Time-Varying Synchronization of European Stock Markets

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and

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Abstract

We study intraday comovements among three developed (France, Germany, and the United Kingdom) and three emerging (the Czech Republic, Hungary and Poland) European stock markets. When applying a Dynamic Conditional Correlation GARCH model to five-minute tick intraday stock price data (2003–2006), we find a strong correlation between the German and French markets and also between these two markets and the UK stock market. However, very little systematic positive correlation during a trading day can be detected between the developed and emerging stock markets, or within the emerging group itself. Hungary exhibits higher correlation with the developing markets and the emerging markets and its dynamics show an increasing trend; Poland and the Czech Republic produce less clear-cut results.

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JEL keywords: stock markets, intraday data, comovements, bi-variate GARCH, European integration.

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1. Introduction

The extent and dynamics of capital market synchronization represents a vital research area as it is important for equity portfolio selection (Erb et al., 1994), understanding the “home country bias” phenomenon (Lewis, 1999) and understanding processes underlying comovements between financial and real economies (Brooks et al., 2003), among other issues. Capital market synchronization, along with that of the real economy, is also closely related to the ongoing process of European integration that has been witnessed by stronger real economic linkages and the convergence between old and new European Union (EU) member states (Fidrmuc and Korhonen, 2006). The strengthening of real economic links has been accompanied by large cross-border capital flows and the deepening of the financial systems in new EU member states in Central and Eastern Europe (CEE). As the ongoing financial market integration in Europe does not seem to have obstacles, the monetary integration of the new EU members is still far from being attainable (Kutan and Orlowski, 2006) despite the fact that financial markets in most developed CEE countries are institutionally advanced (Orlowski, 2005). In this paper we hypothesize that intraday synchronization between developed and emerging European stock markets, as well as among the CEE markets as a group, has been growing, with greater real and financial integration behind the process.

In our analysis we concentrate on comovements among several EU markets during trading hours when the markets are simultaneously opened. We use a multivariate framework, intraday data and a selection of developed as well as emerging European stock markets. The combination of these differentiates our approach from the literature in the field. Our results show a great degree of intraday synchronization among the old EU markets. On other hand we find very little correlation between the CEE markets and the old EU as well as among the CEE markets themselves.

Earlier studies that investigated short-run and long-run comovements and contagions[1] between CEE markets and their Western European counterparts used conventional methodology and did not produce very strong evidence.[2] For instance, Gilmore and McManus (2002, 2003) and Černý and Koblas (2005) did not establish any long-term relationship among the three CEE markets Hungary, the Czech Republic and Poland and the German stock market

[1] The literature distinguishes cross-market comovements during calm periods from those in periods before and after a crisis. Interdependence defines how strong the interlinkage between two markets is during normal times. We speak of contagion if the interlinkage becomes stronger in the aftermath of a crisis than before it (Forbes and Rigobon, 2002).

for daily or intraday data. Voronkova (2004) shows the presence of long-run links using daily stock market data when accounting for structural changes. In a similar vein, Syriopoulos (2004) finds that the CEE markets tend to display stronger linkages with their mature counterparts than with their neighbors. Furthermore, Scheicher (2001) finds evidence of limited interaction between some of the CEE markets and the major markets for daily stock market volatility. There is also little evidence of contagion effects in the CEE stock markets, and CEE stock markets are not more prone to contagion than more developed stock markets (Tse, Wu, and Young, 2003; Serwa and Bohl, 2005).

The above-listed literature uses conventional econometric techniques including cointegration, causality tests and univariate GARCH models. The (G)ARCH revolution entailed the emergence of a number of multivariate GARCH models that provide more efficient tools for analyzing comovements and volatility spillovers among financial assets. In this respect Martens and Poon (2001) state that a multivariate approach is the only right platform for studying the transmission mechanism and correlation dynamics.[3] For these reasons we adopt a multivariate GARCH framework. Further, we employ intraday data because we want to evaluate intraday comovements among the markets during a trading session, while avoiding the possible contamination of those comovements from the daily accumulation of information on the market. Multivariate GARCH applications are largely absent in analyzing intraday data and, to the best of our knowledge, the approach has not been applied to emerging European stock markets at this frequency.[4] We aim to fill this gap by investigating the dynamic correlation of time-varying volatilities between three CEE stock markets and also between these markets and three Western European counterparts over the period from June 2003 to January 2006 on the basis of intraday data recorded in five-minute intervals.

