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Abstract

In this study we examine the dynamic structural relationship between oil price shocks and stock market returns and volatility for a sample of both net oil–exporting and net oil–importing countries between 1995:09 and 2013:07. We accomplish that, by extending the Diebold and Yilmaz (2012) dynamic spillover index using structural forecast error variance decomposition. The results for both stock market returns and volatility suggest that spillover effects vary across different time periods, and that this time–varying character is aligned with certain developments that take place in the global economy. In particular, aggregate demand shocks appear to act as the main transmitters of spillover effects to stock markets during periods characterised by economic–driven events, while supply–side and oil–specific demand shocks during periods of geopolitical unrest. Furthermore, differences regarding the directions and the strength of spillover effects can be reported both between and within the net oil–importing and net oil–exporting countries. These results are of particular importance to investors and portfolio managers, given the recent financialisation of the oil market.

Keywords: Oil price shocks, Stock market, Volatility, Spillover index, Structural Vector Autoregression, Geopolitical unrest, Economic crisis

JEL codes: C32; C51; G11; G15; Q41; Q43

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1. Introduction

The aim of this paper is to investigate the dynamic structural spillover effects between oil price shocks and stock market returns and volatility, of major stock markets around the world. To this end, we extend the Diebold and Yilmaz (2012) spillover index in the following way. Instead of using a generalized vector autoregressive framework in which forecast-error variance decompositions are invariant to the variable ordering, we propose a structural vector autoregressive framework that allows for the identification of the different oil price shocks. The investigation of the time–varying spillover effects among oil price shocks and stock market activity is important given the recent geopolitical unrest and the financialisation of the oil market. According to Büyükşahin and Robe (2014), Hamilton and Wu (2014), Alquist and Kilian (2010) and Fattouh (2010), investors and portfolio managers have increased their positions in the oil market over the last decade or so. In this respect, identifying the aforementioned time–varying spillover effects may be useful to market participants making decisions about portfolio adjustments, asset pricing, as well as, the development of models for forecasting.

Since the seminal paper by Jones and Kaul (1996) there is an ever increasing interest to understand the effects of oil prices on stock markets (some recent studies include those by Filis and Chatziantoniou, 2014; Asteriou and Bashmakova, 2013; Ciner, 2013; Lee and Chiou, 2011; Laopodis, 2011; Filis, 2010; Chen, 2010; Miller and Ratti, 2009). In recent years though, the literature has directed its attention to three different strands.

The first strand is related to the origin of oil price changes; that is, to whether oil prices change due to supply-driven or demand-driven events. Pioneers in this line of inquiry are Hamilton (2009a,b) and Kilian (2009) who, on general principles, argue that different oil price shocks should trigger different responses from economic indicators and stock markets. More specifically, Hamilton (2009a,b) classifies oil price changes (shocks) into supply–side and demand–side shocks, depending on whether these can be attributed to changes in global oil production or changes in global aggregate demand, respectively. Kilian (2009) provides a further classification of demand–side shocks; that is, into aggregate demand shocks – which have their origin in changes in global aggregate demand – and precautionary demand shocks (or oil specific demand shocks) – which pertain to the uncertainty about the future availability of oil. The findings by Hamilton (2009a,b) and Kilian (2009) suggest that, aggregate demand shocks trigger positive responses from the economy, whereas the opposite holds for precautionary demand shocks. On the other hand, supply–side shocks are significantly less important for the economy. A wealth of literature supports the findings reported by Hamilton (2009a,b) and Kilian (2009) and thus providing ample evidence suggesting that supply–side shocks do not seem to affect financial markets, whereas positive aggregate demand shocks (precautionary shocks) exert a positive (negative) impact (see, *inter alia*, Degiannakis et al., 2014; Abhyankar et al., 2013; Kang and Ratti, 2013; Baumeister and Peersman, 2013; Kilian and Park, 2009; Apergis and Miller, 2009).

The second and rather recent strand in the literature focuses on the time–varying relationship between oil prices and stock markets. Authors, such as, Sadorsky (2014), Broadstock and Filis (2014), Filis (2014), Chang et al. (2013), Antonakakis and Filis (2013), Sadorsky

(2012), Broadstock et al. (2012), Filis et al. (2011) and Choi and Hammoudeh (2010), subscribe to the belief that the relationship between oil and stock markets should not be examined within a static framework but rather in a time–varying one, given that the nature of this relationship changes at different points in time. Indicatively, Chang et al. (2013) focusing on the US and the UK markets, show an increase in the correlation between oil and stock market returns in the post–2008 period. Similar findings are reported by Sadorsky (2014) for the emerging stock markets. Furthermore, Broadstock et al. (2012) also provide evidence that the correlation between energy-related stock returns and changes in oil prices exhibits a significant increase during the period of the Great Recession.

