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Stock Market Integration for the Transition Economies: Time-Varying Conditional Correlation Approach

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Abstract

In this paper, we investigate the extent to which the three emerging Central Eastern European stock markets have become integrated with the aggregate eurozone market during the sample period from 1994 to 2006 by utilising the dynamic conditional correlation from the multivariate GARCH model. We find a higher level of the stock market correlation during the period after the Asian and Russian crises and also during the post-entry period to the EU. Empirical analysis reveals that the increase in the co-movement can not be explained by the macroeconomic convergence process, nor by monetary convergence. It is found that financial market integration seems to be a largely self-fuelling process, depending on existing levels of financial sector development for the Czech Republic and Hungary.

Keywords: Transition economies; European Monetary Union; Time-varying conditional correlation; GARCH; Stock market integration

JEL Classification: C2, G1, P2

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1. Introduction

The degree of integration of emerging stock markets with developed markets has been frequently investigated over the recent years, and studies have provided a new perspective on the degree of such integration: The view that the emerging markets exhibit relatively low correlations with developed equity markets as shown by Bekaert and Harvey (1995) and therefore provide diversification opportunities seems to be diminishing. See, for example, Voronkova (2004), Chelley-Steeley (2005) and Schotman and Zalewska (2006), who focus on a number of Central Eastern European markets, Leong and Felmingham (2003) on some of Asia-Pacific markets, and Hunter (2006) on a group of Latin American markets. One of the important implications of the rapidly amassing evidence of substantial integration among both the developed and the emerging markets is the need for international investors to monitor carefully the risk associated with the various benefits of diversification.

In existing literature, a wide range of methodologies has been used to empirically examine the stock market integration, including multivariate cointegration techniques with the allied concept of error correction models, Granger-causality and impulse response functions (e.g. Kasa, 1992, Richards, 1995 and Voronkova, 2004) and a variety of multivariate GARCH models (e.g. Hamao et al 1990 and Booth, et al. 1997). Some simple methods such as rolling historical correlations and exponential smoothing are widely used as well (e.g. King and Wadhwani, 1990, Lee and Kim, 1993 and Forbes and Rigobon 2002). The common limitation of the above-mentioned methodologies is that they cannot provide a view of the evolution of cross-market co-movement or linkages. Financial market integration is largely driven by market forces, however, often constrained by structural changes in the economy or by regulatory barriers and that level of integration is not constant over time (Kim et al, 2005). In order to examine varying degrees of integration, previous studies normally partition the sample period into different phases according to regime changes. Such a subjective designation of cut-off dates cannot effectively describe the evolution of the changes on financial market co-movement over time. On the other hand, while multivariate GARCH models can estimate the variance – covariance transmission mechanism of market volatility it cannot identify the significant changes of this transmission.

In this paper, we aim to examine the extent to which a group of Central Eastern European emerging markets has become integrated with the developed markets, represented by the aggregate eurozone market, during the sample period from 1994 to 2006 with daily data. We utilise the dynamic conditional correlation (DCC) from the multivariate GARCH model recently put forward by Engle (2002)[1]. The DCC-GARCH model represents a significant methodological departure from those in the existing literature by demonstrating a more direct indication of evolution of the financial market comovement, where the dynamics of correlation, which is time dependent, are modelled together with those of the volatility of the returns[2]. By accounting for the time-varying behaviour of data series, a major advantage of the approach is the detection of possible changes in conditional correlations over time, and more importantly, the estimated

[1] Engle (2002) states that the DCC models have clear computational advantages over multivariate GARCH models in that the number of parameters to be estimated in the correlation process is independent of the number of series to be correlated. Thus, potentially very large correlation matrices can be estimated.

[2] As suggested by Forbes and Rigobon (2002), the cross market correlation coefficients are conditional on market volatility, and if such test is not adjusted for heteroskedasticity, the estimated correlation coefficients can be biased.

dynamic conditional correlation can be used to facilitate our second objective of examining the determinants of dynamic correlation.

