Dynamic Spillover Effects in Futures Markets

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Abstract

Previous studies on spillover effects in future markets have so far confined themselves to static analyses. In this study, we use a newly introduced spillover index to examine dynamic spillovers between spot and futures market volatility, volume of futures trading and open interest in the UK and the US. Based on a dataset over the period February 25, 2008 to March 14, 2013, that encompasses both the global financial crisis and the Eurozone debt crisis, we find that spot and futures volatilities in the UK (US) are net receivers (net transmitters) of shocks to volume of futures trading and open interest. The analysis also sheds light on the dynamic interdependence of spot and futures market volatilities between the US and UK. Specifically, the spot and futures volatility spillovers between the UK and US markets are of bidirectional nature, however, they are affected by major economic events such as the global financial and Eurozone debt crisis. Overall, these results have important implications for various market participants and financial sector regulators.

Keywords: Spot and Futures Markets, Volatility, Volume, Open Interest, Spillovers

JEL codes: C32, G11, G12, G15

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1 Introduction

In the aftermath of the global financial crisis, the appetite for risk in financial markets decreased, as investors sought to rebalance their portfolios towards government bonds and other vehicles of safer investments and to hedge their risky positions in spot markets by opening the offsetting positions in futures markets. Thus, the importance of futures markets has grown over time and it has stimulated a renewed research interest in the theme. There is a large body of literature that studies various aspects of futures markets. The relation between spot and futures markets is dominated by the price discovery hypothesis (Chan, 1992; Ghosh, 1993) and the volatility spillover hypothesis (Tao and Green, 2012), accompanied by the "heat wave" and the "meteor shower" hypotheses (Wu et al., 2005). The relation among price volatility, volume of trading and open interest gave rise to the sequential arrival of information (SAI) hypothesis (Copeland, 1976) and to the mixture of distributions hypothesis (MDH) (Clark, 1973).

A common feature of the previous empirical studies on the above hypotheses is that they have confined themselves to the examination of *static* spillover effects (see, for instance, Rittler, 2012; Tao and Green, 2012; Rittler, 2012; Wu et al., 2005; Tse, 1999; Booth et al., 1996; Lin et al., 1994; Hamao et al., 1990, among others). Put differently, previous studies do not investigate the *dynamic* spillover effects between futures return volatility and trading volume and futures return volatility and open interest. Therefore, previous studies do not consider whether shocks in one market could be attributed to time-varying spillovers between US (S&P 500) futures return volatility, trading volume and open interest, and UK (FTSE 100) futures return volatility, trading volume and open interest. This is particularly important as the use of an average measure of spillovers over a fairly long and turbulent period might mask potentially interesting information on secular or cyclical movements in spillover effects. Given that many changes took place over the period 2008-2013, such as the global financial crisis and the Eurozone debt crisis, the transmission mechanism across futures markets needs reconsideration. This study provides new empirical evidence on information transmission in stock index futures markets.

In particular, this study investigates the time-varying linkages between spot, futures, trading volume and open interest in the S&P 500 and FTSE 100 markets using the Diebold and Yilmaz (2009, 2012) models. The approach proposed by Diebold and Yilmaz (2009, 2012) is particularly suited for the investigation of systems of highly interdependent variables and it conveniently allows the identification of the main receivers and transmitters of shocks among the aforementioned variables over time. The aim of this study is to test the extent to which the spillover of volatility between futures and spot market is information driven. Put differently, this study examines the dynamic volatility spillover mechanisms and feedback effects between US and UK cash and futures markets within a generalized VAR framework.

This research contributes to the existing literature in several ways. First, the analysis of Wu et al. (2005) and Tao and Green (2012) is extended by testing the dynamic interdependence between spot and futures market volatility, volume of futures trading and open interest (liquidity variables). Second, the study of Rittler (2012) is extended by estimating volatility spillover effects in UK and US futures markets using the recent econometric methods developed by Diebold and Yilmaz (2009, 2012). The empirical findings of this study can be summarized as follows. First, spot and futures volatilities in the UK (the US) are net receivers (net transmitters) of spillovers to volume of futures trading. Second, shocks to volume of futures trading significantly contribute to the forecast error variance of open interest. Third, we find evidence of bidirectional interdependence between spot and futures volatilities in the UK and the US, which is affected by major economic events, such as the global financial crisis and the Eurozone debt crisis. Overall, there is evidence of spillovers within the volatility-volume-open interest relations. These findings are helpful to financial analysts and risk managers dealing with futures markets, as well as financial sector regulators. For instance, the finding that spot and future volatilities in the UK are net receivers of spillovers from volume of futures trading can raise concerns of the Financial Conduct Authority, a regulator of the financial services industry in the UK. Risk managers (financial analysts) can use the knowledge of futures volume in the UK and of spot and futures market volatility in the US to design optimal hedging strategies against undesired movements (provide a comprehensive analysis of an investment opportunity) in cash and futures markets in the UK.

The rest of this paper is organised as follows: Section 2 present a literature review of the related studies. Section 3 describes the data used, while Section 4 presents the econometric models employed. Section 5 reports the empirical results. Section 6 concludes the paper and discusses points for further research.

2 Literature Review

The advent of futures markets opened up new opportunities for traders, investors and researchers. Specifically, researchers find that stock index futures markets incorporate market-wide information more efficiently (Bohl et al., 2011) and more quickly (Brooks et al., 2001; Chou and Chung, 2006; Koutmos and Tucker, 1996; Pizzi et al., 1998; Stoll and Whaley, 1990; Tse, 1999) than spot markets. The issue of information transmission between spot and futures markets is of interest to financial analysts and policy makers. Numerous studies investigate how information from one market is transmitted to another; empirical investigation of this issue commonly focuses on the price discovery and volatility spillovers.[1]

Price discovery is the process by which a market (usually the futures market) reflects new information before another related market (usually the spot market), see for instance, Sutcliffe (2006). In general, futures markets play a price discovery role, implying that futures prices contain useful information about cash prices; therefore, arbitrage opportunities exist (Floros and Vougas, 2008). Several studies examine the empirical relationship between the spot and futures markets and provide evidence on the dominant role of futures in the price discovery process (Chan, 1992; Ghosh, 1993). In general, empirical studies find that futures returns lead spot returns (Ng, 1987; Kawaller et al., 1987; Stoll and Whaley, 1990; Floros and Vougas, 2008).

Further, volatility spillover hypothesis exists "if volatility spillovers are combined with asymmetries, a bad news shock in either market may increase volatility and its persistence in both markets" (Tao and Green, 2012). Most articles use GARCH-family models to examine the volatility spillovers between spot and futures markets (see Hamao et al., 1990; Lin et al., 1994; Booth et al., 1996; Tse, 1999; Rittler, 2012). They report spillovers from the futures to the spot market. Wu et al. (2005) examine information transmissions between the S&P 500 and FTSE 100 index futures and find that the volatility of the US

[1] Futures markets perform the main functions of risk transfer and price discovery (Silber, 1985). Further, volatility spillovers between spot and futures markets "play an important role in managing risk for portfolio managers and assessing market stability for policy makers" (Pati and Rajib, 2011) in returns.

market is affected by the most recent volatility surprise in the UK market. They report no significant lagged spillovers in the conditional mean returns.[2] Recently, Tao and Green (2012) find significant volatility asymmetries in both the FTSE 100 cash and stock index futures prices. However, volatility spillover effects are not studied among two important financial variables: trading volume and open interest.

An important aspect of volatility is its relation to liquidity variables, such as trading volume and open interest (see Martinez and Tse, 2008). Trading volume has been widely used as a measure for the rate of information arrival; it is the number of transactions in a futures contract during a specified period of time (see Sutcliffe, 2006). Trading volume is viewed as a proxy for new information, consistently with the sequential information model (Copeland, 1976) and the mixture of distributions hypothesis (Clark, 1973); these theories predict a positive relationship between daily volume and volatility (see for example Kawaller et al. (1990); Locke and Sayers (1993); Kawaller et al. (1994); Wang and Yau (2000) for US, and Board and Sutcliffe (1990); Gwilym et al. (1999) for UK). Trading volume measures speculative demand for futures (Lucia and Pardo, 2010). Further, open interest is an important variable and is regarded as a proxy for dispersion of beliefs (Bessembinder et al., 1996; Mougoué and Aggarwal, 2011); it is an important determinant of volume (Mougoué and Aggarwal, 2011). Open interest is the total number of futures contracts which have not been closed out (i.e. it is equal to the sum of either the outstanding long positions or the sum of the outstanding short positions); see Sutcliffe (2006). According to Aguenaou et al. (2011), open interest is an indicator of sentiment

[2] Their results support a "heat wave" hypothesis for returns (i.e. information affects one part of the Earth only) and a "meteor shower" hypothesis for volatility (i.e. information arrives on the Earth like a meteor shower) across markets (Wu et al., 2005).

in futures markets. It is also used as a proxy for market depth and heterogeneous beliefs (Watanabe, 2001). Floros (2007) argues that knowledge of open interest can prove useful towards the end of major market moves. Further, open interest proxies the demand for futures contracts as hedging instruments (see Lucia and Pardo, 2010; Aguenaou et al., 2011). Open interest is demonstrated to contain information about future economic activity that is not captured by futures prices or net supply-demand imbalances among hedgers in futures markets (Hong and Yogo, 2012). Bessembinder and Seguin (1992) explain that there may be a correlation between open interest and the number of active informed traders; i.e. open interest may be significantly related to trading volume and price volatility.[3] They argue that "the effect of volume on volatility depends on whether volume generates changes in open interest". Further, Ferris et al. (2002) report that "open interest in the S&P 500 index futures is a useful proxy for examining the flow of capital into or out of the market, given pricing error information shocks" (Ferris et al., 2002, p. 371).

