European Research Studies,
Volume XIII, Issue (3), 2010

Equity Interconnections in Major European Markets

Panayiotis Alexakis[1], Anna Vasila[2]

Abstract
This paper investigates equity interconnection by analyzing dynamic links and volatility spillover effects between selected stocks of high liquidity from the major regulated European equity markets. A bivariate GARCH-BEKK model is used to study this interaction. By applying the volatility transmission methodology to company level rather than stock indices, the paper deepens our understanding of integration dynamics. The results provide evidence of a high level of dependence between these stocks and, given their high contribution to daily transactions in each market, they also imply a high level of dependence between these markets. This level of interconnection affects both market participants and competent market authorities. However, according to this evidence, there remains room for stronger stock interconnection and market integration within the EU.
Keywords: *equity interconnection, European equity market, volatility spillover, GARCH-BEKK*

1. Introduction

European Union (EU) capital markets have been on the receiving end of a raft of measures aimed at establishing a unified regulatory framework for their operation. Starting with the Listing Admission Directive of 1979 and the "principal of home country control" for investment service companies (ISCs) in 1985, the Investment Services Directive [1] (ISD) in 1996 constituted a landmark in the context of the EU principles of mutual recognition, minimum harmonisation, single licence and single supervision, a special case of a "European passport" (L' Heveder, 1996, Tarnanidou, 2007). Equally important landmarks were the Financial Services Action Plan [2] (FSAP), which specified significant harmonisation measures for the period 1999-2005, coupled with the adoption of the "Lamfalussy process" at the end of 2001, which established a faster and more flexible procedure for EU equity market harmonisation [3]. New developments have emerged since November 2007, through the implementation of the Markets in Financial Instruments Directive [4] (MiFID), which enriched the products and services, the ISC activities by introducing the "many markets principle" (Raffan, 2006), professional practices, investor protection and market efficiency, with the ultimate aim of establishing a single market in financial instruments within the EU domain. EU capital markets have also been significantly affected by the European monetary union with the introduction of the Euro in 1999, (Detken and Hartman, 2000, 2002, Perée and Steinherr, 2001) and

[1] *Department of Economics, University of Athens, 5, Stadiou street, 105 62 Athens, Greece Email: paleks@econ.uoa.gr, Telephone: 0030 210 3689437*
[2] *Department of Economics, University of Athens, 5, Stadiou street, 105 62 Athens, Greece*

the implementation of the international financial reporting standards for all listed EU companies since 2005. The consequences of these developments for European capital markets are manifold. They signal substantial EU - wide liberalisation in the investment services sector, convergence of Eurozone interest rates, reduction of exchange rate volatility and risk, (Adjaoute and Danthine, 2003, Hartman *et al.,* 2003), lower cost of cross country transactions, reduction of statutory, legal, tax, ownership and technical barriers to international investment and execution of transactions which prevent market integration (Errunza and Losq, 1985, Eun and Janakiramanan, 1986, Cooper and Kaplanis, 2000). The quality and spillover of information and price transparency have also improved. Investors take a pan-European approach in selecting stocks by considering the whole spectrum of EU markets rather than being restricted to a local market. Exchanges, following their privatization, as well as ISCs, implement market networking and reduce their operational costs (Domowitz and Steil, 1999), expand their business in many EU markets, consolidate and increase in size, achieving economies of scale. All these in turn enhance the breadth, depth and liquidity of the EU capital markets (Danthine *et al.,* 2001, Fratzscher, 2002).

It becomes evident that an important extension of these developments refers to the deepening of capital market interconnection and co-movement across the EU countries, reinforcing the effects on international portfolio diversification, international asset pricing, risk management and management of investor portfolios. Evidence indicates that market dependence has risen within the Eurozone area since the late nineties (Booth *et al.*, 1997, Alexander, 2001, Engle, 2002, Moloney, 2002, Melle, 2003, Billio and Pelizzon, 2003, Savva *et al.*, 2004, Bekaert *et al.*, 2002, 2005, Goetzmann *et al.*, 2005, Berben and Jansen, 2005, Baele, 2005, Bartram and Karolyi, 2006, Cappiello *et al.*, 2006, Hardouvelis *et al.*, 2001, 2006, Jondeau and Rockinger, 2006, Patton, 2006a,b, Bartram *et al.*, 2007). However, it is important to note that, as yet, equity market dependence tends to be concentrated in major EU markets, full integration is still hindered, while high market dependence does not embrace smaller EU equity markets (Bartram *et al.*, 2007). Despite the financial integration measures undertaken and the absence of foreign exchange risk, remaining capital market imperfections and lack of stronger harmonisation result in significant barriers to EU wide investment, reduced market attractiveness to international investors and hence prevention of a stronger equity market co-movement, enhancement and enrichment of market dependence in the euro area [5].

This paper also addresses the question of equity market dependence in the EU, which should be increasing as a result of continuing deregulatory initiatives. It aims at adding to the findings higher up on EU equity market dependence. It concentrates on the period, 2002-2007, which so far represents the most mature stage for EU markets. Furthermore, as MiFID marks a new era, expected to further speed up the integration process, this paper’s evidence could be useful, now and in the future. As the measure of market interconnection, it follows a generally accepted route and quantifies integration as the information spillover or volatility transmission of stock price returns across national boundaries. It estimates volatility transmission across a sample of thirty European companies belonging to ten industrial sectors, from 2002 to 2007. Cohorts of five companies per country are used. The analysis uses a VAR-GARCH model, which has the BEKK specification, and it is estimated across each pair of company stocks. Shocks to each pair of stocks are modelled as exogenous variables in the conditional variance equation, and it is these coefficients that are reported and analysed in the paper. The main contribution made in this paper is the application of the volatility transmission methodology at company level rather than the standard country level indices. This helps to deepen our understanding of integration dynamics in terms of stocks and sectors that dominate the integration process. It provides additional insights if one takes into account that each EU market does tend to be dominated, in terms of capitalization and daily transactions, by a very small, single figure, number of stocks. In addition, this, complementary to index, equity analysis helps in deriving more robust conclusions on the attractiveness of equity markets to institutional investors and the resulting flow of investment. Evidence on EU markets for 2007 provided by FESE (2009) [6], indicates that despite a lower index interconnection for some of them and market imperfections, their attractiveness has risen as foreign investors have come to dominate them in recent years. Furthermore, for certain highly interconnected EU markets, a lack of dynamism is depicted today. Table 1 shows that, the participation of foreign investors stood between 60% and 70% for the Netherlands, Ireland, Finland and Switzerland, 51,8% for Greece, between 40% and 45% for Portugal, France, Norway and the United Kingdom, between 36% and 39% for Belgium, Sweden and Spain, around 30% for Austria and Denmark, while a rather low foreign ownership is depicted for Germany, at 21,3%, and Italy at 13,9%.

Table 1. Foreign investor participation in the capitalisation of European regulated markets (%)

Country	**1999**	**2007**	**Change 1999-2007**	**Country**	**1999**	**2007**	**Change 1999-2007**
The Netherlands		71,0		Norway	33,8	40,8	+7,0
Ireland		67,0		United Kingdom	33,0	40,0	+7,0
Finland	63,6	61,6	-2,0	Belgium	31,7	38,7	+8,0
Switzerland	40,2	60,2	+14,0	Sweden	36,9	38,0	+1,1
Greece	22,0	51,8	+29,8	Spain	35,2	36,7	+1,5
Portugal	42,5	44,8	+2,3	Austria	29,4	30,6	+1,2
France	38,3	41,1	+2,8	Denmark	26,2	30,2	+4,0
				Germany	14,3	21,3	+7,0
				Italy	15,8	13,9	-1,9

Source: FESE (2009)

What is more, during the 1999 to 2007 period, this participation has increased from 35,9% to 41,6% for all these markets (+5,7 points), while it is stronger for certain individual markets (Greece +30 points, Switzerland +14 points, Belgium +8 points, Germany, UK and Norway +7 points each). The markets of Portugal, France, Spain, Austria and Denmark depict a rise of between 2 to 4 points, while the markets of the Netherlands, Finland and Sweden keep their general positions. The exception seems to be the Italian market where the low foreign participation was reduced by about 2 points. In general, although the degree of internationalisation and globalisation of European markets in terms of share ownership was already important before significant integration measures and the entry of the Euro, the trend towards higher ownership by foreign investors is clearly growing.

