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Abstract

This paper investigates dynamic interdependence, price and volatility transmissions and financial integration between Turkey and major equity markets in EU and USA. We attempt to quantify the dynamic relationship among developed stock exchanges of Germany, France, Britain, US and Turkey, an important emerging market. Using daily data on stock prices we analyze price and volatility spillovers in a vector autoregression-dynamic conditional correlations-multivariate generalized autoregressive conditional heteroskedacticity (VAR-DCC-MVGARCH) framework. This approach enables us to measure the extent to which these equity markets are interrelated by taking into account the time-varying variance-covariance structure. Since the major trade partners of Turkey are EU countries it is of interest to examine any changes in the structure of volatility spillovers. To this end, we analyze the effects of customs union agreement between Turkey and EU on the dynamic interdependence of stock markets by dividing the sample into two periods. The analysis reveals that, although they are small in magnitude as compared to their counterparts in developed markets, the conditional correlations can be assumed to be constant in the pre-customs union agreement while it fluctuates significantly in the post-customs union agreement.

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1 Introduction

This paper is an attempt to uncover the nature of interdependence and to measure the degree of integration between emerging Turkish stock market in Istanbul and stock markets in its four leading trade partners, Germany, France, Britain and USA. Using daily data on stock price indices, we attempt to measure the transmission of stock price shocks and volatility across countries in the post-liberalization period for Turkey: 26.Nov.1990-20.Aug.2004. In this study, we will focus on empirically modeling conditional covariances and dynamic correlations among stock market indices which are to be interpreted as the reasonable proxies for the measure of equity market integration.

Financial market integration is generally defined as the situation in which assets of identical risks command the same return regardless of the domicile of the issuer and of the holder (Bekaert and Harvey (1995); Bekaert and Harvey (2003)). Financial liberalization of asset markets is a prerequisite for the process of market integration to be realized. There is no consensus in the empirical literature over measuring the degree of financial market integration between two asset markets in different countries. The bulk of the literature uses advanced time series techniques, such as cointegration, to answer the question of whether two markets are integrated. Cointegration, however, is neither necessary nor sufficient for financial market integration.[1] Stock prices in a segmented country may still be in a long run relationship with stock prices in other countries through trade and investment linkages. Similarly, a liberalized financial market may not have a cointegrating relationship with the rest of the world markets. Although cointegration analysis can provide useful information on the long run relationship among a set of markets, the test results should be interpreted with caution with regards to determining if the markets are integrated. Another difficulty with the tests of financial market integration is that they provide a binary outcome: markets are either integrated or segmented. However, as discussed in detail in Bekaert and Harvey (1995), market integration is a complicated dynamic process. Markets can be integrated

[1] An analogous problem arises in the context of goods market integration. The existence of a cointegrating relationship among a set of prices is used as evidence for spatially integrated markets. As discussed in length by McNew and Fackler (1997), cointegration of prices is neither necessary nor sufficient for spatial market integration. Prices may be cointegrated due to other reasons without necessarily implying that there exists trade links among regions. Markets will only be integrated if an excess demand shock in one region or country is transmitted completely -or partially- to the other region in the form of price changes. This can only happen if the trade between regions actually takes place. The prices, however, can be cointegrated even if trade does not take place.

in one period while segmented in others. To overcome this problem Bekaert and Harvey (1995) proposed a time varying measure of market integration in which conditionally expected returns in a country are affected by their covariance with a world benchmark portfolio and by the variance of country returns. The time varying market integration measure is, then, the weighted sum of the covariance and variance. In a perfectly integrated market only the covariance counts while in segmented markets, the variance is the relevant measure of market risk. Therefore, the analysis of conditional covariances and correlation coefficients could provide reasonable measures for the process of market integration.

There are several reasons as to why studying the extent and nature of stock market integration is important. First, modern portfolio theory dictates that for the potential gains from international portfolio allocation to be realized the exact nature of correlations among asset returns should be known. The benefits of diversification could be achieved by forming an international portfolio in which correlations among asset returns are low. Emerging equity markets could be an appropriate venue for the purposes of international portfolio diversification since they generally tend to have low correlations with developed markets. The correlations, however, may be time-varying depending on local as well as global factors. The study of the dynamic correlations structure of Istanbul Stock Exchange (ISE) with developed stock markets can provide further insight on whether it has a favorable position for international portfolio diversification.

Second, it is generally claimed that countries with close trade and investment ties tend to have more tightly linked financial markets (e.g., see Cheng and Zhang (1997)). Turkey joined the European Customs Union (CU) effective on January 1996 and eliminated all customs duties, and quantitative restrictions with EU member countries. The CU agreement has intensified already strong trade linkages between EU and Turkey. For example, 50.5% of Turkish exports and 45.1% of imports in 2002 were made with EU countries.[2] Thus, it would be a good exercise to see if intensified economic relations with EU have manifested itself in interdependence among equity markets.

Third, it is generally believed that the market integration process may lead to lower expected returns and increase correlation between emerging market and world markets (Bekaert and Harvey (2003); Bekaert and Harvey (2000)). Turkish government lifted all restrictions on transactions of foreign investors in ISE (including the repatriation of proceeds) in August 1989. Although the comparison of pre and post-liberalization

[2]For a good review of trade relations of Turkey with EU see Utkulu and Seymen (2004).

periods is beyond the scope of this paper, it is important to analyze if the correlation is changed during the sample period. In particular, it is of interest if the dynamic correlation structure (hence the degree of market integration) is similar for the two subperiods under study: before and after the CU agreement with EU following financial liberalization in 1989.

In this study, we use the dynamic conditional correlations multivariate GARCH (DCC-MVGARCH) model (Engle 2002) to estimate the time varying conditional correlations between Turkish stock market and western developed markets. The DCC procedure significantly simplifies the estimation of large multivariate GARCH systems by a two-step procedure. In the first step, univariate GARCH processes are fitted to each series and standardized residuals are obtained. In the second step, the transformed residuals are used to estimate the dynamic correlation structure.

The remainder of this study is structured as follows. In section 2 we provide a brief summary of empirical studies on global and regional stock market interactions. Section 3 discusses statistical properties of the data set under investigation. The econometric model is presented in Section 4 followed by the discussion of estimation results. Section 5 provides concluding remarks.

2 A Brief Review of Empirical Studies

There are several empirical studies focusing on interdependence and volatility spill-overs among pre-selected global and/or regional stock markets, such as Asian emerging markets vs western developed markets, or EU-accession countries vs EU member countries. Although it is not intended to cover all work done in this area, they might be classified according to the empirical procedure they employ. Most studies model short-run behavior of stock markets using a vector auto regression methodology to see the price spill-overs, and a multivariate generalized auto-regressive conditional heteroscedasticity (MVGARCH) to model the interdependence in second moments. For example, Worthington and Higgs (2004) examines volatility transmissions among developed (Hong Kong, Japan an Singapore) and emerging (Indonesia, Korea, the Philippines, Taiwan az Thailand) Asian equity markets using a multivariate GARCH (BEKK) framework. Volatility is found to be higher in emerging markets than in developed markets and HK, Indonesia and Korea exhibit significant spillovers from Japanese market. Scheicher (2001) studies the comovements of stock markets in Hungary, Poland and Czech republic in a VAR-GARCH model for returns and Bollerslev's constant correlation MGARCH model for volatility spillovers. They found statistically significant spillovers of shocks in returns and in volatilities. National and regional spillovers dominate global effects for the volatility series and most pronounced comovements are found between Budapest and Warsaw. In, Kim, Yoon, and Viney (2001) studies volatility transmission and market integration across stock markets in Hong Kong, Korea and Thailand during the Asian financial crises in 1997 and 1998. They found that HK plays an important role as an information producer. Kanas (1998) investigates volatility spillovers among three European stock exchanges namely, London, Frankfurt and Paris, in univariate and bivariate EGARCH framework. They found that reciprocal spillovers exist between London and Paris, and Paris and Frankfurt, and unidirectional spillovers from London to Frankfurt. Almost all of these spillovers are found to be asymmetric and tend to increase after the crash. Koutmos (1996) uses a VAR-EGARCH model for France, Italy, Germany and UK stock markets and find significant asymmetric volatility spillovers, hence high integration in European financial markets. Similarly, Booth, Martikainen, and Tse (1997) provides evidence on volatility spillovers among Scandinavian stock markets, namely Norway, Swede, Denmark and Finland in an EGARCH framework. Their preliminary analysis indicates that there is no cointegration among the variables implying that price spillovers occur in the short run. They found significant asymmetric price and volatility spillovers. Koutmos and Booth (1995) examines the price and volatility spillovers among US, Japanese and British stock markets in a multivariate EGARCH model. They found significant asymmetric volatility spillovers from NY and London to Tokyo, from Tokyo and NY to London and from London and Tokyo and NY. Bad news in one market has a greater impact on the volatility of the next market to trade (to open).

