



2008-01-01

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## Recommended Citation

Morales, L.: Volatility spillovers between stock returns and foreign exchange rates: evidence from four eastern European countries. Paper presented to the Financial Management Association (FMA) European Conference, 4-6 June 2008, Prague, Czech Republic. Conference Proceedings.

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# **Volatility Spillovers Between Stock Returns and Foreign Exchange Rates: Evidence from Four Eastern European Countries**

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**Keywords: Stock Returns, Exchange Rates, Integration, Volatility spillovers, EGARCH modeling.**

**JEL Codes: F, G**

## **Abstract**

This paper investigates the nature of volatility spillovers between stock returns and exchange rates changes for the Czech Republic, Hungary, Poland and Slovakia for the 1999-2006 period. We divide our sample in two sub period, prior to the introduction of the Euro as since the single currency has been introduced. We use an EGARCH modelling which takes into account whether bad news has the same impact on volatility as good news. Our results show that in terms of volatility spillover effects from stock returns to exchange rates returns, there is non-existence of significant spillovers in these countries, what suggest the no existence of integration between these two financial markets. If we analyse the spillover effects from exchange rates to stock markets we found that the overall results is the lack of significant spillovers from exchange rate to stock returns. We also found that volatility in stock returns and exchange rates tends to decrease after the countries joined the European Union.

## **1. Introduction**

The objective of this article is to provide an empirical analysis of the linkage between the volatility of stock prices and the volatility of the exchange rate for four Eastern European countries. As empirical evidence on volatility spillovers between stock markets and exchange rates have tended to focus on the G-7 countries, Yang and Doong (2004); Kanas (2000,2002). There is no evidence to date that this relationship have been analysed for the Eastern European countries. Therefore, our aim is to fill the gap in the literature in this area by investigating this issue, using daily data for the period of 1999 to 2006 for Hungary, Czech Republic, Slovakia and Poland, four transition economies.

As Eastern European countries have experienced remarkable changes in their settings of exchange rate arrangements, as well as in monetary policy, Fromer(2006) being the main characteristic of post-communist countries to start the process of transition by opting for stabilization strategy in term of fixing the exchange rate. Subsequently, this fixed exchange rate regime becomes more flexible (Sachs, 1996), and after widening the bands what is translated in an increase in the flexibility that will leads to an increase in exchange rate volatility. Taking into account these characteristics we decided to analyse the link between stock returns and exchange rate for the period of time before the countries joined the European Union (EU), that is before the 1<sup>st</sup> of May of 2004, and after the period of time that the joined EU. Also, as exchange rate volatility have a direct influence on the labour market, in order to increase or decrease the level of unemployment, that have a direct impact in the growth rate of an economy and as a result will influence the foreign direct investment in a country which is reflected in the stock returns, this issue become of great interest for academics and practitioners.

The layout of the paper is as follows. Section 1 reviews the existing empirical evidence on the issue until today. Section 2 sets out the data and methodology used to investigate this issue. Section 3 discusses the results from the econometric analysis and section 4 summarize and conclude the paper.

## 2. Literature Review

Several theoretical models have analysed the link between stock markets and currency markets. The asset market approach to exchange rate determination (Branson, 1983; Frankel, 1983) posits that causality will run from stock prices to exchange rate changes as expectations of financial asset price movements affect the dynamics of exchange rates. Smith (1992) derives an estimable equation for the exchange rate where the stock price is included as an explanatory variable. The goods market approach suggests causality runs in the opposite direction, from exchange rates to stock prices (Mundell, 1963, 1964; Dornbusch and Fisher, 1980). In these models, movements in exchange rates affect the international competitiveness of firms which affects real income and output and eventually stock prices. Much of the available empirical evidence on the linkages between stock markets and exchange rates has concentrated on the first moments<sup>1</sup>. Yang and Doong (2004) note that there is a dearth of empirical evidence that concentrates on the linkages between the second moments of the distribution of the variables. A number of studies however have examined the extent to which volatility from one stock market spills over into other stock markets or between different assets<sup>2</sup>. Kanas (2000) was one of the first studies which analysed volatility spillovers from stock returns to exchange rate changes in the USA, the UK, Japan, Germany, France and Canada. He found evidence of spillovers from stock returns to exchange rate changes for all countries except Germany, suggesting that the asset approach to exchange rate determination is valid when formulated in terms of the second moments of the exchange rate distribution for the countries included in his analysis. Volatility spillovers from exchange rate changes to stock returns were insignificant for all countries. Yang and Doong (2004) explored the nature of the mean and volatility transmission mechanism between stock and foreign exchange markets for the G-7 countries. The results point to significant volatility spillovers and an asymmetric effect from the stock market to the foreign exchange market for France, Italy, Japan and the US, suggesting integration between stock and foreign exchange markets in these countries. Wang and Yang (2006) find

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<sup>1</sup> See for example Nieh and Lee (2001), Yau and Nieh (2006) for recent evidence on this topic.

