Spillover Effects from London and Frankfurt to Central and Eastern European Stock Markets

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Abstract

This paper investigates comovement in stock markets between the emerging economies of Central and Eastern Europe (CEE) and the developed markets of Western Europe. Three approaches are employed to examine this issue. The first two approaches, time-varying realised correlation ratios and cointegration statistics, use a two-step technique to derive time-varying estimates of the comovement between returns on CEE and EU stock exchanges. The first step uses common factor analysis to define the factors driving CEE stock exchanges, while the second step evaluates the relationship between the leading principal factor for CEE countries and the DAX and FTSE using time-varying realised correlation and rolling cointegration statistics. The third approach employs multivariate GARCH techniques to obtain estimates of mean and variance spillover effects.

Keywords: Comovement; CEE countries; Stock Market; Multivariate GARCH; Cointegration; Realised Correlation Ratios

JEL Classification: G15; F36; P34

1. Introduction

Stock market comovement has been extensively investigated in recent years with the vast majority of research in this area focussing on linkages between major US and European stock markets or major US and Japanese stock markets (see for example, Koch and Koch 1991, Dickinson 2000, Longin and Solnik 2001, Bessler and Yang 2003). There have been fewer investigations into stock market linkages among emerging economies with most focussing on Asia and Latin America (see for example, Koutmos and Booth 1995, Chen, Firth, and Rui 2002, Manning, 2002, Ng, 2002 and Fujii 2005). Only a few studies have investigated comovement between the emerging economies of Central and Eastern Europe (CEE) and the developed markets of Western Europe. The results of investigations generally show that developed equity markets are more integrated than emerging markets.

Most of the former planned economies of CEE have now completed their transition to a market economy and all have functioning stock markets organised along conventional lines with electronic trading systems and the usual stock exchange departments (trading, registry, clearing and settlement etc). Studies have generally shown that stock markets in the CEE countries are efficient (see for example Harrison and Paton 2005, Ajayi, Mehdian and Perry 2004, and Rockinger and Urga 2001) and the recent enlargement of the EU to include ten countries from CEE (Bulgaria, the Czech Republic, Estonia, Hungary, Poland, Latvia, Lithuania, Romania, Slovakia, Slovenia) therefore provides a unique opportunity to investigate the extent of stock market comovement in the enlarged EU.

An accurate assessment of the degree of comovement between international stock markets is important for several reasons. For investors there are benefits from international portfolio diversification only if returns from international stock markets are not significantly correlated. If returns are highly correlated, diversifying a portfolio internationally offers no significant advantages over a well diversified domestic portfolio. Stock market comovement is also of considerable interest to policy makers because, to the extent that investors hold internationally diversified portfolios, highly correlated international returns have a different impact on wealth than returns that are either uncorrelated or only weakly correlated. Through the wealth channel, the impact on expectations and the dissemination of equity market shocks, the differing levels of stock market comovement imply different effects on the macro economy and this has important implications for the planning of monetary policy and the timing of monetary intervention. Policy makers are also interested in whether stock markets exhibit comovement because in a world of increasingly liberalised capital flows, the degree of stock market comovement can impact on the stability of the international monetary system.

There are good reasons for believing that stock markets in CEE might be increasingly integrated with the developed stock markets of Western Europe and, if these linkages do exist, they are likely to be strongest between those countries from CEE which have been granted EU Membership (the Czech Republic, Estonia, Hungary, Poland, Latvia, Lithuania, Slovakia, Slovenia, Bulgaria and Romania) and Frankfurt and London, the latter being the dominant exchanges in the area. As full members of the EU, these CEE countries are establishing stronger economic ties with other EU Members through trade, cross-border investments and policy coordination. The Maastricht Criteria establishes rules for entry into EMU which are deigned to promote economic convergence. Studies by Asprem (1989), Bodurtha et al (1989) and Canova and de Nicolo (1995) have shown the relevance of common factors in international stock market linkages. Nasseh and Strauss (2000) demonstrate that stock prices in European countries are determined by domestic economic variables and by German economic variables for the period 1962-1995. Fratzscher (2002) has shown that increasing integration in European equity markets in the 1990s was due mainly to the drive towards EMU.

More recently, Phengpis et al (2004) have investigated the impact of economic convergence on stock market returns in four stock markets in the EMU (France, Germany, Italy and the Netherlands) and one stock market in the EU (the UK). They find that economic convergence is an important factor contributing to returns in the countries investigated with the exception of Germany implying that Germany plays some role as policy leader in relation to the other countries. Kim et al. (2005) find that the introduction of the euro caused a regime switch among participating country stock markets and deepened stock market linkages both within the EU and between the EU and Japan and the US.

Of more relevance for our purposes is the study by Chelley-Steeley (2005). This study, comparing the periods 1994-96 and 1996-98, finds comovement between the stock markets of Hungary and Poland and, to a lesser extent, the market in the Czech Republic, with the markets in Germany and the UK, as well as other developed markets. Importantly, using a variance decomposition methodology, this study shows that nearly 40 per cent of the variation in equity market returns in Hungary and Poland were explained by non-domestic factors in the latter period compared with about 10 per cent in the earlier period. Little difference was reported for Czech Republic between the two periods.

Lucey and Voronkova (2006) examine the relationship between the Russian and other CEE and developed countries' equity markets between 1995 and 2004. The authors use various cointegration approaches that allow for structural breaks (Gregory and Hansen, 1996), stochastic cointegration and non-linear cointegration. Lucey and Voronkova (2006) find no cointegration with developed markets over the full sample period. However, breaking the sample into period before and after the 1998 Russian crisis, the authors find that Russian markets tend to be more integrated with developed markets, rather than those of other CEE countries. Voronkova (2004) also utilised the Gregory and Hansen (1996) procedure to test for cointegration between three CEE stock markets and more mature markets. In contrast to Lucey and Voronkova (2006), Voronkova (2004), not only finds significant long-run relations with more mature markets, but between CEE markets as well. Gilmore et al (2006) consider the short and long-term comovements of three CEE stock exchanges with European Union stock markets. Similar to the previous papers, the authors find no evidence of cointegration over the entire sample period, but there was evidence of episodic cointegration when dynamic cointegration techniques were applied.