Some studies used cointegration analysis to see the comovements among a set of stock markets. For example, Shamsuddin and Kim (2003) investigates the extent of stock market integration between Austria and two of its leading trade partners US and Japan. The analysis is carried out for both pre and post-Asian crises to see its effects. They take into account the interdependence between exchange rate and stock market in analysing stock market integration. Their analysis indicates that the country specific factors have become more important than the international factors in the post-crises period. Voronkova (2004) investigates the extent of market integration between Central European markets (Czech R., Hungary and Poland) and developed markets of Europe (Britain, France and Germany) and US using cointegration analysis. This study employs a cointegration framework with structural breaks. Using cointegration with weekly data, Baharumshah, Sarmidi, and Tan (2003) examines the dynamic interrelationship among the major stock markets and in the four Asian markets (Malaysia, Thailand, Taiwan and South Korea), both in the short run and in the long run. Their results suggest that all the Asian markets are closely linked with each other and with the world capital markets, namely those of the US and Japan, over the post-liberalization era. Using a vector autoregressive analysis, Assaf (2003) investigates the dynamic interactions among stock market returns from six Gulf Cooperation Council (GCC) countries (Bahrain, Kuwait, Oman, Qatar, Saudi Arabia and United Arab Emirates) and substantial evidence of interdependence and feedback effects.

3 Data and Preliminary Analysis

We have used daily data spanning the period 26.Nov.1990-20.Aug.2004 for all equity indices used in the study, namely Istanbul Stock Exchange 100 Firms Index (ISE100), German DAX, CAC40 (Paris), FTSE100 (London) and Standard and Poors 500 (S&P500).[3] The data set contains 3147 observations over a period of about 14 years. Following the common practice in the empirical literature all indices are defined in terms of local currency. We first discuss the summary statistics of the sample and then analyze the series in a GARCH(1,1) framework.

3.1 Summary Statistics

Figures 1 and 2 plot the index level and returns for our sample. The index values share common deterministic trends such as the upward trend in 1990s led by the so-called IT bubble. Another feature of this picture is that ISE100 experience steeper upward and downward movements than developed markets in the sample such as the marked increase around 1999-2000. Table 1 provides summary statistics, namely sample means, minimums, maximums, medians, standard deviations, skewness, kurtosis and the Jarque-Bera tests and p-values, for the return series generated using $100 * (log(r_t) - log(r_{t-1}))$. While each of the series seem to display "stylized" facts common to many financial assets such as nonnormality in the form of fat tails, there are noticable differences between ISE100 and developed equity markets. First, nominal return on ISE100 index is

[3] The data for ISE100 was obtained from Istanbul Stock Exchange. The rest of the data was obtained from www.yahoo.com/finance and is freely available.

larger than nominal returns on DAX, CAC40, FTSE100 and SP500. The ISE100 returns fluctuate between -20.33% and 26.44% with unconditional mean 0.1969. Second, the unconditional standard deviation of ISE100 index is larger than the rest indicating higher volatility. Third, as indicated by skewness statistics, ISE100 and FTSE100 returns seem to be positively skewed while DAX, CAC40 and SP500 returns are negatively skewed. Leptokurtic behavior is apparent in all series with more pronounced fat tails in ISE100 returns. Also, the Jarque-Bera statistics indicate that the hypothesis of normality is rejected decisively for all return series. The nonnormality is apparent from the fatter tails from the normal distribution and mild negative and positive skewness.

Table 1: Summary Statistics of Returns

Statistic	ISE100	DAX	CAC40	FTSE100	S&P500
Mean	0.1969	0.0301	0.0251	0.0225	0.0393
Min	−20.3303	−9.6832	−8.7750	−5.5888	−7.1139
Max	26.5501	8.0050	7.0023	5.9038	5.5732
Median	0.1787	0.0638	0.0180	0.0175	0.0346
Std. Dev.	3.3113	1.5486	1.4464	1.1107	1.0763
Skewness	0.0701	−0.1626	−0.0410	0.0372	−0.0495
Kurtosis	7.8046	6.7390	5.7419	5.6996	6.1819
Jarque-Bera Test	3026.5	1845.2	985.71	955.42	1327.6
p-value	(< 0.0001)	(< 0.0001)	(< 0.0001)	(< 0.0001)	(< 0.0001)

Notes: p-values are in parentheses. Jarque-Bera normality test is designed to detect departures from the null hypothesis of normality and defined as $T\left[\frac{S^2}{6}+\frac{(K-3)^2}{24}\right]$, where T, S and K denote sample size, skewness and kurtosis, respectively. It has an asymptotic χ^2 distribution with 2 degrees of freedom.

Another stylized fact about financial asset returns is the volatility clustering. To see if there is persistence in volatility in our sample we plot sample autocorrelation functions in Figures 3 for returns and 4 for squared returns. The sample ACF indicate that the non-filtered return series have mild autocorrelation. The ACF for squared returns and Ljung-Box Q statistics (not reported), on the other hand, indicate clearly that there exist significant volatility clustering in all series. This is important because the econometric model will be based on the interdependence of the markets in the form of second moments by modeling the time varying variance-covariance matrix for the sample.

Table 2 shows the unconditional correlation coefficients for our sample. The ISE100

Table 2: Unconditional Correlations

	ISE100	DAX	CAC40	FTSE100	S&P500
ISE100	1	0.1725	0.1683	0.1535	0.0928
DAX	0.1725	1	0.7667	0.6860	0.5071
CAC40	0.1683	0.7667	1	0.7710	0.4594
FTSE100	0.1535	0.6860	0.7710	1	0.4461
S&P500	0.0928	0.5071	0.4594	0.4461	1

index is weakly correlated to developed markets of Europe and USA. The European markets are highly correlated with each other whereas their correlation with SP500 is weaker, with the highest correlation between DAX and SP500.

3.2 Properties of the Data under Full Segmentation

Before carrying out the estimation of the multivariate GARCH specification it may prove to be useful to compare the properties of the series in the sample in a univariate GARCH(1,1) framework. These estimates would be valid if there were no volatility and price spillovers in the sample. Since the GARCH(1,1) model is well-known we do not present its theoretical properties.

Table 3: Univariate GARCH(1,1) Estimation Results

	μ	κ	α	β
ISE100	0.1698(0.0494)	0.2077(0.0332)	0.0885(0.0065)	0.8963(0.0071)
DAX	0.0539(0.0225)	0.0367(0.0050)	0.0726(0.0065)	0.9105(0.0082)
CAC40	0.0414(1.8466)	0.4375(0.0075)	0.0600(0.0070)	0.9175(0.0099)
FTSE100	0.0413(0.0159)	0.0124(0.0029)	0.0668(0.0071)	0.9229(0.0080)
S&P500	0.0545(0.0149)	0.0049(0.0012)	0.0507(0.0048)	0.9458(0.0050)

Notes: The model is $r_t = \mu + \epsilon_t$, $\sigma_t^2 = \kappa + \alpha\epsilon_{t-1}^2 + \beta\sigma_{t-1}^2$. Standard errors are in parentheses.

Table 3 shows the results of univariate GARCH(1,1) estimation. All parameters are significant at 5% level. All series exhibit significant volatility persistence as indicated by large GARCH parameter estimates. ISE100 returns exhibit larger ARCH but smaller GARCH effects than the developed markets. This implies that a typical investor in Istanbul Stock Exchange allocates more weight to the observed volatility in the previous period, whereas a typical investor in the developed markets seem to place more weight on the conditional variance forecast in the previous period. Figure 5 plot the conditional standard deviations obtained from GARCH(1,1) models. All series exhibit volatility clustering as would be expected. Paris, Frankfurt, London and New York Stock Exchanges experienced a relatively calm period between 1993-1998 and, especially after 1998, the shape of the clustering is similar to each other. Istanbul Stock Exchange experienced significant fluctuations in conditional volatility as compared to the rest of the sample. The effects of 1994 currency crisis on the ISE is clearly visible followed by less significant increase in uncertainty.

4 Econometric Model

In this study, we employ a multivariate generalized autoregressive conditional heteroskedasticity (MGARCH or MVGARCH) model to capture the dynamic relationship between exchange rates and stock prices. A multivariate generalized ARCH framework allows us to estimate time-varying conditional covariance matrices much similar to estimating time-varying variances in a univariate framework. There are several ways to generalize univariate GARCH processes into multivariate context including constant correlation model (Bollerslev 1990), vec representation (Bollerslev, Engle, and Wooldridge 1988), BEKK (Baba, Engle, Kraft and Kroner) representation described in (Engle and Kroner 1995), and factor GARCH model (Engle, Ng, and Rothschild 1990), among others (see Ref. (Kroner and Ng 1998) for an evaluation of existing multivariate GARCH models). We use dynamic conditional correlation multivariate GARCH (DCC-MVGARCH) developed by Engle (2002) and Engle and Sheppard (2001). The major advantage of this model is that it enables one to estimate conditional covariance matrices for large number of assets in a two-step procedure with smaller number of parameters than most of the multivariate GARCH specifications. The model assumes that $k \times 1$ return vector r_t is multivariate normal,

$$r_t = \mu_t + \epsilon_t,$$

$$\epsilon_t | \Omega_{t-1} \sim N(0, H_t),$$

and,

$$H_t \equiv D_t R_t D_t,$$

where D_t is the $k \times k$ diagonal matrix of time varying standard deviations from univariate GARCH models with $\sqrt{h_{it}}$ on the ith diagonal, and R_t is the time varying correlation matrix. μ_t is the conditional expectation of asset returns given the information set Ω_{t-1}.