By applying our time varying model to assess the level of dependence between equities in major EU markets, we derive a high degree of equity interconnection depicted through strong effects from one European stock to the other, as well as through significant feedback effects between stocks. Furthermore, it is derived that the stocks of the banking sector are foremost in equity interconnections, in accordance with significant harmonisation measures undertaken in this sector, followed by the stocks of the telecommunications sector and those of the energy sector. These are succeeded by the insurance and pharmaceuticals sectors. In terms of markets, it is the French equity market that depicts the highest equity interconnection, followed in sequence by the British, the German, the Spanish, the Scandinavian and the Italian market. In terms of single equity, France Telecom, AXA, Royal Bank of Scotland, Danske Bank, Vodafone, BSCH, Totalfin Elf, Siemens and SAP A.G. present the highest number of interconnection effects. The analysis also provides detailed evidence in terms of the stronger leading stock for each bilateral relationship [7]. In general, this high equity dependence seems to reflect the increased integration of equity markets and economies derived in the above mentioned studies. However, it becomes evident that it is certain economic sectors of the EU that, as of now, depict and support this interconnection, along with the fact that this refers to stocks with the largest capitalisation and tradability within the EU. Furthermore, even among these stocks, interconnection is observed to be weak or absent in a significant number of cases. Also, despite the fact that these 30 stocks capture almost 50% of EU equity capitalisation and even higher daily equity market liquidity, this in turn should imply a lower degree of equity interconnection for the remaining listed shares, which form the vast majority in these markets. The combination of remaining market imperfections during the period under review, along with expected lower tradability and increased liquidity costs for this group of equities, would seem to imply a residual structural problem in European equity markets, restricting a wide equity interconnection. [8]

The rest of the paper is structured as follows: Section 2 refers to the rationale for equity market integration and to the empirical approach suggested for its testing on EU equities. Section 3 relates to data description and empirical methodology, section 4 refers to the empirical results and, finally, section 5 draws the conclusions and policy implications.

2. Equity market co-movement and the empirical approach to European equity dependence

Equity market interconnection and dependence is of great interest for both market participants and economists. As it grows, it is expected to facilitate the efficient use of funds through the widening of opportunities for international portfolio investment, affect investment behaviour portfolio selection and asset pricing, and lastly, contribute to economic growth (Demirguc-Kunt and Levine, 1996, Levine and Zervos, 1998, Beck *et al.,* 2000, Carettoni *et al.,* 2001, Bartram and Dufey, 2001). Approaching equity market dependence from an operational viewpoint, progress implies converging investment opportunity sets across countries and lack of investment barriers affecting investor's portfolio choices and companies' financial decisions. It implies that the pricing of a stock in a local market comes to be determined by the same international risk factors, common to markets in all countries, instead of local ones, as all investment assets presenting similar risk levels require the same return irrespective of the country of origin (Errunza and Losq, 1985, Eun and Janakiramanan, 1986, Cooper and Kaplanis, 2000, Bartram and Karolyi, 2006). An investor becomes indifferent with regard to the choice of market, since, for the same level of risk, he is to receive the same level of return (Bekaert and Harvey 2003). Equity market integration can change over time (Bekaert and Harvey, 1997, Hardouvelis *et al*., 2001, 2006). In addition, evidence indicates that developed markets are associated with higher capitalisation and liquidity ratios and lower equity return volatility (O'Hara, 2001, Levine and Zervos, 1998, Demirguc-Kunt and Levine, 1996, Schwert 1989). Equity market integration also contributes to this tendency as it reinforces certain desired characteristics such as market liquidity, efficiency, transparency, technology utilisation and economies of scale. As smaller or segmented markets lack such characteristics, integration acts as a driving force for local market participants –exchanges and investment service companies- to change their structure, expand beyond their market, thus fostering market consolidation. It should be stressed that the benefits stemming from stock market integration outweigh possible disadvantages in terms of portfolio differentiation, as these seem to be offset by the reduction of risk obtained through equity market integration.

The degree of equity market dependence is empirically tested by various methods, such as the international asset pricing models which can also incorporate the exchange rate risk in systematic risk factors models (Solnik, 1974, Roll, 1977, Stulz, 1985, Dumas and Solnik, 1995, Levine, 1998, Heimonen, 2002, Hardouvelis *et al*., 2006), the cointegration approach (Becker *et al*., 1992; Kanas, 1998, Aggarwal *et al*., 2003), contagion effects (Calvo and Reinhart, 1996, Bekaert *et al*., 2005) and spillover effects (Koutmos and Booth, 1995, Bekaert and Harvey, 1995, Booth *et al*., 1997, Savva, 2004, Baele, 2005), not to mention also new methodologies estimating time-varying copula dependence models for equity market indices (Patton, 2006a,b, Bartram *et al*., 2007). Concentrating more on spillover effects, these are used to detect equity interconnection or segmentation through the power of information flow from one equity to the other. Furthermore, since information spillovers between equity markets can be related not only to returns but also to volatility (Tauchen and Pitts, 1983, Ross, 1989), studies tend to concentrate on volatility spillovers as higher moments seem to provide more conclusive results. They analyse the causal relationship between second order trends for each equity market with the rest of the equity markets. A bi-directional volatility spillover between two markets implies that a market is affected by the conditional volatility of another market while the latter also feeds back the conditional volatility of its own market. Also, evidence is uniform on the existence of significant volatility spillover effects between equity markets, whether in relation to the bigger stock markets in Europe or globally (Working, 1970, Engle *et al.*, 1990, Theodossiou, 1994, Koutmos and Booth, 1995, Booth *et al.*, 1997, Kanas, 1998, Baele, 2005). This approach is adopted in the present paper since volatility spillovers could imply a significant effect for a market originating from another market. This information flow and its direction between European equity markets can be of particular interest as continuous volatility spillovers can be used by market participants for designing investment policies, by market operators in discovering synergies and implementing alliances, as well as by the authorities in designing market legislation and measures to facilitate integration.

3. Data Description and Empirical Methodology

This study investigates the relationship of second moments between the thirty most traded stocks in the six largest and most liquid European equity markets, namely, Euronext Paris, London Stock Exchange, the Spanish Exchanges, Deutsche Börse, OMX Copenhagen and Borsa Italiana. These markets capture the largest part –approaching 90%- of daily EU transactions. Our intention was to pick the most liquid stocks, and additionally to arrive at a significant liquidity threshold for each market. Our investigation showed that when selecting up to five stocks per market, these add up to a high percentage of liquidity, while the addition of more stocks does not lead to a significant differentiation of this proportion, let alone the need for securing the presence of these stocks throughout the period examined. [9] So, five stocks are selected from each market, while each subset of these thirty shares captures from 30% to 70% of each market's daily liquidity. [10] It is therefore expected that the empirical results will not only provide useful evidence on the degree of integration of the examined stocks and sectors, but also an indication of the dependence of these six major European markets. It should also be stressed that this stock analysis aims at enriching the results in terms of EU regions, companies and sectors, deepening our understanding of interconnection dynamics and complement analyses based on equity market indices. This is expected to be useful to market participants as they could capture different degrees of reaction for different stocks and sectors, in new information.

The data used refers to daily close-to-close returns of thirty stocks, shown in Table 2, (see APPENDIX) trading in the above mentioned exchanges located in EU member states. Out of these shares, 8 belong to the banking sector, 6 to energy, 6 to telecommunications, while the rest belong to insurance, pharmaceuticals, mining, manufacturing, electronics software and industrials. The reviewed period is from January 2, 2002 to November 09, 2007. This selected five year period incorporates all measures and actions to foster capital market integration and therefore it seems the most appropriate to act as a benchmark for the future, following the MiFID implementation since November 2007. It also provides an adequate number of 1,482 observations for each equity. When a holiday occurs, the observation of the previous day is used in its place. Alternatively, when a holiday period occurs (more than one day), the arithmetic average of the observations before and after this period is used. Also, according to the literature (Hamao *et al.,* 1990, Theodossiou and Lee, 1993, Kanas, 1998), adjustments for dividends are not expected to differentiate the results. Furthermore, the trading hours of the European markets have become common during the last decade, allowing for more efficient information transmission.

Summary statistics of daily returns and the logarithmic first differences of daily close-to close prices for each of the thirty stocks are presented in Tables 3 and 4 (see APPENDIX). In all cases, the results indicate significant kurtosis, both positive and negative excess skewness indicating that the series are leptokurtic. Also, the Jarque-Bera (1980) statistics are indicative of a strong rejection of normality in all price series distributions. There is considerable variation both in mean returns and standard deviations, providing an initial view of volatility. Ljung-Box Q(12) and $Q^2(12)$ (Ljung-Box, 1978) tests suggest the existence of serial correlation and heteroscedasticity in the series. All these indicate that the Generalized ARCH model is the most appropriate to capture these inefficiencies of the series. Stationarity of the price series is examined using the Augmented Dickey-Fuller (1981) and the Phillips and Perron (1988) unit root tests. The results indicate that all series have a unit root on the log-levels and all are first difference stationary.