Recently, Kim et al. (2005) adopted the time-variations in conditional correlations from the EGARCH model in the study of developed EU stock market and found a clear regime shift in European stock market integration with the introduction of EMU, though their construction of time-varying correlation is different to that provided by Engle (2002). Chiang, et al (2007) applied the dynamic conditional correlation model to nine Asian stock markets over the period from 1990 to 2003 and found that there is an increase in correlation during the financial crisis, which they referred to as a contagion effect, and a continued high correlation in the aftermath of the crisis, referred to as herding.[3]

Our objective in this study is, first, to explore the dynamic co-movement, represented by the time-varying conditional correlation coefficient, of the stock market in the Czech Republic, Hungary and Poland with that of the eurozone, and, second, to investigate the driving force behind the dynamic co-movement from the aspect of economic and monetary integration and currency risk. Our key findings are, largely, fourfold. First, the DCC-GARCH model identifies statistically significant correlation estimators for these emerging markets with the eurozone markets. Second, the presence of shifts towards an increased correlation and fluctuation is observed faced with external shocks. Third, since entry to the EU in May 2004, an increasing trend of integration towards EMU is evident. Fourth, linear regression analysis demonstrates that the

[3] The DCC models are also utilized for macroeconomics empirical analyses. For example, Bautista (2006) examines the relationship between the real exchange rate and the real interest differential in six East Asian countries. Lee (2006) investigates the comovement between overall price level and output.

dynamic correlation is significantly attributable to the development of financial markets for Hungary and the Czech Republic.

The rest of the paper is organized as follows. Section 2 describes the factors which may affect the return and volatility of these emerging stock markets, thereby the conditional correlation with the eurozone market. The DCC-EGARCH model and data are described in Sections 3 and 4 respectively. In Section 5, the results are presented. Section 6 is for modeling the determinants of time-varying conditional correlation in a linear equation framework. The conclusion is found in Section 7.

2. The emerging stock markets

For the Central Eastern European economies, the reconstruction of economies emerged in the 1990s after the end of communism involves a massive exercise in privatization, where state-owned enterprises were reformulated into public companies. Stock exchanges, which were closed during the socialist period, re-emerged during the transition, whilst establishing legal structures for property rights, corporations and contracts, and transparency in accounting and transactions of shares. The earlier stage of stock markets was, as yet, characterised by the lack of adequate regulatory framework and the dominance of a small number of firms. There was also less incentive for firms to list due to the requirement of disclosure and the high cost of raising funds through the equity market. Moreover, around the mid 1990's the return on stock market investments in transition economies was often negative on a risk-adjusted basis. The earlier period of emerging stock markets was prone to instability.

The transition economies also experienced a shift of exchange rate regimes from a fixed exchange rate regime with varying bands to a managed or full floating rate system. A managed flexible exchange rate system was introduced in May 1997 from crawling bands of $\pm 7.5\%$ in the Czech Republic. In Hungary, narrow bands of $\pm 2.25\%$ were introduced in March 1995 from a fixed exchange rate regime, the bands were widened to $\pm 15\%$ in February 1998, and a managed floating rate was adopted in October 2001. Poland's exchange rate system altered from a crawling peg to crawling bands of $\pm 7.5\%$ in May 1995, and then full exchange rate flexibility was introduced in April 2001. Theoretically, stock prices are found to be interdependent with exchange rates. The uncovered interest rate parity suggests that the expectations of relative currency values influence the levels of interest rate differential between domestic and foreign countries. This may affect the cost of capital, and therefore the profitability of a firm, affecting its share price. The interaction between the two variables can also arise through the influences on price competitiveness or on input costs. Empirically, significant interrelation is found elsewhere (e.g. Mercereau 2006 and Moore, 2007). It follows that the impact of varying exchange rate systems may be transmitted to the behaviour of stock markets.

Over the sample period, financial crises were experienced in Asia in 1997 and in Russia in 1998. The impact of the financial crises on emerging stock markets is well-documented in literature[4]. In particular, for the former communist countries, the Russian economy had a predominant role prior to the transition from command to market

[4] For the transition economies, it is found that the volatility of stock returns substantially increased during the Asian and Russian financial crises (Moore and Wang , 2007)

economy, thus the spillover effect of the Russian crisis may not be trivial on the emerging stock markets.

Entry to the EU is potentially an important factor in affecting the stock returns. For the new member states, joining the EU implies the increase in capital, factor and product market integration among member states (Moore and Pentecost 2006), while competition may intensify in the real and monetary sectors. This may further advance a market-determined economy with an increased efficiency in resource allocation. The reconstruction of fundamentals being associated with entry to the EU is likely to change the behaviour of stock markets[5].