In most cases, the appropriate filtration of the data is an empirical problem. The time varying conditional standard deviations (elements of D_t) are obtainable from univariate GARCH models:

$$h_{it} = \omega_i + \sum_{p=1}^{P_i} \alpha_{ip}\epsilon_{it-p}^2 + \sum_{q=1}^{Q_i} \beta_{iq} h_{it-p},$$

for $i = 1, 2, ..., k$. The usual nonnegativity and stationarity conditions can be imposed, i.e.,

$$\sum_{p=1}^{P_i} \alpha_{ip} + \sum_{q=1}^{Q_i} \beta_{iq} < 1.$$

Engle and Sheppard (2001) writes the standardized residuals as $\eta_t = D_t^{-1}\epsilon_t$ where $\eta_t \sim N(0, R_t)$ which is then used in the proposed dynamic correlation structure as

$$Q_t = \left(1 - \sum_{m=1}^{M} \alpha_m - \sum_{n=1}^{N} \beta_n\right) \bar{Q} + \sum_{m=1}^{M} \alpha_m(\eta_{t-m}\eta'_{t-m}) + \sum_{n=1}^{N} \beta_n Q_{t-n},$$

and

$$R_t = \tilde{Q}_t^{-1} Q_t \tilde{Q}_t^{-1},$$

where $\bar{Q}$ is the unconditional covariance of the standardized residuals resulting from first stage estimation and $\tilde{Q}_t$ is a diagonal matrix containing the square root of the diagonal entries of Q_t. Engle (2002) shows that the likelihood function can be written as

$$L = -\frac{1}{2}\sum_{t=1}^{T} \left(klog(2\pi) + 2log|D_t| + log(|R_t|) + \eta'_t R_t^{-1}\eta_t\right).$$

The DCC estimation involves two stages: in the first stage the univariate GARCH models are estimated for each residual series. In the second stage, residuals are normalized by their standard deviation to estimate the dynamic correlation structure above. Engle and Sheppard (2001) shows that the parameters of the DCC model are consistent and asymptotically normal. The details on theoretical and empirical properties of the DCC-MVGARCH model can be found in Engle (2002) and Engle and Sheppard (2001).

5 Estimation Results

5.1 The Order of Statistical Integration

Before carrying out the multivariate GARCH procedure it is of interest to see the nature of the comovement of the series under investigation. To this end, we first tested for the existence of a unit root in the stock index values (in natural logs). We carried out usual ADF tests including both constant and constant plus time trend in the test equations separately. We chose the lag length for the differenced series using the Schwarz information criterion. The test results[4], which are robust to the choice of the testing procedure, indicate the existence of a unit root in all index series.

Table 4: Cointegration Tests

H_0:	Eigenvalue	Trace Statistic	5% CV	1% CV	Max-Eigen Statistic	5% CV	1% CV
			Full Sample				
$r = 0$	0.0114	73.9517*	68.52	76.07	36.2811*	33.46	38.77
$r \leq 1$	0.0064	37.6707	47.21	54.46	20.4927	27.07	32.24
$r \leq 2$	0.0036	17.1779	29.68	35.65	11.4559	20.97	25.52
$r \leq 3$	0.0015	5.7220	15.41	20.04	4.7259	14.07	18.63
$r \leq 4$	0.0003	0.9960	3.76	6.65	0.9961	3.76	6.65
			Sub-Sample 1				
$r = 0$	0.0214	61.9681	68.52	76.07	25.1207	33.46	38.77
$r \leq 1$	0.0170	36.8474	47.21	54.46	19.9099	27.07	32.24
$r \leq 2$	0.0114	16.9374	29.68	35.65	13.3802	20.97	25.52
$r \leq 3$	0.0030	3.5571	15.41	20.04	3.5533	14.07	18.63
$r \leq 4$	3.25E-06	0.0037	3.76	6.65	0.0037	3.76	6.65
			Sub-Sample 2				
$r = 0$	0.0224	83.3764**	68.52	76.07	45.0484**	33.46	38.77
$r \leq 1$	0.0106	38.3280	47.21	54.46	21.3438	27.07	32.24
$r \leq 2$	0.0054	16.9841	29.68	35.65	10.8239	20.97	25.52
$r \leq 3$	0.0026	6.1601	15.41	20.04	5.2883	14.07	18.63
$r \leq 4$	0.0004	0.8718	3.76	6.65	0.8718	3.76	6.65

Notes: r is the number of cointegration equations. * and ** denote significance at 5% and 1% levels, respectively.

Having established that the series are all integrated of order one, we now proceed to testing for cointegration. The purpose is to model the long and short run interactions among stock indices. If the series are cointegrated then a vector error correction (VEC) model will be estimated. Otherwise, an unrestricted vector autoregression (VAR) would be appropriate. We summarized the results of Johansen cointegration tests in Table 4. All test equations contain one lag for the differenced endogenous variables chosen by Schwarz and Hannan-Quin information criteria. We include linear deterministic trend in the test equation. For the full sample, the trace and maximum eigenvalue test results indicate that the hypothesis of at most one cointegration relationship among series cannot be rejected at 5% level. However, at 1% significance level tests result point to no cointegration for the full sample. We carried out the cointegration test for the two

[4]Not reported but available upon request.

sub-samples: before the customs union agreement covering 26.Nov.1990-31.12.1995 and the period after the agreement covering 1.1.1996-20.Aug.2004. The results for the first sub-sample indicate that there is no cointegration relationship between ISE and the developed markets. We can safely assume that Turkish equity market did not have a long-run relationship with the EU and global markets before 1996. The last part of Table 4 show the results for the post-customs union agreement with EU. We see that the null hypothesis of no cointegration is rejected in favor of one long-run cointegration relationship at 1% level. Thus, an ECM model for the full sample and sub-sample two and a VAR in log-differences (returns) would be appropriate filtering procedures for the series.

5.2 DCC(1,1)-MVGARCH Results

We first carry out tests for constant correlation developed by Engle and Sheppard (2001). We test for the null hypothesis of constant correlation against an alternative of dynamic correlation. More specifically,

$$H_0 : R_t = \bar{R}, \quad t = 1, ..., N,$$

against,

$$H_1 : vech(R_t) = vech(\bar{R}) + \gamma_1 vech(R_{t-1}) + \gamma_2 vech(R_{t-2}) + ... + \gamma_p vech(R_{t-p}).$$

This test is carried out by running artificial regression of the outer products of the standardized residuals from univariate GARCH processes which are jointly standardized by the symmetric square root decomposition of $\bar{R}$ on a constant and lagged outer products. Letting

$$Y_t = vech^u \left[(\bar{R}^{-1} D_t^{-1} \epsilon_t)(\bar{R}^{-1} D_t^{-1} \epsilon_t)' - I_k, \right]$$

where $\bar{R}^{-1} D_t^{-1} \epsilon_t$ is $k \times 1$ vector of jointly standardized residuals which, under the null hypothesis, will be iid with a variance covariance matrix given by $k \times k$ identity matrix, I_k, and $vech^u$ is the half-vectorization operator that stacks only the elements above the main diagonal in a column vector. Then, the artificial regression is a pth order vector autoregression:

$$Y_t = C + A_1 Y_{t-1} + A_2 Y_{t-2} + ... + A_p Y_{t-p} + error.$$

Under the null hypothesis of constant correlations, all of the parameters of the lagged terms, A_1 through A_p, should be zero. This can easily be tested by forming the Y_t vectors as described above and the explanatory variables matrix by $X = [Y_{t-1}, Y_{t-2}, ..., Y_{t-p}]$. Then, the test statistic is $\frac{\hat{\theta} X' X \hat{\theta}'}{\hat{\sigma}^2}$, where $\hat{\theta}$ is the vector of VAR parameter estimates, and it is asymptotically χ^2_{p+1}.

In the following subsections, we discuss the estimation results for the return equations and apply the DCC test and estimate the DCC-MVGARCH model to the residuals from appropriate conditional mean equations.

5.2.1 Full Sample: 26.Nov.1990-20.Aug.2004

Table 5: DCC Test Results

Sample	Test Statistic	p-value
Full sample	12.9688	0.0015
Sub-sample 1	0.3509	0.8391
Sub-sample 2	12.7947	0.0017

The results from the previous section indicated that an ECM model would be appropriate for the whole sample. An ECM model incorporates long-run relationship among the variables while allowing for short run deviations captured by the error correction term. We have fit a first order ECM using the log-index levels and carried out the DCC(1,1)-MVGARCH on the residuals from the estimated VEC model.

The results of the VEC estimation for the full sample are presented in the first part of Table 6. There are three noticeable features: first, lagged stock returns are not statistically significant in none of the stock exchanges except ISE and DAX. This may be regarded as weak form of market inefficiency for the ISE and Frankfurt stock exchange as compared to the rest of the markets. Second, Istanbul Stock Exchange returns are significantly and positively related to own lag and lagged S&P500 index returns. For the sample spanning 1990-2004 none of the European Union equity markets has significant influence on ISE. Third, the EU equity markets seem to have experienced significant price spillovers both among themselves and US. Returns on DAX is significantly and negatively related to lagged own returns, and positively related to returns on US market portfolio. Return on CAC40 is mostly influenced by lagged returns on DAX, FTSE100 and SP500. Similarly, FTSE100 return is negatively related to lagged DAX returns and positively related to lagged SP500 returns. However, SP500 is not influenced by any stock markets in the system as indicated by the insignificant F-statistic. The US equity markets seem to be the sole disseminator of the information for the global markets.