Looking at spillover methodology, a volatility spillover from one stock to another implies that a stock is being seriously affected by volatility transmission, which comes from another stock's information release. When paired stock prices are found to be stationary in first-differences, $I(1)$, then causality must exist in at least one direction (Granger, 1988). In other words, if variable (series) s_1 causes variable (series) s_2, then changes in s_1 should precede changes in s_2, implying that there are lead-lag relationships in any pair of trading stocks (Granger, 1988). If both variables (series) cause each other then, according to Granger (1988), there is a bi-directional relationship (feedback) between s_1 and s_2 stocks. A parsimonious VAR model is applied in order to test for causal dynamics and look for possible lead-lag relationships of the stocks. As this approach has been considered by the literature to be the most appropriate to provide consistent results about the volatility transmission effects, a large number of articles have contributed to the theoretical and methodological background of this study (Domowitz and Hakkio, 1985, Hsieh, 1985, Engle and Bollerslev, 1986, McCurdy and Morgan, 1988, Diebold and Nerlove, 1988, Engle *et al.*, 1990). The VAR specification estimated is of the following form:

$$\Delta V_{1,t} = a_{V1i}\Delta V_{1,t\text{-}i} + b_{V1,i}\Delta V_{2,t\text{-}i} + \varepsilon_{V1,t} \quad (1a)$$

$$\varepsilon_{i,t} \mid \Omega_{t\text{-}1} \sim IN(0, H_t)$$

$$\Delta V_{2,t} = a_{V2,i}\Delta V_{1,t\text{-}i} + b_{V2,i}\Delta V_{2,t\text{-}i} + \varepsilon_{V2,t} \quad (1b)$$

where $a_{V1,i}$, $b_{V1,i}$, $a_{V2,i}$, $b_{V2,i}$ are the short-run coefficients, and $\varepsilon_{V1,t}$ and $\varepsilon_{V2,t}$ are residuals.

In order to test for volatility spillover effects on paired stocks, a bivariate generalized autoregressive conditional heteroscedasticity model (GARCH) (Bollerslev 1986) is applied to daily stock price data covering an approximate six-year period in order to investigate the volatility transmission between the thirty stocks. The key insight of GARCH specification lies in the distinction between conditional and unconditional variances of the innovations process $\{\varepsilon_t\}$. The "conditional" term implies explicit dependence on a past sequence of observations. The "unconditional" term is more concerned with long-term behaviour of a time series and assumes no explicit knowledge of the past. A GARCH model characterizes the conditional distribution of ε_t by imposing alternative parameterisations to capture serial dependence on the conditional variance of the innovations. The VAR-GARCH (p, q) model is estimated using the Student-t as the density function. Lag lengths p and q, based on Likelihood Ratio (LR) tests of alternative specifications, fit a VAR-GARCH (1,1) model. Finally, the GARCH model is used under the following BEKK parameterisation of Baba *et al*. (1989), which results in a more parsimonious specification and allows the conditional variances to provide the time-varying character of the model:

$$H_t = A'A + B'H_{t\text{-}1}B + C'\varepsilon_{t\text{-}1}\varepsilon_{t\text{-}1}'C + V_1'u_{1,t\text{-}1}u_{1,t\text{-}1}'V_1 + V_2'u_{2,t\text{-}1}u_{2,t\text{-}1}'V_2 \quad (2)$$

where A is a 2x2 lower triangular matrix of coefficients while B and C are 2x2 matrices of coefficients. Matrices V_1 and V_2 contain parameters of spillover effects, $u_{1,t\text{-}1}$ and $u_{2,t\text{-}1}$ whose elements are lagged square error-terms. Specifically, $u_{1,t\text{-}1}$ represents the volatility spillover effect from stock 1 to stock 2 and $u_{2,t\text{-}1}$ represents the volatility spillover effect from stock 2 to stock 1. The advantage of this model is that it is guaranteed to be positive definite.

The general form of the likelihood function is:

$$L(\varepsilon_t, H_t) = \frac{\Gamma[(2+v)/2]}{\Gamma(v/2)[\pi(v-2)]}\left|H_t\right|^{-1/2} [1 + \frac{1}{v-2}\ \varepsilon_t', H_t^{-1}\ \varepsilon_t]^{-[(2+v)/2]} \quad \text{for } v > 4 \quad (3)$$

where Γ(.) is the gamma function. The Student-t distribution is used as the density function because the values of the degrees of freedom, *v*, were found to be greater than 4 in all cases (Bollerslev, 1986).

4. Volatility Transmission and Results

The diagnostic tests based on the GARCH standardized residuals (ε_{it} / $\sqrt{}$ h_{it}), indicate no serial correlation and no ARCH effects in almost all cases. [11] They indicate that markets exhibit no serial dependence on the conditional variance of past information and absence of dependence on past volatility rates.

Next, the conditional variance of the VAR-GARCH model for each pair of stocks is examined. Table 5 (see APPENDIX) presents the volatility spillover parameters, while Tables 6 and 7, based on Table 5, summarise the volatility spillover directions on a sectoral and market/regional basis.

Referring to Table 5, (see APPENDIX) the coefficients of volatility spillover effects V1 and V2 define the effect of lagged squared residuals of the stock 1 equation in explaining the volatility rates of stock 2, and of the stock 2 equation in defining the volatility rates of stock 1, respectively. Complete interconnection between two equities would imply that the direction of spillover works both ways, and is bi-directional. Partial interconnection between two equities could take the form of one stock affecting the other but not the other way around (uni-directional). For example, the coefficient of the volatility spillover from Vodafone UK (e_{21}) to Telecom Italia (e_{11}) is (0.023), and statistically significant at the 5% level, while the coefficient of the volatility spillover from Telecom Italia to Vodafone UK is (0.085) and insignificant, which implies that there is a uni-directional effect in volatility spillovers between the British stock and the stock of the Italian telecommunication company. Interesting results are obtained from Table 5 as the biggest part of the volatility spillover effects is statistically significant. More specifically, the 435 pairs of stocks entail 870 volatility spillover effects. Out of this total, 545 effects, 63%, are statistically significant, while 325 effects, 37%, are statistically insignificant. With respect to the statistically significant effects, 392 of them, 45% of total effects and 72% of the statistically significant effects, are bi-directional while the remaining 153 effects, 18% and 28%, respectively, are unidirectional. Finally, 172 effects, 20% of total effects, depict no relationship. Adding to these the 153 unidirectional statistically insignificant effects, one comes up with 325 statistically insignificant effects in total. These findings indicate a rather high degree of interconnection among the thirty most traded stocks in these significant European financial centres. This interconnection seems to be particularly strong for the bi-directional cases which cover almost half of the total effects, where no predictions can be made for the pricing of a stock solely by taking into consideration another stock's movements. An increase of bi-directional effects in the future could further intensify this equity co-movement.

At the same time 172 effects refer to lack of any interconnection, which is particularly high for about 6 of the 30 stocks examined. Taking into account the proportion of statistically insignificant effects (37%) as well as the fact that 17% of the significant effects depict unidirectional links, this evidence tends to demonstrate that even in the most EU interconnected markets of the reviewed period (Bartram *et al*., 2007), there is still significant room for further equity interconnection, which is desirable for a stronger EU equity market integration. At the same time it may imply that interconnection is rather less pronounced for the vast majority of the remaining less liquid stocks of these markets, while equity and market interconnection is expected to be lower when including other smaller EU financial centres. Despite these findings, it remains true that the majority of the volatility effects in this study seem to suggest that these major European equity markets have achieved a significant degree of dependence, reinforcing the results of previous studies which may increase in the future.