Since the studies above, the economies of CEE have become increasingly more integrated with Western European economies. Ten are now full EU Members and one country (Slovenia) adopted the euro on January 1 2007. The remainder are committed to adopting the euro when the necessary conditions are fulfilled and four (Estonia, Latvia, Lithuania and Slovakia) participate in the Exchange Rate Mechanism of the EU. Furthermore, all of these countries remain committed to the Maastricht Criteria and to this extent share certain macroeconomic aims. The main goal of the study is therefore to evaluate the existence of comovement between CEE countries and more developed markets in Europe. The paper adds to the earlier literature by including an increased number of countries beyond the 'big three' CEE states (Hungary, Poland and the Czech Republic). In addition, to the time-varying assessment of comovement between the exchanges, this study also adds to the literature by providing estimates of mean and variance spillover effects **between markets** through the use of multivariate GARCH modelling. We therefore provide estimates of the source and magnitude of spillover effects from London and Ferankfurt to the other markets in our study. As a final contribution to the literature we test for volatility transmission between European and CEE exchanges. Bauwens and Giot (2003) provide a survey of various MGARCH models. The information provided by this approach should be especially useful to asset managers seeking to diversify their portfolios.

The remainder of this paper is structured as follows. Section 2 analyses the observations on stock market returns for CEE countries and Section 3 outlines the three approaches employed to evaluate stock market comovement. In Section 4 we detail our empirical results and Section 5 provides a summary and conclusions.

2. Data and Summary Statistics

The study uses data on the stock market indices for 10 CEE countries[1]Slovenia, Slovak Republic, Estonia, Latvia, Lithuania, Bulgaria, Czech Republic, Romania, Hungary and Poland) and two European stock exchanges (Frankfurt – DAX 30 and London – FTSE 100). The data were obtained from *Datastream*. Table 1 provides summary statistics for the daily returns between 1994 and 2006. Daily returns are calculated as $r^i_{t,d} = ln(p^i_{t,d} / p^i_{t,d-1})*100$, where $p^i_{t,d}$ is the stock market index of *i-th* country, in year t on

[1] **SBI Index, Ljubljana stock exchange (Slovenia), SAX Index, Bratislava stock exchange (Slovak Republic), OMX Index Tallinn Stock Exchange (Estonia), OMX Index Riga stock exchange (Latvia), OMX Vilnius stock exchange (Lithuania), SOFIX Index (Bulgaria), PX Index (Czech Republic), BET Index (Romania), BUX Index (Hugary) and WIG Index (Poland).**

trading day d.[2] The highest mean returns were in Bulgaria (0.159 percent) and Latvia (0.104 percent). In addition, mean daily returns are generally higher across the stock exchanges for the CEE countries than for either the DAX or the FTSE; the average daily returns for CEE countries is 0.073 percent compared to 0.036 and 0.016 for the DAX and FTSE, respectively.

Despite the larger daily returns available on CEE exchanges, volatility was also significantly higher on these equity markets relative to those in London and Frankfurt. The average volatility across the CEE countries (measured by the standard deviation of daily returns) is 1.446 compared to 1.478 for the DAX and 1.123 for the FTSE. Of the CEE countries investigated, the Czech Republic, Lithuania and Slovenia are the least volatile. Corroborating evidence regarding the volatility of CEE exchanges can also be obtained by examining Figure 1 which provides a plot of the daily returns.

Although stock exchanges in CEE countries have been created in different ways, they have generally experienced similar problems during development (see Claessens et al., 2000.) Initially, liquidity of newly established stock markets was relatively low and trading was thin with the result that in the early days at least, markets tended to be open for only a few hours a day and only one or two days a week. Consequently stock prices were volatile compared with developed stock markets and it seems likely that this inhibited the growth of trading activity because of the increased risk. In addition, in the early days there was an absence of reliable information about the companies traded on these emerging stock markets. The information disclosed by companies was often inaccurate or incomplete, and was frequently based on different accounting standards and practices. In other words, reliable corporate governance structures of the type common in developed market economies were not in place and

[2] **Panel unit root tests suggests that the hypothesis of non-stationary returns can not be accepted at normal levels of testing. The Levin, Lin and Chu (2002) t* test was -186.656[0.000], while the Im, Pesaran and Shin (2003) W-stat was -149.507[0.000].**

companies were subject to few, if any, mandatory disclosure requirements (see, for example, Kawalec and Kluza, 2001).

In addition to the relatively higher level of volatility in CEE countries, the distribution of returns also seems to be non-normal. With the exception of equity markets in Slovenia, Estonia and Hungary, most of the returns (including the DAX and the FTSE) are negatively skewed. The measure of excess kurtosis for all the exchanges deviate significantly from that expected from returns drawn from a normal distribution. In particular, Slovenia, Estonia, Latvia, Lithuania and Bulgaria all had measured excess kurtosis significantly above 3. The non-normality is confirmed by the significance of the Jarque-Bera statistic.

3. Empirical Approach

The paper uses three approaches to evaluate stock market comovement in the daily returns of European stock exchanges: (1) time-varying realised correlation ratios; (2) time-varying cointegration statistics, and; (3) a multivariate GARCH model. The first two approaches utilise a two step technique. The first step consists of estimating a common factor model of stock markets in CEE countries. The second step evaluates the relationship between the common factor and the stock market index for the mature European stock exchange. Let y_{it} denote a vector of stock market indicators for country $i = 1...10$ for period $t = 1...T$. The common factor (f_t) approach assumes that there is an unobservable variable (the factor) that accounts for the correlations among the stock exchanges:

$$y_{it} = \sum_{j=1}^{r} \lambda_{ij} f_{jt} + \varepsilon_{it} \qquad (1)$$

where λ_{ij} are the factor loading coefficients associated with each of the z common factors and ε_{it} is a well-behaved error term. The common factors are obtained using principal component analysis and therefore account for the maximum portion of the variance present in the stock exchanges in CEE countries (see Johnson and Wichern, 2002, for more details on principal component analysis).

Following Andersen, et al. (2003), the authors define daily returns as $r_{t,d}^{i} = ln(p_{t,d}^{i} / p_{t,d-1}^{i})*100$, where $p_{t,d}^{i}$ is the stock market index of *i-th* country, in year t on trading day d. A consistent estimate of annual index volatility is obtained using the sum of the squared returns, $\sigma_{t,i}^{2} = \sum_{d=1}^{D_t}(r_{t,d}^{i})^{2}$, and a measure of realised covariance between the annual stock returns of country i and country j:

$$\rho_{t}^{i,j} = \frac{\sigma_{t}^{i,j}}{\sigma_{t}^{i} \bullet \sigma_{t}^{j}} \tag{2}$$

where $\rho^{i,j}$ is the realised correlation ratio. Compared to standard coefficients of correlations, the realised correlation approach improves the accuracy of the measure of association between the two exchanges under consideration (Andersen et al., 1999). Pairwise realised correlations are estimated for each of the ten countries investigated relative to the DAX and the FTSE (All Shares) and for 12 years of data (1994 to 2006).