Table 6: Estimation Results for the Conditional Mean Equation

	D(LISE100)	D(LDAX)	D(LCAC40)	D(LFTSE100)	D(LSP500)
		Full Sample: Vector Error Correction Model			
ECT	0.0003	0.0004**	0.0001	-8.46E-05	0.0001
D(LISE100(-1))	0.0681**	-0.0086	-0.0018	-0.0003	-0.0049
D(LDAX(-1))	-0.0271	-0.2222**	-0.0524*	-0.0508**	-0.0181
D(LCAC40(-1))	-0.1433	0.1363**	-0.0272	-0.0312	0.0528*
D(LFTSE100(-1))	0.1216	-0.0484	-0.0924*	-0.0523	-0.0229
D(LSP500(-1))	0.3982**	0.3748**	0.4066**	0.3509**	-0.0266
Constant	0.0017**	0.0002	0.0001	0.0001	0.0004*
R^2	0.0205	0.0628	0.0672	0.0853	0.0031
F-statistic	10.97**	35.06**	37.67**	48.82**	1.63
		Sub-Sample 1: Vector Auto Regression Model			
DLISE100(-1)	0.1419**	-0.0157	-0.0005	0.0051	-0.0017
DLDAX(-1)	0.0242	-0.1618**	-0.1289**	-0.0328	-0.0288
DLCAC40(-1)	-0.1226	0.1926**	0.0259	-0.0505	0.0481*
DLFTSE100(-1)	0.0702	0.0047	-0.0173	0.0294	-0.0455
DLSP500(-1)	0.1033	0.3719**	0.3419**	0.3150**	0.0301
Constant	0.1654	0.0255	-0.0007	0.0277	0.0582**
R^2	0.0212	0.1036	0.0389	0.0602	0.0049
F-statistic	5.01**	26.67**	9.35**	14.78**	1.14
		Sub-Sample 2: Vector Error Correction Model			
ECT	0.0007	0.0019*	0.0003	-0.0011*	0.0019**
D(LISE100(-1))	0.0266	-0.0033	-0.0019	-0.0018	-0.0087
D(LDAX(-1))	-0.0710	-0.2233**	-0.0099	-0.0533	-0.0119
D(LCAC40(-1))	-0.1305	0.0949	-0.0644	-0.0198	0.0564
D(LFTSE100(-1))	0.1686	-0.0489	-0.1170*	-0.0785*	-0.0279
D(LSP500(-1))	0.4623**	0.3910**	0.4141**	0.3565**	-0.0333
Constant	0.0018*	0.0001	0.0002	1.05E-05	0.0003
R^2	0.0267	0.0568	0.0794	0.0955	0.0080
F-statistic	9.0488**	19.89**	28.45**	34.85**	2.67*

This was also confirmed by the pairwise Granger-causality tests (not reported). These tests indicated that the returns on ISE100 are only influenced by the S&P500 and the EU equity markets can be regarded as exogenous to the system. As would be expected, the ISE is exogenous to the EU and US markets while all the EU markets except the Paris stock exchange are exogenous to the US markets.

We have applied the DCC constant correlations test to the residuals from the VEC model for the whole sample. The results are presented in Table 5. For the full sample the DCC test statistic is calculated as 12.97 with probability 0.0015. Thus, we decisively reject the null of constant correlations for the whole sample.[5] Since the DCC procedure essentially fits separate univariate GARCH processes to the individual series, we do not report the estimation results for conditional variance equation (see Table 3 and Figure 5 for univariate GARCH results and conditional volatilities).[6] The dynamic correlation coefficient structure is estimated as follows:

$$Q_t = 0.0055\bar{Q} + 0.0127(\hat{\eta}_{t-1}\hat{\eta}'_{t-1}) + 0.9817Q_{t-1}.$$

As discussed earlier, $\hat{\eta} = \hat{D}_t^{-1}\hat{\epsilon}_{t-1}$ is the standardized residuals using the conditional standard deviations from the univariate GARCH processes and $\bar{Q}$ is the unconditional covariance of the standardized residuals resulting from the first stage estimation (see Section 3). All parameters are significant at 1% level. The dynamic correlation is a weighted sum of unconditional correlation coefficients, the news term and the dynamic correlation forecast from the previous period. The DCC results indicate that investors typically put more weight on the conditional correlations forecast from the previous period. The news from the previous period is positively related to the dynamic correlation forecast in time t. To see the relationship between ISE and world markets in terms of second moments, we plot dynamic correlations and conditional covariances in Figure 6 and 7, respectively.[7] The time varying correlations fluctuate significantly within the full sample ranging from -20% to about 50%. Although there is no clear trends we see that for all four pairs considered, the correlation coefficient fluctuates around zero up until around 1996-1997 and then crosses its long-run value. We also see that the conditional covariance fluctuates rather stably around zero until 1996-1997. A similar pattern may be observed from the plot of dynamic correlations among world equity markets in Figure 8. For example, the dynamic correlation between German and French equity markets fluctuate around 60% until 1996-1997 and then increases steeply and settles around its long-run value of 77%. A similar pattern is seen from the rest of the sub-plots in Figure 8. This is perhaps due the Asian and Russian financial crises at the times that led to increased comovement among world indices. Another feature of the dynamic correlations is that, as opposed ISE, the developed equity market indices are always move in the same direction.

[5]We chose the lag order as one for the artificial VAR regression in the test procedure.

[6]There are 17 parameters in the model, three GARCH(1,1) parameters for each of five series plus two dynamic correlation parameters.

[7]Since the conditional volatility estimates are essentially the same we did not plot them. See Figure 5.

5.2.2 Sub-Sample 1: 26.Nov.1990-31.12.1995

This period covers post-financial liberalization (about 14 months after August 1989) but pre-CU agreement portion of the sample. This sub-sample contains 1160 daily observations. Our purpose is to compare the characteristics of the two samples in terms of financial integratedness of stock markets. As mentioned earlier, we found no cointegration relationship among the variables in the system for this sample. Therefore, we fit an unrestricted VAR(1) model whose lag order is chosen by Schwarz' and Hannan-Quin information criteria. The results for this sub-period are summarized in the second part of Table 6. The ISE100 return is significantly and positively related only to own lagged return. The ISE seemed to be relatively segmented for this period as the parameters on the lagged EU and US market returns are all insignificant. The results of the DCC constant correlations test also indicate that correlation coefficient was stable during this period. The DCC test statistics is 0.3509 with probability 0.8391 (see Table 5). Hence, we can safely assume that the correlation coefficients between ISE and EU markets were constant over the period before 1996.

$$\begin{bmatrix} & ISE100 & DAX & CAC40 & FTSE100 & SP500 \\ ISE100 & 1 & 0.0770 & 0.0627 & 0.0455 & 0.0426 \\ DAX & & 1 & 0.5768 & 0.4453 & 0.2519 \\ CAC40 & & & 1 & 0.6289 & 0.3248 \\ FTSE100 & & & & 1 & 0.3519 \\ SP500 & & & & & 1 \end{bmatrix}$$

The unconditional correlation matrix based on the residuals from the estimated VAR system is shown above. ISE seems to have very low correlations with the EU markets and the global market. The correlation coefficient between ISE100 and German DAX returns is 7.7% which is the highest in this sub-sample. The lowest correlation coefficient is between SP500 and ISE100, 4.26%. In fact, as can be seen from Figure 7, the conditional covariances between ISE and world equity markets were relatively stable around zero for this period. Overall, it seems that the Istanbul market has been segmented for this subperiod in terms of both price and volatility spillovers. If we take the time varying conditional covariances and dynamic conditional correlations as our measure of financial market integration, then we may conclude that the Istanbul stock market has been very weakly integrated with the developed markets in EU and USA.

5.2.3 Sub-Sample 2: 1.1.1996-20.Aug.2004

For this sub-period, German, British and US equity markets respond to short run deviations from the cointegrating relationship as indicated by the significant parameter estimates for the error correction term (ECT). The ISE100 return does not respond to own lagged return for this sub-period, but significantly influenced by the information contained in the lagged return on S&P500. The DAX return is negatively related to own lagged return and positively related to S&P500 return. The CAC40 return is influenced by the lagged FTSE100 and S&P500 returns. The return on British market portfolio only responds to own lagged return and S&P500 return. However, the S&P500 return is influenced by none of the returns in the sample and only responds to the short run deviations from the cointegrating relationship. To conclude, the Istanbul Stock Exchange has not experienced price spillovers from the EU equity markets in the post customs union agreement period. We only see that there exists an improvement in terms of weak-form market efficiency as the ISE return has not respond to own lagged return but only to lagged S&P500 returns.