3 Data

Daily spot and futures returns from the US (S&P 500) and UK (FTSE 100) are examined. Returns are calculated as the continuously compounded day–to–day capital gain on the stock index. Closing spot and futures prices are obtained from Bloomberg. The sample spans the period from February 25, 2008 to March 14, 2013, and includes 1247 trading days (near-time delivery futures contracts are considered). The standard S&P 500 (FTSE

[3]The authors suggest that greater market depth tends to lower volatility associated with a given volume, implying that a trade that leads to an increase in trading volume and open interest has a smaller effect on volatility than a trade that leads to high volume without a corresponding increase in open interest.

100) futures contract size is 250 US dollars (10 Great Britain pounds) per index point of the underlying. In and Kim (2006), in their study on the relation between the S&P 500 stock index and futures markets, provide details of the S&P 500 market characteristics. In particular, they argue that the FTSE 100 stock index futures are heavily traded in the last three months before expiration. As a futures contract approaches its expiration, investors close their positions and open new positions in the next near contract. The S&P 500 and FTSE 100 stock index futures contracts have maturity dates in March, June, September and December and are settled in cash.

Daily spot and futures returns in the US and the UK in conjunction with the total volume of contracts and the open interest in the US and UK futures markets are analysed. The daily trade volume counts the number of contracts that have been traded in a given day. The open interest, which measures the size of open positions, equals the number of outstanding long positions at the end of a day.

[Insert Table 1 about here]

Table 1 gives the descriptive statistics for returns, trading volumes and open interest. On average, daily returns are positive and higher for the S&P 500 stock index. In the S&P 500 (FTSE 100) stock index futures market, there are on average 27.5 (119) thousand daily trade contracts. The average daily open interests in the S&P 500 and FTSE 100 stock index futures markets are 333 and 592 thousand contracts, respectively. The trading volume and open interest show higher volatility for the FTSE 100 stock index futures market. The negative values for skewness of returns indicate that the sampling distributions are skewed to the left, making the occurrence of large negative values more likely than large positive values. Returns from the S&P 500 stock index futures (spot) market are relatively less (more) skewed than returns from the FTSE 100 stock index futures (spot) market. The volumes of trading are positively skewed, whereas the open interest in the FTSE 100 (S&P 500) stock index futures market is positively (negatively) skewed. The values of excess kurtosis are positive, indicating that the sampling distributions are leptokurtic or peaked.

Unit root tests based the Augmented Dickey-Fuller (ADF) procedure were conducted and suggest that the series are stationary. As a result, spot and futures returns, the trading volume and the open interest are used in the subsequent analyses.

The Ljung-Box Q test shows evidence of serial correlation up to order 20 in the variables and variables squared. This motivates using a generalised autoregressive conditional heteroscedasticity (GARCH) approach to model the observed volatility clustering. Evidence of conditional volatility in futures market is reported in the literature (for survey, see Lien and Tse, 2002). Tao and Green (2012) use the dynamic conditional correlation (DCC) based GARCH model to study the volatility asymmetries in the FTSE 100 stock index spot and futures markets.

[Insert Figures 1 and 2 about here]

Figure 1 depicts variation over time in the FTSE 100 stock index spot and futures prices (Panel A), and spot and futures continuously compounded returns (Panel B). Panel A shows that the stock and futures prices were generally decreasing in 2008, following the sub-prime mortgage crisis in the US and the global financial crisis, until they reached a trough in the first quarter of 2009. They started to recover since then with occasional reversals. As expected, the two series showed very similar variation over time. Panel B shows that the stock and futures returns became volatile in the bearish stock market.

Spot and futures return volatility started to decrease in 2009. Figure 2 depicts variation over time in the S&P 500 stock index spot and futures prices (Panel A), and spot and futures continuously compounded returns (Panel B). As for the case of the FTSE 100 stock market index, the S&P 500 stock index spot and futures prices were decreasing until the first quarter of 2009, and they started to recover since then (Panel A). In the bearish stock market stance spot and futures returns also saw increased variability (Panel B).

Figure 3 depicts variation over time in the volume of trading in FTSE 100 stock index futures market (Panel A), and the open interest (Panel B). Panel A shows that the volume of trading has undergone significant variation overtime. Graphical inspection allows identifying seasonal effects that are caused by increased trade activity with a futures contract approaching its expiration in March, June, September and December. Trade activity particularly intensifies in the last days of a contracts maturity. Fluctuations of the volume of trading tend to revert to a gradually declining mean. The largest increase in the volume of trading occurred around the beginning of the global financial crisis in October 2008.

[Insert Figure 3 about here]

The open interest also shows significant seasonal effects. Unlike with the volume of trading, the open interest decreases the near is a futures contract to its expiration, as traders close their positions. When the futures contract expires, traders start opening new positions in the next near contract. As with the volume of trading, the open interest increased abruptly in the beginning of the global financial crisis and has permanently remained higher than its pre-crisis level. Given the above observations, the FTSE 100 futures volume and open interest series are adjusted for the systematic seasonal effects using the following respective regression equations

$$FTSE100FV_t = \alpha_0 + \alpha_1 D_{MARt} + \alpha_2 D_{JUNt} + \alpha_3 D_{SEPt} + \alpha_4 D_{DECt} + \gamma_t \quad (1)$$

$$FTSE100FOI_t = \alpha_0 + \alpha_1 D_{MARt} + \alpha_2 D_{JUNt} + \alpha_3 D_{SEPt} + \alpha_4 D_{DECt} + \delta_t, \quad (2)$$

where D_{MARt}, D_{JUNt}, D_{SEPt} and D_{DECt} are the dummy variables that equal to one if the month is March, June, September and December, respectively, and zero otherwise, α_i are the parameters to be estimated, and γ_t and δ_t are the error terms. The residuals, γ_t and δ_t, from Equations 1 and 2 above are the seasonally adjusted FTSE 100 futures volume and open interest series. Throughout the remainder of the paper, the analysis is based on the seasonally adjusted returns series, γ_t and δ_t.

Figure 4 depicts variation over time in the volume of trading in S&P 500 stock index futures market (Panel A), and the open interest (Panel B). The volume of trading and the open interest show a different pattern from that depicted in Figure 3. First of all, both the volume of trading and the open interest show a clear tendency to decrease. Second, the observed increase in the open interest in the beginning of the global financial crisis is transitory. Therefore, the S&P 500 futures volume and open interest series are adjusted for the systematic seasonal effects and the declining trend using the following respective regression equations

$$FTSE100FV_t = \alpha_0 + \alpha_1 D_{MARt} + \alpha_2 D_{JUNt} + \alpha_3 D_{SEPt} + \alpha_4 D_{DECt} + \alpha_5 Trend + \zeta_t \quad (3)$$

$$FTSE100FOI_t = \alpha_0 + \alpha_1 D_{MARt} + \alpha_2 D_{JUNt} + \alpha_3 D_{SEPt} + \alpha_4 D_{DECt} + \alpha_5 Trend + \theta_t, \quad (4)$$

where D_{MARt}, D_{JUNt}, D_{SEPt} and D_{DECt} are defined similarly as the ones above, $Trend$ is a linear time trend, α_i are the parameters to be estimated, and ζ_t and θ_t are the error terms. The residuals, ζ_t and θ_t, from Equations 3 and 4 above are the seasonally adjusted S&P 500 futures volume and open interest series. Throughout the remainder of the paper, the analysis is based on the seasonally adjusted returns series, ζ_t and θ_t.

[Insert Figure 4 about here]

4 Empirical Model and Methodology

In the following, the application of the spillover index approach introduced by Diebold and Yilmaz (2009) is outlined. Building on the seminal work on VAR models by Sims (1980) and the well-known notion of variance decompositions, it allows an assessment of the contributions of shocks to variables to the forecast error variances of both the respective and the other variables of the model. Using rolling-window estimation, the evolution of spillover effects can be traced over time and illustrated by spillover plots.

For the purpose of the present study, the variant of the spillover index in Diebold and Yilmaz (2012) is used, which extends and generalizes the method in Diebold and Yilmaz (2009) in two respects. First, they introduce refined measures of directional spillovers and net spillovers, providing an 'input-output' decomposition of total spillovers into those coming from (or to) a particular source and allowing to identify the main recipients and transmitters of spillovers.

Second, in line with Koop et al. (1996), Pesaran and Shin (1998) and Diebold and Yilmaz (2012), a generalized vector autoregressive framework is employed, in which forecast-error variance decompositions are invariant to the ordering of the variables (in contrast to Cholesky-factor identification used (Diebold and Yilmaz, 2009)). In the context of the present study, this is particularly important since it is hard if not impossible to justify one particular ordering of the variables on spot and futures volatility.[4]

Starting point for the analysis is the following P-th order, K-variable VAR

$$y_t = \sum_{i=1}^{P} \Theta_i y_{t-i} + \varepsilon_t \tag{5}$$

where $y_t = (y_{1t}, y_{2t}, \ldots, y_{Kt})$ is a vector of K endogenous variables, $\Theta_i, i = 1, ..., P$, are $K \times K$ parameter matrices and $\varepsilon_t \sim (0, \Sigma)$ is vector of disturbances that are independently distributed over time; $t = 1$, ..., T is the time index and $k = 1$, ..., K is the variable index.