The limited evidence of intraday comovements we found between the CEE and the Western European markets indicates that stock market synchronization between two EU segments is still weak. The literature suggests a number of factors that could increase

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[2] Influential research measuring links among developed markets includes Bekaert and Harvey (1995) and Forbes and Rigobon (2002).
[3] The use of multivariate ARCH specifications to model the conditional mean and volatility of stock prices is still not as widespread as the use of conventional univariate models. The methodology is usually used in two strands of financial modeling. One is the modeling of the behavior of stock prices, related financial instruments or stock indices in order to exploit the effect of conditional variance and covariance. Ledoit, Santa-Clara and Wolf (2003), Bystrom (2004), Hutson and Kearney (2005), and McKenzie and Kim (2007) are examples of such applications. Testing the validity of the CAPM model is another line of research where Engle and Rodrigues (1989) and Clare et al. (1998) can serve as examples in which the CAPM model with time-varying covariances is rejected.
[4] Lucey and Voronkova (2005) used a multivariate approach for daily Russian stock market returns, Crespo-Cuaresma and Wójcik (2006) analyzed interest rate data, and Babetskaia-Kukharchuk et al. (2008) analyzed exchange rates.

synchronization of stock markets in general. Chinn and Forbes (2004) argue that the intensity of international trade play an important role in this respect. Trade intensity has been very high in the old EU-15 countries (above 80% over GDP in 2004). While trade flows between CEE countries on the one hand and old EU-15 countries on the other have been on the rise since the early 1990 (reaching around 50%-60% to GDP in 2004), CEE countries trade among themselves relatively little. Business cycle synchronization is another driver of stock market synchronization (Wälti, 2006). The empirical literature shows that business cycles are very strongly correlated between old EU countries and that the correlation between new and old member countries is less pronounced, although increasing over time (Fidrmuc and Korhonen, 2006). Third, a deeper and higher quality banking system is associated with a lower volatility of stock returns and greater synchronization in the movements of domestic and world returns (Dellas and Hess, 2005). Taking credit to the private sector ratio as an indicator of financial deepening, CEE countries seem to be far away from private credit levels reached in old EU countries. Finally, the presence of foreign investors may also promote stock market synchronization. 55-60% and 77-79% of the Czech and Hungarian stock market turnover was generated by foreign investors, while their presence in Poland is less pronounced (Hanousek, Kočenda and Kutan, 2009).

The outline of the paper is as follows: section 2 describes the model and testing procedure to estimate it. Section 3 deals with data issues. Section 4 presents the estimation results and section 5 provides concluding remarks.

2. Model Specification

We aim to study the pairwise dynamic correlations for two stock market returns, Δr_1 and Δr_2, at the six markets under research. We hypothesize that the correlations between pairs of returns vary over time. Formally we establish evidence of the time varying correlations by applying the test of the null of constant correlation against an alternative of dynamic conditional correlation devised by Engle and Sheppard (2001).[5] We also document the time varying correlations between stock market returns later in Figures 2 to 4.

Since we want to specifically model the dynamics between two markets at a time, we employ the bi-variate version of the Dynamic Conditional Correlation GARCH model (DCC-GARCH) from Engle (2002). The model allows circumventing the substantial computing

[5] The Matlab code to run the test is available at www.kevinshephard.com/wiki/UCSD_GARCH.

requirements implied by the first class of multivariate GARCH models (Kearney and Poti, 2006) as the DCC model represents a non-linear combination of univariate GARCH models and estimates are obtained using two-stage estimation.