The DCC test is calculated as 12.7947 with p-value 0.0017 (Table 5) which indicate that the correlation coefficients are dynamic for this sub-sample. Hence, we have fit a DCC-MVGARCH model whose results are given below:

$$Q_t = 0.0199\bar{Q} + 0.0261(\hat{\eta}_{t-1}\hat{\eta}'_{t-1}) + 0.9539Q_{t-1}.$$

The results indicate that market participants in ISE put relatively more weight on market news (captured by the term $\hat{\eta}_{t-1}\hat{\eta}'_{t-1}$) as compared to pre-customs union period. Also, the weight on the conditional correlation forecast from the previous period decreased from 0.9817 to 0.9539. We plot the dynamic correlations and conditional correlations between ISE and world equity markets in Figures 9 and 10, respectively. The correlations between ISE100 and German DAX indexes fluctuate around its unconditional value between about -14.2% and 51.2%. Similarly, the dynamic correlations between ISE100 and CAC40, and ISE100 and FTSE100 fluctuate considerably between -16.6% and 61,1%, and -25.5% and 47.3%, respectively. Also, ISE100 and SP500 correlations fluctuate between -41.9% and 48.1%. Closer inspection of dynamic correlations reveals that the negative values mostly correspond to the periods of hightened volatility in ISE, such as 1999 and 2000. We use the conditional covariances among stock indices, which reflect the degree of comovement among them, as the measure for the degree of market integration. In a more integrated market the covariance will be higher whereas in a segmented market the conditional variance will be more important (Bekaert and Harvey 1995). The plots of conditional covariances between ISE and world equity markets reflect that Istanbul stock market has been segmented from the world capital markets at times of increased market-specific risk while it has become more integrated at other times. Overall, the degree of integration between ISE and EU markets seem to be higher in the post-CU period, it changes considerably over the sample. Comparing the unconditional correlation coefficients for this sample with those from the pre-CU subsample, we see there is considerable increases: 16.3% between ISE100 and DAX as compared to 7.7%; 16.2% between ISE100 and CAC40 as compared to 6.27%; 12.87% between ISE100 and FTSE100 as compared to 4.5% and 11.2% between ISE100 and SP500 as compared to 4.2%.

6 Conclusion

This paper studied dynamic interactions among equity markets of Turkey, Germany, France, Britain and USA for the period covering 26. Nov.1990-20.Aug.2004. The empirical analysis is carried out for two sub-samples: before and after the customs-union agreement of Turkey with EU in order to reveal the affects of increased trade interactions on financial integration. We first tested for statistical integration among stock index values. The Istanbul stock exchange is found to be in a cointegration relationship for the whole sample and the post-CU period. The Johansen tests revealed that there is no cointegration in the pre-CU agreement period. Based on these test results, we then estimated an ECM for the full sample and the post-CU sub-sample and a VAR for the pre-CU sub-sample. The analyses indicate that there are significant price spillovers from USA to Turkey in the full sample and post-CU sub-sample. The price spillovers from European equity markets to Istanbul stock markets were small and insignificant in all samples considered.

This paper used conditional covariances and time-varying correlations as the measures of market integration. To this end, we estimated dynamic conditional correlations MVGARCH model of Engle (2002) to the residuals obtained from error correction and vector autoregression models. We found that the dynamic conditional correlations of Turkish stock market with developed stock markets fluctuate considerably in the whole sample. Interestingly, although the developed markets always move in the same direction, the conditional covariances of ISE take negative values at some time periods. The

ISE100 returns were found to have a weak association with the rest of the markets in the pre-customs-union agreement period. In fact, the DCC test results indicated that they are stable with unconditional values less than 8%. The DCC analysis for the post-CU sub-sample revealed that there is a shift in the unconditional value of the correlation coefficients. How much of this increase can be attributed to trade linkages and to involvement of foreign investors in ISE deserve the attention of future work. Still, ISE is found to be weakly integrated with the developed markets indicating that it possesses potential for the portfolio diversification needs of international investors.

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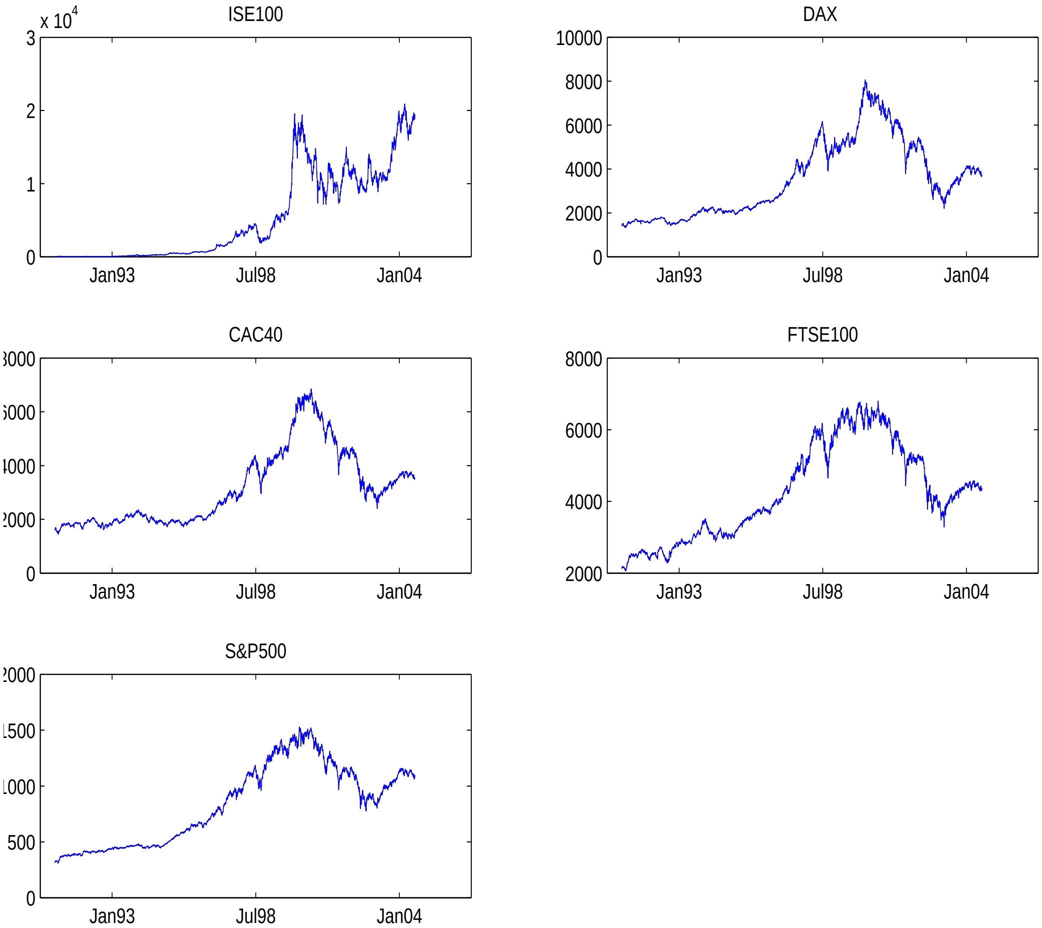