Key to the dynamics of the system is the moving average representation of model 5, which is given by $y_t = \sum_{j=0}^{\infty} A_j \varepsilon_{t-j}$, where the $K \times K$ coefficient matrices A_j are recursively defined as $A_j = \Theta_1 A_{j-1} + \Theta_2 A_{j-2} + \ldots + \Theta_p A_{j-p}$, where A_0 is the $K \times K$ identity matrix and $A_j = 0$ for $j < 0$.

Following Diebold and Yilmaz (2012) the generalized VAR framework of Koop et al. (1996) and Pesaran and Shin (1998) is used, which produces variance decompositions invariant to the variable ordering. According to this framework, the H-step-ahead forecast error variance decomposition is

$$\phi_{ij}(H) = \frac{\sigma_{jj}^{-1} \sum_{h=0}^{H-1} (e_i' A_h \Sigma e_j)^2}{\sum_{h=0}^{H-1} (e_i' A_h \Sigma A_h' e_i)}, \tag{6}$$

where Σ is the (estimated) variance matrix of the error vector ε, σ_{jj} the (estimated) standard deviation of the error term for the j-th equation and e_i a selection vector with one as

[4]We nevertheless explore the robustness of the results against a more structural approach, using Cholesky-factorizations with alternative orderings and our main findings are almost identical. These results are available from the authors upon request.

the i-th element and zeros otherwise. This yields a $K \times K$ matrix $\phi(H) = [\phi_{ij}(H)]_{i,j=1,\ldots K}$, where each entry gives the contribution of variable j to the forecast error variance of variable i. The main diagonal elements contains the (own) contributions of shocks to the variable i to its own forecast error variance, the off-diagonal elements show the (cross) contributions of the other variables j to the forecast error variance of variable i.

Since the own and cross-variable variance contribution shares do not sum to one under the generalized decomposition, i.e., $\sum_{j=1}^{K} \phi_{ij}(H) \neq 1$, each entry of the variance decomposition matrix is normalized by its row sum, such that

$$\tilde{\phi}_{ij}(H) = \frac{\phi_{ij}(H)}{\sum_{j=1}^{K} \phi_{ij}(H)} \tag{7}$$

with $\sum_{j=1}^{K} \tilde{\phi}_{ij}(H) = 1$ and $\sum_{i,j=1}^{K} \tilde{\phi}_{ij}(H) = K$ by construction.

This ultimately allows to define a total (volatility) spillover index, which is given by

$$TS(H) = \frac{\sum_{i,j=1, i\neq j}^{K} \tilde{\phi}_{ij}(H)}{\sum_{i,j=1}^{K} \tilde{\phi}_{ij}(H)} \times 100 = \frac{\sum_{i,j=1, i\neq j}^{K} \tilde{\phi}_{ij}(H)}{K} \times 100 \tag{8}$$

which gives the average contribution of spillovers from shocks to all (other) variables to the total forecast error variance.

This approach is quite flexible and allows to obtain a more differentiated picture by considering directional spillovers: Specifically, the directional spillovers received by variable i from all other variables j are defined as

$$DS_{i\leftarrow j}(H) = \frac{\sum_{j=1, j\neq i}^{K} \tilde{\phi}_{ij}(H)}{\sum_{i,j=1}^{K} \tilde{\phi}_{ij}(H)} \times 100 = \frac{\sum_{j=1, j\neq i}^{K} \tilde{\phi}_{ij}(H)}{K} \times 100 \tag{9}$$

and the directional spillovers transmitted by variable i to all other variables j as

$$DS_{i\to j}(H) = \frac{\sum_{j=1,j\neq i}^{K}\tilde{\phi}_{ji}(H)}{\sum_{i,j=1}^{K}\tilde{\phi}_{ji}(H)} \times 100 = \frac{\sum_{j=1,j\neq i}^{K}\tilde{\phi}_{ji}(H)}{K} \times 100. \tag{10}$$

Notice that the set of directional spillovers provides a decomposition of total spillovers into those coming from (or to) a particular source.

By subtracting Equation (9) from Equation (10) the net spillover from variable i to all other variables j are obtained as

$$NS_i(H) = DS_{i\to j}(H) - DS_{i\leftarrow j}(H), \tag{11}$$

providing information on whether a country (variable) is a receiver or transmitter of shocks in net terms. Put differently, Equation 11 provides summary information about how much each market contributes to the volatility in other markets, in net terms.

Finally, the net pairwise spillovers can be calculated as

$$\begin{aligned} NPS_{ij}(H) &= \left(\frac{\tilde{\phi}_{ji}(H)}{\sum_{i,m=1}^{K}\tilde{\phi}_{im}(H)} - \frac{\tilde{\phi}_{ij}(H)}{\sum_{j,m=1}^{K}\tilde{\phi}_{jm}(H)}\right) \times 100 \\ &= \left(\frac{\tilde{\phi}_{ji}(H) - \tilde{\phi}_{ij}(H)}{K}\right) \times 100. \end{aligned} \tag{12}$$

The net pairwise volatility spillover between markets i and j is simply the difference between the gross volatility shocks transmitted from market i to market j and those transmitted from j to i.

The spillover index approach provides measures of the intensity of interdependence across countries and variables and allows a decomposition of spillover effects by source and recipient.

5 Empirical findings

The generalized VAR framework of Diebold and Yilmaz (2012) is used to construct total, directional and net (pairwise) spillovers. The Schwarz Bayesian Information Criterion (BIC) is used to determine the optimal lag length for the VAR models. Moreover, the volatilities of the spot and futures returns of FTSE 100 and S&P 500 are obtained from the DCC GARCH model of Engle (2002).[5] Section 5.1, presents the estimation results of the bivariate VARs featuring spot and futures return volatility in the US and the UK. Section 5.2 reports the estimation results of the four-variate VARs that allow for international spot and futures return volatility spillovers. Section 5.3 presents the results of the four-variate VARs to study volatility spillovers among spot and futures return volatility, volume of trading and open interest in the US and the UK.

5.1 Spot-Futures Return Volatility Spillovers

Tables 2 and 3, report the decomposition of the total volatility spillover index between futures and spot returns and the UK and the US, respectively.

[Insert Tables 2 and 3 about here]

According to Tables Tables 2 and 3, directional spillovers between spot and futures return volatilities are around 50%, suggesting that both spot and futures return volatilities are equally informative about the variability in the spot and futures markets.[6] This result holds for both FTSE 100 and S&P 500 indices. In other words, shocks to futures or spot

[5]We employ a four-variate DDC GARCH model to obtain the conditional variances of spot and futures returns so as to take into account the interdependencies in these two markets' spot and futures returns. However, conditional variances obtained by bivariate DCC GARCH models in the UK and US do not alter the results.

[6]Using the squared returns of spot and futures returns as an alternative proxy of volatility, the results remained qualitatively similar.

return volatility tend to have similar percentage contributions in both the spot and futures markets. Theoretical and empirical developments in the literature suggest that both the spot and futures market adjust similarly in response to the same market-wide news. A standard forward pricing model, used for pricing stock index futures contracts, implies that futures and spot returns must have the same variance (Abhyankar, 1995). Chan et al. (1991) report evidence of bilateral dependence between spot and futures markets' return volatilities. They argue that "new market information disseminates in both the futures and stock markets and that both markets serve important price discovery roles". Tao and Green (2012) maintain that market-wide news is impounded into the FTSE 100 spot and futures markets simultaneously. Moreover, the result that own directional spillover is greater than directional spillover to the other market is probably related to the fact that some news may be related to futures trading but not to the spot market (Antoniou and Holmes, 1995).

Given that many changes took place during the years in our sample, 2008-2013, such as the global financial and the Eurozone debt crisis, the use of an average measure of spot and futures volatility spillovers over a fairly long and turbulent period might mask potentially interesting information on secular or cyclical movements in spillover effects. Hence, we estimate the model in Equation (5) using 200-day rolling windows and calculate the variance decompositions and spillover indices. As a result, we obtain time series of estimated spillover indices, allowing us to judge the evolution of total and (net) directional spillovers within and between markets over time.

Figures 5 and 6, report variation over time in the total, directional and net volatility spillover indices in the UK and the US, respectively.

[Insert Figures 5 and 6 about here]

Figures 5 and 6 suggest that volatility spillovers experienced significant variation over time. The total spillover index in the UK (US) varies between the values of 44.5% (45.8%) and 49.7% (50%). Directional volatility spillovers show time-varying patterns in the spot and futures returns in the UK and the US, and the net volatility spillover tend to switch between positive and negative values in the UK and the US. For instance, the beginning of the sample (2008/2009) is marked by the period wherein futures return volatility is a net receiver of shocks in the UK and US. This tendency is then reversed several times in the subsequent sample. Altogether, consistent with Abhyankar (1995), there is no any clear-cut evidence which of the two variables - futures or spot return volatility - leads volatility spillovers to the other market.

5.2 Spot-Futures Return Volatility Spillovers between the UK and US

Table 4, reports the decomposition of the total volatility spillover index in the volatility of spot and futures returns between the UK and US. Wu et al. (2005) argue that futures market appears to impound new information into asset prices faster than the spot market. Kung and Yu (2008) emphasize the leading role of the US spot and futures return market in volatility transmission to other developed markets, including UK. We provide evidence on price discovery between the UK and US markets.