Following Engle (2002), the DCC-GARCH model for the bivariate vector of stock index returns $\Delta r_t \equiv [\Delta r_{1t}, \Delta r_{2t}]'$ is specified as follows:

$$\Delta r_t | \Omega_{t-1} \sim N(0, D_t R_t D_t), \quad (1)$$

$$D_t^2 = diag\{\omega_1 \omega_2\} + diag\{\kappa_1 \kappa_2\} \circ \Delta r_{t-1} \Delta r'_{t-1} + diag\{\lambda_1 \lambda_2\} \circ D_{t-1}^2, \quad (2)$$

$$\varepsilon_t = D_t^{-1} \Delta r_t, \quad (3)$$

$$Q_t = S(1 - \alpha - \beta) + \alpha(\varepsilon_{t-1}\varepsilon'_{t-1}) + \beta Q_{t-1}, \quad (4)$$

$$R_t = diag\{Q_t\}^{-1} Q_t diag\{Q_t\}^{-1}. \quad (5)$$

The conditional variance-covariance matrix $D_tR_tD_t$ is composed of a 2x2 diagonal matrix of time-varying standard deviations from univariate GARCH models ($D_t = diag\left\{\sqrt{h_{it}}\right\}$) and a correlation matrix containing conditional correlation coefficients (R_t). The symbols ω_i, κ_i, and λ_i stand for constants and coefficients associated with ARCH and GARCH terms, respectively. Standardized residuals are denoted by ε_t. Further, S is the unconditional correlation matrix of the standardized residuals in a dynamic correlation structure Q_t. The symbol $\circ$ denotes the Hadamard product of two matrices of the same size (element-by-element multiplication). The parameters of the DCC-GARCH model can be estimated using maximum likelihood.

If $\alpha + \beta < 1$, equation (4) is mean reverting (mean-reverting DCC-GARCH). On the other hand, $\alpha + \beta = 1$ results in an integrated DCC-GARCH model as equation (4) collapses to equation (4'):

$$Q_t = (1 - \phi)(\varepsilon_{t-1}\varepsilon'_{t-1}) + \phi Q_{t-1}. \quad (4')$$

A standard Likelihood Ratio test ($LR = 2(\log L_{\alpha+\beta=1} - \log L_{\alpha+\beta<1}), LR \sim \chi^2$) can be used to discriminate between (4') and (4).

To sum up, the model is estimated in two stages as in Engle (2002): the univariate GARCH models in the first stage and the conditional correlation matrix in the second stage. Parameters are also estimated in stages. As shown by Engle (2002) and Engle and Sheppard (2001) the DCC model can be estimated consistently using a two step approach to avoid the dimensionality problem of the most multivariate GARCH models.[6] The above DCC model is parsimonious and ensures that time varying correlation matrices between the stock exchange returns are positive definite.

3. Description of the Intraday Dataset

Our dataset consists of intraday data available from Bloomberg in five-minute intervals (ticks) for the stock markets in Budapest (BUX), Prague (PX 50), Warsaw (WIG 20), Frankfurt (DAX 30), Paris (CAC 40) and London (UKX). Thus, in our analysis we consider three emerging EU markets (Hungary, the Czech Republic and Poland) and three developed EU markets (Germany, France and the United Kingdom). The sample starts on June 2, 2003 and ends on January 24, 2006. The time difference between the markets is accounted for by using Central European Daylight Time (CEDT) for all indices, which eliminates the time difference between London and continental Europe.

We compute the index returns as log first differences where each trading day is a separate sub-sample in order to prevent our results from being distorted by overnight returns.[7] This means that the first return observation on each day is not based on the closing price of the previous day. Following Engle (2002), we demean the index return series and then use the demeaned returns for the estimations.[8]

Besides the above data transformation, there are two data issues that need to be addressed. The first one relates to the fact that trading hours are longer in Western Europe than in the new EU markets. In order to make our analysis fully comparable and executable, we need a common denominator. Table 1 provides an overview of the trading hours at the six stock markets. From Table 1 we infer that a suitable common denominator can be the shortest trading window, i.e. the one for WIG 20 running from 10:00 to 15:55 CEDT.

Another, and perhaps more substantial, problem is the observed fact that absolute returns and volatility exhibit a *U*-shaped pattern during the trading day both in mature and

[6] In this respect, Bauwens and Laurent (2005) show that both the one-step and two-step methods give very similar estimates.

[7] Kwapien et al. (2003) show that overnight returns affect returns distribution and that eliminating overnight returns is sufficient to remove fatter tails in returns distribution.