<sup>2</sup> See also for example, Nelson (1991), Koutmos and Booth (1995), Laopodis (1998).

evidence of asymmetric volatility in daily realized volatilities of AUD, GBP and JPY against USD, as well as daily GARCH-estimated volatilities in trade weighted indices; the found that there is no asymmetric volatility in EUR against USD and its trade weighted indices, they also document a strong impact from long-run price trend to daily realized volatility. Savva et al. (2005) investigates the transmission of price and volatility spillovers across the New York, London, Frankfurt and Paris stock markets under the framework of the multivariate EGARCH model, the found evidence that domestic stock returns and volatilities are influenced by the behaviour of foreign markets, with both volatilities and conditional correlations responding asymmetrically to news/innovations in other markets. Their findings also indicate that the correlations of returns have increased for all markets since the launch of the Euro. Wu (2005) who examines volatility spillovers between stock prices and exchange rates for Japan, South Korea, Indonesia, Philippines, Singapore, Thailand and Taiwan for the period 1997-2000, splitting the sample into crises and recovery periods. He found a bi-directional relationship between the volatility of stock returns and exchange rate changes during the recovery period in all countries except South Korea, as well as significant contemporaneous relationships between the two markets for most of the countries. Furthermore, he found volatility spillovers increased in the recovery period. Dark et al (2005) examined the return and volatility spillover effects between the US dollar/Australian dollar (USD/AUD), and the Australian All Ordinaries index (AOI). The empirical findings provide evidence of unidirectional return and volatility spillover effects from the USD/AUD to the AOI.

### **3. Data and Methodology**

The analysis will be conducted with the purpose of investigating volatility spillovers between stock returns and exchange rate changes for four Eastern European countries, Czech Republic, Hungary, Poland and Slovakia, for the period 1 January 1999 to 11 July 2006. In order to analyze the relationship between these two variables, we consider that splitting our sample into two sub samples that will provide more detail and a better understanding of volatility spillovers between stock returns and exchange rates. Therefore, we split our into two sub sample samples, initially we

will analyze the relationship between these two variable before the introduction of the Euro, so our first sub sample will analyze from 01/01/1999 to 30/04/2004 pre introduction of the Euro period, then we analyze the time period after the introduction of the Euro that will cover from 30/04/2004 to 11/07/2006 post Euro period. Our sample has a total of 1963 observations. Data was taken from DataStream and the Federal Reserve Statistic Release. Following Kanas (2000) we use continuously compounded stock returns and exchange rate changes calculated as the first differences of the natural log. That is, S= Stock Prices;  $S_t = \ln(P_t^s) - \ln(P_{t-1}^s)$  and E= Exchange Rates;  $E_t = \ln(P_t^e) - \ln(P_{t-1}^e)$ .

As an initial step we provide descriptive statistics for stock returns and exchange rates, in order to summarize the statistical characteristics of our sample. We then proceed and perform a stationarity test on each of the relevant variables that are included in our analysis to ensure that the results from the analysis are not spurious. We apply the Dickey Fuller (DF) test or Augmented Dickey-Fuller test (ADF) procedure if serial correlation is present. We also apply the Lagrange Multiplier (LMF) test, to ensure that a sufficient number of lags have been added in the ADF test to ensure that there is no serial correlation present and the results of the ADF test are valid. The LMF test is applied given that it is valid in the presence of lagged dependent variables as well as having the advantage of testing for first and higher orders of serial correlation. If our variables are non-stationary in levels, we then proceed and perform a cointegration test on our variables using the Johansen Cointegration test to investigate the long-run relationship between Stock Prices and Exchange Rates. As Enders (2004) notes given that the results of the test can be quite sensitive to the lag length, the most common procedure is to estimate a Vector Autoregression (VAR) model on the undifferenced data in order to determine the lag length for the Johansen test. We estimate the lag selection tests up to 20 lags. In terms of choosing between the various lag length selection criteria we follow Johansen *et al.* (2000) who suggest that when different information criteria suggest different lag lengths, it is common practice to prefer Hannan-Quinn (HQ) criteria. Again, we ensure that the lag length selected for the VAR model is free from serial after performing by applying the LMF test to test for serial correlation up to the number of

lags in the VAR model. There are five possible models to choose from for the Johansen test as follows.

$$H_2(r) : \Pi y_{t-1} + B x_t = \alpha B' y_{t-1} \quad (1)$$

$$H^*_1(r) : \Pi y_{t-1} + B x_t = \alpha (B' y_{t-1} + p_0) \quad (2)$$

$$H_1(r) : \Pi y_{t-1} + B x_t = \alpha (B' y_{t-1} + p_0) + \alpha_{\perp} \gamma_0 \quad (3)$$

$$H^*(r) : \Pi y_{t-1} + B x_t = \alpha (B' y_{t-1} + p_0 + p_1 t) + \alpha_{\perp} \gamma_0 \quad (4)$$

$$H(r) : \Pi y_{t-1} + B x_t = \alpha (B' y_{t-1} + p_0 + p_1 t) + \alpha_{\perp} (\gamma_0 + \gamma_1 t) \quad (5)$$