Looking at Tables 6 and 7, (see APPENDIX) which illustrate the empirical results of Table 5 on sectoral and market/regional level, one could obtain an additional useful insight into the existing degree of stock market interconnection between these equities and the related equity markets. Banking with 153 volatility effects, 118 bi-directional and 35 uni-directional effects, telecommunications with 115 effects (68 and 47 effects) and energy depicting 101 effects (86 and 15) seem to be the most interconnected sectors in EU. Insurance and pharmaceuticals seem to come next. As far as the markets are concerned, the French equity market with 113 volatility spillover effects, depicts the higher degree of interconnection followed by the rest: the British (97 effects), the German (93 effects), the Spanish (88 effects), the Scandinavian/Danish (80 effects) and the Italian market (74 effects). Analysing the findings by equity it can be seen that France Telecom (29 effects), AXA (23), Royal Bank of Scotland (23), Danske Bank (22), Vodafone (22), BSCH (22), Totalelf Fin (21), Siemens (21) and SAP A.G. (21) present the highest number of effects in the EU markets, and are closely followed by the stocks of Deutsche Bank, Allianz, British Petroleum, Telefonica, Sanofi-Aventis and HSBC. Then, a group of about ten stocks depict significant links. In addition, the findings of Table 5 (see APPENDIX) provide even more detailed results in terms of the stronger leading stock for each bilateral relationship, as well as for the stock that activates each unidirectional effect. Finally, the findings regarding the banking sector, which scores the highest integration, seem to match the significant developments on the harmonisation of the regulatory framework on financial services, the freedom in capital mobility and the banking expansion throughout the EU.

5. Conclusions

The results on equity interconnection in the six major EU equity markets suggest a high current degree of equity co-movement. This situation is depicted through strong effects from one stock to the other, as well as through significant feedback effects between stocks. Enhanced equity interconnection in turn brings forth the desired characteristics in the European equity markets as well as the expected benefits to the European economy. The results imply significant effects on the level of effective operation of markets and the pricing of the assets traded. Therefore, they are deemed to be useful to portfolio managers, since in designing and implementing their investment strategies they need to evaluate the effect that a stock receives from other stocks and the degree to which a stock's value is determined in conjunction with other stocks. The analysis of stock pair coefficients seems to be detailed enough to be useful, as an understanding of these equity and sectoral market links is needed in investment choice and in risk management. The same is true for other market participants such as investment service companies and exchanges. These, in the light of the findings, need to formulate their strategy for business growth through networking and consolidation throughout the EU in order to satisfy investor needs and achieve in this way adequate transactions and liquidity. This competition seems to be turning into an endurance race and these institutions need to intensify their efforts to remain within the game. As experience indicates from the other side of the Atlantic, it is eventually a few markets that would take on the bulk of the business and be in the lead (McAndrews and Stefanidis, 2002).

At the same time this empirical analysis indicates that there remains a notable group of stocks, which achieve lower interconnection as feedback effects are absent, while for a significant number of highly liquid stocks there is complete lack of interconnection. Also, it should be taken into account that this study was based upon the most liquid European stocks leaving aside the largest number of stocks in these liquid and the remaining less liquid EU markets. Therefore, one would tend to expect a lesser degree of interconnection for them, reducing partially or significantly EU market interconnection. It also implies investment portfolios geared towards home assets, as the benefits of international diversification are not large enough to offset costs due to remaining market imperfections. While the latter cannot be fully reduced, owing to slowly changing structural factors affecting the financial markets and the real economies within the EU, it is true at the same time that there is room for the enhancement of European equity market interconnection in the future. This seems to be the challenge for the new EU regulatory arrangements which are infusing a strong wind of competition into all market activity. At the same time the EU competent authorities are determined to enforce EU legislation for a complete link of markets on trading and execution and for the eradication of certain legal and fiscal barriers still prevailing inside the EU. [12] This could in turn lead to a further reduction of the remaining market segmentation related to these aspects. In this way cross border transactions would be accelerated under lower transaction costs and absence of other barriers. Given the current status of EU equity integration, it will be of great interest to observe its future evolution, as there is more to be done for establishing a fully-fledged single equity market.

Endnotes

[1] European Council, 1993. Directive 93/22/EEC on investment services in the securities field (OJ L 141, 11.06.1993).
[2] Communication of the Commission, 1999. Financial Services: Implementing the framework for financial markets: Action Plan, May.
[3] The Committee of Wise Men. 2001. Final Report of the Committee of Wise Men on the regulation of European Securities Markets. (http://ec.europa.eu/internal_market/securities/lamfalussy/index_en.htm).
[4] European Parliament and European Council, 2004. Directive 2004/39/EC on Markets in Financial Instruments, (OJ L 145, 30.04.2004).
[5] It is worth mentioning the findings and the European Commission's warnings of remaining very high costs in cross country transactions, the problems in their execution and the need for the unification of the clearing and settlement systems within EU (J.P. Morgan and McKinsey, 2002, European Commission, 2008).
[6] Federation of European Securities Exchanges (2009).
[7] A more complete understanding on EU market interconnections, beyond the major EU markets, would need to include stocks of remaining EU markets, provided that one faces successfully the gathering of data for each market that safeguards the most liquid stocks with continuous presence throughout the examined period.
[8] It would be useful in this case to also analyse a number of low capitalisation and tradability stocks of these markets, having faced of course the issues mentioned in note 6.
[9] Federation of European Securities Exchanges (FESE), historical data (www.fese.be).
[10] It could be pointed perhaps that one could take a selection of thirty stocks from anywhere in the world and produce results or even close findings. While this could be done, the task of this paper is to report on the extend of EU equity interconnection.
[11] The diagnostic tests results are available upon request.
[12] On execution –clearing and settlement- it should be mentioned that market operators have been committed to the implementation of a Code of Conduct by 2008, which links and harmonises the operation of clearing and settlement systems at a EU level.

References

1. Adjaoute, K. and J.-P. Danthine, 2003, "European financial integration and equity returns: A theory-based assessment", in Gaspar, V., Hartmann, P. and Sleijpen, O. (Eds.), The Transformation of the European Financial System, 185-245.

2. Aggarwal, R., Lucey, B.M. and C. Muckley, 2003, "Time varying equity market integration in Europe", paper presented at the Symposium on International Equity Market Integration. Institute for International Integration Studies, Trinity College, Dublin.
3. Alexander, C.O., 2001, "Orthogonal GARCH", in Measuring Risk, vol.2. Prentice-Hall, 21-38.
4. Baba, Y., Engle, R.F., Kraft, D.F. K.F. and Kronner, 1989, "Multivariate simultaneous generalized ARCH", working paper, University of California, San Diego, California.
5. Baele, L., 2005, "Volatility Spillover Effects in European Equity Markets", Journal of Financial and Quantitative Analysis 40, 373-401.
6. Bartram, S.M. and G. Dufey, 2001, "International portfolio investment: Theory, evidence and institutional framework", Financial Markets, Institutions and Instruments 10, 85-155.
7. Bartram, S.M. and G.A. Karolyi, 2006, "The impact of the introduction of the Euro on foreign exchange rate risk exposures", Journal of Empirical Finance 13, 519-549.
8. Bartram, S.M., Taylor, S.J. and Yaw-Huei Wang, 2007, "The Euro and European financial market dependence", Journal of Banking and Finance 31, 1261-1481.
9. Beck, T., Demirguc-Kunt, A. and R. Levine. 2000, "A New Database on the Structure and Development of the Financial Sector", The World Bank Economic Review 14, 597-605.
10. Becker, K.G., Finnerty, J.E. and A.L. Tucker 1992, "The Intraday Interdependence between US and Japanese Equity Markets", Journal of Financial Research 15, 27-37.
11. Bekaert, G. and C.R. Harvey 1995, "Time-varying world market integration", Journal of Finance 50, 403-444.
12. Bekaert, G. and C.R. Harvey, 1997, "Emerging Equity Market Volatility", Journal of Financial Economics 43, 29-78.
13. Bekaert, G., Harvey C.R. and R.L. Lumsdaine, 2002, "Dating the integration of world equity markets", Journal of Financial Economics 65, 203-247.
14. Bekaert, G. and C.R. Harvey, 2003, "Emerging Markets Finance", Journal of Empirical Finance 10, 3-56.
15. Bekaert, G., Harvey C.R. and A. Ng, 2005, Market integration and contagion, Journal of Business 78, 39-69.
16. Berben, R.-P. and W.J. Jansen, 2005, "Comovement in international equity markets: A sectoral view", Journal of International Money and Finance 24, 832-857.
17. Billio, M. and L. Pelizzon, 2003, "Volatility and shocks spillover before and after EMU in European stock markets", Journal of Multinational Financial Management 13, 323-340.