[8] As an alternative approach, we follow Lee (2006) and Crespo-Cuaresma and Wójcik (2006) and estimate a bivariate Vector Autoregressive (VAR) model for the return series to initially remove potential linear structure between pairs of stock index returns. We then use the residuals of the VAR model as inputs for the DCC-GARCH model. The results based on the residuals of the VAR are available upon request but they are not presented here because they are very similar to those obtained using the demeaned returns series.

emerging markets.[9] We show the *U*-shaped pattern in our data in Figure 1 where we plot computed average squared returns during the trading day for the six stock market indices introduced above and for the Standard & Poor's index. It is visible that the volatility tends to be higher after market opening and before market closing than during the rest of the trading day. From Figure 1 we see that The *U*-shaped pattern is present for all stock indices and volatility is much higher after market opening than before its closing. Especially for BUX and WIG 20, the *U*-shape is highly asymmetric as a result. For these two indices, a bump emerges during the first 15 to 30 minutes after market opening, implying that markets need some time to react and incorporate news that materialized between the two trading days. The *U*-shape is actually an inverted *J* curve for the other stock indices, as squared returns before market closure do not differ on average from those observed during the day.

Second, volatility in the CEE stock markets appears to be larger during the early hours of trading than in their Western counterparts, with the exception of the tick at 9:05 CEDT of DAX. Third, as evidenced by the developments in the squared returns of the Standard & Poor's index, Western European stock markets are clearly influenced by U.S. macroeconomic announcements at 14:30 CEDT and by the opening of the U.S. stock market at 15:30 CEDT. Yet the CEE markets seem to be affected by none of these events to a similar extent.

To summarize, the *U*-shape pattern is present in the data because of the arrival and incorporation of news during the beginning of the trading day, differences in intraday trading activity, and also because of the opening and closing of positions at the beginning and at the end of the trading session. We account for the presence of the seasonal pattern in intraday volatility seasonality in order to avoid compounded results and its negative influence on estimated coefficients in the following way. We take the shortest common window given by WIG 20, i.e. from 10:00 to 15:55 CEDT and account for the *U*-shaped pattern and the impact of the U.S. event within this window. This leads us to downsize the WIG 20 window to the period running from 11:00 to 14:20 CEDT The resulting common trading window has yet another advantage. We have several market indices in our sample and not all of them account for dividends payment (for example Prague). On a day when a firm pays dividends, the value of its stock temporarily decreases. If such a firm is substantially represented in an index, the decrease affects the opening index value despite the fact that nothing negative happened to the firm in

[9] See McMillan and Speight (2002) for the UK, Fan and Lai (2006) for Taiwan and Égert and Kočenda (2007) for Central Europe.

reality. The common trading window filters this temporary decrease away and does not affect the index value during the trading window.

To sum up, the above approach yields data originating from a common trading window that is free from the *U*-shaped pattern, eliminates the unwanted overnight returns effect as well as the effect of dividend payments, and avoids the problem of non-synchronous data voiced by Martens and Poon (2001).[10] Table 2 shows some descriptive statistics for the window corrected for the *U*-shaped pattern according to which the stock returns exhibit a high degree of autocorrelation (Ljung-Box test for residuals). Finally, in none of the series was a structural break detected.[11]

4. Empirical Findings

We present the degree of intra-day market synchronization in Figures 2, 3, and 4. A graphical form is the best way to capture the time varying nature of the intra-day correlations among the pairs of markets. All three figures exhibit varying patterns in the correlation dynamic path, which justifies the use of the modeling strategy. The presented time varying correlations are in accord with the results of the constant correlation test of Engle and Sheppard (2001) that rejects the null of constant correlation in favor of the dynamic correlation alternative for all nine pairs of stock returns.[12] We present our results in three sections: correlations among developed EU markets, among old and new EU markets, and finally among new EU markets. Our findings show a relatively high degree of intra-day synchronization among the developed EU markets, while the rest of the correlations is fairly low.[13]

4.1 Old EU markets

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[10] It should be noted that some index quotes are infrequently missing for some of the series. These are treated as missing observations.

[11] Terzi (2003) argues that a significant benefit of using intraday data is that the estimates are more robust with respect to structural breaks given the relatively short time horizon (two years) as compared to studies employing daily data (up to 10 years). The fact that our data do not exhibit any structural breaks is an advantage with respect to estimation stage.

[12] Results of the test are not presented but are available upon request.