Equation 1 has no deterministic trends in the level data and no intercepts in the cointegrating equations. Equation 2 has no deterministic trends in the level data and the cointegrating equations have intercepts. Equation 3 has linear trends in the level data but the cointegrating equations only have intercepts. Equation 4 has linear trends in both the level data and the cointegrating equations, and equation 5 has quadratic trends in the level data and linear trends in the cointegrating equations. Harris and Sollis (2003) note that model 1 i.e. with no deterministic components in the data or cointegration relations, is unlikely to occur in practice, as generally an intercept is needed to take account of the units of measurement of the variables; they also note that model 5 with quadratic trends, is economically hard to justify, as if the variables are entered in logs, as they are in our model, as this would imply an every increasing or decreasing rate of change. This leaves a choice between models 2-4. Johansen (1992) suggests choosing the appropriate model according to the Pantula principle; all three models are estimated; the Pantula principle involves moving through each model for the null hypothesis of  $r=0$ , then  $r=1$  etc., and picking the model where the null hypothesis is rejected for the first time. Chang and Caudill (2005) note that the  $\lambda_{\text{trace}}$  test statistic is more robustness to both skewness and excess kurtosis than the  $\lambda_{\text{max}}$  test statistic; for comparative purposes, we show both the results of the  $\lambda_{\text{trace}}$  and the  $\lambda_{\text{max}}$  test statistics.

We then proceed with our volatility analysis and apply a bivariate extension of the EGARCH ( $p,q$ ) model in order to examine whether the volatility of stock returns affects and is affected by the volatility of exchange rate changes within each

economy. The EGARCH specification (Nelson, 1991) is used in order to test whether the volatility spillover effects are asymmetric. For example, an asymmetric spillover from stock returns to exchange rate changes would suggest that the effect of “bad” stock market news on the exchange rate change is greater than the effect of “good” news. The model is specified as follows:

$$S_t = a_{s,0} + \sum_{i=1}^r a_{s,i} S_{t-i} + \sum_{i=1}^r a_{e,i} E_{t-i} + \beta_s \lambda_{s,t-1} + e_{s,t} \quad (6)$$

$$E_t = a_{E,0} + \sum_{i=1}^r a_{E,i} E_{t-i} + \sum_{i=1}^r a_{S,i} S_{t-i} + \beta_E \lambda_{E,t-1} + e_{E,t} \quad (7)$$

$$e_{S,t} / \Omega_{t-1} \approx N(0, \sigma_{S,t}^2)$$

$$e_{E,t} / \Omega_{t-1} \approx N(0, \sigma_{E,t}^2)$$

The conditional variances of stock returns and exchange rates changes are specified as follows:

$$\sigma_{S,t}^2 = \exp \left\{ c_{S,0} + \sum_{j=1}^{ps} b_{S,j} \log(\sigma_{S,t-j}^2) + \delta_{S,S} \left[ \left( |z_{S,t-1}| - E|z_{S,t-1}| + \theta_{S,Sz_{S,T-1}} \right) + \delta_{S,E} \left[ \left( |z_{E,t-1}| - E|z_{E,t-1}| + \theta_{S,Ez_{E,T-1}} \right) \right] \right] \right\} \quad (8)$$

$$\sigma_{E,t}^2 = \exp \left\{ c_{E,0} + \sum_{j=1}^{ps} b_{E,j} \log(\sigma_{E,t-j}^2) + \delta_{E,E} \left[ \left( |z_{E,t-1}| - E|z_{E,t-1}| + \theta_{E,Ez_{E,T-1}} \right) + \delta_{E,S} \left[ \left( |z_{S,t-1}| - E|z_{S,t-1}| + \theta_{E,Sz_{S,T-1}} \right) \right] \right] \right\} \quad (9)$$

$$\sigma_{S,E,T} = \rho_{S,E} \sigma_{S,t} \sigma_{E,t}$$

We summarize each of the relevant terms in equations (6-9) in Table 1.