The realised correlation coefficients are only able to evaluate co-movements in the returns of CEE countries and Europe, but can provide misleading inferences during periods of significant volatility (Forbes and Rigobon, 2002). To address this shortcoming, the authors use the Hansen and Johansen (1992) recursive cointegration method with a rolling window. The recursive approach is adopted since traditional cointegration tests over the entire sample period would tend to reject the hypothesis that the series are cointegrated if equity prices are in the process of converging. The time-varying cointegration technique allows for changes in the relationship between the variables in a system. To obtain time-varying measures of convergence, the step size is set at $k = 20$ and rolling daily 3 year sub-samples and the number of observations employed to calculate each unit root statistic is therefore $3D + k = 3(262) + 20 = 806$, where D is the number of trading days in a year. The eigen value statistics are scaled by the critical values at the 5 percent significance level and plotted in the next section.

The third, and final, approach employs a multivariate GARCH model to assess comovements in CEE countries and European stock exchanges. Similar to Liao and Williams (2004), the Baba *et al.* (1990) model formulation, commonly referred to as the BEKK GARCH, is used in this study. The approach is chosen since it provides estimates of informational spillover effects in the mean and variance.

Assume that the conditional expected return equation can be written as:

$$R_t = \omega + AR_{t-1} + \upsilon_t \tag{3}$$

where R_t is an $n \times 1$ vector of daily returns for each market and $\upsilon_t \mid I_{t-1} \sim N(0, H_t)$. The elements of the A matrix would provide measures of the own and cross-mean spillovers. The BEKK approach assumes that H_t depends on the squares and cross products of the innovations, υ_t and the lagged volatility for each market:

$$H_t = B'B + C'\upsilon_t\upsilon_{t-1}C + G'H_{t-1}G \tag{4}$$

where B is a matrix of constants, C is matrix of the degree of innovation from market i to j, and G provides estimates of the persistence in conditional volatility from market i to j.

The model is estimated using the BHHH algorithms and the econometric programme Eviews 6.

4. Empirical Results

4.1 Rolling Realised Correlation Ratios and Cointegration Statistics

In this section, the authors apply the principal components approach to a dataset of daily closing values for the stock exchanges for 10 CEE countries over the period 1994 to 2006. Table 2 summarises the eigenvalues and the proportion of total variance explained. Two factors are generated: the first uses data on the five countries (group 1) that have observations for the entire sample period (Slovenia, Slovak Republic, Czech Republic, Hungary and Poland), while the other factor employs observations on all the countries investigated. The table shows that the first principal component for group 1 countries accounts for 89 percent of the total variance, while for the group containing all countries the first principal components account for 95 percent of the total variation.

To further evaluate the goodness-of-fit of the factors, Table 3 presents the bivariate correlation ratios (between the stock exchange for country i and first principal component) with associated test statistics, while Figure 2 plots the evolution of the common factor and stock price indices for each country. The table shows that all the correlation ratios are at least 0.89 and significant at standard levels of testing.

Given that the common factors provide an adequate representation of stock market fluctuations in CEE countries, Figure 3 plots the rolling realised correlation ratios between group 1 countries and two European stock exchange indexes: the DAX and the FTSE. The figure shows that the realised correlation ratio fluctuated around 0.4 for most of the sample period. There was, however, a rise in the realised correlation ratio from the beginning 2006 onwards, particularly with the FTSE. The results from using the common factor generated from the full sample of CEE countries are quite similar (Figure 4). The implication is that although there is correlation between CEE and European exchanges, the degree of comovement remains, as yet, fairly weak.

To evaluate equity price convergence, Figure 3 presents the rolling cointegration tests for the selected group of CEE countries and the two European exchanges. The eigenvalue statistics are standardised at the five percent critical value, so that values above one suggest that the null hypothesis of no cointegration can not be accepted (all values above the horizontal line that intercepts the vertical axis at one**)**. Looking first at the results for the DAX, Figure 3 shows that the null hypothesis of no cointegration could not be rejected for the early part of the sample period: 1997 to 2000. From 2001 to 2005, the standardised eigenvalue statistic was generally significant at the five percent level of testing. This suggests that there was a common stochastic trend between CEE countries and the London and Frankfurt exchanges. There was, however, a break in this relationship in 2006. When the FTSE is employed in the bivariate cointegrating equation, the null hypothesis of no cointegration was rejected for most of the rolling 3-year sample period.

When the full sample of countries is employed, the rolling eigenvalue statistic is only available from 2003 onwards. However, Figure 4 shows that the findings are quite similar. The common factor for CEE countries is generally cointegrated with the FTSE and DAX for most of the restricted sample period. However, there seems to have been a break in the relationship with the DAX since the beginning of 2006.

4.2 Multivariate GARCH

One of the drawbacks of the rolling cointegration approach is that it does not allow one to consider both mean and variance transmission across exchanges. As a result, it can not inform investors whether investing in CEE countries provide avenues for mean or volatility diversification. To test this, we estimate the MGARCH model outlined in Section 3 using observations on stock market returns for three of the larger CEE countries (Czech Republic, Hungary and Poland) as well as the DAX and FTSE. The restricted sample of CEE countries was chosen since observations on these exchanges are readily available for the entire sample period and daily returns for these three countries are highly correlated with those on other CEE exchanges.

The estimated coefficients and standard errors for the conditional mean return equations are provided in Table 4. The results suggest that there are mean spillover effects between European and CEE equity markets. In the Czech Republic, lagged returns on the DAX significantly influence current returns while the FTSE had an insignificant impact on returns in this country. In contrast, there were positive mean spillover effects between the FTSE and the Hungarian exchange, but very little transmission from the DAX. The results also suggest that Poland experiences positive mean spillover effects from both European exchanges. The mean spillover effects are not homogenous for CEE countries. For example, while a 1 percent increase in the DAX would increase daily returns on the Czech Republic exchange by 0.1 percent, in Poland market returns would only rise by 0.05 percent. In general, the DAX seems to have larger mean effects on the Czech exchange, while the FTSE has a relatively stronger impact on the exchanges of Hungary and Poland. The leading role that European exchanges play in CEE countries is consistent with our findings that own mean spillover effects are insignificant.