[13] The likelihood ratio tests reject the null of integrated DCC against the alternative of a mean reverting DCC model for the Western European stock market pairs. At the same time, the test cannot reject the null of an integrated DCC for CAC-Central European pairs and the mean reverting models did not converge for the Eastern European stock market index pairs. As a result, we show the dynamic correlation coefficients based on the mean reverting DCC for the first country group, and those obtained on the basis of the integrated DCC for the two remaining country pair groups.
As a complementary estimation as well as a model specification robustness check we estimate the Baba-Engle-Kraft-Kroner GARCH model (BEKK-GARCH) developed by Engle and Kroner (1995). Results from this model are comparable with the patterns obtained from the DCC models but the dynamic correlation series exhibit much more volatile patterns and are not reported here.

The French and German stock market indices exhibit the highest correlation for returns in general. The plotted DCC ranges are in a corridor of 0.5 and 0.9 between June 2003 and January 2006; the average dynamic correlations of the more stable part appear above 0.7, which means there is a very high correlation between the two markets. These two stock markets seem to be less correlated with the UK market, where the DCC typically varies between 0.3 and 0.6. Nevertheless, the weakening of the correlation between the French and German markets during the period under study broadly coincides with changes in the DCC between those two markets and the UK stock market, indicating a rising integration of the three markets. Further, despite the fact that the degree of correlation between German and UK markets slightly weakens over the researched period, our results support those reported by Berben and Jansen (2005) for an earlier period.[14]

4.2 Old versus new EU markets

Next, in order to assess our hypothesis of higher synchronization between developed and emerging European stock markets, we observe the comovement of returns between the three Central and Eastern European stock markets and the French index CAC that we take as a benchmark for Western Europe. The choice of the French index has been made for several reasons. First, market capitalization of the Paris stock exchange has recently been more than double that of Frankfurt and close to that of London and has also registered the largest increases among the three markets (WFE, 2007). Since the Paris and Frankfurt markets are extremely correlated, as shown above, Therefore, in opting for Paris we exploit the benefit of high market capitalization that is important for price formation. Second, in those cases when the stocks traded on the CEE markets are subject to a dual listing, they are usually listed on the London or Paris stock exchange rather than in Frankfurt (Korczak and Bohl, 2005). Third, due to a time-zone difference between continental Europe and London there is a shorter overlap in trading hours between London and CEE stock exchanges. By opting for Paris stock exchange that operates in the same time-zone as the CEE markets, we eliminate data losses due to a time zone difference with London.[15]

The comovements between studied markets reveal a completely different picture from the one between the pairs of developed EU markets. While all three CEE stock markets are positively correlated with Western Europe, the correlation is very low, ranging between 0.01

[14] Based on weekly data, Berben and Jansen (2005) find increased correlations among the German and UK markets in the period 1980–2000.
[15] Using the Frankfurt index as a benchmark, instead of the Paris index, yields results that are not materially different from those reported below.

and 0.03 (Figure 3). The low correlation goes against the higher synchronization hypothesis and hints at an existing potential for portfolio diversification. Still, the pattern of varying correlations is different for each market pair. Budapest exhibits a mild increase in correlation, Prague seems to be quite level and Warsaw levels off after a sharp decrease in correlation.

4.3 New EU markets

Finally, we assess the hypothesis of higher synchronization among the CEE markets as a group (Figure 4). The market synchronization is low as the time-varying correlation coefficients are moving in a band of 0.02 to 0.05 for the country pairs BUX-PX 50, BUX-WIG 20 and PX 50-WIG 20. Still, the magnitude of varying correlations among the new EU members is about double of that between individual CEE markets and the Western European benchmark. The result does not support the high synchronization hypothesis but still warrants plausible portfolio diversification among the three markets. Notwithstanding the low magnitude of the correlation, it started to increase during the second half of our sample. This might be an effect of the three countries joining the EU in May 2004. Any stronger statement on the subject would be premature, though.

4.4 Robustness check

In addition to the DCC correlations we perform robustness checks.[16] We compute the empirical correlations between pairs of indices (see Table 3). In general, magnitudes of empirical correlations are in line with dynamic correlation patterns derived by the DCC-GARCH methodology. The empirical correlations provide an indication that the DCC results are robust. The results from the DCC model shed light on the time-varying nature of the correlation coefficients and document the dynamics of markets' synchronization or its lack.