Theory predicts that the structural changes in the domestic or international economy potentially alter the dynamic linkage of stock returns. Empirical literature is supportive to this contention, since it is likely to find the presence of a shift in the stock market integration in the face of a structural change in the economy. For example, Shamsuddin and Kim (2003) found that the presence of a stable long run relationship among the Australian, US and Japanese markets existed prior to the Asian crisis and disappeared in the post-Asian crisis period. Fujii (2005) reported that the causal linkages among several emerging stock markets varied considerably during the time of rapid growth and major upheaval from 1990 in Asia and Latin America. In the case of the EU, the effect of the Euro on the linkage among the developed EU stock markets is investigated by Cheung and Westermann (2001), Billio and Pelizzon (2003), Westermann (2004) and Kim et al (2005). Westermann (2004) empirically showed that

[5] The dividend discount model and the capital asset pricing model predict that stock prices or returns reflect expectations of future dividends, interest rates and risk premia, which in turn depend on macroeconomic conditions.

the introduction of the Euro shifted the linkage across the eurozone stock markets, and Kim et al. (2005) found that increased stability and higher levels of integration have emerged in the post-Euro era. The observed shifts in the post-Euro period may have reflected the fact that an overall macroeconomic convergence process associated with the single currency has emerged. For the transition economies, Chelley-Steeley (2005) found movement towards increased equity market integration by analyzing a smooth transition model[6] over the period 1994-1999. More recently Moore (2007) investigated the impact of entry to the EU on the dynamic links between the stock market indices of the Czech Republic, Hungary, Poland and Slovakia versus those of the eurozone by utilizing the international version of the feedback trading model, where evidence appears to demonstrate the emergence of financial integration of these transition economies within the EU.

Given the existing empirical literature on the shift in the stock return linkages corresponding to structural changes in economies, it provides a strong case study to apply the time-varying conditional correlation to the Central Eastern European stock markets, which have gone through phases of domestic and international shifts in the economy with that of the eurozone[7].

3. Model specification

[6] The smooth transition trend model can indicate the speed at which a market is becoming integrated (Chelley-Steeley, 2005).

[7] We place emphasis on the stock return integrations with the European Monetary Union (EMU). Note that the integration with US stock returns are also conducted, however, the scale of conditional correlation is very small as compared with that of EMU, besides the DCC-GARCH model fails to converge, so we do not pursue the integration with the US.

The bivariate EGARCH model with dynamic conditional correlation (DCC) specification (Engle, 2002) is utilized to investigate the market interdependence and volatility transmission. More specifically, we use the following first-order Vector Autogressive (VAR) model to capture the dynamic relationship in returns:[8]

$$R_{it} = \alpha_{i0} + \sum_{j=1}^{n} \alpha_{ij} R_{t-1} + u_t \tag{1}$$

where R is a *n x 1* vector of stock return index and α_0 is a *n x 1* vector of constant. α_{ij} is a $n \times n$ vector, of which the off-diagonal elements capture the mean transmission cross the markets. u is an $n \times 1$ vector of innovations conditional on the information at time $t-1$, which is assumed to be conditionally multivariate normal with mean zero and conditional covariance matrix H_t:

$$u_t | \xi_{t-1} \sim N(0, H_t) \tag{2}$$

and

$$H_t = D_t C_t D_t \tag{3}$$

where D_t is a $n \times n$ diagonal matrix with the time varying standard deviations from EGARCH models on the diagonal and C_t is the time varying symmetric conditional correlation matrix.

As indicated, the conditional variances in each market are modeled as an exponential function of past standardized innovations (Nelson, 1991) as follows[9],

$$h_{i,t} = \exp[\beta_{i0} + \sum_{j=1}^{n} \beta_{ij} f_j(z_{jt-1}) + \delta_i \ln(h_{t-1})] \tag{4}$$

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[8] The first-order VAR is adopted since we anticipate that the stock markets will quickly respond to information available at *t-1*. Note also that with the first-order, serial correlation is eradicated.
[9] Koutmos and Booth (1995) find that the volatility transmission in international market is asymmetric.

$$f_j(z_{jt-1}) = (| z_{jt-1} | - E(| z_{jt-1} |) + \gamma_j z_{jt-1}) \quad (5)$$

Equation (4) shows that the conditional variance in each market is an exponential function of past standardized innovations ($z_{jt-1} = \varepsilon_{jt-1} / \sigma_{jt-1}$). Persistence in volatility is measured by δ_i, with the unconditional variance being finite if $\delta_i < 1$ (Nelson, 1991). The volatility spillovers are captured by the coefficients β_{ij} ($j \neq i$), while asymmetry implies negative γ_j. One of the most important advantages of the EGARCH model is that it does not need parameter restrictions to ensure positive variances.