There is also some evidence of intra-regional spillover effects with lagged returns for the Czech Republic significantly influencing returns in Poland, while the Hungarian exchange had positive mean spillover effects from Poland. These mean spillover effects are, however, quite small. In the case of Poland, a 1 percent increase in returns on the stock exchange in the Czech Republic would only lead to a 0.046 expansion in returns on the equity market in Poland.

There is some evidence of mean return feedback effects from CEE countries to European stock markets. In the case of the DAX, returns on the stock exchange in Hungary and Poland are statistically significant predictors of performance on this market. The magnitude and directional impact are, however, different; while positive returns on the Polish exchange are associated with higher mean returns for the DAX, the opposite is the case for the Hungarian exchange. In the case of the FTSE, only the Hungarian exchange has statistically significant feedback effects. The negative sign on the coefficient could suggest that Hungary could be used as a vehicle for diversification for FTSE investors. The magnitude of these feedback effects though is quite small: a 1 percent increase in returns on the Hungarian exchange reduces returns on the DAX and FTSE by 0.036 and 0.023, respectively.

In addition to mean spillover effects, it is also probable that there could be volatility transmission between European and CEE exchanges. To investigate this possibility, the estimated conditional variance-covariance equations are presented in Table 5. The b's are the intercepts in the GARCH equation, the c's provided estimates of the ARCH effects or the degree of innovation transmission, while the g's are the GARCH effects and provide estimates of the persistence in conditional volatility transmission.

Own-volatility spillover effects in all the countries are larger than the cross-volatility spillover effects and are significant indicating the presence of important ARCH effects. In the CEE countries, the own-volatility spillover effects range from 0.226 in Hungary and Poland to 0.154 in Poland. In terms of the transmission of volatility from Europe to CEE countries, both the DAX and the FTSE are significant and the effects on all three markets are quite similar. However, the own-volatility spillover effects are larger than the cross-volatility spillover effects indicating that past volatility in CEE countries is a more important predictor of future volatility in these markets.

Volatility persistence in the CEE countries is very high. The lagged volatility persistence ranges from 0.915 to 0.986. In the case of the CEE countries, the DAX and the FTSE had relatively similar effects on future volatility persistence although these effects were somewhat larger for Poland. Overall volatility persistence is highest in Poland, as the own-volatility persistence 0.986 compared 0.959 in Hungary and 0.954 in the Czech Republic. Most of the volatility persistence in CEE countries therefore seems to emerge from within the domestic market.

The MGARCH model is only consistent when the standardised residuals are independently and identically distributed. Therefore the Ljung-Box statistic is calculated for each country and the results provided in Table 6. At the 5 percent level of testing, the p-values suggest that the test statistic is insignificant implying that the conditional mean return equation is correctly specified.

5. Conclusions

The study uses daily data on the stock market indices for 10 CEE countries (Slovenia, Slovak Republic, Estonia, Latvia, Lithuania, Bulgaria, Czech Republic, Romania, Hungary and Poland) and two European stock exchanges to evaluate the extent of stock market comovement between these exchanges. The paper uses three approaches to evaluate stock market comovement in the daily returns of European stock exchanges: (1) time-varying realised correlation ratios; (2) time-varying cointegration statistics, and; (2) a multivariate GARCH model. The first two approaches utilise a two step technique to evaluate the issue of stock market comovement. The first step estimates a common factor model of stock markets in CEE countries, while the second step uses realised correlation and time-varying cointegration analysis to examine the relationship between this common factor for CEE countries and stock exchanges in Europe (Germany and the UK).

The rolling realised correlation ratios fluctuated around 0.4 for most of the sample period, with an increase in the ratio from the beginning of 2006 onwards – particularly with respect to the FTSE. Using the time-varying cointegration approach, the null hypothesis of no cointegration could not be rejected for the early part of the sample period: 1997 to 2000. However, from 2001 to 2005, the standardised eigenvalue statistic was generally significant at the 5 percent level of testing, suggesting that there was a common stochastic trend between

CEE countries and those in Europe. The results presented in this paper show that there are linkages between stock exchanges in CEE countries and those in Europe, and this relation has been augmented since 2001. However, the degree of comovement between these exchanges is not, as yet, sufficiently strong to raise issues for monetary policy or international financial stability stemming from symmetrical changes in wealth that well developed comovement implies. Nevertheless, our results do suggest that policy makers continue to monitor evolving developments in this area.

One of the drawbacks of the rolling cointegration approach is that it does not allow one to consider both mean and variance transmission across exchanges. To take account of this, the authors also estimate a MGARCH model using observations on stock market returns for three of the larger CEE countries (Czech Republic, Hungary and Poland) as well as the DAX and FTSE. The results suggest that there are mean spillover effects between European and CEE equity markets. The mean spillover effects are, however, not homogenous across CEE countries. The DAX seems to have larger mean effects on the Czech Republic, while the FTSE has a relatively greater impact on the exchanges of Hungary and Poland. In addition, there is evidence to suggest that Hungary could serve as an effective vehicle for mean return diversification for FTSE investors. Only small mean spillover effects from one CEE country to another are reported.

Own-volatility spillover effects in all the countries are larger and significant indicating the presence of important ARCH effects. In terms of the transmission of volatility from Europe to CEE countries, both the DAX and the FTSE are significant and the effects on all three markets are quite similar. However, the own-volatility spillover effects are larger than the cross-volatility spillover effects indicating that past volatility in CEE countries is a more important predictor of future volatility in these markets. Most of the volatility persistence in CEE countries seems to emerge from within the domestic market.

The absence of significant comovement between the stock exchanges investigated implies that there are no important considerations for policy makers over the timing and implementation of monetary policy. Nevertheless, the wealth channel does have important implications for the conduct of policy in certain countries and policy makers would be advised to keep the extent of comovement under review since changes might well materialise as CEE countries become increasingly integrated with the rest of Europe.

References

Ajayi, R., A., Mehdian, S., and Perry, M. J., (2004) The Day of the Week Effect in Stock Returns: Further Evidence from Eastern European Markets, Emerging Markets Finance and Trade, Vol. 40(4): 53-62.

Andersen, T.G., T. Bollerslev, F.X. Diebold, and P. Labys (2003) Modelling and Forecasting Realised Volatility, Econometrica, Vol. 71(2): 579-625.