[Insert Table 4 about here]

Table 4 indicates that the volatility of spot and futures returns in the US spills over to the volatility of spot and futures returns in the UK and vice versa. In particular, the S&P 500 spot index (futures) volatility is responsible for 18.2% (18.5%) and 18.5% (19%) of the forecast error variance of the FTSE 100 spot index (futures) volatility, while the FTSE 100 spot index (futures) volatility is responsible for 15.5% (17.9%) and 13.8% (16.5%) of the forecast error variance of the S&P 500 spot index (futures) volatility. This finding suggests that futures investors and traders in both the UK and US markets should monitor developments in both the UK and US. These results are consistent with Wu et al. (2005) who report evidence of bilateral spillovers between the S&P 500 and FTSE 100 stock index futures volatility, and with Booth et al. (1997) who find evidence supporting the meteor shower hypothesis in the S&P 500 and FTSE 100 stock index futures volatility. The results are also partly consistent with Hamao et al. (1990) who find evidence of volatility transmission from S&P500 to FTSE 100, as such evidence over specific sub-periods is found.

[Insert Figure 7 about here]

Specifically, Figure 7 which plots the time–varying spillover indices, provides further insights into volatility interdependencies in spot and futures markets between the UK and the US. Notably, the time–varying net volatility spillovers between spot and futures return volatility in the FTSE 100 and in the S&P 500 stock markets are time– and event–specific. For instance, during the global financial crisis originated in the US, the US market leads the UK market as the net spillovers of spot and futures volatilities are positive (negative) in the US (UK) between the end of 2008 and beginning of 2010, while from them mid of 2010 and until the mid of 2011 when the debt crisis erupted in the Eurozone, the UK market leads the US market, as the net spillovers of spot and futures returns are negative (positive) in the US (UK). Thus, by employing a time-varying approach more light is shed on time-specific effects of volatility transmission in the spot and futures indexes between the UK and the US.

5.3 Futures Volume and Open Interest Spillovers

Tables 5 and 6 and Figures 8 and 9 report the results of the analysis of spillovers among spot and futures return volatility, futures volume and open interest in the UK and the US, respectively. The relation between futures return volatility and volume of trading is extensively investigated in the research that tests for the mixture of distribution hypothesis (MDH) and the sequential arrival of information (SAI) hypothesis (Mougoué and Aggarwal, 2011). Volume of trading (open interest) can be used to measure speculative (hedging) demand in the futures market (Lucia and Pardo, 2010) and to measure futures-trading activity (Bessembinder and Seguin, 1993). Open interest approximates market depth and it provides information about the average informativeness of traders during the day (Bessembinder and Seguin, 1992). Bessembinder and Seguin (1992) use both trading volume and market depth to study price volatility in the futures market.

[Insert Table 5 and Figure 8 about here]

Table 5 suggests that volume of trading in the FTSE 100 futures market explains 52% of the forecast error variance (FEV) of the other variables in the VAR. Volume of trading contributes 33.4% to the FEV of open interest and it contributes further 9.6% and 8.9%to the FEV of spot and futures return volatility, respectively. By contrast, only 10% of the FEV of volume of trading is explained by the other variables. This result is further supported by Figure 8, where the net spillover of the volume of trading unambiguously appears to be a net transmitter of shocks throughout the sample period.

Besides, eyeballing suggests that the FTSE 100 stock index futures volatility has been, in general, less important transmitter of shocks than the futures volume. In fact, the futures return volatility explains 44% of the FEV of the other variables in the VAR. Specifically, it accounts only for 1.7% of the FEV of volume of trading. Therefore, these results suggest unidirectional spillovers from the volume of trading to futures market volatility which is also supported by the negative net pairwise spillovers between futures return volatility and futures volume in Figure 8. Put differently, the results are consistent with the SAI hypothesis developed by Copeland (1976), who postulates that the volume of trading, which stems as a proxy of arrival of price-relevant new information, contains significant explanatory power for return volatility.

Contrary to the the theoretical implications emphasizing informational content of open interest (e.g., Hong and Yogo (2012)) empirical findings are mixed.[7] Therefore, these findings suggest that the contribution of open interest to the FEV of the other variables is relatively weak and is not inconsistent with the previous literature. Open interest accounts for 5.3% and 5.6% of the FEV of the spot and futures markets volatility, respectively. It further contributes 10.8% to the FEV of volume of trading. The net spillover of open interest in Figure 8 further indicates that open interest is a net receiver of spillovers from the other variables. Bessembinder and Seguin (1993) and Chang et al. (2000) assert that open interest is endogenously determined in the futures market. Consistent with the background provided in Figure 3 (Panel B) the largest increase in open interest is seen in the beginning of the global financial crisis, when rapidly falling asset prices triggered

[7] Mougoué and Aggarwal (2011) find that open interests is statistically significant in both the conditional mean and variance equations in foreign exchange futures contracts. In contrasts, Hong and Yogo (2012) document that open interest is a statistically insignificant determinant of stock index futures returns.

large increases in hedging demand, as predicted by Chang et al. (2000).

[Insert Table 6 and Figure 9 about here]

Table 6 indicates that the S&P 500 stock index spot and futures market volatilities account for 53% and 48%, respectively, of the FEV of the other variables in the VAR. Volume of trading accounts for 38% of the FEV. By contrast, open interest contributes 19% to the FEV of the other variables. Conversely, 38% of the FEV of the spot and futures market volatilities and open interest owes to the other variables. 14% of the FEV of volume of trading owes to the other variables. Taken together, the results imply that, as with the FTSE 100 stock index, volume of trading is a net transmitter of volatility spillover to the other variables in the VAR. However, relative to the UK stock market, the results of S&P 500 suggest that the SAI hypothesis is less characteristic to the US stock market than to the UK stock market, insofar as futures volume explains at best 6% of the FEV in the S&P500 spot and futures index volatilities, while the spot and futures index volatilities capture at best 1.7% of the FEV of volume of trading. However, looking at the net pairwise spillovers between futures volatility and futures volume we observe that futures volatility generally leads the futures volume in the US. These results are in line with Merrick (1987) who finds that volatility can significantly cause futures volume in the US stock market, but evidence of causality in the opposite direction is weak. Bryant et al. (2006) reject the hypothesis that large speculator and small trader activity, calculated as twice the level of open interest, causes futures market volatility. Along similar lines, Chen and Daigler (2008) find that the general public's and institutional traders' volume does not Granger cause futures market volatility of the S&P 500 stock index. Following Xu et al. (2006), the sensitivity of volume of trading to lagged return volatility can be explained by microstructure, public information or inventory control effects. According to Daigler and Wiley (1999), the relation between trading volume and volatility depends upon the type of traders that prevail in the futures market. Specifically, Daigler and Wiley (1999) argue that a positive relation between volume and volatility is driven by the general public who reach decisions based on publicly available information, whereas a negative relation is generated by clearing members, floor traders and other informed traders. These results imply that a positive relation driven by the general public is offset by a negative relation driven by informed traders.

The analysis of pairwise volatility spillover between futures volume and open interest further suggests that futures volume are responsible of 26.9% of the FEV of open interest, whereas shocks to open interest contributes 12% to the FEV of futures volume. Informational content of futures volume received empirical support in the literature (Telser and Higinbotham, 1977). Figure 9 provides further insights into the relation between volatilities, futures volume and open interest. As in the UK market and consistent with the results reported in Table 6, futures volume (open interest) is clearly a net transmitter (receiver) of volatility spillover throughout the sample period. Spot and futures return volatilities tend to transmit spillovers to all other variables.[8]

6 Conclusion

The relation between futures return volatility and volume of trading is extensively investigated in the research that tests for the mixture of distribution hypothesis (MDH) and

[8] As a final note, we explored the robustness of our results by: i) using the first lag of the FTSE 100 series for the analysis of spot and futures return volatility spillovers between the UK and the US in section 5.2 so as to take into account any bias in our results due to asynchronous trading hours in the US and the UK markets, and ii) using alternative H-step-ahead forecast error variance decompositions and alternative m-day rolling windows. Our results remained robust (results available upon request).

the sequential arrival of information (SAI) hypothesis (Mougoué and Aggarwal, 2011). Volume of trading (open interest) can be used to measure speculative (hedging) demand in the futures market (Lucia and Pardo, 2010) and to measure futures-trading activity (Bessembinder and Seguin, 1993). Open interest approximates market depth and it provides information about the average informativeness of traders during the day (Bessembinder and Seguin, 1992). Bessembinder and Seguin (1992) use both trading volume and market depth to study price volatility in the futures market.

The goal of this research is to explicitly examine the dynamic interdependence between spot and futures return volatility, volume of futures trading and open interest in the UK and the US. In light of the growing interest in trading stock index futures for hedging purposes, it is interesting to address the issue of volatility spillover effects between futures returns-trading volume and futures returns-open interest. In this study, the Diebold and Yilmaz (2009, 2012) models are used to study volatility asymmetries in the S&P 500 and FTSE 100 cash and stock index futures markets, and investigate further the linkages between spot, futures, trading volume and open interest.

The empirical findings are summarized as follows. First, spot and futures volatilities in the UK (the US) are net receivers (net transmitters) of spillovers to volume of futures trading. This finding also conveys an important message to financial sector regulators. The widely-accepted belief that an increased speculative activity can destabilize financial market is supported by the results for the UK. On the contrary, for the US, speculative demand for futures tends to endogenously adjust to shocks to spot and futures market volatility. Second, shocks to volume of futures trading significantly contribute to the forecast error variance of open interest. Third, evidence of time- and event-specific bidirectional interdependence between spot and futures volatilities in the UK and the US is present. This finding suggests that, futures investors and traders in the UK (US) market should monitor developments in the US (UK) market. Overall, it is concluded that there is evidence of spillovers within the volatility-volume-open interest relations. However, the spillovers are sensitive to time-specific events such as the global financial crisis and the Eurozone debt crisis. It is thus conjectured that, futures investors should consider adjusting their hedging techniques according to key economic events in specific markets and regions so as to minimize risk associated with spot and futures trading.