**Table 1** Description of Parameters Equations (6)-(9)

	Stock Returns	Exchange Rate Returns
Error correction terms (lagged residuals from the cointegrating regression of $S_t, E_t$ )	$\lambda_{S,t-1}$	$\lambda_{E,t-1}$
Stochastic error terms	$e_{S,t}$	$e_{E,t}$
Information set at time $t-1$	$\Omega_{t-1}$	$\Omega_{t-1}$
Conditional (time varying) variances	$\sigma_{S,t}^2$	$\sigma_{E,t}^2$
Standardized residuals assumed to be normally distributed with 0 mean and variances of $\sigma_{S,t}^2, \sigma_{E,t}^2$	$z_{S,t} = e_{S,t} / \sigma_{S,t}$ $e_{S,t} / \Omega_{t-1} \sim N(0, \sigma_{S,t}^2)$	$z_{E,t} = e_{E,t} / \sigma_{E,t}$ $e_{E,t} / \Omega_{t-1} \sim N(0, \sigma_{E,t}^2)$



Persistence of Volatility	$\sum_{j=1}^{ps} b_{S,j}$	$\sum_{j=1}^{pE} b_{E,j}$
ARCH effect where the parameters $\theta_{S,S}, \theta_{E,E}$ allow this effect to be asymmetric	$\left[  z_{S,t}  - E z_{S,t}  + \theta_{S,Sz_{S,t}} \right]$	$\left[  z_{E,t}  - E z_{E,t}  + \theta_{E,Ez_{E,t}} \right]$
Volatility Spillover	$\delta_{S,E} \left[  z_{E,t-1}  - E z_{E,t-1}  + \theta_{S,Ez_{E,t-1}} \right]$	$\delta_{E,S} \left[  z_{S,t-1}  - E z_{S,t-1}  + \theta_{E,Sz_{S,t-1}} \right]$
Measures of spillovers	$\delta_{S,E}$	$\delta_{E,S}$
Asymmetry of Spillovers	${}^3 \theta_{S,E}$	$\theta_{E,S}$
Correlation Coefficient for Standardized Residuals	$\rho_{S,E}$	$\rho_{E,S}$

We specify the number of lags for the conditional mean equations (6) and (7) using the HQ criterion; Griffin *et al* (2005) Andersen *et al* (2004) and Stulz *et al* (2002) all note that the Hannan-Quinn selection criterion is preferable to the more commonly used Akaike's Information Criteria (AIC), as the latter tends to over parameterize the models<sup>4</sup>. Next we apply the likelihood ratio (LR) test to determine the lag truncation length,  $p$ . We perform separate LR test on the stock returns and exchange rate conditional variance equations (8) and (9) to determine the optimal lag length for the EGARCH specification of each equation. Hamilton (1994) defines the LR test as follows:  $2[L(\hat{\theta}) - L(\tilde{\theta})] \approx \chi^2(m)$ , where  $L(\hat{\theta})$  denotes the value of the log likelihood function at the unrestricted estimate and  $L(\tilde{\theta})$  denotes the value of the log likelihood functions of the restricted estimate. Bollerslev-Woolridge robust  $t$ -statistics are derived to take into account possible non-normality of the residuals.

Given that our sample period covers the period before and after the introduction of the Euro, we split our sample in order to compare the effect of volatility spillovers before and after the introduction of the Euro. All results are generated using the EVIEWS statistical program. This will yield seven separate sets of results for the various exchange rates included in the analysis.

<sup>3</sup>  $\theta_{S,E} < 0, \theta_{E,S} < 0$ , implies that negative exchange rate shocks increase the volatility of stock returns more than positive shocks

<sup>4</sup> For brevity here we do not report the number of lags selected for the conditional mean equations for stock prices and exchange rates for each period.

#### 4. Empirical Results

Our study starts presenting the results obtained from the descriptive statistics for stock returns and exchange rates that will set the characteristics of our sample. As is possible to observe in table 1 for the entire period, the sample means of stock returns are positive for Slovakia and Poland, while the mean is negative for Hungary and the Czech Republic. The results are positive for all the countries during the period that the countries did not join the European Union (EU), and after 1<sup>st</sup> of May 2004, when the countries joined the EU. The highest mean returns were for Poland, 6.35E-04, followed by Slovakia 6.99E-05, for the pre-European period, the mean returns were highest for Czech Republic, 0.000546 and Poland, 0.000455, followed by Slovakia and Hungary, and for the post-European period they were highest for Slovakia (0.001336) followed by Hungary (0.00122), Poland (0.000996) and Czech Republic (0.000897). The standard deviation of the stock returns range from 0.29% to 1.26% for the entire period and from 1, 29% to 1.52% for the pre-European period and from 1.40% to 1.01% to the post-European period, indicating that the volatility of stock returns in general were lower in the period after the countries joined the EU, than during the period of time previous to join the European Union. The skewness and kurtosis coefficients indicates that stock returns are leptokurtic in relation to the normal distribution, being this a common finding for stock returns, as Caporale et al (2002) notice. The Jarque-Bera (JB) tests are very high, meaning that the null hypothesis of stock returns normally distributed is rejected for all the countries in all the periods.

The descriptive statistics for the exchange rate returns show that the sample means are positive for the entire period for the Czech Republic, Slovakia and Poland. For the pre-European period the means are positive just for Poland and for the post-European Union being positive only for Hungary. The volatility of the exchange rate returns ranged from 1.33% (Poland) to 4% (Czech Republic) for the entire period. During the pre-European period the highest volatility was found in Poland with 6.6% and the lowest in Slovakia with 3%, and in post-European period it moved between 2.6% (Slovakia) to 5% (Poland), being the highest volatility period the pre-European.