Andersen, T.G., T. Bollerslev, F.X. Diebold and P. Labys (1999) "(Understanding, Optimizing, Using and Forecasting) Realised Volatility and Correlation," LN Stern School of Finance Department Working Paper 24, University of Pennsylvania, Philadelphia, P.A.

Asprem, M. (1989) Stock Prices, Asset Portfolios and Macroeconomic Variables in Ten European Countries, Journal of Banking and Finance, Vol. 13(4-5): 589-612.

Baba, Y., Engle, R.F., Krafet, D., and Kroner, K.F. (1990). "Multivariate Simultaneous Generalised ARCH." Unplublished manuscript, Department of Economics, University of California, San Diego.

Bauwens, Luc and Pierre Giot (2003), Asymmetric ACD Models: Introducing Price Information in ACD Models, Empirical Economics, 28(4), 709-31.

Bessler, D.A. and Yang, J. (2003) The Structure of Interdependence in International Stock Markets, Journal of International Money and Finance, Vol. 22: 261-287.

Bodurtha, J.N., Cho, D.C. and Senbet, L.W. (1989) Economic Forces in the Stock Market, Global Finance Journal, 1: 21-46.

Canova, F. and De Nicoló, G. (1995) Stock Returns and Real Activity: A Structural Approach, European Economic Review, Vol. 39(5): 981-1015.

Chelley-Steeley, P.L. (2005) Modelling Equity Market Integration using Smooth Transition Analysis: A Study of Eastern European Stock Markets, Journal of International Money and Finance, Vol. 24(5): 818-831.

Chen, G., Firth, M., and Rui, O., M., (2002) Stock Market Linkages: Evidence from Latin America, Journal of Banking and Finance, Vol. 26(6): 1113 – 1141.

Claessens, S. Djankov, S. and Klingbiel, D. (2000) Stock Markets in Transition Economies, World Bank Discussion Paper No 5, Washington D.C.

Dickinson, D.G. (2000) Stock Market Integration and Macroeconomic Fundamentals: An Empirical Analysis, 1980-1995, Applied Financial Economics, 10: 261-276.

Forbes, K.J. and Rigobon, R. (2002) "No Contagion, Only Interdependence: Measuring Stock Market Comovements," *Journal of Finance*, Vol. 57: 2223-2261.

Fratzscher, M. (2002) Financial Market Integration in Europe: On the Effects of EMU on Stock Markets, International Journal of Finance and Economics, Vol. 7(3): 165-193.

Fujii E., (2005) Intra and Inter-regional Causal Linkages of Emerging Stock Markets: Evidence from Asia and Latin America in and out of Crises, Journal of International Financial Markets and Money, Vol. 15(4): 315-342.

Gregory, A.W. and Hansen, B.E. (1996) Residual-based tests for cointegration in the models with regime shifts. *Journal of Econometrics*, 70: 99-126.

Gilmore, C.G., Lucey, B.M. and McManus, G.M. (2006) The dynamics of central European equity market comovements, *Quarterly Review of Economics and Finance*, forthcoming.

Hansen, H. and S. Johansen (1992) "Recursive Estimation in Cointegrated VAR Models", University of Copenhagen Economics Working Papers, Copenhagen.

Harrison, B. and Paton, D. (2005) Transition, the Evolution of Stock Market Efficient and Entry into EU: The Case of Romania, Economics of Planning, Vol. 37(3): 203-223.

Johnson, R.A. and Wichern, D.W. (2002). *Applied Multivariate Statistical Analysis*. Prentice-Hall, Upper Saddle River, New Jersey.

Kawalec, S. and Kluza, K. (2001) "Challenges of Financial System Development in Transition Economies," in Lajos Bokros et al (eds.) *Financial Transition in Europe and Central Asia* (pp.29-44). Washington, DC: World Bank.

Kim, S. J. Moshirian, F. and Wu, E. (2005) Dynamic Stock Market Integration Driven By the European Monetary Union: An Empirical Analysis, Journal of Banking and Finance, 29(10): 2475-2502.

Koch, P.D. and Koch, T.W. (1991) Evolution in Dynamic Linkages across Daily National Stock Indexes, Journal of International Money and Finance, Vol. 10(2): 231-251.

Koutmos and Booth (1995) Asymmetric Volatility Transmission in International Stock Journal of International Money and Finance Vol. 14(6): 747 – 762.

Liao, A. & J. Williams (2004), 'Volatility transmission and changes in stock market interdependence in the European Community', *European Review of Economics and Finance*, 3, 3, 203-231.

Longin, F. and Solnik, B. (2001) Extreme Correlation of International Equity Markets, Journal of Finance, Vol. 56: 649-676.

Lucey, B.M. and Voronkova, S. (2006) The Relations between Emerging European and Developed Stock Markets before and after the Russian Crisis of 1997-1998, in: J.A. Batten and C. Kearney (Eds.), *Emerging European Financial Markets: Independence and Integration Post-Enlargement, International Finance Review*, Vol. 6: 383-413.

Manning, N., (2002) Common Trends and Convergence? South East Asian Equity Markets 1998-1999, Journal of International Money and Finance Vol. 21, p 183 – 202

Nasseh, A. and Strauss, J. (2000) Stock Prices and Domestic and International Macroeconomic Activity: A Cointegration Approach, Quarterly Review of Economics and Finance, 40: 229-245.

Ng, T., H., (2002) Stock Market Linkages in South East Asia, Asian Economic Journal, Vol. (16)4: 353 – 377

Phengpis, C., Apilado, V.P. and Swanson, P.E. (2004) Effects of Economic Convergence on Stock Market Returns in Major EMU Member Countries, Vol. 23(3): 207-227.

Rockinger, M., and Urga, (2001) A Time varying parameter model to test for predictability and integration in the stock markets of transition economies, Journal of Business and economic Statistics, Vol. 19, No 1, pp 73-84.

Voronkova, S. (2004) Equity market integration in Central European emerging markets: a cointegration analysis with shifting regimes, *International Review of Financial Analysis*, Vol. 13, No. 5, pp 633-647.