Figure 1: Plots of Stock Market Indices

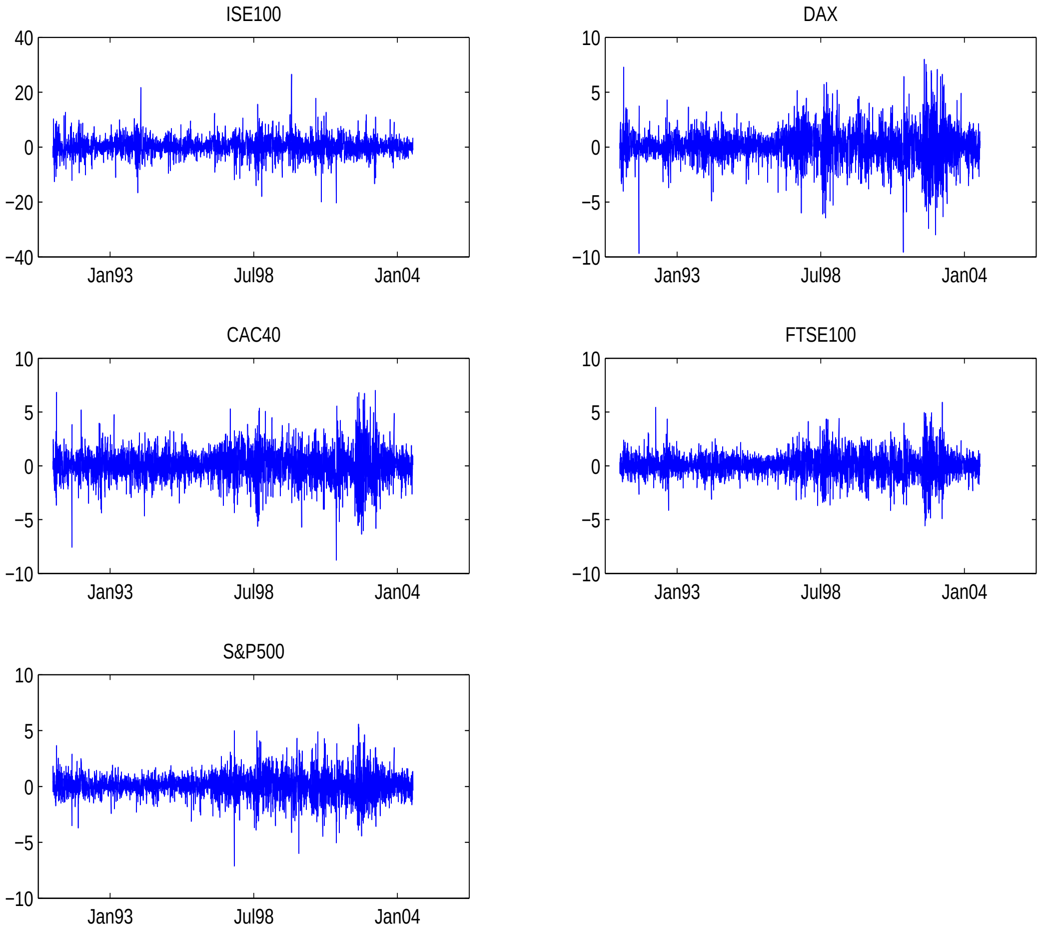

Figure 2: Plots of Stock Market Returns

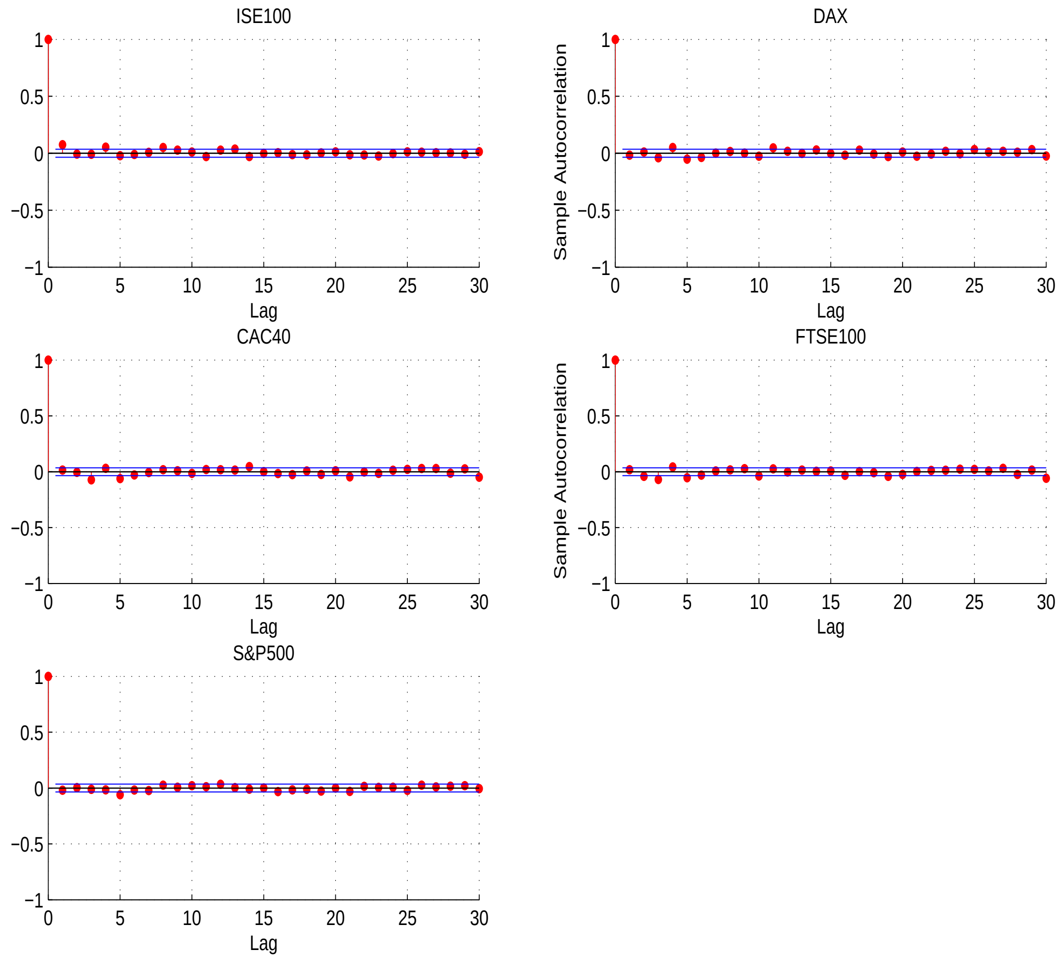

Figure 3: Sample Autocorrelation Functions for Returns

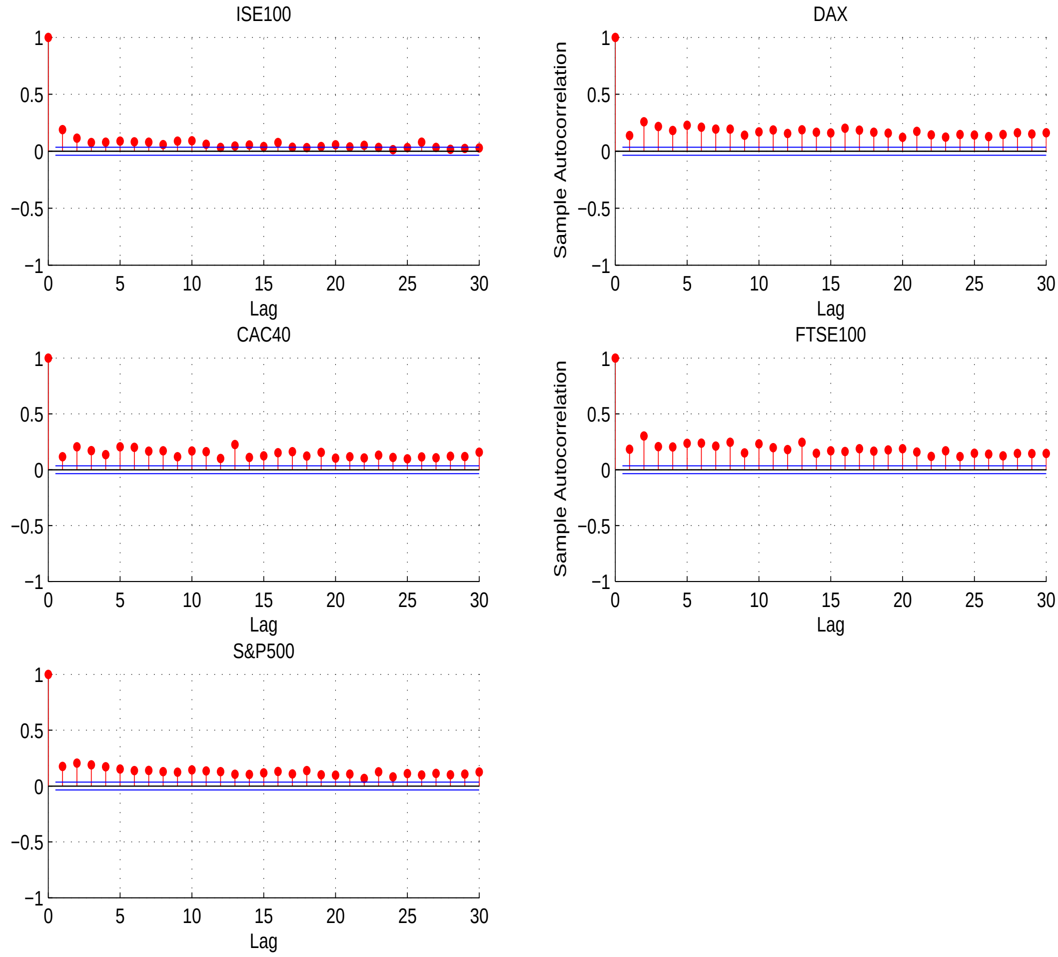

Figure 4: Sample Autocorrelation Functions for Squared Returns

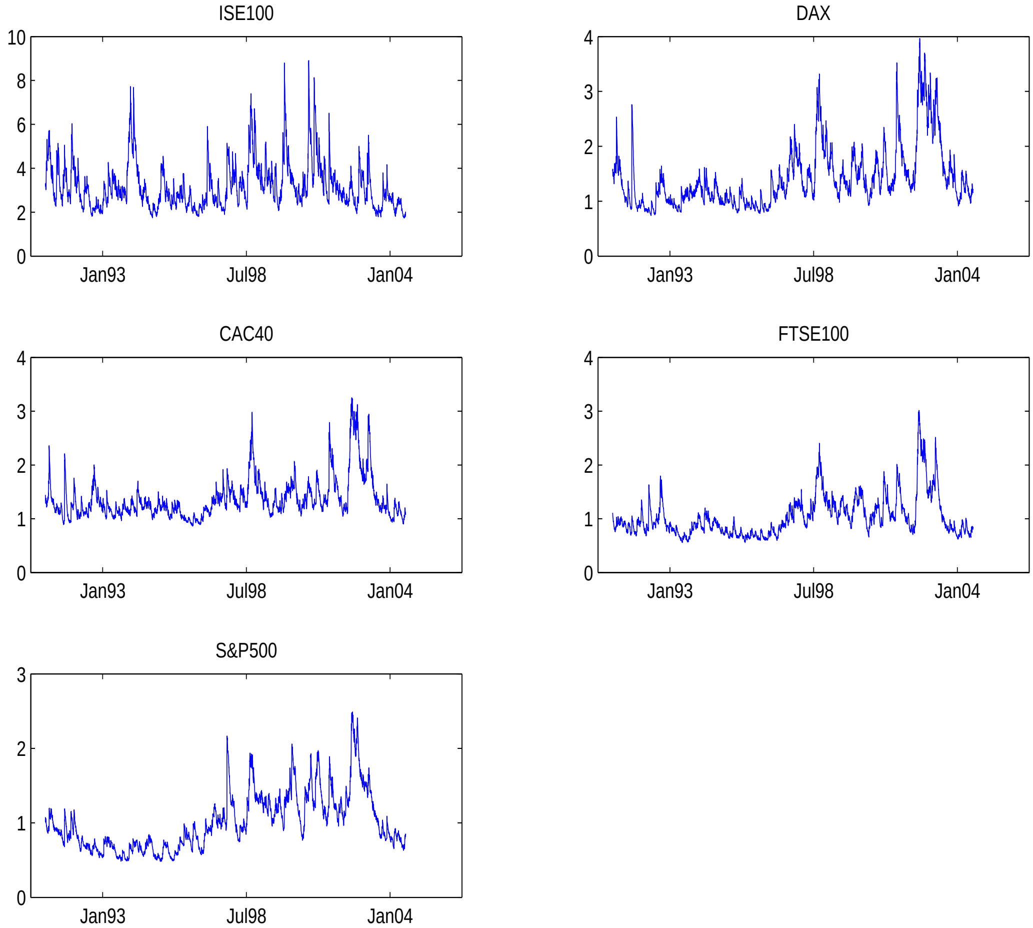