**Table 1 Descriptive Statistics**

<b>Stock Returns</b>		<b>Mean</b>	<b>SD</b>	<b>Skewness</b>	<b>Kurtosis</b>	<b>JB</b>
<b>Hungary</b>	Total sample	-5.94E-05	0.0029	0.52	19.65	22741
	Pre Europe	0.000408	0.0152	0.08	7.16	1003
	Post Europe	0.001222	0.0140	-0.34	4.47	63
<b>Czech Republic</b>	Total sample	-1.18E-05	0.0062	0.82	7.55	1911
	Pre Europe	0.000546	0.0129	-0.08	4.19	83
	Post Europe	0.000897	0.0117	-0.51	8.84	837
<b>Slovakia</b>	Total sample	6.99E-05	0.0104	0.38	13.05	8308
	Pre Europe	0.000447	0.0145	-0.62	9.87	2826
	Post Europe	0.001336	0.0114	-0.04	6.21	246
<b>Poland</b>	Total sample	6.35E-04	0.0126	-0.18	5.20	407
	Pre Europe	0.000455	0.0145	0.01	5.43	343
	Post Europe	0.000996	0.0101	-0.71	5.96	257

  

<b>Exchange Rates</b>		<b>Mean</b>	<b>SD</b>	<b>Skewness</b>	<b>Kurtosis</b>	<b>JB</b>
<b>Hungary</b>	Total sample	-1.10E-04	0.0034	0.04	7.91	1971
	Pre Europe	-5.03E-06	0.0040	2.29	25.50	30550
	Post Europe	0.000172	0.0038	0.51	4.96	116
<b>Czech Republic</b>	Total sample	4.65E-05	0.0040	1.83	20.40	25840
	Pre Europe	-5.79E-05	0.0036	0.05	8.30	1625
	Post Europe	-0.00023	0.0029	-0.09	3.43	5
<b>Slovakia</b>	Total sample	7.08E-04	0.0137	-0.55	9.77	3843
	Pre Europe	-4.79E-05	0.0030	0.62	21.90	20778
	Post Europe	-8.18E-05	0.0026	0.19	9.88	1130
<b>Poland</b>	Total sample	6.21E-04	0.0133	-0.09	5.88	681
	Pre Europe	0.000112	0.0066	0.87	7.61	1407
	Post Europe	-0.00029	0.0050	0.28	3.56	15

After analysing the descriptive statistics of our data, we proceed to present the findings of our econometric models. The results from the ADF tests are given in table 2. The statistics are showing that we can reject the null hypothesis of the existence of unit root in levels for all variables in all periods, indicating that all series are  $I(0)$ .

**Table 2 Augmented Dickey Fuller Test Results**

	Variables	Total Sample	Pre Europe	Post Europe
<b>Hungary</b>	E	-44.1	-16.1	-18.4
	S	-28.7	-26.5	-5.1
<b>Czech Republic</b>	E	-31.6	-22.7	-24.5
	S	-9.6	-36.2	-21.5
<b>Slovakia</b>	E	-19.7	-24.2	-8.1
	S	-13.6	-20.6	-8.2
<b>Poland</b>	E	-42.5	-16.7	-23.3
	S	-42.2	-36.1	-21.6

1% critical values for the ADF test are

Given that all our variables are integrated at levels we can conclude that our variables are cointegrated, this means, that there is a long-run relationship between stock returns and exchange rate returns for all the countries in all the periods. Therefore, is not necessary to implement the Johansen's (1992) cointegration test. Hence, we proceed to apply the likelihood ratio (LR) test in order to determine the truncation length (p) for our conditional equations in the bivariate EGARCH model. We perform an individual LR test on the stock returns and exchange rate conditional variance equations to determine the optimal lag length for the EGARCH specification of each equation.

**Table 3 Likelihood Ratio Test for EGARCH Model Selection for Conditional Variance Equations**

<b>Country</b>	<b>Stock Returns</b>			<b>Exchange Rates</b>		
	<b>Total Sample</b>	<b>Pre Europe</b>	<b>Post Europe</b>	<b>Total Sample</b>	<b>Pre Europe</b>	<b>Post Europe</b>
<b>Hungary</b>	1.032	0.078	0.264	1.058	0.03	0.66
<b>Czech Republic</b>	0	4.5	0.006	2.358	0.046	5.392
<b>Slovakia</b>	6439.36*	5.378	2.248	5.88	0.118	0.59
<b>Poland</b>	0.138	5.016	1.268	0.486	1.082	0.006

Note:  $H_0$ : EGARCH (1,1),  $H_1$ : EGARCH(2,1) The 5% critical value for the LR test distributed as  $\chi^2$  with 2 degrees of freedom is 5.99. \* indicates rejection of the null hypothesis at 5% significance.