18. Bollerslev, T., 1986, "Generalized autoregressive conditional heteroscedasticity", Journal of Econometrics 31, 307-327.
19. Booth, G., Martikainen, T. and Y. Tse, 1997, "Price and Volatility Spillovers in Scandinavian Stock Markets", Journal of Banking and Finance 21, 811-823.
20. Calvo, S., and C. Reinhart, 1996, "Is There Evidence of Contagion Effects?" policy research working paper [1619], The World Bank Economic Development Institute.
21. Cappiello, L., Engle, R.F. and K. Sheppard, 2006, "Asymmetric dynamics in the correlations of global equity and bond markets", Journal of Financial Econometrics 4, 537-572.
22. Carettoni, A., Manzocchi, S. and C. Padoan, 2001, "The Growth-Finance Nexus and European Integration. A Review of the Literature", EIFC – Technology and Finance working papers [5], United Nations University, Institute for New Technologies.
23. Cooper, I., and E. Kaplanis, 2000, "Partially Segmented International Capital Markets and International Capital Budgeting", Journal of International Money and Finance 19, 309-329.
24. Danthine, J.-P., Giavazzi, F. and E.-L. von Thadden, 2001, "European financial markets after EMU: A first assessment", in Wyplosz, C. (Ed.), EMU: Its impact on Europe and the World, Oxford University Press.
25. Demirguc-Kunt, A. and R. Levine, 1996, "Stock Market Development and Financial Intermediaries: Stylized Facts", The World Bank Economic Review 10, 291-321.
26. Detken, C. and P. Hartmann, 2000, "The Euro and international capital markets", International Finance 3, 53-94.
27. Detken, C. and P. Hartmann, 2002, "Features of the Euro's role in international financial markets", Economic Policy 24, 555-575.
28. Dickey, D. and W.Fuller, 1981, "Likelihood Ratio Statistics for Autoregressive Time Series with a Unit Root", Econometrica 49, 1057-1072.
29. Diebold, F.X. and M. Nerlove, 1989, "The Dynamics of Exchange Rate Volatility: A Multivariate Latent-Factor ARCH Model", Journal of Applied Econometrics 4, 1-21.
30. Domowitz, I. and C.S. Hakkio, 1985, "Conditional Variance and the Risk Premium in the Foreign Exchange Market", Journal of International Econometrics 19, 47-65.
31. Domowitz, I. and B. Steil, 1999, "Automation, Trading Costs and the Structure of the Trading Services Industry", Brookings-Wharton Papers on Financial Services.
32. Dumas, B. and B. Solnik, 1995, "The world price of foreign exchange risk", Journal of Finance 50, 445-479.
33. Easterly, W. and R. Levine, 1994, "Africa's Growth Tragedy", mimeo, The World Bank.

34. Engle, R.F., 2002, "Dynamic conditional correlation: A simple class of multivariate generalized autoregressive conditional heteroscedasticity models", Journal of Business and Economic Statistics 20, 339-350.
35. Engle, R.F. and T.P. Bollerslev, 1986, "Modelling the Persistence of Conditional Variances", Econometric Review 5, 1-50.
36. Engle, R.F., Takatoshi, I. and W.-L. Lin, 1990, "Meteor Showers or Heat Waves? Heteroscedastic Intra-Daily Volatility in the Foreign Exchange Market", Econometrica 58, 525-542.
37. Errunza, V. and E. Losq, 1985, "International Asset Pricing Under Mild Segmentation: Theory and Test", Journal of Finance 40, 105-124.
38. Eun, C.S. and S. Janakiramanan, 1986, "A Model of International Asset Pricing with a Constraint on the Foreign Equity Ownership", Journal of Finance 41, 897-914.
39. European Commission, 2008, "Improving the Efficiency, Integration and Safety and Soundness of Cross-Border Post-Trading Agreements in Europe", Third progress report to Economic and Financial Affairs Council (EcoFin), March, Brussels.
40. Federation of European Securities Exchanges, 2009, Share Ownership Structure in Europe, Brussels.
41. Fratzscher, M., 2002, "Financial market integration in Europe: On the effects of EMU on stock markets", International Journal of Finance and Economics 7, 165-194.
42. Goetzmann, W.N., Li, L and K.G. Rouwenhorst, 2005, "Long-term global market correlations", Journal of Business 78, 1-37.
43. Granger, C.W.J., 1988, "Some Recent Developments in a Concept of Causality", Journal of Econometrics 39, 199-211.
44. Hamao, Y., Masulis, R.W. and V. Ng, 1990, "Correlations in price changes and volatility across international stock markets", Review of Financial Studies 3, 281-307.
45. Hardouvelis, G., Malliaropoulos, D. and R. Priestley, 2001, "EMU and European Stock Market Integration", CEPR discussion paper [2124], Centre for Economic Policy Research, London.
46. Hardouvelis, G., Malliaropoulos, D. and R. Priestley, 2006, "EMU and European stock market integration", Journal of Business 79, 365-392.
47. Hartmann, P., Maddaloni, A. and S. Manganelli, 2003, "The Euro area financial system: Structure, integration and policy initiatives", Oxford Review of Economic Policy 19, 180-213.
48. Heimonen, K., 2002, "Stock Market Integration: Evidence on Price Integration and Return Convergence", Applied Financial Economics 12, 415-429.
49. Hsieh, D.A., 1985, "The Statistical Properties of Daily Foreign Exchange Rates: 1974-1983", memo. University of Chicago, Graduate School of Business.

50. Jarque, C.M. and A.K. Bera, 1980, "Efficient Test for Normality, Homoscedasticity and Serial Dependence of Regression Residuals", Economics Letters 6, 255-259.
51. Jondeau, E. and M. Rockinger, 2006, "The copula-GARCH model of conditional dependencies: An international stock-market application", Journal of International Money and Finance 25, 827-853.
52. Kanas, A., 1998, "Volatility Spillovers across Equity Markets: European Evidence", Applied Financial Economics 8, 245-256.
53. Koutmos G. and G.G. Booth, 1995, "Asymmetric Volatility Transmission in International Stock Markets", Journal of International Money and Finance 14, 747-762.
54. Kwiatkowski, D., Phillips, P.C.B., Schmidt, P. and Y. Shin, 1992, "Testing the Null Hypothesis of Stationarity against the Alternative of a Unit Root," Journal of Econometrics 54, 159-178.
55. Levine, R., 1998, "The Legal Environment, Banks, and Long-Run Economic Growth", Journal of Money, Credit and Banking 30, 596-613.
56. Levine, R. and S. Zervos, 1998, "Stock Markets, Banks and Economic Growth", The American Economic Review 88, 537-558.
57. L'Heveder, C., 1996, "The Investment Services Directive and its Implications for Participants in Europe's Financial Markets", Journal of International Banking and Financial Law, Butterworths.
58. Ljung, M. and G. Box, 1978, "On A Measure of Lack of Fit in Time Series Models", Biometrica 65, 297-303.
59. McAndrews, J. and C. Stefanidis, 2002, "The Consolidation of European Stock Exchanges", Federal Reserve Bank of New York.
60. McCurdy, T.H. and I.G. Morgan, 1988, "Testing the Martingale Hypothesis in the Deutsche Mark Futures with Models Specifying the Form of Heteroscedasticity", Journal of Applied Econometrics 3, 187-203.
61. Melle, M., 2003, "The Euro effect on the integration of the European stock markets", Universidad Complutense de Madrid, working paper.
62. Moloney, N., 2002, "EC Securities Regulation", Oxford EC Law Library, Oxford University Press.
63. Morgan, J.P., Securities Ltd and McKinsey & Company, 2002, "The Future of Equity Trading in Europe. Balancing Scale, Scope and Segmantation. A Joint Research Initiative", February, London.
64. O'Hara, M., 2001, "Designing Markets for developing Countries", ASAIN Management review, APFA, supplement 7.
65. Patton, A.J., 2006a, "Modelling asymmetric exchange rate dependence", International Economic Review 4, 527-556.
66. Patton, A.J., 2006b, "Estimation of multivariate models for time series of possibly different lengths", Journal of Applied Econometrics 21, 147-173.
67. Perée, E. and A. Steinherr, 2001, "The Euro and capital markets: A new era", The World Economy 24, 1295-1308.