High correlation among the old EU markets is in contrast with low correlations among the new EU markets. Empirical correlations between the new and old EU market indices are also low and their values alter only marginally with respect to specific old EU market index. This low correlation might be due to the delay with which CEE markets react to impulses coming from Western markets (since the data set consists of 5-minute returns). We study this effect by computing the empirical correlations of the lagged effects of the old EU markets on the CEE markets. We present the empirical correlations graphically in Figure 5 where the results for the Paris CAC40 index are shown.[17] While the results show a small delay related to

[16] We would like to thank an anonymous referee for these suggestions.
[17] The results with respect to the DAX and UKX indices are not reported but they are virtually the same and available upon request.

the impact of old EU markets on CEE markets, the overall size of the correlation does not change dramatically. Furthermore, the lagged impact vanishes completely after 25 to 50 minutes (5 to 10 ticks). Thus, lagged responses cannot fully explain why the concurrent returns between old and new EU markets exhibit very low static and dynamic correlation.

5. Conclusions

In this paper, we analyzed the time-varying correlation of intraday stock market volatilities for three Western European stock markets (CAC, DAX and UKX) and for three CEE markets (BUX, PX 50, WIG 20). The bivariate version of the Dynamic Conditional Correlation GARCH (DCC-GARCH) model shed light on the strong correlation between the German and French markets and also between these two and the UK stock market for a common daily window adjusted for the observed *U*-shaped pattern for the period from June 2003 to January 2006. By contrast, very little systematic positive correlation can be detected between the Western European stock markets and the three CEE counterparts. Perhaps even more surprising is the finding that the CEE markets among themselves are not very well synchronized in terms of comovements in their stock market returns. Based on the evidence we conclude that intraday market synchronization between the CEE markets and matured EU markets is weak as there is only a marginal dynamic correlation between the two EU market segments.

The findings on dynamic correlations indicates that volatility in these specific CEE markets is apparently driven by local innovation and does not reflect transferred swings in asset prices at other markets. In this respect, the policy implication is that regulators on the CEE markets should strive to enhance the participation of the large institutional investors whose presence should favorably impact market volatility. For example in Poland, where the presence of institutional investors is the largest in the region, investment funds are required to maintain certain proportions of the values of specific instruments in their portfolios. This condition means that when the prices of stocks begin rising unusually fast, the value of the stock part of a portfolio increases beyond the proportional limit and the investment fund starts selling some of its stock, thus pushing the prices down. The reverse process begins when stock prices are falling. In effect, large investors assist in curtailing market volatility. A secondary and maybe even more important effect is that lower volatility on the market attracts more investors and positively affects firms' decisions regarding their listing. This cumulative effect is conducive to the prepared pension reforms that will require the participation of investment funds beyond the extent that is present on stock markets today.

Our research bears the following implications. The fact that we found very little intraday comovements for stock market returns between the stock markets of CEE and Western Europe on the one hand and among the CEE countries on the other hand may be of importance for international portfolio diversification into the CEE. This is also supported by the heavy presence of foreign investors in the region and we conjecture that trading preferences based on diversification benefits and less on fundamentals might be a contributing factor behind low market synchronization. Nevertheless, the situation may be changing because of two reasons. First, the process of deepening in the CEE capital markets is advancing, and second, the degree of the CEE markets' economic integration with Western Europe is increasing as a result of the European integration process and advancements of the CEE countries towards the Eurozone (Kočenda, Kutan and Yigit, 2006; 2008). These facts are supported by the recent increase, albeit small, in the pairwise correlations among the CEE markets. Thus, the missing or weak linkages found today may emerge or become stronger in the future.

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Table 1. Overview of Trading Hours

	Start	End	Ticks
BUX	9:00 a.m.	4:25 p.m.	90
PX 50	9:30 a.m.	4:00 p.m.	79
WIG 20	10:00 a.m.	3:55 p.m.	72
DAX	9:00 a.m.	5:40 p.m.	105
CAC	9:05 a.m.	5:25 p.m.	101
UKX	9:00 a.m.	5:35 p.m.	104