The results are showed in table 3 indicating that we select the EGARCH (1,1) for all the countries in all the periods with the exception of Slovakia where the EGARCH (2,1) model is selected for the entire period. The results from the EGARCH model estimations are set out in tables 4 to 6 for the total sample, pre-European period and post-European period respectively. Our analysis will present results in terms of volatility persistence, volatility spillover effects and asymmetric spillover effects.

In relation to the coefficients on the volatility persistence term the results indicate that there is significant persistence in stock returns volatility for all the countries during the three periods. For the exchange rate equation, the results are showing that the coefficients are all significant for the entire period and for the pre-European period, while we found that for the post-European period volatility persistence for exchange rate returns are not significant in the case of Hungary and Poland, being significant for the Czech Republic and Slovakia.. A necessary condition to the volatility persistence terms to be stable is that the value of the estimated coefficients should be less than one, Wu (2005), for our results this condition applies in all of the cases.

The coefficients for the volatility spillover effects from stock returns to exchange rate returns shown that the coefficients are not significant for all the countries, for the three periods of analysis with the exception on Czech Republic were the coefficient is significant after the country joined the EU. The non-existence of significant spillovers in these countries indicate the existence of potential for diversification between stock markets and currency markets. Surprisingly, these results show that volatility of stock returns is not a determinant of the volatility of the exchange rate, suggesting the no existence of integration between these two markets. The results also, indicate that volatility information contained in stock prices does not impact in the behaviour of exchange rates in these markets.

In terms of volatility spillovers from exchange rates to stock markets, we found that the estimated coefficients were insignificant for all the countries for the entire period, insignificant as well for the pre-European periods with the exception of Poland and same results were found for the post-European periods, being in this case

Hungary the exception, where we found a significant coefficient. The lack of significant spillovers from exchange rate changes to stock returns found in most of the cases are consistent with the results found by Jorion (1990) and Yang and Doong (2005). Jorion (1990) explained that the lack of spillovers could be due to positive exchange rate volatility on stock returns for some firms offsetting negative exchange rate volatility on stock returns for other firms, to give an insignificant or weak effect overall. In addition to this, the use of instruments to hedge exchange rate risk, may reduce the impact of exchange rate volatility on stock markets; Grant and Marshall (1997) and Bodnar et al. (1995) both note that the use of hedging instruments to ameliorate exchange rate risk is pervasive amongst larger companies which are the main components of national stock market indices.

Finally, for the asymmetric spillover effects from stock returns to exchange rates, we find that the coefficients are significant in the case of asymmetric spillover effects from stock returns to exchange rates and vice versa in all the countries for all time periods. The positive sign on all significant coefficients indicates that unexpected good news has a greater impact on volatility than unexpected bad news. A possible explanation for this is that good news on stock prices may have a greater impact on demand for currency so increasing volatility as foreign investors want to increase holdings of risings stock, also, good news on exchange rates may have a greater impact on demand for stocks as investors switch between holdings of stocks and currency, so impacting on stock market volatility.

The diagnostic tests on the standardized residuals are showed as part b of the respective tables. The Jarque-Bera (JB) test indicates that we reject the null hypothesis of residuals normally distributed (justifying the use of Bollerslev-Woolridge robust t-statistics), being the exception of the residuals for the exchange rate equation in the post-European period for Czech Republic and Poland were the residuals are normal distributed.

The Ljung-Box statistics for all three periods for all countries indicates that there are no residual linear or nor linear dependencies, with two exceptions, where there is linear dependency in the stock return equation for Hungary and Slovakia for

the total sample, although for the pre-European period and post-European period separately the dependencies are absent.

Finally, and in order to check the validity of the assumption of constant correlation adopted in the estimation of the bivariate models the LB statistics for the cross products of the standardised residuals from the stock returns equation and from the exchange rate equation were calculated for the three countries for each time period. We found that in almost all the cases the p-values were insignificant, just with the following exceptions: During the post Euro period we found that the LB for Hungary become significant at LB(30) and in the case of Poland in become significant for the LB(4). We also found that for the pre Euro period again the coefficient become significant at LB(29) and for Poland at LB(3) indicating that the assumption of constant correlation over time can be accepted in all the cases.