Figure 5: Conditional Standard Deviations from Univariate GARCH(1,1) Models

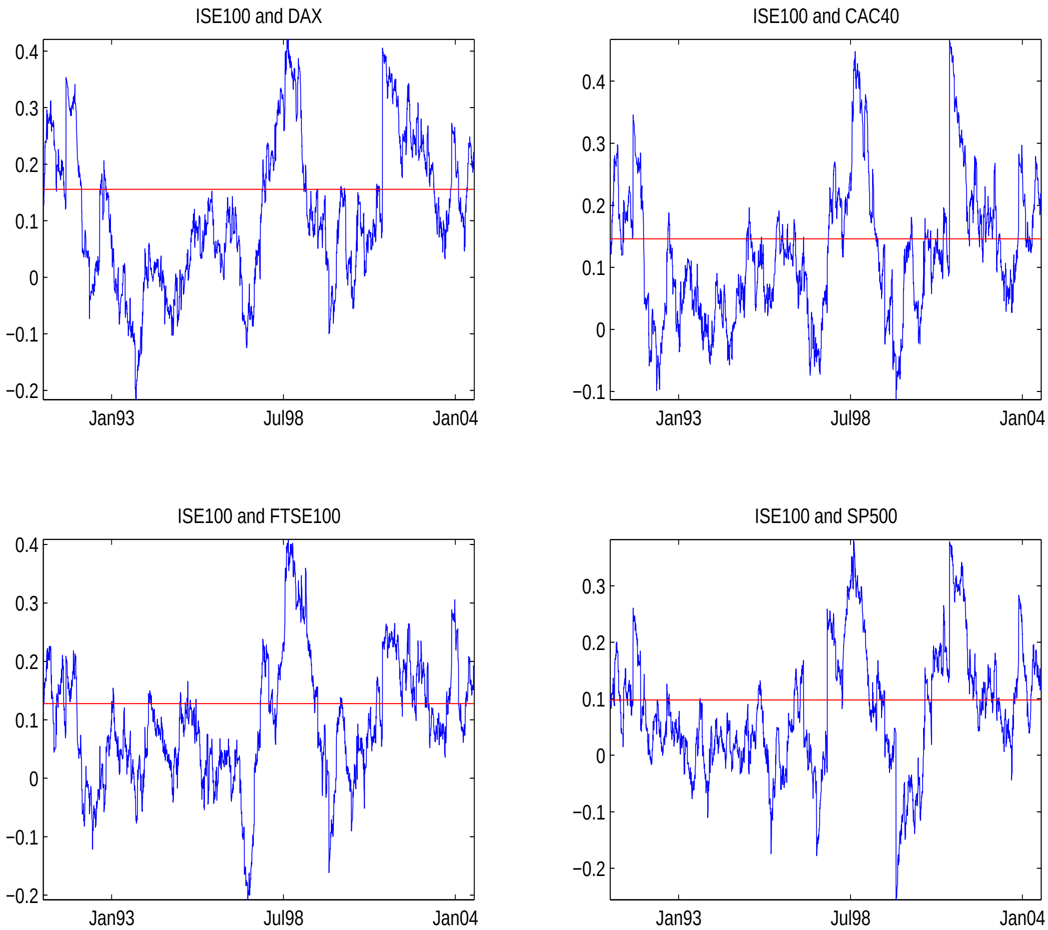

Figure 6: Dynamic Conditional Correlations between ISE and World Equity Markets – Full Sample

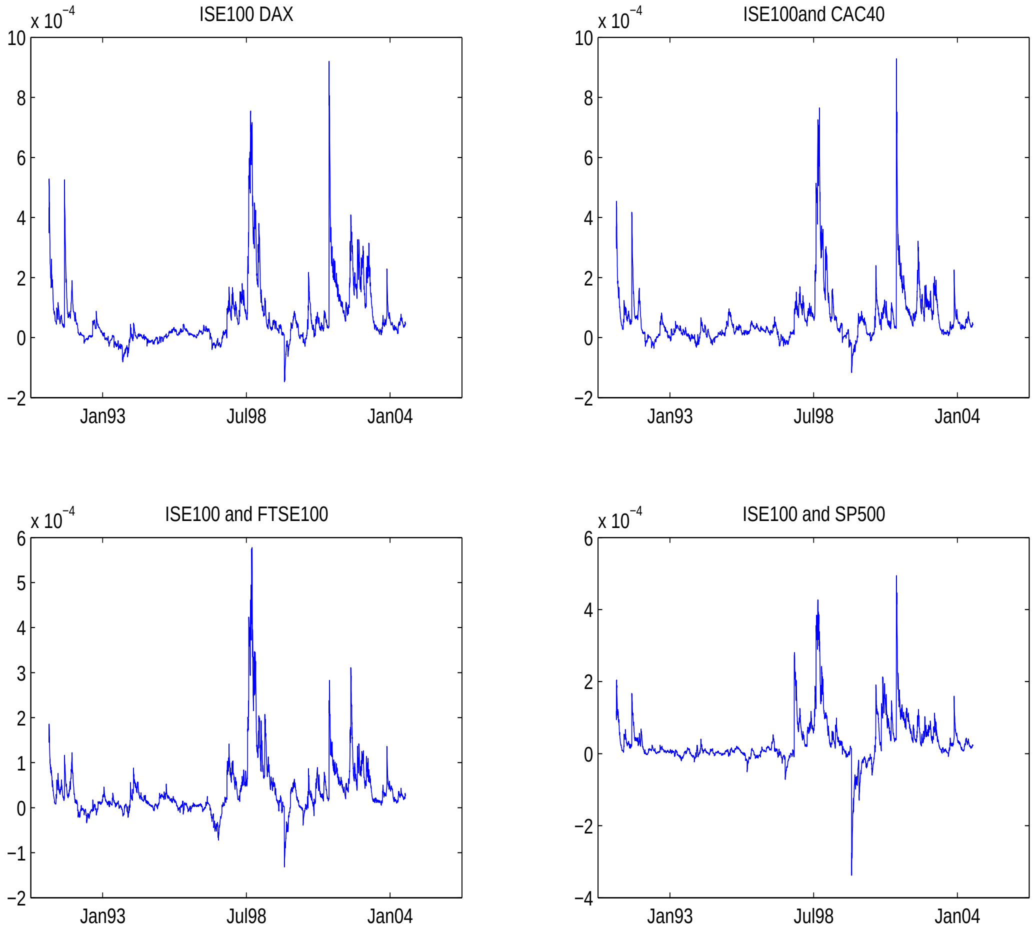

Figure 7: Conditional Covariance between ISE and World Equity Markets – Full Sample