The results are in line with previous studies, such as these by (i) Chan et al. (1991); Tao and Green (2012), who also report a volatility spillovers between spot and futures volatilities, by (ii) Wu et al. (2005) who report evidence of bilateral spillovers between the S&P 500 and FTSE 100 futures volatility, and by (iii) Booth et al. (1997) who find evidence supporting the meteor shower hypothesis in the S&P 500 and FTSE 100 stock index futures volatility. The results partly agree with Hamao et al. (1990) who report evidence of volatility transmission from S&P 500 to FTSE 100. The results, reported in section 5.3, are in part consistent with the sequential arrival of information hypothesis, advanced by Copeland (1976). We also provide evidence that volatility can significantly cause futures volume, supported by Merrick (1987), but the converse is not necessarily true (Chen and Daigler, 2008). The result that open interest does not cause futures market volatility is endorsed by Bryant et al. (2006). However, this finding is in contrast with (Mougoué and Aggarwal, 2011), who emphasize the role of open interest as an important determinant of trading volume. Nevertheless, these studies did not consider the Diebold and Yilmaz (2009, 2012) methodology to investigate the dynamic volatility spillover mechanism between UK and US futures markets by measuring directional and net spillovers in a time-varying fashion.

Further research may (i) examine the volatility spillover effects in commodities markets, (ii) explore other explanatory variables that might influence this dynamic interdependence relationship, and (iii) consider another method (Regime-Switching MGARCH or asymmetric volatility spillovers as in Baruník et al. (2013)) to compare the results with those reported from the Diebold and Yilmaz models estimated in this study.

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Figure 1: FTSE 100 - Spot & Futures Prices and Returns