**Table 4a Volatility Spillovers between Stock Returns and Exchange Rate Changes: Total Sample**

<b>Estimated Parameters</b>	<b>Hungary</b>	<b>Czech Republic</b>	<b>Slovakia</b>	<b>Poland</b>
Volatility Persistence (Stock Returns) ( $\sum b_S$ )	0.2596 (0.000)	0.1846 (0.000)	0.4905 (0.000)	0.2175 (0.000)
Spillover: from Stock Returns to Exchange Rates ( $\sum \delta_{S,E}$ )	0.0490 (0.2183)	0.0524 (0.0353)	-0.0209 (0.3951)	-0.0433 (0.169)
Asymmetric Spillover effect: From Stock Returns to Exchange Rates ( $\sum \theta_{S,E}$ )	0.9105 (0.000)	0.9517 (0.000)	0.9987 (0.000)	0.9478 (0.000)
Volatility Persistence (Exchange Rates) ( $\sum b_E$ )	0.2103 (0.000)	0.2986 (0.001)	0.2186 (0.002)	0.1064 (0.000)
Spillover: from Exchange Rates to Stock Returns ( $\sum \delta_{S,E}$ )	-0.0274 (0.423)	0.0719 (0.259)	0.0093 (0.0778)	-0.0028 (0.829)
Asymmetric Spillover effect: From: Exchange Rates to Stock Returns ( $\sum \theta_{S,E}$ )	0.9263 (0.000)	0.9188 (0.000)	0.8894 (0.000)	0.9898 (0.000)
Correlation Coefficient ( $\rho_{S,E}$ )	0.3200	0.3810	0.0147	0.3744

**Table 4b Diagnostics on Standardised Residuals: Residuals: Total Sample**

	Hungary	Czech Republic	Slovakia	Poland
Stock return equation				
Jarque-Bera	2678 40.00	311 27.91	2442 228.54	289 23.22
LB(20)	(0.005)	(0.112)	(0.000)	(0.278)
LB <sup>2</sup> (20)	6.83 (0.997)	21.35 (0.377)	18.86 (0.531)	18.66 (0.544)
Exchange rate equation				
Jarque-Bera	2320 13.63	61371 14.52	6912 24.66	78 17.59
LB(20)	(0.849)	(0.803)	(0.215)	(0.615)
LB <sup>2</sup> (20)	10.24 (0.964)	1.11 (1.000)	11.54 (0.931)	12.41 (0.901)
Cross Products				
Jarque-Bera	213777 31.093	17330730 10.064	213122 30.993	90184 29.999
LB(20)	(0.054)	(0.967)	(0.055)	(0.070)
LB <sup>2</sup> (20)	14.146 (0.823)	0.0992 (1.000)	20.159 (0.448)	3.888 (1.000)

**Table 5a Volatility Spillovers between Stock Returns and Exchange Rate Changes: Pre Europe**

Estimated Parameters	Hungary	Czech Republic	Slovakia	Poland
Volatility Persistence				
(Stock Returns) ( $\sum b_S$ )	0.0756 (0.007)	0.1577 (0.000)	0.2023 (0.005)	0.1020 (0.000)
Spillover: from Stock Returns to				
Exchange Rates ( $\sum \delta_{S,E}$ )	-0.0370 (0.063)	-0.0249 (0.350)	0.0142 (0.749)	-0.0069 (0.642)
Asymmetric Spillover effect:				
From Stock Returns to Exchange				
Rates ( $\sum \theta_{S,E}$ )	0.9788 (0.000)	0.9620 (0.000)	0.8756 (0.000)	0.9783 (0.000)
Volatility Persistence				
(Exchange Rates) ( $\sum b_E$ )	0.3073 (0.002)	0.2460 (0.000)	0.3053 (0.000)	0.1608 (0.006)
Spillover: from Exchange Rates				
to Stock Returns ( $\sum \delta_{S,E}$ )	0.0813 (0.250)	-0.0346 (0.431)	0.0440 (0.3280)	0.0953 (0.004)
Asymmetric Spillover effect:				
From: Exchange Rates to Stock				
Returns ( $\sum \theta_{S,E}$ )	0.9117 (0.000)	0.9060 (0.000)	0.8959 (0.000)	0.9032 (0.000)
Correlation Coefficient ( $\rho_{S,E}$ )	0.0298	0.0017	-0.0502	0.0274



**Table 5b Diagnostics on Standardised Residuals: Residuals: Pre Europe**

	Hungary	Czech Republic	Slovakia	Poland
Stock return equation				
Jarque-Bera	104 20.54	63 30.33	5019 21.89	78 19.56
LB(20)	(0.424)	(0.065)	(0.346)	(0.486)
LB <sup>2</sup> (20)	24.83 (0.208)	16.46 (0.688)	10.62 (0.956)	16.93 (0.658)
Exchange rate equation				
Jarque-Bera	106756 11.78	2110 11.44	1572 34.56	1976 30.90
LB(20)	(0.924)	(0.934)	(0.023)	(0.057)
LB <sup>2</sup> (20)	0.64 (1.000)	8.82 (0.985)	5.61 (0.999)	7.15 (0.996)
Cross Products				
Jarque-Bera	30499 32.007	102855 19.671	82782 19.958	24582 20.345
LB(20)	(0.043)	(0.479)	(0.461)	(0.437)
LB <sup>2</sup> (20)	47.237 (0.001)*	2.4561 (1.000)	9.5307 (0.976)	98.423 (0.000)**

\*LB(29):48.924(0.012);\*\*LB(3):4.925(0.177)