68. Phillips, P. and P. Perron, 1988, "Testing for a unit root in time series regression, Biometrica 75, 335-346.
69. Raffan, M., 2006, "The Investment Services Directive and the Markets in Financial Investments Directive, in A Practitioner's Guide to EU Financial Services Directive, Freshfields Bruckhaus Derigner, 2nd edition.
70. Roll, R., 1977, "A Critique of the Asset Pricing Theory's Tests Part I: On Past and Potential Testability of the Theory", Journal of Financial Economy 4, 129-176.
71. Ross, S.A., 1989, "Information and Volatility: The No-Arbitrage Martingale Approach to Timing and Resolution Irrelevancy", Journal of Finance 44, 1-17.
72. Savva, C.S., Osborn, D.R. and L. Gill, 2004, "Volatility, spillover effects and correlations in U.S. and major European markets", University of Manchester, working paper.
73. Schwert, G.W., 1989, "Why Does Stock Market Volatility Change Over Time?", Journal of Finance 44, 1115-1153.
74. Solnik, B., 1974, "An equilibrium model of the international capital market", Journal of Economic Theory 8, 500-524.
75. Stulz, R. 1985, "Pricing Capital Assets in an International Setting: An Introduction, in Lessard D.R. (Ed.), International Financial Management: Theory and Applications, John Wiley & Sons, New York.
76. Tarnanidou, C., 2007, "The path of the European Law on Capital Markets: Preceding, New Law and European Integration", Review of Banking and Financial Law, 11-92.
77. Tauchen, G. and M. Pitts, 1983, "The Price Variability-Volume Relationship on Speculative Markets", Econometrica 51, 485-505.
78. Theodossiou, P. and U. Lee, 1993, "Mean and volatility spillovers across major national stock markets: further empirical evidence", The Journal of Financial Research XVI, 337-350.
79. Theodossiou, P., 1994, "Models for Predicting Prices and Volatility Patterns in Major International Stock Markets", Managerial Finance 20, 5-13.
80. Working, H., 1970, "Economic Functions of Futures Markets, in Bakken, H. (Ed.), Futures Trading in Live- Stock-Origins and Concepts, Chicago Mercantile Exchange, Chicago.

APPENDIX

Table 2. Presentation of the 30 stocks by country and sector

	Stocks	Country/Exchange	Sector/Industry
1	Totalelf Fin	France / Euronext Paris	Energy
2	Sanofi-Aventis	France / Euronext Paris	Pharmaceutical
3	BNP Paribas	France / Euronext Paris	Banking
4	France Telecom	France / Euronext Paris	Telecommunications
5	AXA	France / Euronext Paris	Assurance
6	Siemens	Germany / Deutsche Börse	Telecommunications
7	SAP A.G	Germany / Deutsche Börse	Software
8	Deutsche Bank	Germany / Deutsche Börse	Banking
9	E.ON	Germany / Deutsche Börse	Energy
10	Allianz	Germany / Deutsche Börse	Assurance
11	Telecom Italia	Italy / Borsa Italiana	Telecommunications
12	ENI	Italy / Borsa Italiana	Energy
13	STMicroElectronics	Italy / Borsa Italiana	Electronics
14	Unicredito	Italy / Borsa Italiana	Banking
15	Generali	Italy / Borsa Italiana	Assurance
16	Danske Bank	Denmark / OMX	Banking
17	Novo Nordisk	Denmark / OMX	Pharmaceutical
18	Vestas Wind Systems	Denmark / OMX	Manufactoring
19	TDC	Denmark / OMX	Telecommunications
20	Moeller Maersk	Denmark / OMX	Industrials
21	Vodafone	UK / LSE	Telecommunications
22	British Petroleum	UK / LSE	Energy
23	HSBC	UK / LSE	Banking
24	RBS	UK / LSE	Banking
25	Rio Tinto	UK / LSE	Mining
26	Telefonica	Spain / The Spanish Exchanges	Telecommunications
27	BSCH	Spain / The Spanish Exchanges	Banking
28	Repsol	Spain / The Spanish Exchanges	Energy
29	Endesa	Spain / The Spanish Exchanges	Energy
30	BBVA	Spain / The Spanish Exchanges	Banking

Table 3. Descriptive Statistics of daily returns from January 2002 to November 2007

	E1	E2	E3	E4	E5	E6	E7	E8	E9	E10	E11	E12	E13	E14	E15
Mean	0.000094*	0.000373*	0.000540*	0.000396*	0.000441*	0.000253*	0.000189*	0.000730*	0.000091	0.000097*	0.000152*	0.000553*	0.000177*	0.000166*	0.000373*
Std. Dev.	0.017104	0.019035	0.027792	0.024699	0.020696	0.023625	0.019642	0.016764	0.023698	0.031279	0.013503	0.022752	0.014526	0.015146	0.014836
Skewness	0.099	0.174	0.907	0.585	0.365	0.377	0.099	0.336	0.238	0.861	-0.330	0.654	0.125	0.005	0.181
Kurtosis	6.958	8.831	4.083	9.109	5.853	6.496	6.046	6.590	7.561	4.350	5.431	7.381	7.283	6.735	8.631
Jarque-Bera	968.2724*	2102.456*	7773.471*	2384.234*	534.2434*	1169.331*	574.2177*	822.1759*	1296.271*	1824.833*	391.1804*	1288.651*	1134.550*	859.6494*	1962.032*
Probability	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	E16	**E17**	**E18**	**E19**	**E20**	**E21**	**E22**	**E23**	**E24**	**E25**	**E26**	**E27**	**E28**	**E29**	**E30**
Mean	0.000585*	0.001262*	0.000652*	0.000930*	0.000223*	0.000183*	0.000073*	0.000104*	0.001219*	0.000445*	0.000477*	0.000470*	0.000769*	0.000259*	0.000131*
Std. Dev.	0.018543	0.034859	0.018033	0.019816	0.020188	0.014692	0.011157	0.016637	0.020559	0.016635	0.015919	0.019009	0.016505	0.017746	0.016751
Skewness	-0.446	0.099	0.166	0.794	0.371	-0.255	0.402	0.193	0.924	0.625	0.275	0.327	0.312	0.404	0.357
Kurtosis	5.212	9.331	3.945	2.964	7.331	5.820	6.723	8.347	11.882	10.429	7.997	8.338	9.840	7.043	5.015
Jarque-Bera	3045.326*	4302.497*	7718.523*	2004.265*	1190.084*	506.2058*	894.3402*	1771.580*	5072.876*	3497.488*	1557.313*	1782.648*	4529.622*	1048.039*	3462.422*
Probability	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Notes: *1.Results are for the return series $R_t = \ln (P_t/P_{t-1})*100$, where P = stock price.*

2. Number of observations is 1.482.

3. t-statistics in parentheses.

*4. *: Statistically significant at 5% significance level.*

Table 4. Descriptive statistics of Logarithmic-First Differences of Stock Prices (01/2002 - 11/2007)

Stocks	Q (12)	Q^2 (12)	ARCH LM	ADF (L)	ADF (D)	PP (L)	PP (D)	KPSS
Totalfin Elf (F)	251.223	287.30	46.751 [0.000]	-1.321	-15.523	-1.701	-36.465	0.606
Sanofi-Aventis (F)	75.505	45.75	20.841 [0.000]	-1.141	-35.336	-1.656	-35.360	0.879
BNP Paribas (F)	44.212	149.00	36.788 [0.000]	-1.435	-34.603	-1.522	-34.733	0.521
France Telecom (F)	56.648	235.97	44.986 [0.000]	-1.329	-35.582	-1.824	-36.492	0.568
AXA (F)	67.597	432.82	52.363 [0.000]	-1.219	-38.869	-1.684	-38.967	0.743
Siemens (G)	96.034	71.23	54.03 [0.000]	-1.546	-24.055	-1.682	-46.998	0.679
SAP A.G. (G)	45.759	131.37	41.617 [0.000]	-1.884	-25.976	-1.441	-41.651	0.861
DB (G)	66.345	43.59	49.022 [0.000]	-1.603	-59.533	-1.356	-54.032	0.876
E.ON (G)	74.643	69.57	26.423 [0.000]	-1.597	-42.895	-1.553	-42.922	0.615
Allianz (G)	54.213	68.97	51.94 [0.000]	-1.599	-24.603	-1.523	-66.744	0.793
Telecom Italia (I)	49.789	290.64	59.02 [0.000]	-1.693	-28.954	-1.794	-122.593	0.555
ENI (I)	57.135	145.50	87.36 [0.000]	-1.252	-22.690	-1.522	-34.502	0.680
STMicroelectronics (I)	49.881	243.64	77.44 [0.000]	-1.693	-43.220	-1.607	-54.201	0.790
Unicredito (I)	112.151	52.24	76.155 [0.000]	-1.532	-34.693	-1.325	-123.451	0.789
Genearali (I)	78.693	66.395	77.592 [0.000]	-1.424	-37.524	-1.562	-89.592	0.692
Danske Bank (C)	129.959	270.11	36.424 [0.000]	-1.605	-38.623	-1.630	-38.525	0.650
Novo Nordisc (C)	92.004	66.75	67.92 [0.000]	-1.455	-45.693	-1.794	-40.687	0.677
Vestas Wind Systems (C)	93.040	134.60	63.91 [0.000]	-1.633	-34.606	-1.603	-32.444	0.730
TDC (C)	53.525	45.522	68.692 [0.000]	-1.592	-59.625	-1.592	-83.525	0.682
Moeller Maersk (C)	89.735	100.525	89.592 [0.000]	1.424	-67.792	-1.784	-69.725	0.769
Vodafone (UK)	77,39	58.37	77.98 [0.000]	-1.223	-35.033	-1.602	-65.784	0.678
BP (UK)	141.998	48.39	43.422 [0.000]	-1.367	-36.289	-1.391	-36.198	0.880
HSBC (UK)	81.809	53.79	58.16 [0.000]	-1.762	-28.231	-1.449	-30.811	0.662
RBS (UK)	56.584	86.252	95.521 [0.000]	-1.491	65.036	-1.384	-66.894	0.894
RIO TINTO (UK)	99.683	87.783	37.693 [0.000]	-1.582	68.693	-1.522	22.5o2	0.733
Telefonica (Sp)	34.857	30.14	86.842 [0.000]	-1.034	-27.701	-1.060	-94.231	0.735
Repsol (Sp)	69.045	39.78	35.77 [0.000]	-1.593	-45.021	-1.653	-77.845	0.853
BSCH (Sp)	132.778	256.41	28.435 [0.000]	-1.747	-32.462	-1.921	-126.503	0.939
Endesa (Sp)	100.932	49.21	79.023 [0.000]	-1.783	-44.693	-1.602	-112.402	0.922
BBVA (Sp)	56.592	58.602	83.692 [0.000]	-1.592	-66.525	-1.5i2	-59.693	0.674