Table 2. Descriptive Statistics over Common Window

	Log levels						**Log differences (before demeaning)**					
	BUX	**PX 50**	**WIG 20**	**CAC**	**DAX**	**UKX**	**BUX**	**PX 50**	**WIG 20**	**CAC**	**DAX**	**UKX**
Mean	9.51	6.82	7.52	8.25	8.33	8.46	1.2E-05	1.5E-05	8.3E-06	1.5E-06	3.0E-06	-3.1E-06
Median	9.46	6.79	7.50	8.23	8.32	8.44	0.0E+00	0.0E+00	-3.9E-06	4.4E-06	2.6E-06	0.0E+00
Maximum	10.08	7.33	7.99	8.50	8.62	8.66	0.01	0.02	0.01	0.01	0.01	0.004
Minimum	8.95	6.27	7.08	8.01	8.01	8.29	-0.01	-0.02	-0.01	-0.02	-0.02	-0.01
Std. Dev.	0.33	0.31	0.19	0.12	0.13	0.09	0.00	0.00	0.00	0.00	0.00	0.00
Skewness	0.10	-0.05	0.22	0.18	0.16	0.36	-0.22	-0.31	0.10	-1.30	-0.69	-1.59
Kurtosis	1.67	1.72	2.92	2.25	2.50	2.04	8.46	105.71	6.45	50.64	26.39	55.73
Jarque-Bera	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
No. of Obs.	27,423	27,379	27,456	28,040	27,919	27,481	27,422	27,269	27,449	28,036	27,916	27,478

Note: p-values are reported for the Jarque-Bera normality test.

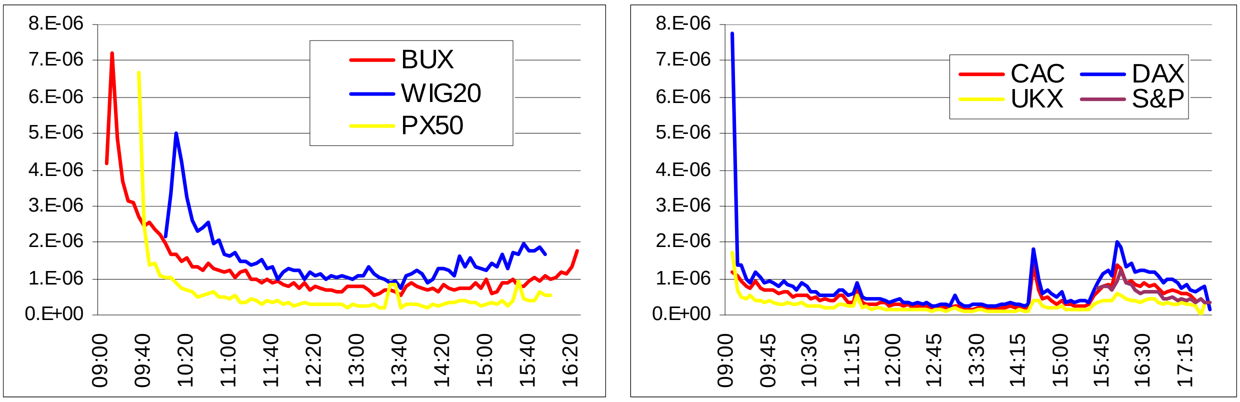
Table 3. Correlation coefficients of intraday stock market returns over Common Window

	BUX	PX50	WIG20	CAC	DAX	UKX
BUX	1					

PX50	0.035	1.000				
	(5.626)	-----				
WIG20	0.022	0.024	1			
	(3.484)	(3.759)	-----			
CAC	0.015	0.017	0.030	1.000		
	(2.316)	(2.653)	(4.758)	-----		
DAX	0.014	0.007	0.031	0.760	1.000	
	(2.228)	(1.070)	(4.873)	(186.413)	-----	
UKX	0.011	0.013	0.034	0.544	0.506	1.000
	(1.813)	(2.068)	(5.386)	(103.333)	(93.383)	-----

Note: t-statistics are reported in parentheses

Figure 1. *U*-Shaped Pattern of the Intraday Volatility



Source: Authors' calculations.