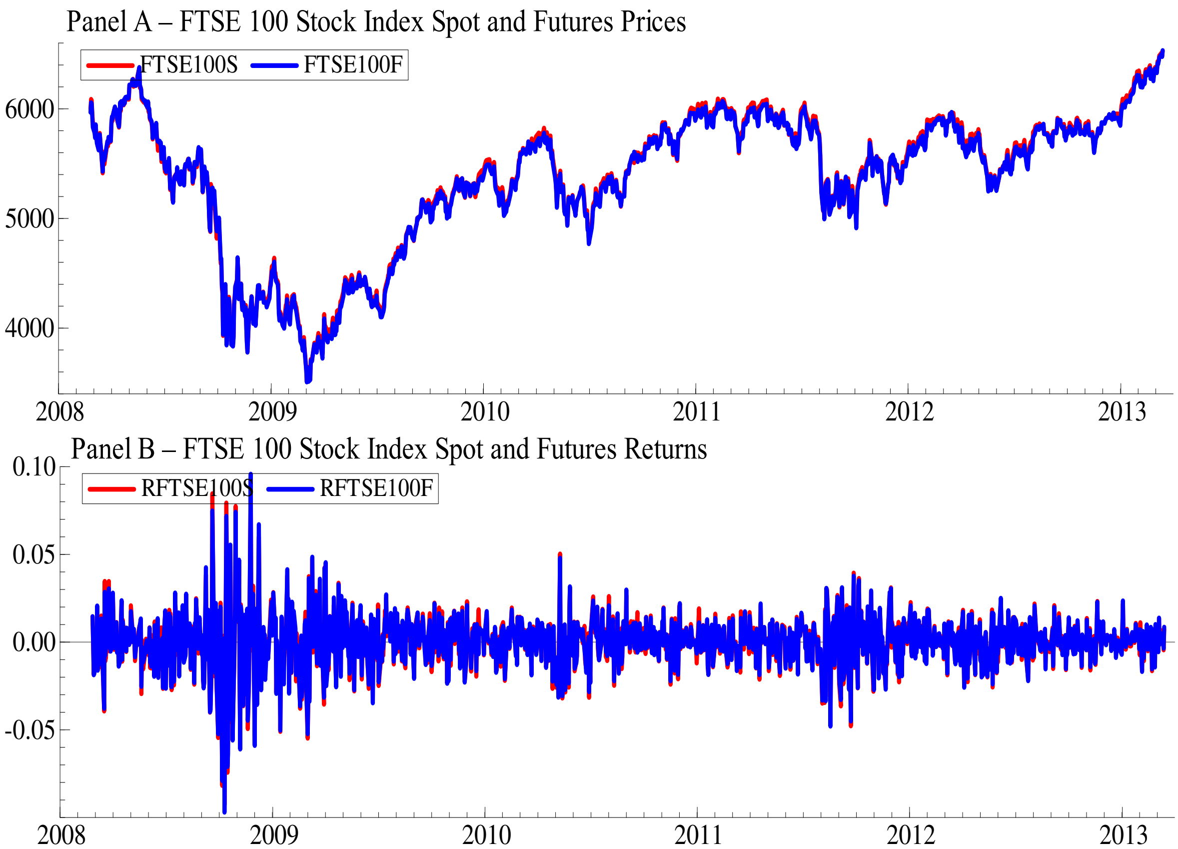


Figure 2: S&P 500 - Spot & Futures Prices and Returns

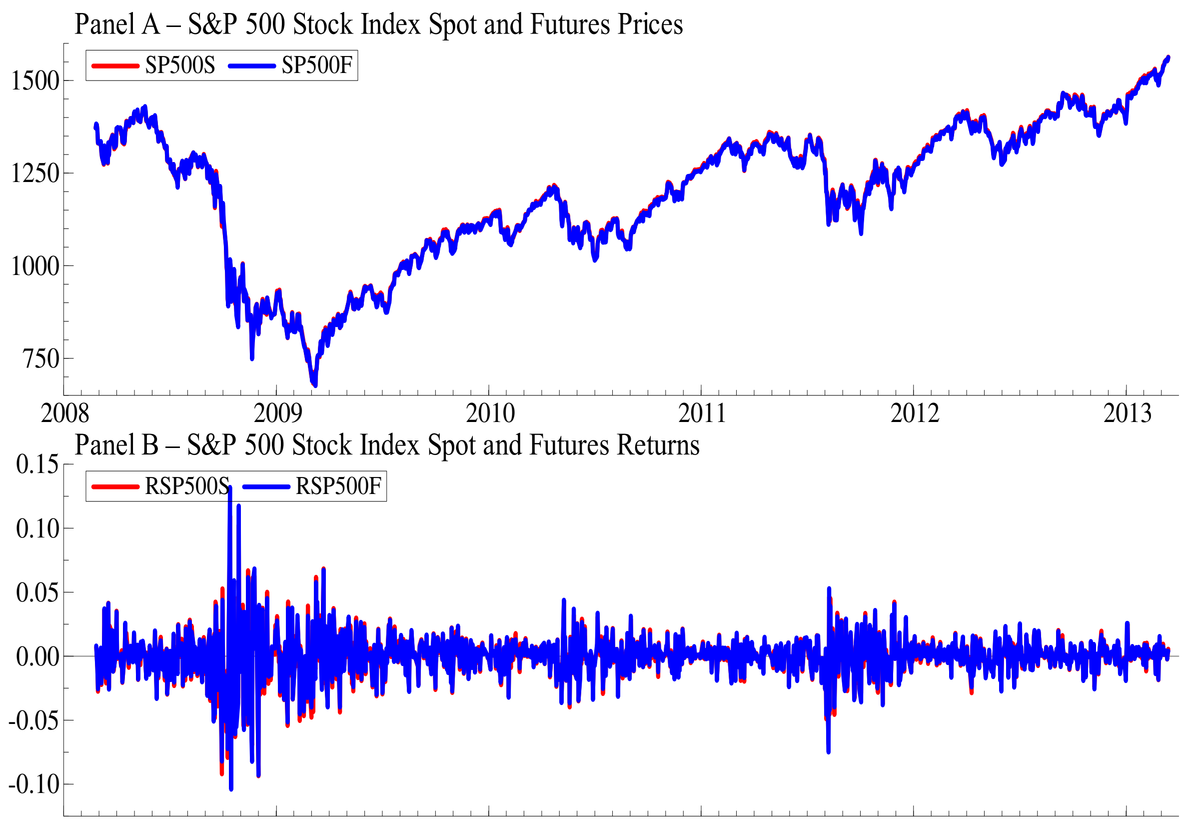


Figure 3: FTSE 100 - Trading Volume & Open Interest

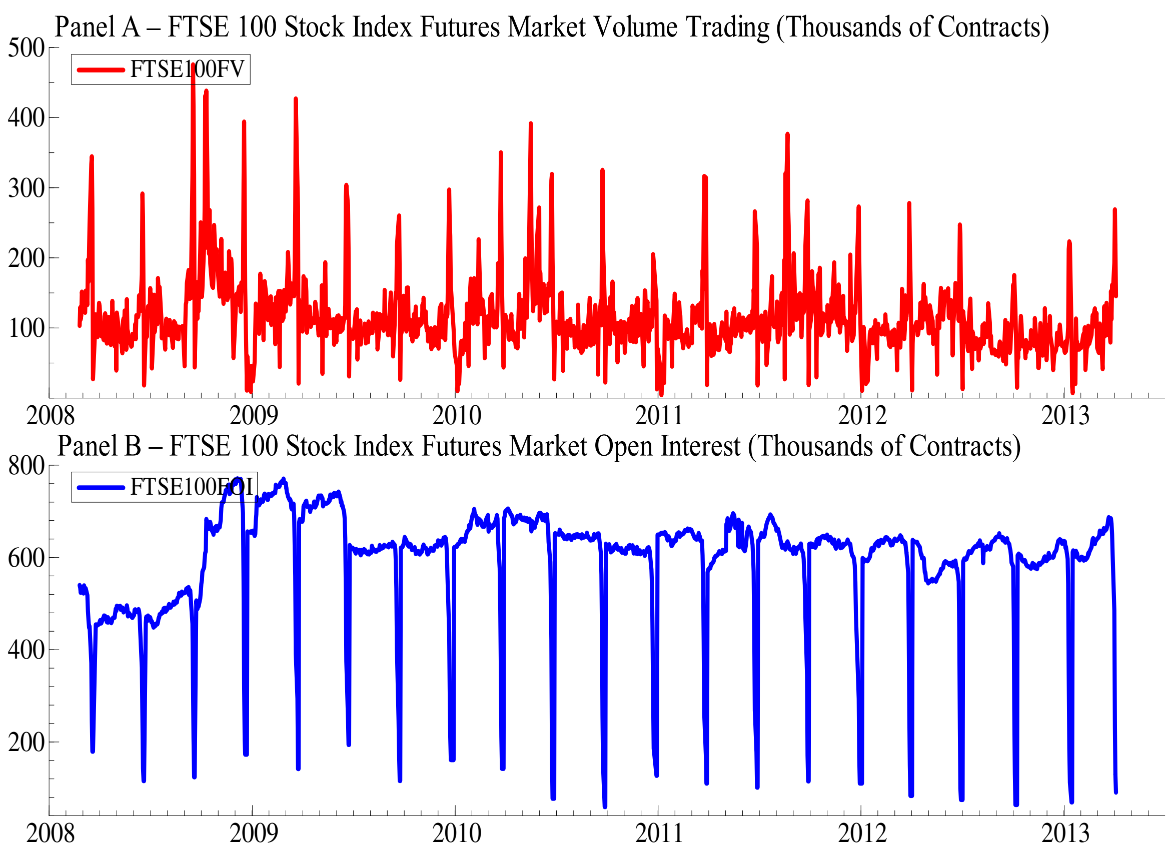


Figure 4: S&P 500 - Trading Volume & Open Interest

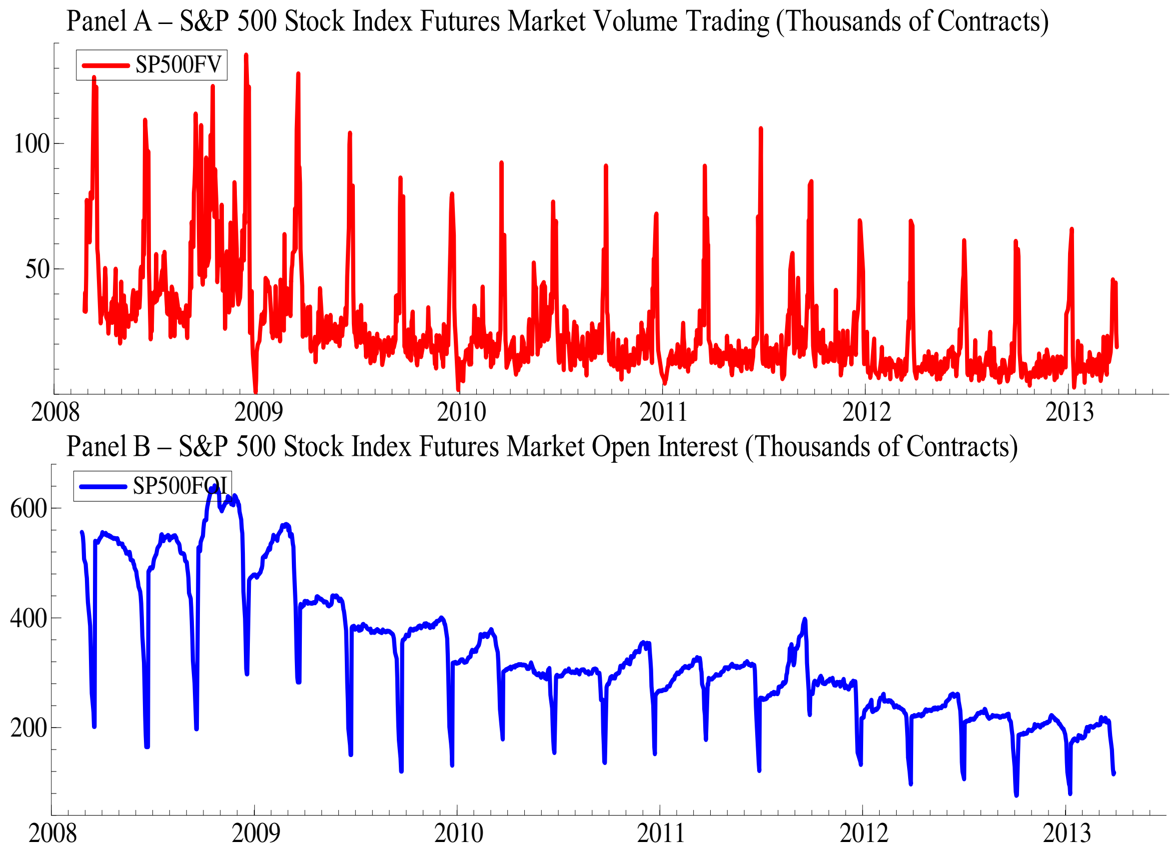
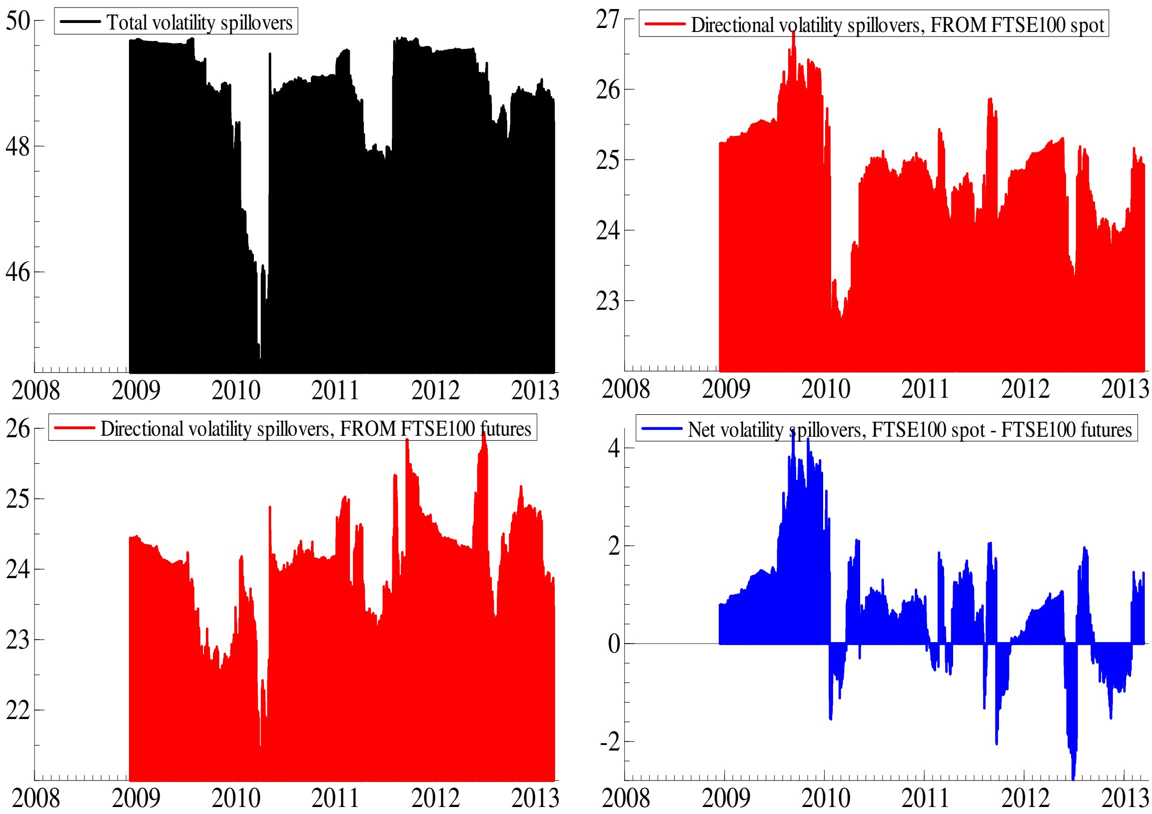
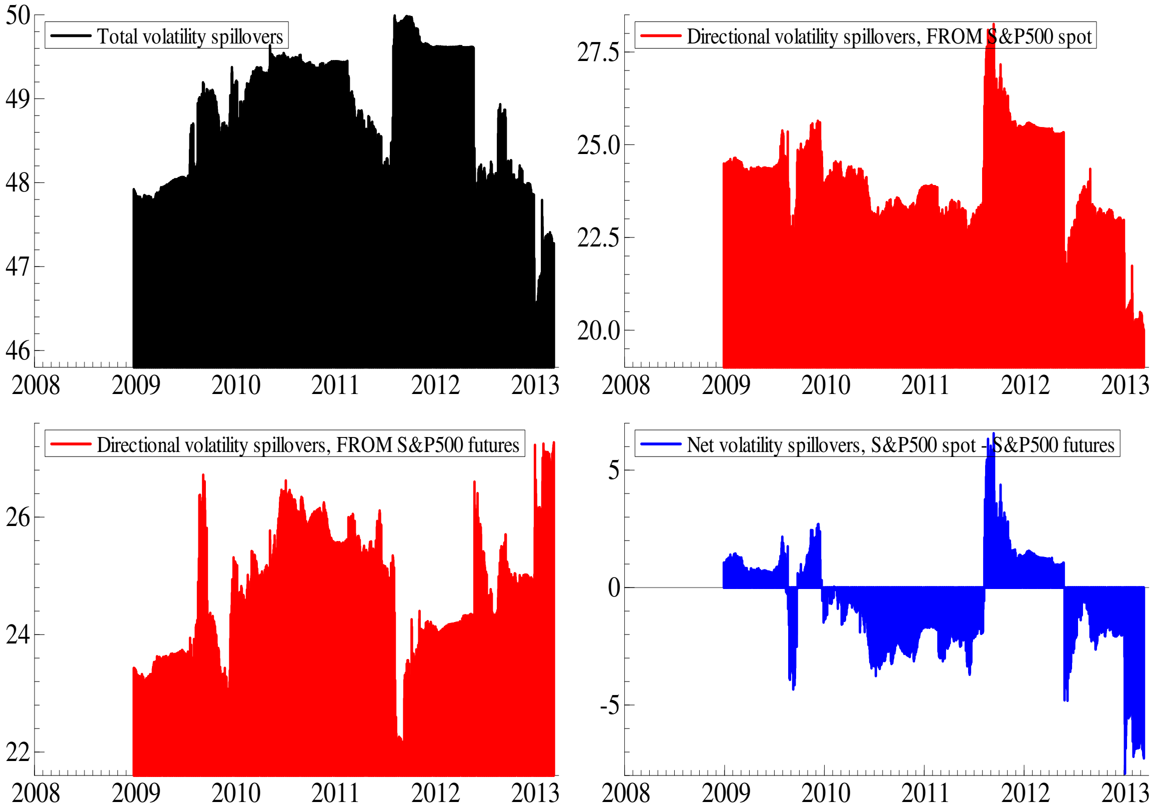