Notes: *1. ADF(L) and PP(L) are test results in levels, while ADF(D) and PP(D) are test results in first differences.*

2. Critical values for ADF and PP tests are -3.4369 for 1%, -2.8636 for 5% and -2.5678 for 10%, respectively.

3. Q(12) and Q^2(12) are Q test statistics of Ljung and Box (1978) for the 12 first lags of the autocorrelation function in series and squared series, respectively. Test critical value is 21.026 for 5%.

4. Asymptotic critical values for KPSS test (Kwiatkofski, Phillips, Schmidt and Shin) is 0.739 for 1%, 0.463 for 5% and 0.347 for 10%, respectively (K-P-S-S, 1992).

*5. *: Statistically significant at 5% significance level.*

Table 5. Volatility spillover effects

		France					Germany					Italy					Denmark					UK					Spain				
		e1	e2	e3	e4	e5	e6	e7	e8	e9	e10	e11	e12	e13	e14	e15	e16	e17	e18	e19	e20	e21	e22	e23	e24	e25	e26	e27	e28	e29	e30
e1	V1																														
	V2																														
e2	V1	-0.007																													
	V2	-0.089																													
e3	V1	-0.139	0.104																												
	V2	-0.050	0.067																												
e4	V1	-0.017	-0.062	-0.029																											
	V2	0.101	0.109	0.089																											
e5	V1	0.176	-0.168	0.087	-0.118																										
	V2	0.030	0.029	-0.056	-0.120																										
e6	V1	0.142	0.045	0.031	-0.078	0.089																									
	V2	0.080	0.104	0.058	-0.039	0.136																									
e7	V1	-0.137	-0.138	-0.183	-0.177	-0.143	-0.126																								
	V2	0.072	0.084	-0.085	0.046	-0.087	0.109																								
e8	V1	0.122	-0.124	0.065	0.090	-0.085	0.101	0.200																							
	V2	0.070	0.066	0.097	0.100	0.091	-0.029	0.141																							
e9	V1	0.123	0.075	0.007	0.049	0.091	0.084	-0.062	0.084																						
	V2	0.065	0.144	0.140	-0.030	-0.136	0.080	-0.178	0.091																						
e10	V1	-0.119	-0.135	-0.059	-0.100	-0.046	0.087	0.089	0.040	0.097																					
	V2	0.071	0.099	0.085	0.141	0.095	0.052	-0.170	0.131	0.074																					
e11	V1	-0.041	0.141	0.047	0.531	0.140	0.088	0.659	0.049	-0.011	0.147																				
	V2	0.016	0.202	0.105	0.044	0.215	0.131	-0.214	0.130	-0.027	0.215																				
e12	V1	0.077	0.085	0.079	0.052	0.061	0.085	0.111	0.012	0.043	0.077	0.075																			
	V2	-0.044	0.090	0.142	-0.121	-0.215	0.173	0.031	0.045	-0.144	0.146	0.048																			
e13	V1	0.118	0.127	0.110	-0.097	0.063	0.087	0.131	0.140	0.072	0.101	0.014	0.187																		
	V2	0.056	0.087	0.063	-0.011	0.105	0.066	0.045	0.138	0.079	0.021	0.079	0.064																		
e14	V1	-0.076	0.069	0.048	0.052	0.053	0.078	0.048	0.072	0.041	0.044	0.015	0.047	-0.040																	
	V2	0.102	-0.049	0.102	-0.081	-0.035	0.123	-0.144	-0.050	0.138	-0.014	0.037	0.167	-0.076																	
e15	V1	0.058	-0.044	-0.075	0.042	0.054	0.052	0.028	0.040	0.131	0.048	0.071	0.108	0.050	0.031																
	V2	0.099	0.136	0.137	-0.100	-0.095	0.151	-0.183	0.111	0.051	-0.139	0.112	0.095	0.097	0.087																
e16	V1	0.218	0.164	0.107	0.008	0.151	-0.097	0.201	0.134	0.158	0.112	0.141	0.177	-0.072	-0.199	0.216															
	V2	0.172	0.189	0.121	0.050	-0.138	0.165	0.115	0.153	0.117	-0.084	0.047	0.139	-0.136	-0.028	0.095															
e17	V1	0.415	0.288	0.380	0.344	0.482	0.588	0.174	-0.253	0.297	0.205	0.176	-0.313	0.414	0.324	0.018	0.183														
	V2	0.023	0.045	-0.032	0.045	0.111	0.068	-0.111	0.048	0.017	-0.218	0.084	-0.015	0.106	-0.059	0.041	-0.066														
e18	V1	0.072	0.204	-0.659	0.507	-0.633	-0.625	-0.539	-0.648	-0.238	0.524	-0.834	0.247	0.546	0.018	0.497	-0.041	-0.031													
	V2	0.038	0.043	0.039	0.014	0.031	0.046	0.034	0.025	0.021	0.032	0.092	0.032	0.026	0.072	0.035	0.053	-0.002													
e19	V1	0.196	0.137	0.094	0.073	0.102	0.102	0.042	0.178	0.289	0.161	0.126	0.235	0.098	0.139	0.088	0.131	0.070	0.141												
	V2	0.050	0.083	0.063	-0.034	-0.052	-0.115	0.094	0.064	-0.072	-0.051	0.021	0.108	0.068	-0.040	0.031	0.111	-0.320	0.678												
e20	V1	0.245	0.255	0.266	0.119	0.257	0.131	0.089	0.135	0.015	0.089	0.015	0.547	0.297	0.050	0.180	0.140	0.087	0.075	0.073											
	V2	0.106	0.090	0.094	-0.077	0.098	0.079	0.156	0.089	-0.005	0.035	0.270	0.071	0.072	0.113	0.215	0.142	-0.195	0.166	0.177											
e21	V1	0.200	-0.081	0.107	0.089	0.062	0.097	-0.045	0.101	-0.218	0.215	0.023	0.212	0.086	0.048	0.126	-0.042	0.094	0.119	-0.022	0.111										
	V2	0.046	0.114	0.084	0.067	-0.107	0.094	-0.145	0.096	0.143	0.305	0.085	0.050	0.088	0.031	0.064	0.122	0.492	0.314	0.100	0.147										
e22	V1	-0.018	0.085	0.071	0.068	0.061	0.095	0.089	0.083	0.053	0.200	0.055	0.152	0.086	0.015	0.103	0.043	0.043	0.042	0.077	0.215	0.072									
	V2	0.095	0.097	0.091	-0.111	-0.145	0.098	0.076	0.126	0.077	0.117	0.067	0.119	0.130	0.018	-0.076	0.165	0.386	-0.011	0.235	0.147	0.213									
e23	V1	0.066	0.089	0.048	0.055	0.041	0.087	0.072	0.093	0.064	0.064	0.099	0.116	0.015	0.071	0.077	0.081	-0.047	0.019	0.053	-0.019	0.078	0.070								
	V2	-0.100	0.087	0.110	-0.089	0.149	0.186	0.011	0.133	0.105	0.021	0.072	0.096	0.089	-0.083	-0.072	-0.253	-0.832	0.051	0.131	0.323	0.145	0.093								
e24	V1	-0.158	0.160	0.137	0.107	0.095	0.187	0.227	0.116	0.080	0.041	0.023	-0.164	0.096	0.077	0.189	0.132	0.088	0.036	0.091	0.086	0.121	-0.109	0.181							
	V2	0.097	0.057	-0.127	0.067	0.116	0.219	-0.215	0.115	0.119	0.121	-0.111	0.121	-0.136	0.094	0.064	0.215	0.332	-0.712	0.182	0.157	0.109	0.071	-0.048							
e25	V1	0.025	0.081	0.045	-0.022	0.100	0.025	-0.030	0.083	0.017	0.015	0.078	0.161	-0.140	-0.053	0.185	0.076	0.052	0.024	0.118	0.082	0.029	-0.041	-0.049	0.017						
	V2	-0.048	0.053	-0.072	-0.039	0.041	-0.066	0.063	0.038	0.118	0.219	-0.469	0.034	-0.035	0.102	0.065	-0.088	-0.143	0.582	0.213	0.102	-0.080	0.062	0.039	0.023						
e26	V1	-0.110	0.142	-0.049	0.305	0.215	0.020	0.085	-0.082	0.101	0.044	-0.094	-0.161	0.081	-0.106	0.115	-0.180	0.068	0.045	0.029	-0.018	-0.065	-0.093	0.180	0.212	0.151					
	V2	0.112	-0.111	-0.129	-0.129	0.041	0.147	-0.288	-0.171	-0.085	-0.161	0.547	0.095	-0.185	0.098	0.015	0.156	0.347	0.151	-0.102	0.105	0.102	0.134	0.114	-0.197	0.059					
e27	V1	0.081	0.007	-0.031	0.095	0.039	0.211	0.106	0.091	0.039	0.086	0.029	0.044	0.020	0.139	0.019	0.087	-0.033	0.015	0.060	0.079	0.120	0.081	0.206	0.091	-0.042	0.155				
	V2	0.107	0.087	0.141	-0.113	-0.249	0.131	-0.177	0.115	-0.085	-0.119	-0.090	-0.110	0.084	0.089	0.095	0.117	0.097	0.047	0.310	0.446	0.166	0.108	0.073	0.091	0.069	0.135				
e28	V1	0.143	-0.192	0.093	0.145	0.043	0.167	-0.147	0.105	-0.078	0.106	0.086	0.228	-0.053	-0.048	-0.161	0.172	-0.039	0.057	0.032	-0.045	-0.102	-0.078	0.265	-0.261	-0.064	0.178	0.254			
	V2	-0.061	-0.080	-0.033	-0.104	-0.146	0.114	-0.211	-0.063	0.061	-0.035	0.017	0.092	0.100	0.115	-0.018	-0.091	-0.274	0.667	0.030	0.364	0.024	0.082	0.043	0.125	-0.037	-0.297	-0.196			
e29	V1	0.266	0.210	0.195	-0.401	-0.156	0.115	0.169	-0.209	0.183	0.143	0.086	-0.198	0.169	0.138	0.276	-0.310	0.073	0.047	0.076	0.089	0.202	0.221	0.389	0.209	0.052	0.237	0.307	0.224		
	V2	0.147	0.070	-0.047	-0.530	0.095	-0.073	-0.216	-0.052	0.074	-0.057	0.062	0.061	-0.098	0.049	0.079	0.275	-0.002	0.045	0.029	0.102	-0.022	0.089	0.031	-0.118	-0.141	0.341	0.104	-0.475		
e30	V1	-0.135	0.089	-0.175	0.995	-0.210	0.005	-0.103	-0.216	-0.126	0.198	0.059	0.057	-0.071	0.040	0.093	-0.131	0.018	0.015	0.018	-0.064	0.080	0.081	-0.042	-0.160	0.066	0.210	-0.102	-0.033	0.052	
	V2	0.147	0.304	0.149	0.110	-0.177	0.011	-0.383	0.119	0.162	-0.152	0.040	0.080	-0.133	0.031	0.117	0.173	0.140	0.367	0.040	0.126	0.045	0.172	0.107	0.209	-0.096	0.119	0.189	0.159	0.210	