Figure 2. Dynamic Conditional Correlation: CAC, DAX and UKX
June 2003 to January 2006

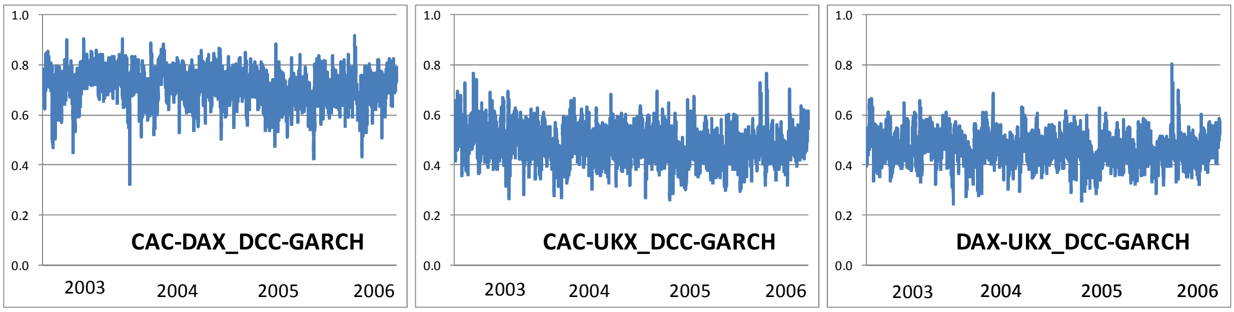


Figure 3. Dynamic Conditional Correlation Between the CAC and CEE Stock Markets: CAC, BUX, PX 50 and WIG 20, June 2003 to January 2006

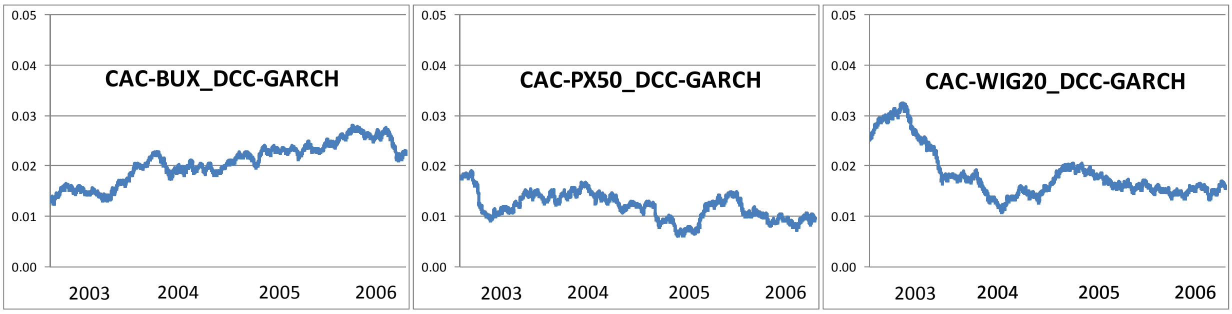


Figure 4. Dynamic Conditional Correlation Among the CEE Stock Markets: BUX, PX 50 and WIG 20, June 2003 to January 2006

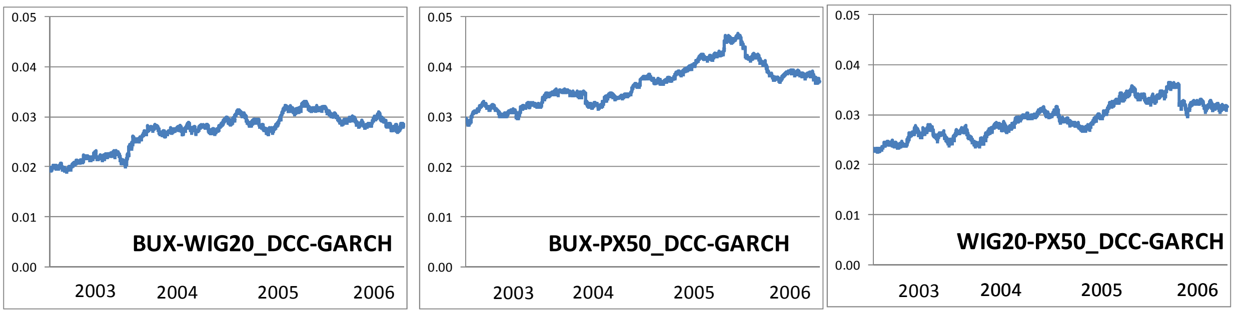


Figure 5. Correlation Between lagged CAC and CEE Stock Markets: June 2003 to January 2006