**Table 6a Volatility Spillovers between Stock Returns and Exchange Rate Changes: Post Europe**

Estimated Parameters	Hungary	Czech Republic	Slovakia	Poland
Volatility Persistence				
(Stock Returns) ( $\sum b_S$ )	0.2103 (0.000)	0.2615 (0.000)	0.2310 (0.003)	0.1426 (0.000)
Spillover: from Stock Returns to				
Exchange Rates ( $\sum \delta_{S,E}$ )	-0.0352 (0.471)	-0.1821 (0.000)	0.0364 (0.466)	0.0212 (0.383)
Asymmetric Spillover effect:				
From Stock Returns to Exchange				
Rates ( $\sum \theta_{S,E}$ )	0.9592 (0.000)	0.8801 (0.000)	0.8658 (0.000)	0.9907 (0.000)
Volatility Persistence				
(Exchange Rates) ( $\sum b_E$ )	0.0828 (0.111)	0.0873 (0.037)	0.2150 (0.002)	0.0623 (0.306)
Spillover: from Exchange Rates				
to Stock Returns ( $\sum \delta_{S,E}$ )	0.1459 (0.003)	-0.0087 (0.763)	-0.0134 (0.827)	0.1261 (0.013)
Asymmetric Spillover effect:				
From: Exchange Rates to Stock				
Returns ( $\sum \theta_{S,E}$ )	0.9654 (0.000)	0.9648 (0.000)	0.9690 (0.000)	0.8495 (0.000)
Correlation Coefficient ( $\rho_{S,E}$ )	-0.084	-0.012	0.045	0.0142

**Table 6b Diagnostics on Standardised Residuals: Residuals: Post Europe**

	Hungary	Czech Republic	Slovakia	Poland
Stock return equation				
Jarque-Bera	29 19.55	213 25.58	432 38.76	46 16.19
LB(20)	(0.487)	(0.180)	(0.007)	(0.705)
LB <sup>2</sup> (20)	26.71 (0.144)	15.55 (0.744)	8.79 (0.985)	16.65 (0.676)
Exchange rate equation				
Jarque-Bera	91 25.38	2 19.38	1308 26.65	6 20.49
LB(20)	(0.187)	(0.497)	(0.145)	(0.428)
LB <sup>2</sup> (20)	9.71 (0.973)	18.78 (0.536)	6.44 (0.998)	12.66 (0.891)
Cross Products				
Jarque-Bera	2454 24.511	6912 35.081	155026 19.7	892 25.013
LB(20)	(0.221)	(0.020)	(0.477)	(0.201)
LB <sup>2</sup> (20)	49.315 (0.000)*	19.026 (0.520)	2.1996 (1.000)	65.884 (0.000)**

\*LB(30):51.032; LB(4):10.848(0.028)

## 5. Summary and Conclusions

The aim of this study was to provide empirical evidence of the linkage between volatility of stock prices and volatility of exchange rate for four Eastern European countries (Hungary, Czech Republic, Slovakia and Poland). We proceed in two main steps. First we analyzed the descriptive statistics of our data and we check that the data fulfil the requirements that are needed in order to implement our econometric methodology. The second step was to employ EGARCH modelling to analyze the relationship between our two variables.

Our empirical results showed that volatility in stock returns and exchange rates tends to decrease after the countries joined the European Union, these results could be explained by the fact that transition economies start their stabilization process influencing exchange rates, where they normally move from a float exchange rate regime, to a fixed exchange rate regime. After the exchange rate becomes stable they come back to a more flexible regime (Sachs, 1996) this whole process is translated in an increase in the exchange rate volatility, but after the countries joined the EU, the exchange rate becomes peg to the Euro. And as fixed exchange rates

regimes are strongly associated with open economies a country will be increasing its credibility in the financial markets, which will be more attractive conditions for potential investors. The last years in terms of exchange rates policies for these countries have been marked by two main trends, that is an increasing flexibility of the exchange rates regimes and an increasing orientation of the exchange rate prices policies towards the Euro, where the exchange rates of these economies will be peg to the European currency, Egert and Lahroche Revil (2003).

In terms of volatility spillover effects from stock returns to exchange rates returns, there is non-existence of significant spillovers in these countries, what suggest the no existence of integration between these two markets. If we analyse the spillover effects from exchange rates to stock markets we found that the overall results is the lack of significant spillovers from exchange rate to stock returns, situation that can be explained as Jorion (1990) suggest, that is, the positive exchange rate volatility on stock returns for some firms offsetting negative exchange rate volatility for other firms, to give an insignificant effect afterwards.

Finally, for the asymmetric spillover effects we found that this effect is relevant for all the countries, from stock returns to exchange rates, having all the coefficients a positive signs what is interpreted as follow: good news has a greater impact on volatility than unexpected bad news.

Our results are showing that the lack of volatility spillovers between stock markets and exchange rates in most of the countries create the perfect conditions for investors in terms to diversify their portfolios in the Eastern European countries that have been included in our analysis.

## 6. References

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