Table 1: Summary Statistics of Daily Returns of CEE and European Stock Exchanges

	Mean	Median	Max	Min	Std. Dev.	Skew	Kurt.	Jarque-Bera	p-value
DAX	0.036	0.055	7.553	-6.652	1.478	-0.167	5.943	1144.093	0.000
FTSE	0.016	0.003	5.904	-5.589	1.123	-0.143	5.559	719.681	0.000
Slovenia	0.046	0.000	18.933	-11.613	1.094	0.818	46.409	246096.900	0.000
Slovak Republic	0.032	0.000	9.574	-11.484	1.283	-0.411	10.470	7056.424	0.000
Estonia	0.076	0.000	12.867	-21.577	1.746	-1.313	27.164	67916.250	0.000
Latvia	0.104	0.029	9.461	-14.705	1.558	-1.236	24.265	34851.770	0.000
Lithuania	0.087	0.033	8.686	-10.216	0.910	-0.214	18.807	19013.440	0.000
Bulgaria	0.159	0.028	21.073	-20.899	1.843	-0.417	39.829	91319.210	0.000
Czech Republic	0.027	0.000	7.048	-7.077	1.158	-0.285	6.090	1287.294	0.000
Romania	0.073	0.000	10.113	-11.902	1.680	-0.159	9.544	4328.895	0.000
Hungary	0.079	0.000	13.616	-18.033	1.669	-0.963	17.946	29615.620	0.000
Poland	0.050	0.000	7.893	-10.286	1.521	-0.168	7.071	2176.203	0.000

Table 2: Principal Component Analysis

	Group 1		All Countries	
Value	Eigenvalue	% of Total Variance	Eigenvalue	% of Total Variance
1	4.461	0.892	9.476	0.948
2	0.288	0.058	0.259	0.026
3	0.194	0.039	0.161	0.016
4	0.044	0.009	0.035	0.004
5	0.014	0.003	0.031	0.003
6	-	-	0.016	0.002
7	-	-	0.010	0.001
8	-	-	0.007	0.001
9	-	-	0.004	0.000
10	-	-	0.003	0.000

Table 3: Correlation with Principal Component

	Group 1	All Countries
Slovenia	0.899	0.892
	(112.432)	(79.405)
	[0.000]	[0.000]
Slovak Republic	0.904	0.960
	(115.786)	(138.647)
	[0.000]	[0.000]
Czech Republic	0.985	0.994
	(309.087)	(378.558)
	[0.000]	[0.000]
Hungary	0.971	0.986
	(224.235)	(237.801)
	[0.000]	[0.000]
Poland	0.960	0.957
	(187.987)	(132.872)
	[0.000]	[0.000]
Estonia	-	0.995
		(401.066)
		[0.000]
Latvia	-	0.985
		(228.218)
		[0.000]
Lithuania	-	0.983
		(214.763)
Bulgaria	-	0.988
		(264.185)
		[0.000]
Romania	-	0.988
		(256.171)
		[0.000]

Note: (1) t-statistics are given in parentheses below correlation ratio.
(2) p-values are provided in square brackets below t-statistics.

Table 4: Estimated Coefficients for Conditional Mean Return Equations

	Coefficient	Standard Error	Coefficient	Standard Error
	$DAX\,(i=1)$		$FTSE(i=2)$	
ω	0.078	0.023**	0.048	0.016**
a_{i1}	-0.036	0.026	-0.045	0.025*
a_{i2}	0.047	0.034	0.037	0.017**
a_{i3}	-0.001	0.023	0.001	0.017
a_{i4}	-0.036	0.017**	-0.023	0.012*
a_{i5}	0.042	0.019**	0.015	0.014
	$CZEHX\,(i=3)$		$HUNX\,(i=4)$	
ω	0.063	0.021**	0.074	0.029**
a_{i1}	0.101	0.021**	0.014	0.023
a_{i2}	0.028	0.029	0.098	0.039**
a_{i3}	-0.009	0.021	0.014	0.028
a_{i4}	-0.003	0.015	0.011	0.029
a_{i5}	0.023	0.016	0.042	0.023*
	$POLX\,(i=5)$			
ω	0.059	0.024**		
a_{i1}	0.054	0.020**		
a_{i2}	0.083	0.030**		
a_{i3}	0.046	0.022**		
a_{i4}	-0.001	0.024		
a_{i5}	0.002	0.016		

Note: ** and * indicates significance at the 5 and 10 percent level of testing.

Table 5: Estimated Coefficients for Variance-Covariance Equations

	$DAX\,(i=1)$		$FTSE(i=2)$		$CZEHX\,(i=3)$		$HUNX\,(i=4)$		$POLX\,(i=5)$	
	Coefficient	Standard Error	Coefficient	Standard Error	Coefficient	Standard Error	Coefficient	Standard Error	Coefficient	Standard Error
b_{i1}	0.011	0.002**	0.007	0.001**	0.009	0.002**	0.014	0.002**	0.005	0.001**
b_{i2}	0.007	0.001**	0.006	0.001**	0.007	0.001**	0.010	0.002**	0.004	0.001**
b_{i3}	0.009	0.002**	0.007	0.001**	0.052	0.007**	0.022	0.003**	0.013	0.002**
b_{i4}	0.014	0.002**	0.010	0.002**	0.022	0.003**	0.081	0.006**	0.022	0.002**
b_{i5}	0.005	0.001**	0.004	0.001**	0.013	0.002**	0.022	0.002**	0.011	0.002**
c_{i1}	0.204	0.007**	0.043	0.000**	0.046	0.000**	0.046	0.000**	0.031	0.000**
c_{i2}	0.043	0.000**	0.209	0.007**	0.047	0.000**	0.047	0.000**	0.032	0.000**
c_{i3}	0.046	0.000**	0.047	0.000**	0.226	0.010**	0.051	0.000**	0.035	0.000**
c_{i4}	0.046	0.000**	0.047	0.000**	0.051	0.000**	0.226	0.007**	0.035	0.000**
c_{i5}	0.031	0.000**	0.032	0.000**	0.035	0.000**	0.035	0.000**	0.154	0.006**
g_{i1}	0.978	0.002**	0.955	0.000**	0.933	0.000**	0.938	0.000**	0.964	0.000**
g_{i2}	0.955	0.000**	0.976	0.002**	0.931	0.000**	0.936	0.000**	0.962	0.000**
g_{i3}	0.933	0.000**	0.931	0.000**	0.954	0.004**	0.915	0.000**	0.941	0.000**
g_{i4}	0.938	0.000**	0.936	0.000**	0.915	0.000**	0.959	0.002**	0.946	0.000**
g_{i5}	0.964	0.000**	0.962	0.000**	0.941	0.000**	0.946	0.000**	0.986	0.001**

Note: ** and * indicates significance at the 5 and 10 percent level of testing.