Figure 5: Total, Dir. and Net Spillover Indices - FTSE 100 Spot and Futures Volatility



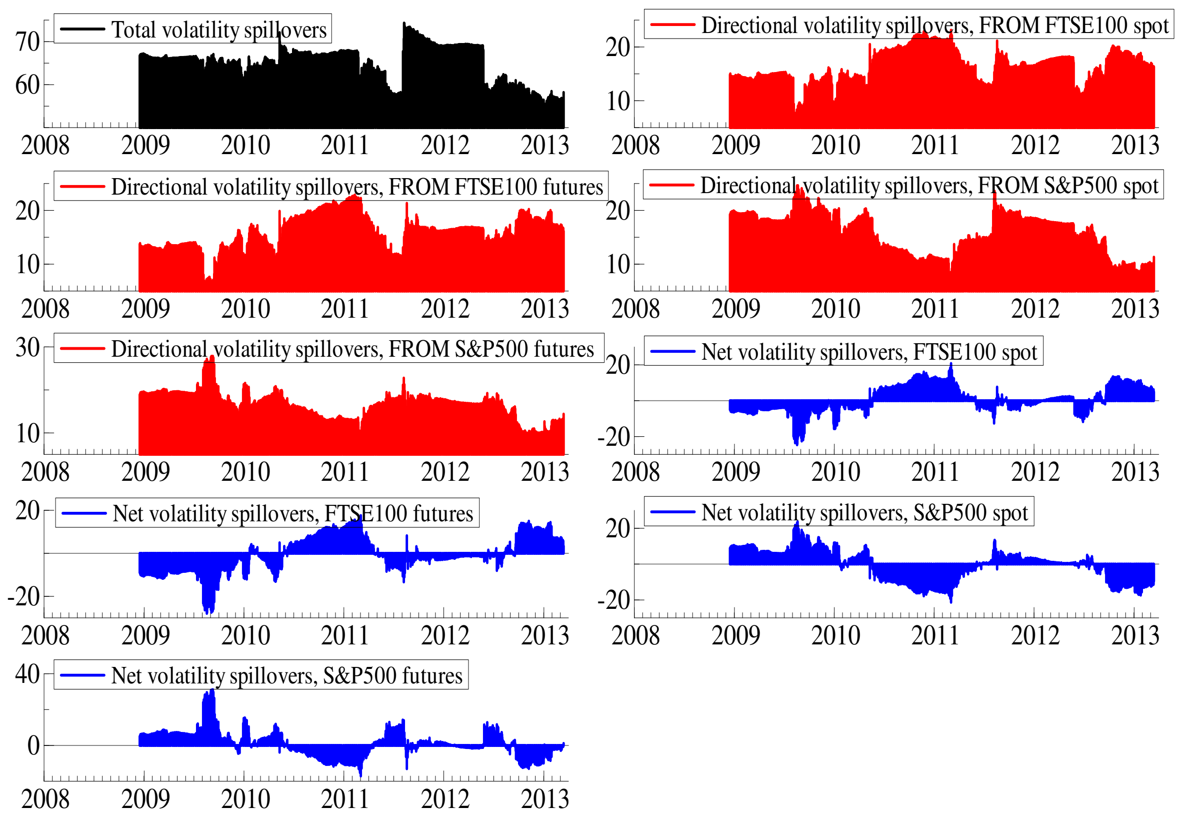
Notes: Plots of moving spillover indices estimated using 200-day rolling windows.

Figure 6: Total, Dir. and Net Spillover Indices - S&P 500 Spot and Futures Volatility



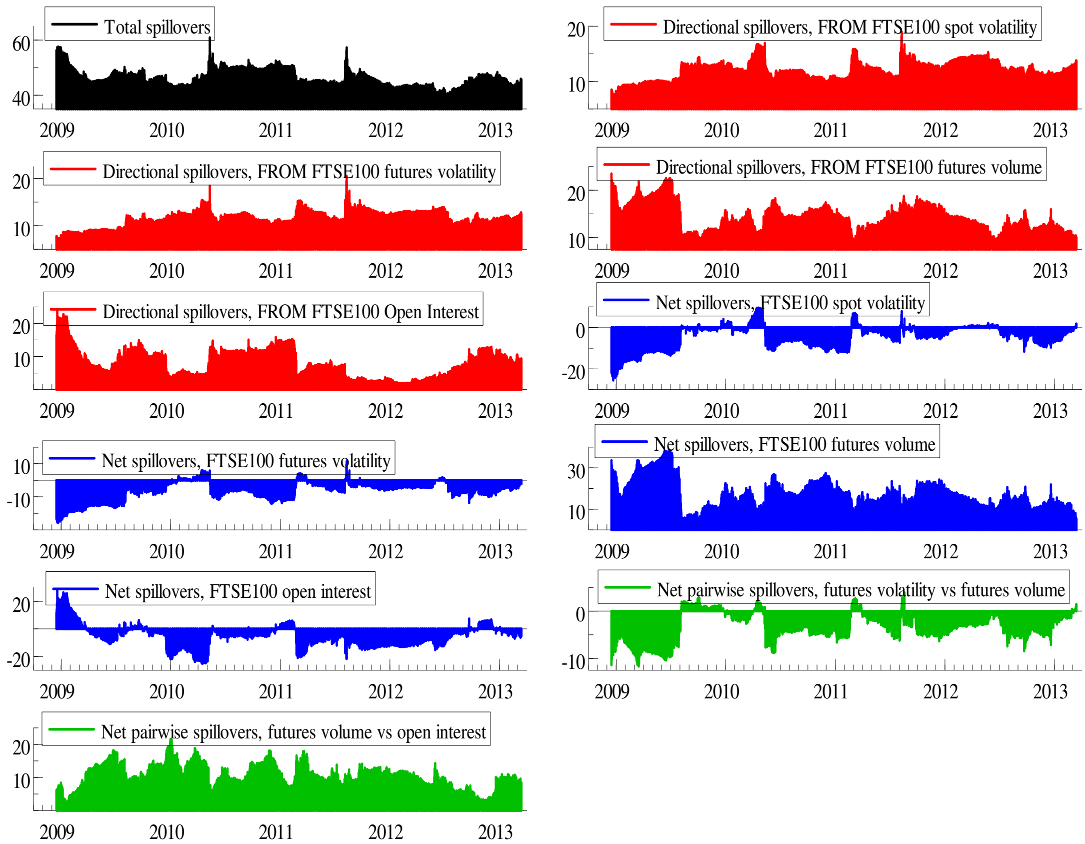
Notes: Plots of moving spillover indices estimated using 200-day rolling windows.