The evolution of the correlation in the DCC model is given as

$$Q_t = (1 - q_a - q_b)\overline{Q} + q_a \varepsilon_{t-1}\varepsilon'_{t-1} + q_b Q_{t-1} \quad (6)$$

where $Q_t = \{q_{ij}\}_t$ is a $n \times n$ conditional variance-covariance matrix of residuals with its time-invariant variance-covariance matrix $\overline{Q} = E(\varepsilon_t \varepsilon_t^{'})$, and q_a and q_b are nonnegative scalar parameters satisfying ($q_a + q_b < 1$). Because Q_t in (6) does not have unit diagonal elements, it is then scaled to get a proper correlation matrix C_t,

$$C_t = diag(Q_t)^{1/2} Q_t diag(Q_t)^{-1/2} \quad (7)$$

A typical element of C_t has the form of $\rho_{ij} = q_{ij,t} / \sqrt{q_{ii,t} q_{jj,t}}$, $i, j = 1,2,...,n,$ and $i \neq j$, which is the key element in this methodology, as it represents the conditional correlation between stock prices.

4. Data

The dataset used in this study is the daily closing price indices: Prague PX50 of the Czech Republic, Budapest BUX of Hungary and Warsaw General Index of Poland. The stock market index for the aggregate eurozone is calculated as the (market) value-weighted average indexes of the 12 EMU (European Monetary Union) member markets that have already adopted the Euro, i.e., Austria, Belgium, Finland, France, Germany, Greece, Ireland, Italy, Luxembourg, Netherlands, Portugal and Spain. The data started from the 6th April, 1994 and ended on the 29th December, 2006, yielding 3323 observations in total for each series.[10] All the data are retrieved from Datastream, and the daily returns are constructed as the first difference of logarithmic prices multiplied by 100.

Stationarity in the time series is checked by applying the Augmented Dickey Fuller (ADF) test. The results fail to reject the null of a unit root in the logarithm of price series, but overwhelmingly reject the null for the first difference of logarithmic price series[11]. This is consistent with much of the empirical evidence found for mature stock markets, in which the behaviour of stock prices is characterized by a martingale process.

{Table 1 and 2 around here}

Table 1 presents the statistical properties of the returns from these emerging markets and the aggregate eurozone market. Over the sample period, the emerging market of Poland is the most volatile with the standard deviation at 1.77 percent followed by the Hungarian market with around 1.69 percent, while the aggregate eurozone market appears to have a lower volatility of around 1.02. In terms of average returns, Hungary has the highest daily average return of 0.08 percent, whereas the Czech Republic, the

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[10] The starting data of our sample reflects the earliest data available for the Czech Republic.
[11] The results are available from the authors upon request.

lowest with 0.01 percent. The average return of Poland is close to that of the eurozone with around 0.04 over the sample period.

The distribution of returns over time is negatively skewed for all of the markets, and returns are characterized by a statistically significant kurtosis for the emerging markets, **s**uggesting that the underlying series are leptokurtic, that is, the series have a fatter tail and a higher peak as compared with a normal distribution. Correspondingly, the Jarque-Bera test indicates that the distribution of returns is non-normal. In Table 1, we also report the Ljung-Box Q-statistic for the 8^{th} orders in the levels and squares of the residuals. It clearly indicates that there is no serial correlation in levels, but the squared residuals do show serial correlation in all cases, suggesting the existence of volatility clustering.

The unconditional correlation is presented in Table 2, which shows that the unconditional correlation of the emerging markets with the eurozone ranges between 0.26-0.37.

5. Empirical results

Table 3 is the estimated result from the bivariate DCC-EGARCH model for the three emerging markets with the eurozone market. Before interpreting the results, there are a number of important points to be noted. First, the DCC-EGARCH is estimated using the quasi-maximum likelihood method to generate consistent standard errors that are robust to non-normality. Second, a comparison of the log-likelihood values among alternative lag specifications suggests that our data are best captured by a DCC(1,1), where each of the conditional variance is captured by a univariate GARCH(1,1) model.[12]

Panel A in Table 3 is the results from the mean equation.[13] It is observed that the constant term is statistically significant above 1 percent for all markets and the conditional mean of return is dependent on its first lag for all of the markets as well. Further, it reveals that, apart from the Czech Republic, there exists a price spillover effect from the Eurozone market to Hungary and Poland, which is evidenced by the significant parameter, α_{12}, at 1 percent level; while the insignificant parameter α_{21} suggests that such a price spillover effect does not exist from these emerging markets to eurozone market. This is intuitively plausible given the small size of these emerging markets.