Table 6: Tests for Randomness of Standardised Residuals

	DAX	FTSE	CZEHX	HUNX	POLX
L-B Statistic	1.089	1.334	1.212	0.209	1.375
p-value	0.297	0.248	0.271	0.647	0.241

Figure 1: Daily Returns of CEE and European Stock Exchanges

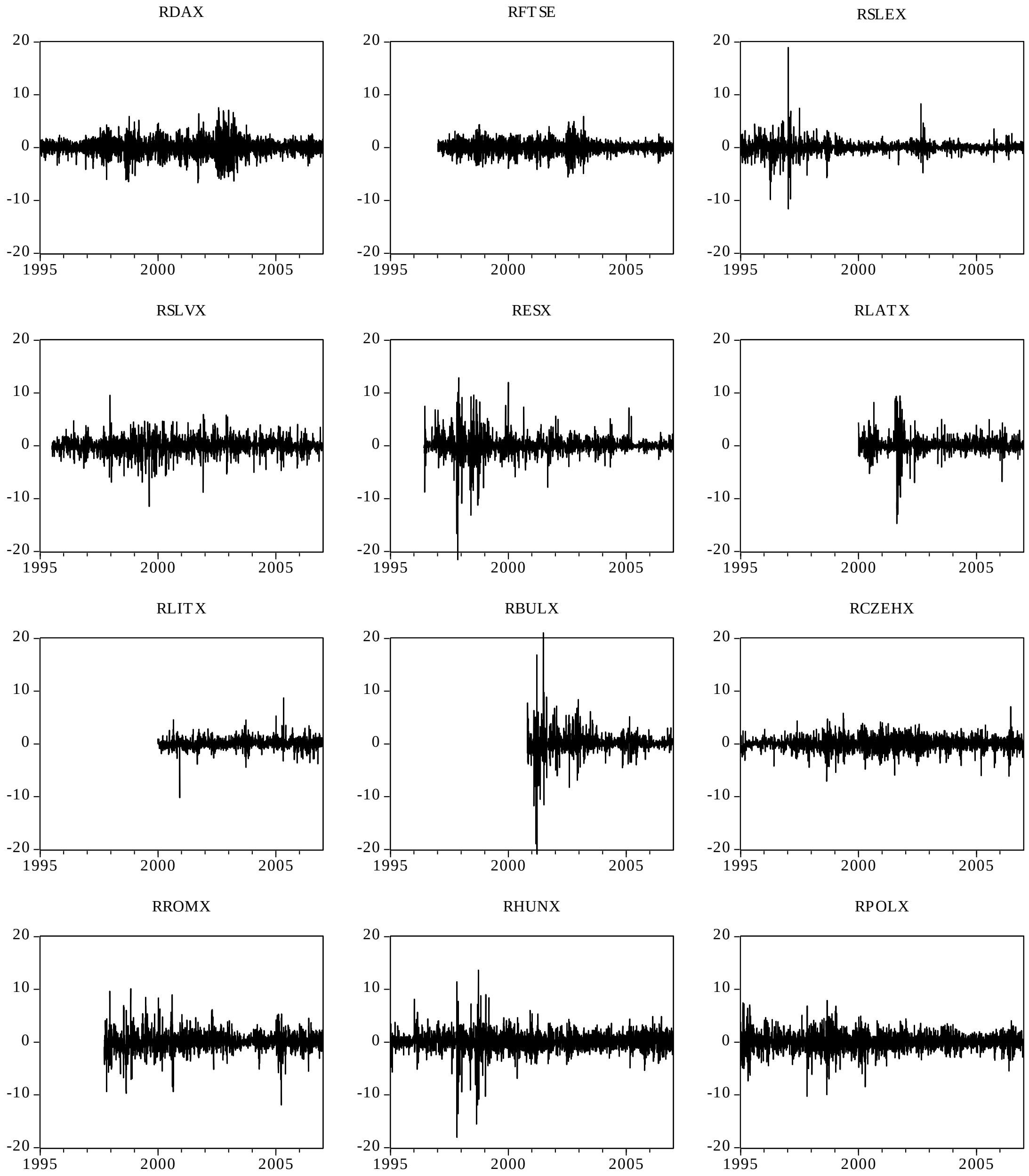

Figure 2: Evolution of Common Factor and Stock Markets in CEE Countries

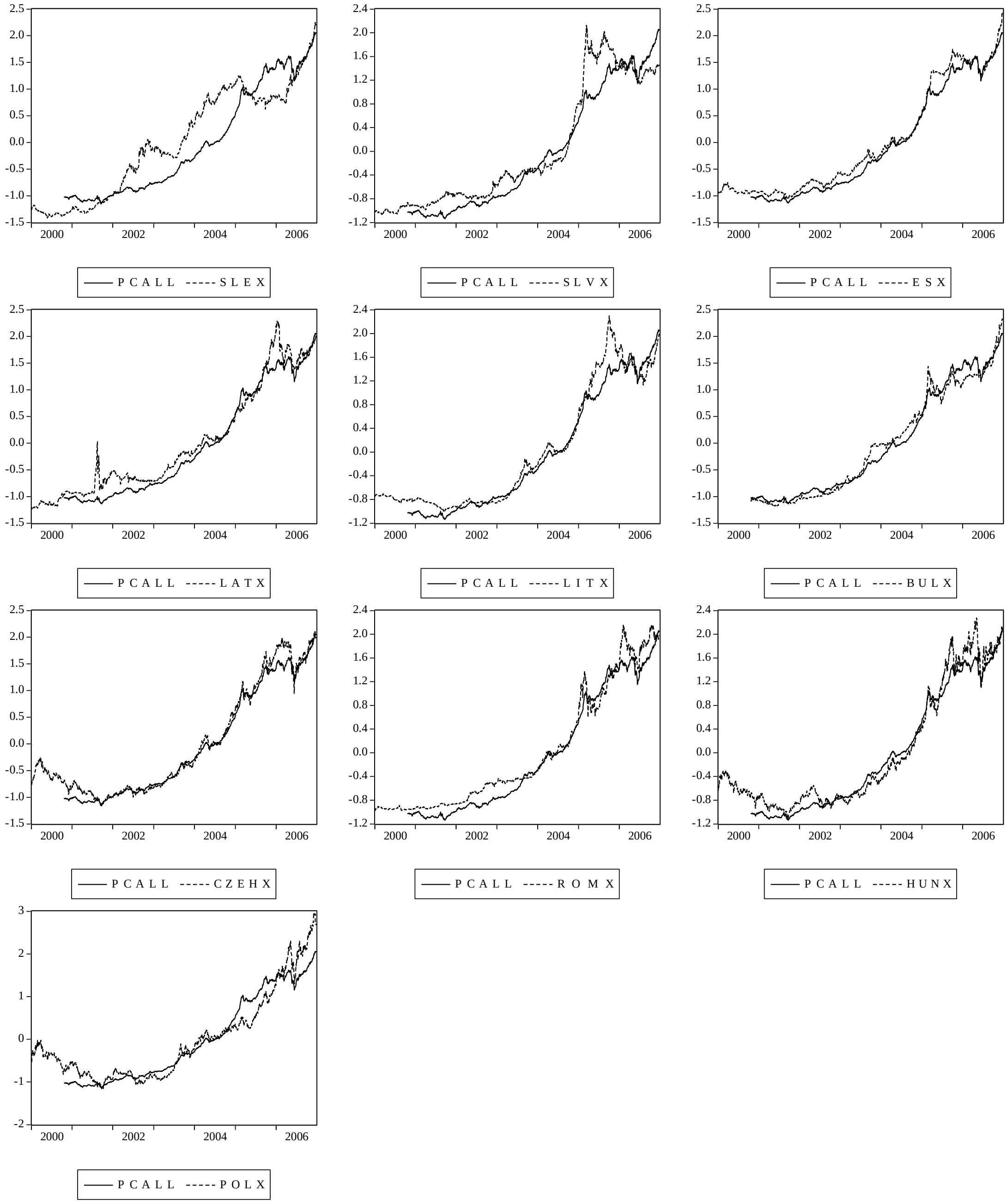

Figure 3: Comovement between Group 1 CEE Countries and European Exchanges (Rolling Realised Correlation Coefficients)

