prepared by the author based on the research.

exchange rate movements on stock returns (α_{31} and α_{32}) are not statistically significant across emerging countries. This reveals that fluctuations in US dollar exchange rates do not have a strong influence on the dynamics of stock market returns. This result, which
corroborates the studies of Chkili and Nguyen (2014), Yang and Doong (2004) and Sosa *et al.* (2018).

On the other hand, the coefficients ((β_{31} and β_{32}) detect the impacts of stock returns on exchange rate movements are statistically significant for the markets of Brazil and Mexico. The relationship is negative in the high volatility regime for Brazil, i.e. an increase in stock market returns resulting to exchange rate appreciation. This result correlates with the studies Chkili and Nguyen (2014), Granger *et al.* (2000).

CONCLUSION

This paper examines the dynamic linkages between stock market returns and the exchange rate, using monthly data for selected emerging countries (Brazil, Argentina, Mexico and India)). The methodology is based on the Markov Switching Vector Autoregressive (MS-VAR) model in order to detect regime shifts in stock returns and exchange rate variation.

The low volatility regime has more persistence than the high volatility regime. Specifically, exchange rate changes do not influence emerging country stock market returns regardless of regimes. On the other hand, the impacts of stock returns on exchange rate movements are statistically significant, especially for the markets in Brazil and Mexico. The relationship is negative in the high volatility regime for Brazil, i.e. an increase in stock market returns resulting to exchange rate appreciation.

Portfolio investors and currency hedge managers can use these results to design international investment strategies that include emerging country stock markets as well as exchange rate variation, in order to better hedge against risk during future crises.

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