Panel B in Table 3 is the result from the variance equation. A closer inspection of the estimated parameters shows that the GARCH parameters are all significant above 1 percent level, indicated by β_i. Furthermore, the coefficients for the lagged conditional volatility, as shown by δ_1 for all three emerging market, and δ_2 for the eurozone market, are all close to one, suggesting a high persistence in shocks to the conditional volatility. The coefficient γ measures the asymmetry, that is, the positive shock and negative news may have different effect to the volatility. It is observed that this parameter is negative and statistically significant for all of the markets, which reinforce the assertion that bad news increases volatility more than good news does. As far as the volatility transmission mechanism across the markets is concerned, it is also asymmetric, that is, the volatility

[12] We also add the variance into the mean equation to investigate whether spillover of volatility would affect the return, however the LR test suggests that this is not strongly significant.

[13] Note that subscript 1 is for three emerging markets, and 2 for eurozone market. The order of subscript, for example, α_{12}, means that the volatility from eurozone spills over to the emerging market.

generated from the eurozone market is transmitted to all three emerging markets, indicated by the statistically significant parameter β_{12}, but not vice versa, as can be seen from the insignificant parameter, β_{21}.

In addition to the high conditional volatility, our result also shows significant time varying comovement. This effect is captured in the coefficients of q_a and q_b, which are the parameters governing the GARCH process of the Q sequence as in equation (6). Both are all statistically highly significant at above 1 percent level, and the conditional correlation also exhibits high persistence, with the average being 0.95 over the three emerging markets during the sample period.

Finally, the diagnostic test is reported in the last panel of Table 3, where the Ljung-Box Q-statistic for up to 8th orders in the levels and squares of the residuals is represented. It clearly shows that joint linear and non-linear serial correlations in the standardized residual have been successfully eliminated for all markets in the bivariate DCC-EGARCH model.

{Table 3 around here}

Figure 1 plots the evolution of the conditional correlation of three emerging markets with the eurozone market[14]. In general, it tends to show a gradual increase in the correlation in the earlier sample periods. Note that there is a similar pattern of correlation observed around 1997-98 with the occurrence of the Asian and Russian crises, where the correlation tends to peak in all cases. This accords with finance literature, in which international correlation increases when global factors (e.g. the oil crisis or Gulf war)

[14] We have also investigated the conditional correlation for the stock markets of Slovakia and Slovenia. However, given a relatively lower correlation, we have concentrated on the three major emerging stock markets.

dominate domestic ones and affect all financial markets. Several studies have found that international correlation tends to increase in periods of high turbulence (e.g. Longin and Solnik 1995, Ramchad and Susmel 1998 and Chiang et al. 2007). The results found for the transition economies seems to be indicative of contagion effects across emerging markets, whilst exhibiting the vulnerability of these stock markets[15]. It is noteworthy that there seems to be a shift in the dynamic conditional correlation, as a higher level of correlation is observed in the post crises period as compared with the earlier sample period. Another similar pattern of movement is evident among these transition economies: an gradual upward trend of correlation towards the eurozone market around 2005 with a sharp short-lived increase in 2006, reflecting an increase of financial market integration within the EU since these economies joined the EU in May 2005.

Apart from periods of financial crisis and the entry to the EU, the pattern of correlation seems to diverge among these countries. Some observable country-specific movements are as follows. First, for the Czech Republic, the period of its own currency crisis, which began in May 1997[16], compounded with external financial crises, seems to have caused a sudden sharp correlation with the EU, exhibiting its highest at around 0.65 in 1998. The graph also shows that the correlation sharply decreases at around 0.3 after the outbreak of the crises around 1999. A fall in correlation may be attributed to the effect of an inflation targeting policy implemented in 1998, lowering the inflation rate from 10.7% in 1998 to 2.1% in 1999, which may have led to a sudden disintegration with

[15] Our finding is contrasted with the study among developed EU markets by Kim et al (2005), where the spillover effect from the financial crises is rarely observable in the context of time-varying conditional correlation.

[16] With a worsening trade deficit and an economic slowdown the Czech koruna reached a ten month low against its currency basket in April 1997. In May 1997, the target band was abandoned and the koruna depreciated almost immediately by around 10%.

the EU. On average, the level of correlation appears to increase since the introduction of a floating exchange rate regime in 1997, however, it remains to be quite volatile until the end of the sample period. As to Hungary, a sharp increased correlation around 1997 may be due to the Asian crisis, but also the consequence of a substantial development in company performance and foreign direct investment during the period 1993-1996. After 1998, correlation is downward till around 2003 with a considerable fluctuation.