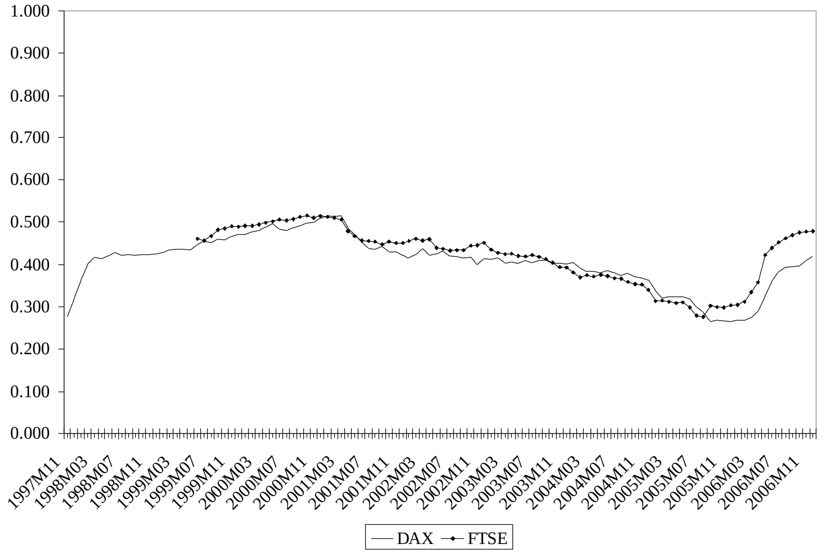

Figure 4: Comovement between All CEE and European Exchanges (Rolling Realised Correlation Coefficients)

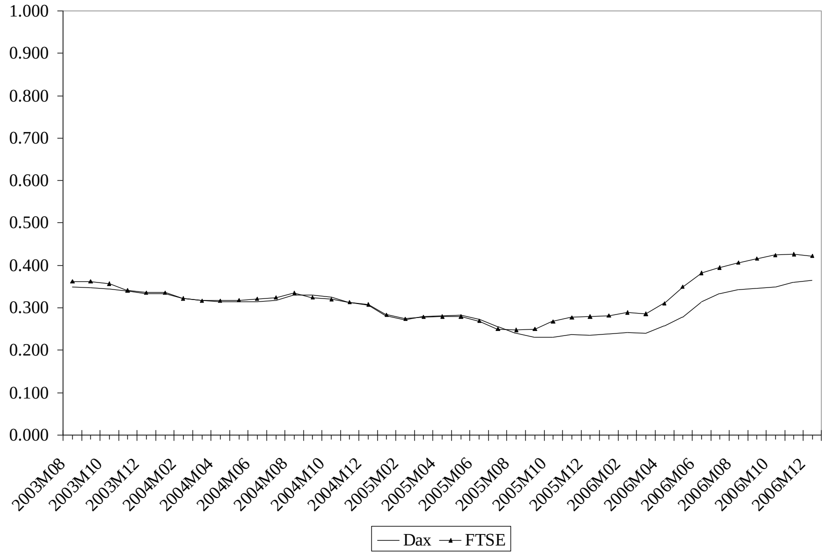

Figure 5: Convergence between Group 1 CEE Countries and European Exchanges (Rolling Eigenvalue Statistic)

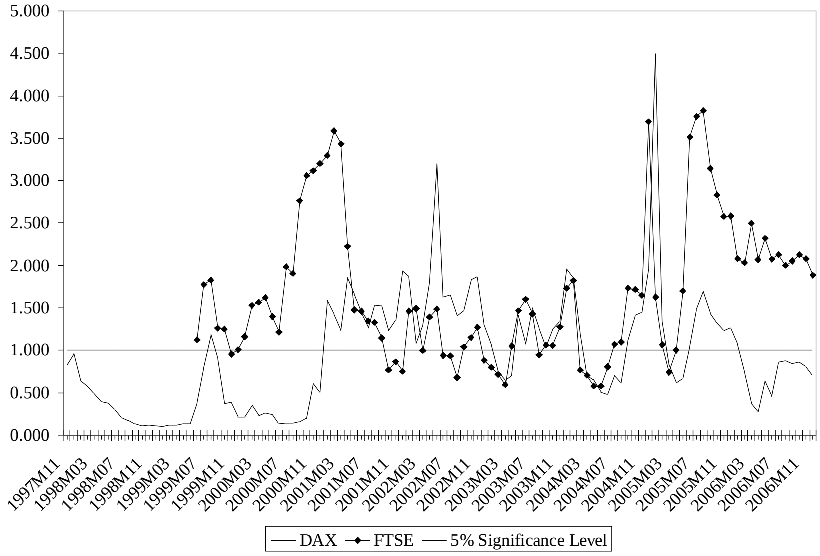

Figure 6: Convergence between All CEE and European Exchanges (Rolling Eigenvalue Statistic)