Note: *The upper diagonal of this output matrix is not repeated as it mirrors the bottom half.*

Table 6. Volatility spillover directions, sectoral analysis

	Stocks	Sector/Industry	Bidirectional	Unidirectional		No interconnection
			Stat. Signif. effects	Stat. Signif. effects	Stat. Insignif. effects	Stat. Insignif. effects
s3	BNP Paribas	Banking	18	3	4	4
s8	Deutsche Bank	Banking	17	3	4	5
s14	Unicredito	Banking	9	2	7	11
s16	Danske Bank	Banking	19	3	5	2
s23	HSBC	Banking	15	4	7	3
s24	RBS	Banking	20	3	2	4
s27	BSCH	Banking	10	12	2	5
s30	BBVA	Banking	10	5	4	10
s4	France Telecom	Telecommunications	9	20	0	0
s6	Siemens	Telecommunications	15	6	3	5
s11	Telecom Italia	Telecommunications	6	4	4	15
s19	TDC	Telecommunications	11	2	10	8
s21	Vodafone	Telecommunications	15	7	4	3
s26	Telefonica	Telecommunications	12	8	1	8
s2	Sanofi-Aventis	Pharmaceutical	10	9	8	2
s17	Novo Nordisk	Pharmaceutical	12	1	12	4
s1	Totalelf Fin	Energy	18	3	8	0
s9	E.ON	Energy	10	1	7	11
s12	ENI	Energy	15	3	5	6
s22	British Petroleum	Energy	16	4	4	5
s28	Repsol	Energy	11	4	10	4
s29	Endesa	Energy	16	0	11	2
s5	AXA	Insurance	15	8	2	4
s10	Allianz	Insurance	11	9	3	6

s15	Generali	Insurance	13	5	2	9
s25	Rio Tinto	Mining	5	8	2	14
s18	Vestas Wind	Manufactoring	8	6	7	8
s20	Moeller Maersk	Industrials	17	1	6	5
s13	STMicroElectronics	Electronics	16	1	7	5
s7	SAP A.G	Software	13	8	4	4
	TOTAL EFFECTS	870	392	153	153	172
	Stat. Significant	545	392	153		
	Stat. Insignificant	325			153	172

Table 7. Volatility spillover directions, regional analysis

	Stocks	Country/Exchange	Bidirectional	Unidirectional		No interconnection
			Stat. Sign. Effects	Stat. Sign. Effects	Stat. Insign. Effects	Stat. Insign. Effects
s1	Totalelf Fin	Euronext Paris	18	3	8	0
s2	Sanofi-Aventis	Euronext Paris	10	9	8	2
s3	BNP Paribas	Euronext Paris	18	3	4	4
s4	France Telecom	Euronext Paris	9	20	0	0
s5	AXA	Euronext Paris	15	8	2	4
s6	Siemens	Deutsche Börse	15	6	3	5
s7	SAP A.G	Deutsche Börse	13	8	4	4
s8	Deutsche Bank	Deutsche Börse	17	3	4	5
s9	E.ON	Deutsche Börse	10	1	7	11
s10	Allianz	Deutsche Börse	11	9	3	6
s11	Telecom Italia	Borsa Italiana	6	4	4	15
s12	ENI	Borsa Italiana	15	3	5	6
s13	STMicroElectronics	Borsa Italiana	16	1	7	5
s14	Unicredito	Borsa Italiana	9	2	7	11
s15	Generali	Borsa Italiana	13	5	2	9
s16	Danske Bank	Denmark / OMX	19	3	5	2
s17	Novo Nordisk	Denmark / OMX	12	1	12	4
s18	Vestas Wind	Denmark / OMX	8	6	7	8
s19	TDC	Denmark / OMX	11	2	8	8
s20	Moeller Maersk	Denmark / OMX	17	1	6	5

s21	**Vodafone**	**LSE**	15	7	4	3
s22	**British Petroleum**	**LSE**	16	4	4	5
s23	**HSBC**	**LSE**	15	4	7	3
s24	**RBS**	**LSE**	20	3	2	4
s25	**Rio Tinto**	**LSE**	5	8	2	14
s26	**Telefonica**	**Spanish Ex.**	12	8	1	8
s27	**BSCH**	**Spanish Ex.**	10	12	2	5
s28	**Repsol**	**Spanish Ex.**	11	4	10	4
s29	**Endesa**	**Spanish Ex.**	16	0	11	2
s30	**BBVA**	**Spanish Ex.**	10	5	4	10
	TOTAL EFFECTS	**870**	**392**	**153**	**153**	**172**
	Stat. Significant	**545**	**392**	**153**		
	Stat. Insignificant	**325**			**153**	**172**