For Poland**,** as the privatization progressed in the earlier sample period, there is a tendency for a mild upward trend of integration towards the eurozone. Although the pattern of correlation is drastic around 1998 similar to the other two emerging markets, since the introduction of a free floating exchange rate regime in 2000, the volatility of correlation appears to be contained until 2005. This may be due to the fact that as country-specific economic shocks could be adjusted by the domestic monetary and exchange rate policies, the volatility may be dampened.

{Figures 1 around here}

6. The determinants of stock market integration

Having found the time varying correlation of three emerging markets, in this section, we investigate the potential explanatory variables driving the stock market integration.

We first examined the impact of major events on the dynamic correlation by regressing the time varying correlation with dummy variables, i.e. dummy one for the 27th May 1997 onwards for the currency crisis in the Czech Republic, for the 14th October 1997 onwards for the Asian crisis, for the 17th August 1998 onwards for the Russian crisis and for the 5th May 2004 for entry to the EU, and zero otherwise. Due to the collinearity problem, the dummies were specified one at a time, and the results are found in Table 4.

{Tables 4 and 5 around here}

It is evident that the financial crises exerted a statistically highly significant impact on the conditional correlation, confirming that these emerging markets are vulnerable to external shocks with a large regime shift in integration. As to the EU dummy variable, although the extent of the effect seems to be less than that for the financial crises, the dummy variable is found to be significant at the 5% and 10% for Poland and the Czech Republic respectively.

We now explore the driving factors behind the conditional correlation from the aspect of economic and monetary integration and currency risk. It has long been found that business cycle conditions are intricately linked with the performance of asset returns (Fama and French, 1989 and Rouwenhorst, 1995). If countries are in similar phases of the business cycle, the degree to which shocks are transmitted across financial markets will be increased. Thus, we expect, on a priori ground, that an increase in real economic convergence will stimulate higher stock market integration, where the real convergence variable is captured by the correlation in industrial production. As to the proxy for the monetary convergence variable, the correlation of three months' interest rates is used, since it may characterise the integration process towards the EU. As a major impediment to financial integration, currency risk premia are considered. The risk premia are specified in the international asset pricing models where it has been recognized as a factor for financial disintegration (Solnik, 1974). Theoretically, the reduced exchange rate volatility should increase the co-movement between the markets.

In addition to these variables, we introduce country specific control variables including aggregate stock market liquidity and development of financial markets, which might alter stock market returns, therein, the time varying correlation.

Specifically, we estimate the following linear equation for these new member states with respect to the aggregate eurozone market:

$$\begin{aligned}\tilde{TCC}_{i,t} = {} & \beta_{1i} + \beta_{2i} Corr\_ip_{it-1} + \beta_{3i} Corr\_ir_{it-1} + \beta_{4i} FX\_risk_{it-1} + \beta_{5i} FIN\_depth \\ & + \beta_{6i} \log(vo) + \beta_{7i} \tilde{TCC}_{i,t-1} + \beta_{8i} \tilde{TCC}_{i,t-2} + u_{it}\end{aligned} \tag{8}$$

where the dependent variable $\tilde{TCC}_{it}$ is the estimated time varying conditional correlation series for each country *i*. *Corr_ip* and *Corr_ir* are the time varying conditional correlations in the growth rate of seasonally adjusted industrial production and the nominal three-month interbank rate respectively between the emerging countries versus the eurozone. *FX_risk* is the conditional exchange rate volatility to capture the currency risk premia[17]. *FIN_depth* is the ratio of stock market capitalization to GDP, which is commonly used to capture the stock market development of a country and *log(vo)* is the logarithm of the stock market turnover by volume to proxy the liquidity. $\tilde{TCC}_{it-1}$ and $\tilde{TCC}_{it-2}$ are the first and second lags of the dependent variable. All data are monthly observations.[18]

Equation (8) is estimated by linear regression analysis and the results are shown in Table 5. Diagnostic test results indicate that the explanatory power of the model is quite high with the R^2 around 95% in all cases, and this is not the result of spurious regression

[17] *FX_risk* is estimated by fitting the local currency with respect to ECU (European Currency Unit) into a GARCH(1,1) model.
[18] The monthly series of time varying correlation is calculated as the average of each month over the sample period, which runs from April 1994 to December 2006.

since the ADF test tends to indicate the stationarity of residuals. The absence of serial correlation is also evident.