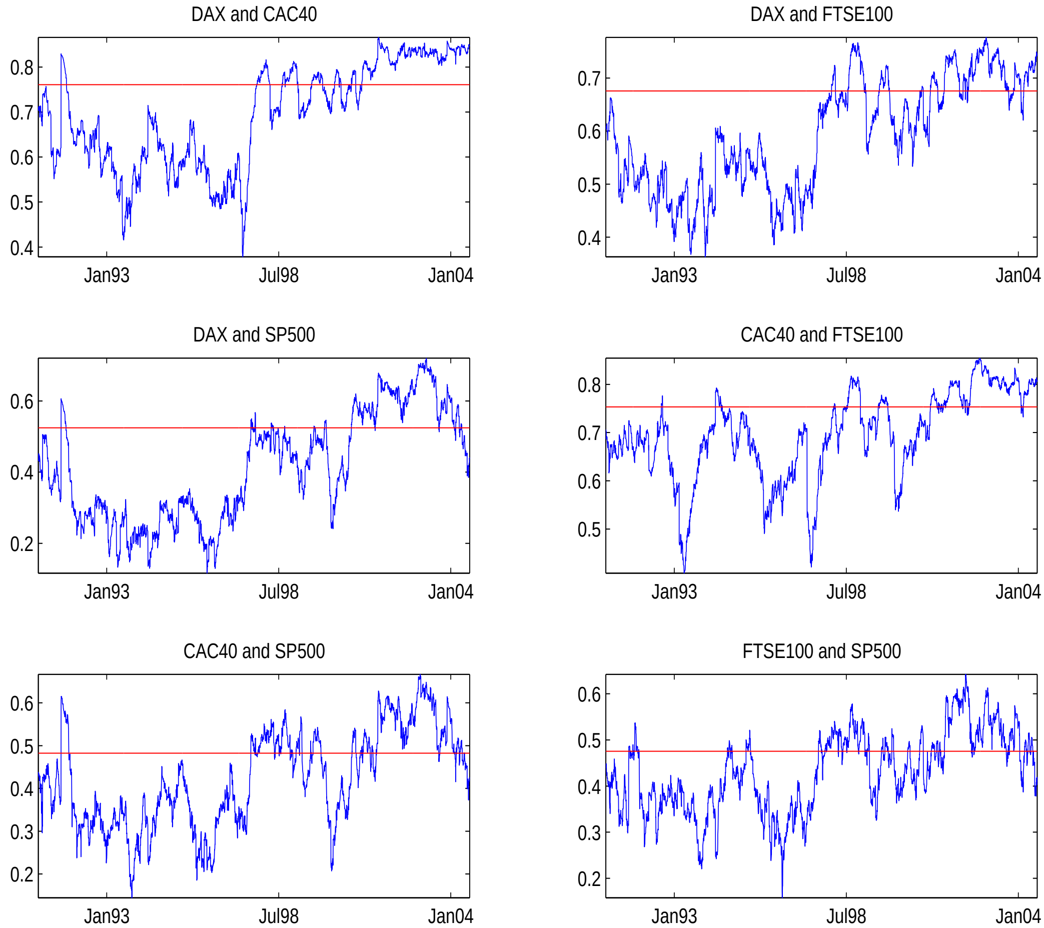

Figure 8: Dynamic Conditional Correlations among World Equity Markets – Full Sample

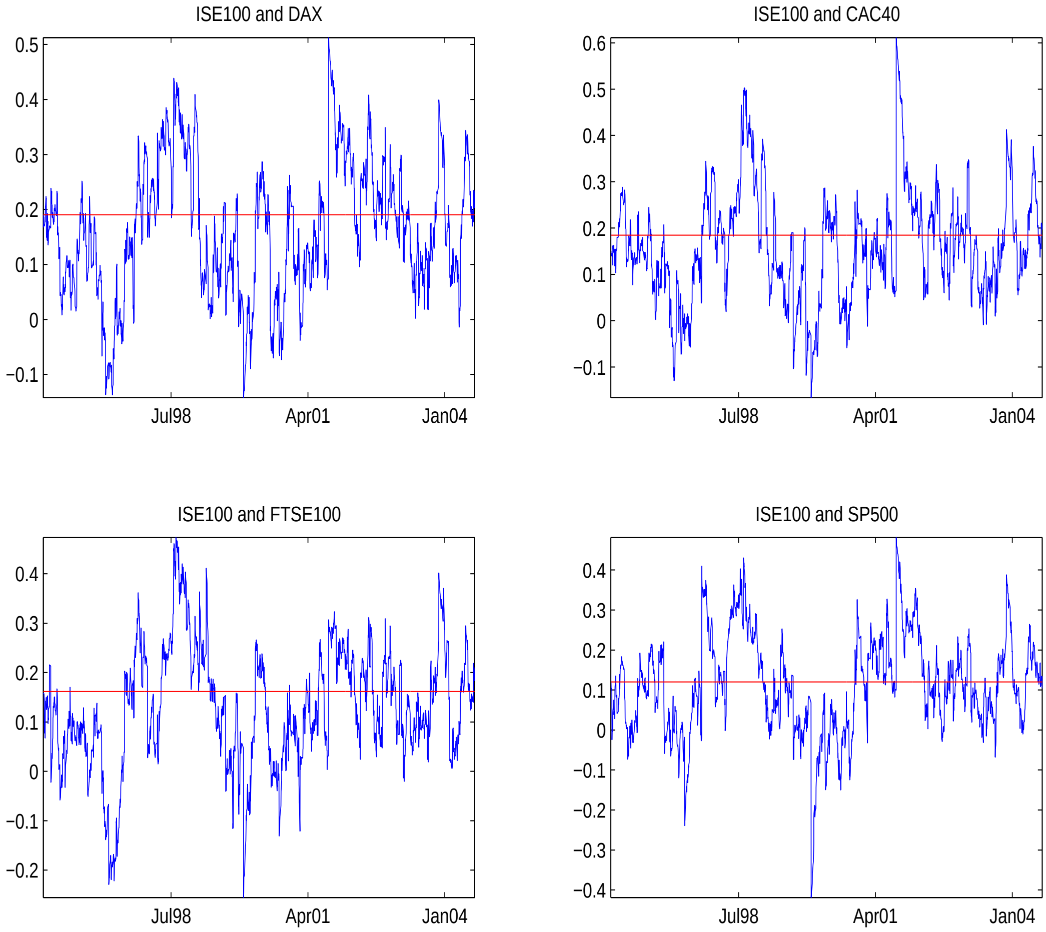

Figure 9: Dynamic Conditional Correlations between ISE and World Equity Markets – Sub Sample 2

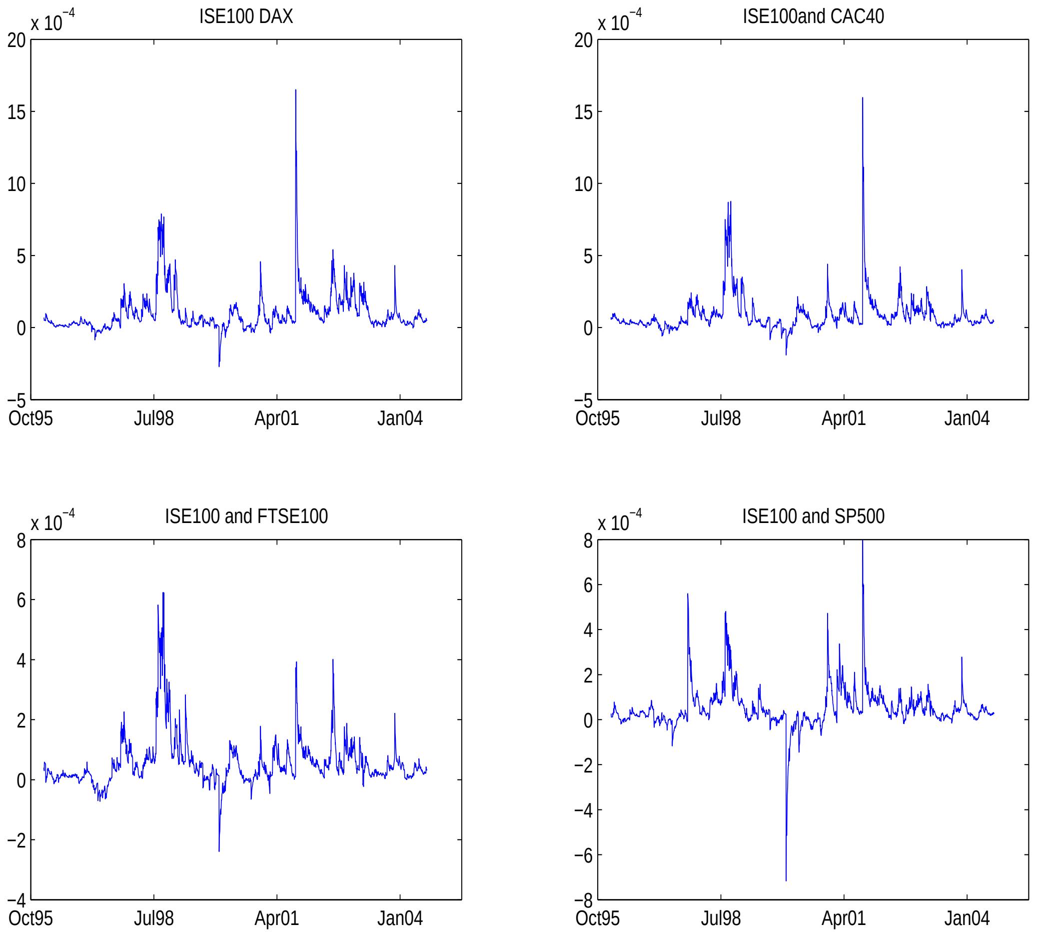

Figure 10: Conditional Covariance between ISE and World Equity Markets – Sub Sample 2