Figure 7: Total, Dir. and Net Spillover Indices - FTSE 100 & S&P500 Spot and Futures Volatility



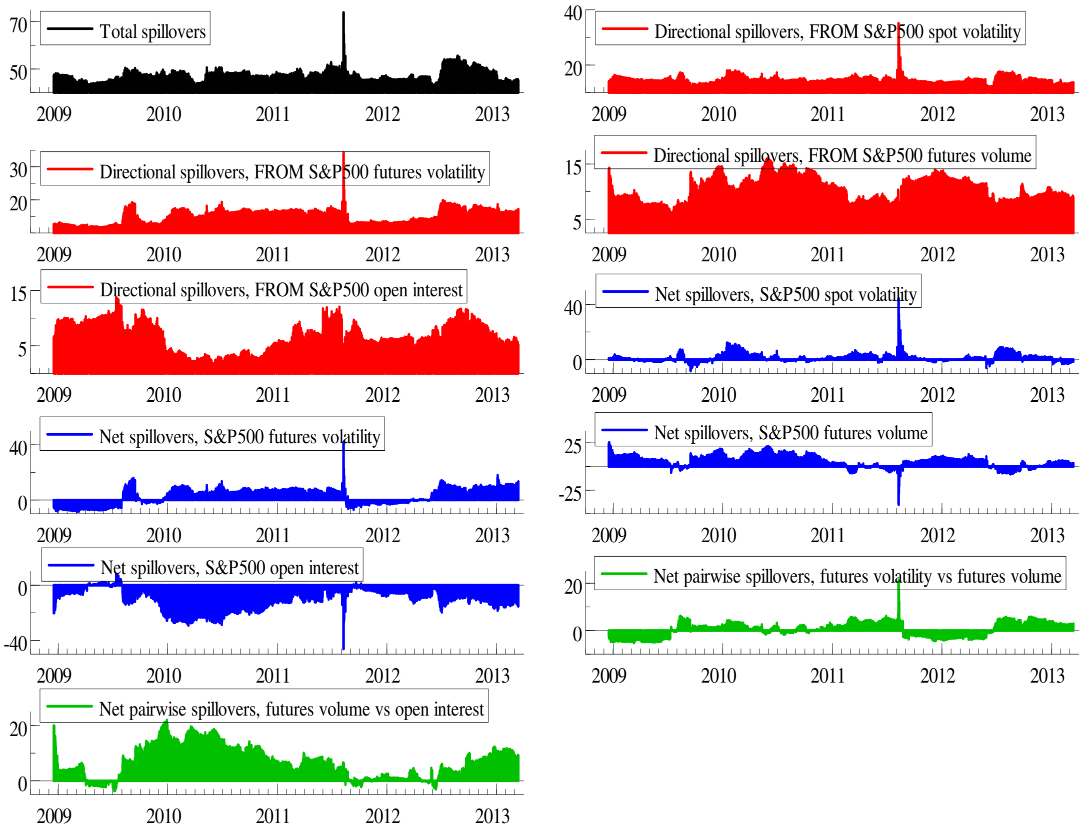
Notes: Plots of moving spillover indices estimated using 200-day rolling windows.

Figure 8: Total, Dir. and Net Spillover Indices - FTSE 100 Spot & Futures Volatility, Futures Volume and Open Interest



Notes: Plots of moving spillover indices estimated using 200-day rolling windows.

Figure 9: Total, Dir. and Net Spillover Indices - S&P 500 Spot & Futures Volatility, Futures Volume and Open Interest



Notes: Plots of moving spillover indices estimated using 200-day rolling windows.

Table 1: Descriptive statistics of FTSE 100 & S&P 500, Spot, Futures, Futures Volume, Open Interest

Statistic	RFTSE100S	RFTSE100F	RSP500S	RSP500F	FTSE100FV	SP500FV	FTSE100FOI	SP500FOI
Mean	6.79E-05	7.23E-05	0.000105	0.0001	118.98	27.468	591.78	332.64
Median	0.0003	0.0004	0.0008	0.0007	107.08	20.272	624.9	305.8
Maximum	0.0938	0.0958	0.1096	0.132	475.54	135.31	770.93	640.9
Minimum	-0.0927	-0.097	-0.0947	-0.104	7.303	0.87	59.409	76.178
Std. Dev.	0.015	0.0149	0.0166	0.0167	55.04	21.139	131.3	121.07
Skewness	-0.0735	-0.1495	-0.2546	-0.0102	2.1114	1.9233	-2.2601	0.6815
Kurtosis	9.4264	9.4331	10.151	12.388	10.344	7.139	8.4413	2.7361
Jarque-Bera	0	0	0	0	0	0	0	0
$Q(20)$	0.0001	0.0004	0	0	0	0	0	0
$Q^2(20)$	0	0	0	0	0	0	0	0
ADF	0	0	0	0	0	0	0	0.0004
Observations	1247	1247	1247	1247	1247	1247	1247	1247

Note: This table summarizes the descriptive statistics. RFTSE100S (RFTSE100F) denotes returns on the FTSE 100 stock index spot (futures) price. RSP500S (SP500F) denotes returns on the S&P 500 stock index spot (futures) price. Returns have been calculated as the first log-difference of the stock market index. FTSE100FV (SP500FV) denotes the trading volume in the FTSE 100 (S&P 500) futures market. FTSE100FOI (SP500FOI) denotes the open interest in the FTSE 100 (S&P 500) futures market. The trading volume and open interest are denominated in thousands of contracts. Q(20) denotes results of the Ljung-Box Q test for autocorrelation of order 20 in variables. Q^2 (20) denotes results of the Ljung-Box Q test for autocorrelation of order 20 in squared variables. For the Jarque-Bera, Ljung-Box Q, and Augmented Dickey-Fuller (ADF) tests, p-values are provided. We use daily data for the period 02/25/2008 23/04/2013 (a total of 1247 observations).

Table 2: Spillover table - FTSE 100 Spot and Futures Volatility

	From (j)		
To (i)	$CVFTSE100S$	$CVFTSE100F$	Contr. from Others
$CVFTSE100S$	51.6	48.4	48
$CVFTSE100F$	50.7	49.3	51
Contr. to others	51	48	Total Spillover
Contr. incl. own	102	98	Index= 49.6%

Notes: CVFTSE100S (CVFTSE100F) denotes the conditional variance of the FTSE 100 stock index spot (futures) returns. The underlying variance decomposition is based upon a VAR of order 5. Spillover indices, given by Equations (8)-(11), calculated from variance decompositions based on 10-step-ahead forecasts.

Table 3: Spillover table - S&P 500 Spot and Futures Volatility

	From (j)		
To (i)	$CVSP500S$	$CVSP500F$	Contr. from Others
$CVSP500S$	52.7	47.3	47
$CVSP500F$	48.8	51.2	49
Contr. to others	49	47	Total Spillover
Contr. incl. own	101	99	Index= 48.1%

Notes: CVSP500S (CVSP500F) denotes the conditional variance of the S&P 500 stock index spot (futures) returns. The underlying variance decomposition is based upon a VAR of order 12. Spillover indices, given by Equations (8)-(11), calculated from variance decompositions based on 10-step-ahead forecasts.

Table 4: Spillover table - FTSE 100 & S&P 500 Spot and Futures Volatility

	From (j)				
To (i)	$CVFTSE100S$	$CVFTSE100F$	$CVSP500S$	$CVSP500F$	Contr. from Others
$CVFTSE100S$	33.0	30.3	18.2	18.5	67
$CVFTSE100F$	31.8	30.6	18.5	19.0	69
$CVSP500S$	15.5	13.8	37.3	33.4	63
$CVSP500F$	17.9	16.5	31.5	34.1	66
Contr. to others	65	61	68	71	Total Spillover
Contr. incl. own	98	91	106	105	Index= 66.3%

Notes: CVFTSE100S (CVFTSE100F) denotes the conditional variance of the FTSE 100 stock index spot (futures) returns. CVSP500S (CVSP500F) denotes the conditional variance of the S&P 500 stock index spot (futures) returns. The underlying variance decomposition is based upon a VAR of order 12. Spillover indices, given by Equations (8)-(11), calculated from variance decompositions based on 10-step-ahead forecasts.

Table 5: Spillover table - FTSE 100 Spot and Futures volatility, Futures Volume & Open Interest

	From (j)				
To (i)	$CVFTSE100S$	$CVFTSE100F$	$FTSE100FV$	$FTSE100FOI$	Contr. from Others
$CVFTSE100S$	44.1	40.9	9.6	5.3	56
$CVFTSE100F$	43.5	42.1	8.9	5.6	58
$FTSE100FV$	2.0	1.7	85.5	10.8	10
$FTSE100FOI$	1.2	1.5	33.4	63.9	41
Contr. to others	47	44	52	22	Total Spillover
Contr. incl. own	91	86	137	86	Index= 41.1%

Notes: CVFTSE100S (CVFTSE100F) denotes the conditional variance of the FTSE 100 stock index spot (futures) returns. FTSE100FV denotes the seasonally adjusted series, γ_t, of trading volume in the FTSE 100 futures market based on Equation (1). FTSE100FOI denotes the seasonally adjusted series, δ_t, of open interest in the FTSE 100 futures market based on Equation (2). The underlying variance decomposition is based upon a VAR of order 5. Spillover indices, given by Equations (8)-(11), calculated from variance decompositions based on 10-step-ahead forecasts.

Table 6: Spillover table - S&P 500 Spot and Futures volatility, Futures Volume & Open Interest

	From (j)				
To (i)	$CVSP500S$	$CVSP500F$	$SP500FV$	$SP500OFOI$	Contr. from Others
$CVSP500S$	47.8	42.7	6.0	3.5	52
$CVSP500F$	44.7	47.0	5.3	3.0	53
$SP500FV$	1.7	0.7	85.5	12.0	14
$SP500FOI$	6.5	4.7	26.9	62.0	38
Contr. to others	53	48	38	19	Total Spillover
Contr. incl. own	101	95	124	81	Index= 39.4%

Notes: CVSP500S (CVSP500F) denotes the conditional variance of the S&P 500 stock index spot (futures) returns. SP500FV denotes the seasonally adjusted series, ζ_t, of trading volume in the S&P 500 futures market based on Equation (3). SP500FOI denotes the seasonally adjusted series, θ_t, of open interest in the S&P 500 futures market based on Equation (4). The underlying variance decomposition is based upon a VAR of order 6. Spillover indices, given by Equations (8)-(11), calculated from variance decompositions based on 10-step-ahead forecasts.