The lagged dependent variables have shown to be statistically highly significant, except for $T\tilde{C}C_{it-2}$ in Hungary. This indicates strong persistence in the dynamic correlation. However, the coefficients on *Corr_ip* and *Corr_ir* are insignificant for all cases, implying that the economic and monetary convergences do not seem to affect the stock returns' integration. The absence of the impact of the real and monetary convergence on the conditional correlation may suggest the fact that there is a substantial degree of difference in terms of macroeconomics conditions between the developed EU and emerging economies of our study. The coefficient on the conditional foreign exchange volatility (*FX_risk*) is significant at the 10 percent only for Hungary with a positive sign. It implies that the higher the conditional foreign exchange volatilities, the higher the integration, which is contrasted with the prediction. However, given the fact that the volatility of exchange rates in the emerging markets tends to increase with the financial crises, and as shown in Figure 1, a sharp rise in conditional correlation was evident during the period of financial turmoil, the positive relationship between DCC and *FX_risk* may be plausible.

Although the coefficients of *log(vo)* is insignificant, those of *FIN_depth* are found to be statistically significant at the 1% level for the Czech Republic and Hungary with the expected positive sign, indicating the crucial role of financial deepening for integration with the eurozone market.

7. Conclusions

This paper investigates the co-movement of three major Central European emerging markets with the aggregate eurozone market by utilising the dynamic conditional correlation technique. The DCC measures the contemporaneous conditional correlation between the two series and has been used to provide an indirect measure of the degree of integration between the stock market in the euro-zone and the new EU countries. The estimated dynamics of the correlation demonstrate comprehensive evidence of the evolution of stock market co-movements, while providing the extent of the linkage over the period of time. We find significant dynamic correlations for these emerging markets with the eurozone market during the financial crises and a higher level of linkage in the aftermath of crises. The entry to the EU seems to have strengthened the correlation also.

The linear estimation of the conditional correlation reveals that the increase in stock market co-movements can not be explained by the macroeconomic convergence process, nor by monetary convergence with the euro-zone. We find that the development of financial markets seems to be an important driving factor behind higher levels of co-movement in the Czech Republic and Hungary with the eurozone. This implies that financial market integration seems to be a largely self-fuelling process depending on existing levels of financial sector development. In terms of investment opportunities, this may narrow the scope for portfolio diversification. For Poland, such a discernible factor is not in evidence, other than in the persistence of the correlation.

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Table 1 Descriptive statistics

	Czech Rep.	Hungary	Poland	Eurozone
Mean	0.0139	0.0795	0.0390	0.0384
Std. E	1.1862	1.6893	1.7717	1.0192
Skewness	-0.2736	-0.8667	-0.3247	-0.2456
Excess Kurtosis	3.02	13.78	6.70	2.56
Jarque-Bera	1307.34	26690.42	6265.03	943.45
Q(8)	3.42	4.77	5.66	9.92
$Q^2(8)$	654.26	714.49	1301.59	1184.93

Note: Q(8)and $Q^2(8)$ are the Ljung-Box Q-statistic for the 8^{th} orders in the levels and squares of the residuals, respectively. Under the hypothesis of no serial correlation, the critical value is 15.50 at the 5% level.

Table 2 Unconditional correlation matrix

	Czech Rep.	Hungary	Poland	Eurozone
Czech Rep.	1	0.3982	0.2686	0.3316
Hungary		1	0.3771	0.3651
Poland			1	0.2643
Eurozone				1

Table 3 Estimation from the DCC-EGARCH model with respect to eurozone

	Czech Rep.	Hungary	Poland
Panel A: Mean equation			
α_{10}	0.0545***	0.1172***	0.0685***
	(0.0129)	(0.0150)	(0.0198)
α_{20}	0.0519***	0.0588***	0.0531***
	(0.0137)	(0.0117)	(0.0120)
α_{11}	0.1500***	0.0873***	0.1179***
	(0.0160)	(0.0147)	(0.0161)
α_{21}	0.0114	-0.0066	-0.0024
	(0.0125)	(0.0076)	(0.0074)
α_{12}	0.0192	0.0948***	0.1214***
	(0.0142)	(0.0158)	(0.0227)
α_{22}	0.0448***	0.0397***	0.0320*
	(0.0158)	(0.0156)	(0.0175)
Panel B: Variance equation			
β_{10}	0.0165***	0.0712***	0.0207***
	(0.0029)	(0.0020)	(0.0041)
β_{20}	0.0002	-0.0006	-0.0012
	(0.0011)	(0.0011)	(0.0017)
β_{11}	0.1937***	0.2532***	0.1704***
	(0.0167)	(0.0077)	(0.0167)
β_{21}	0.0111	-0.0015	0.0007
	(0.0074)	(0.0063)	(0.0118)
β_{12}	0.0252**	0.1583***	0.0447***
	(0.0126)	(0.0063)	(0.0139)
β_{22}	0.1291***	0.1444***	0.1443***
	(0.0119)	(0.0063)	(0.0117)
δ_1	0.9585***	0.9364***	0.9824***
	(0.0059)	(0.0023)	(0.0040)
δ_2	0.9868***	0.9853***	0.9879***
	(0.0026)	(0.0019)	(0.0026)
γ_1	-0.1831***	-0.0463*	-0.0996**
	(0.0358)	(0.02449)	(0.0484)
γ_2	-0.3274***	-0.2681***	-0.2971***
	(0.0514)	(0.0229)	(0.0576)
q_a	0.0277***	0.0417***	0.0209***
	(0.0030)	(0.0029)	(0.0061)
q_b	0.9617***	0.9347***	0.9577***
	(0.0042)	(0.0046)	(0.0153)
Log-value	-9038.64	-10054.75	-10096.18
Panel C: Diagnostic test			
Q(8)	13.4075	10.7762	12.3727
$Q^2(8)$	9.2312	7.8009	10.7696

Notes: Standard errors are in parenthesis. *, ** and ***: significant at the 10%, 5% and 1% level respectively.Q(8)and $Q^2(8)$ are the Ljung-Box Q-statistic for the 8^{th} orders in the levels and squares of the residuals, respectively. Under the hypothesis of no serial correlation, the critical value is 15.50 at the 5% level.

Table 4 Impact of events on the DCC

	Currency crisis in Czech Rep. 27th May 1997	Asian crisis 14th Oct 1997	Russian crisis 17th August 1998	Entry to EU 5th May 2004
Czech Republic	0.1442*** (0.0252)	0.1576*** (0.0234)	0.1803*** (0.0204)	0.0522* (0.0290)
Hungary	0.1287*** (0.0216)	0.1178*** (0.0209)	0.0723*** (0.0209)	-0.0187 (0.0252)
Poland	0.1323*** (0.0140)	0.1254*** (0.0135)	0.0887*** (0.0142)	0.0372** (0.0184)

Notes: Standard errors are in parenthesis. *, ** and *** significant at the 10%, 5% and 1% level respectively. Dummy one since the event took place and zero otherwise.

Table 5 Determinants of stock market integration

	Czech Rep.	Hungary	Poland
Intercept	1.0886*	0.2136*	0.0443
	(0.5750)	(0.1171)	(0.0909)
Corr_ip	-0.0070	-0.0222	-0.0121
	(0.0276)	(0.0485)	(0.0174)
Corr_ir	-13.3282	-0.0359	0.0369
	(8.6995)	(0.0580)	(0.0606)
FX_risk	0.0079	0.0132*	0.0035
	(0.0082)	(0.0080)	(0.0038)
FIN_depth	0.0903***	0.0670***	0.0085
	(0.0416)	(0.0277)	(0.0247)
Log(vo)	-0.0239	-0.0139	0.0028
	(0.0192)	(0.0115)	(0.0091)
$\tilde{TCC}_{it-1}$	1.0271***	0.6588***	0.8918***
	0.1048	(0.0864)	(0.0838)
$\tilde{TCC}_{it-2}$	-0.3016***	0.0088	-0.1679***
	(0.1057)	(0.0855)	(0.0843)
ADF test lag4	-3.503	-4.191	-3.836
R^2	0.9609	0.9458	0.9728
Q(8)	5.9817	4.1458	13.2685
$Q^2(8)$	3.6244	5.8235	6.1925

*Notes: D*ependent variable: time varying conditional correlation, $\tilde{TCC}_{it}$

Standard errors are in parenthesis. *, ** and *** represent significant at the 10%, 5% and 1% level respectively. Q(8)and $Q^2(8)$ are the Ljung-Box Q-statistic for the 8^{th} orders in the levels and squares of the residuals, respectively. Under the hypothesis of no serial correlation, the critical value is 15.50 at the 5% level.

Figure 1 Dynamic conditional correlations with the aggregate eurozone market