The third strand is associated with the spillover effects between the two markets under consideration. This line of research purports to identify whether there are any volatility spillovers between oil and stock markets, as well as, the direction of these spillovers (see, among others, Chang et al., 2013; Mensi et al., 2013; Arouri et al., 2012, 2011a,b; Malik and Ewing, 2009; Malik and Hammoudeh, 2007). To illustrate this, Mensi et al. (2013) and Arouri et al. (2012) find significant volatility spillover effects between the oil market and the US or the European stock markets, respectively. However, Mensi et al. (2013) suggest that spillovers run from the S&P500 to the oil market, while Arouri et al. (2012) report that the reverse is true for the case of the European stock market. Arouri et al. (2011b) provide further evidence regarding the significant increase of the volatility spillover effects during the global financial crisis. By contrast, Chang et al. (2013) do not report any volatility spillover effects between the oil market and key global stock market indices (FTSE100, Dow Jones, NYSE and S&P500).

The aim of this paper is to bring together the three aforementioned strands of existing literature. That is, we concentrate on the time–varying spillover effects between the three different types of oil price shocks and 11 major global stock markets for the period September 1995 to July 2013. In particular, we examine the time–varying effects between oil price shocks and stock market returns, as well as the time–varying effects between oil price shocks and stock market volatility – by considering two current measures of volatility (i.e. conditional and realised volatility) and one forward-looking measure (i.e. implied volatility). It should be noted that the implied volatility measure is mainly introduced to the analysis for robustness purposes. As mentioned earlier, we extend the spillover index approach by Diebold and Yilmaz (2012) for the purpose of our study. Specifically, instead of using the generalised vector autoregressive framework, we propose a structural variance decomposition, that allows us to identify the supply-driven, demand-driven and aggregate demand oil market shocks. Our study builds upon the study of Awartani and Maghyereh (2013), who employ a similar methodology in an attempt to investigate the spillover effects between oil prices (i.e. instead of oil price shocks disaggregated by virtue of their origin as in our study) and GCC stock market returns. It is worth mentioning that the results reported by Awartani and Maghyereh (2013) suggest the existence of important spillover effects flowing from oil prices to the GCC markets but not the reverse, and that spillover effects increase considerably during the global economic crisis.

As discussed below, our results stress the necessity to investigate spillover effects between oil prices and the stock market both over time and by disaggregating oil price shocks by virtue of their origin. In particular, we show that spillover effects vary across different time periods and that this time-varying character is aligned with certain developments that take place in the global economy. In this regard, aggregate demand shocks appear to act as the main transmitters of spillover effects to stock markets during periods of economic and financial uncertainty, while supply-side and oil-specific demand shocks during periods of geopolitical unrest.

On a secondary level, we provide evidence that differences regarding the direction and the strength of the effects can be found both between and among the two groups of countries under investigation (i.e. net oil–importing and net oil–exporting countries) emphasizing the fact that these differences mainly pertain to the time–varying character of the relationship between oil prices and the stock market. On a final note, our results indicate no notable differences between the alternative proxies of stock market volatility.

The remainder of the paper is organized as follows. Section 2 discusses the methodology and describes the data. Section 3 presents the empirical findings, while Section 4 provides an in-depth discussion of the findings. Finally, Section 5 summarises and concludes the paper.

2. Methodology and Data

2.1. Spillover methodology

The spillover index approach introduced by Diebold and Yilmaz (2009) builds 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. Starting point for the analysis is the following p–order, N–variable VAR

$$\mathbf{y}_t = \sum_{i=1}^{P} \mathbf{\Theta}_i \mathbf{y}_{t-i} + \varepsilon_t \tag{1}$$

where $\mathbf{y}_t = (y_{1t}, y_{2t}, \ldots, y_{Nt})$ is a $N \times 1$ vector of N endogenous variables, $\mathbf{\Theta}_i, i = 1, ..., P$, are $N \times N$ parameter matrices and $\varepsilon_t \sim (0, \Sigma)$ is a $N \times 1$ vector of disturbances that are independently distributed over time; $t = 1$, ..., T is the time index and $n = 1$, ..., N is the variable index.

Key to the dynamics of the system is the moving average representation of model (1), which is given by $\mathbf{y}_t = \sum_{j=0}^{\infty} \mathbf{A}_j \varepsilon_{t-j}$, where the $N \times N$ coefficient matrices $\mathbf{A}_j$ are recursively defined as $\mathbf{A}_j = \mathbf{\Theta}_1 \mathbf{A}_{j-1} + \mathbf{\Theta}_2 \mathbf{A}_{j-2} + \ldots + \mathbf{\Theta}_p \mathbf{A}_{j-p}$, where $\mathbf{A}_0$ is the $N \times N$ identity matrix and $\mathbf{A}_j = 0$ for $j < 0$.

Diebold and Yilmaz (2009) use Cholesky decomposition, which yields variance decompositions dependent on the ordering of the variables, whereas Diebold and Yilmaz (2012) extend the Diebold and Yilmaz (2009) model, using the generalized VAR framework of Koop et al. (1996) and Pesaran and Shin (1998), in which variance decompositions are invariant to the order of the variables. Both models yield an $N \times N$ matrix $\phi(H) = [\phi_{ij}(H)]_{i,j=1,...N}$, where each entry gives the contribution of variable j to the forecast error variance of variable

i. The main diagonal elements contain 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., $\sum_{j=1}^{N} \phi_{ij}(H) \neq 1$, each entry of the variance decomposition matrix is normalized by its row sum, such that

$$\tilde{\phi}_{ij}(H) = \frac{\phi_{ij}(H)}{\sum_{j=1}^{N} \phi_{ij}(H)} \tag{2}$$

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

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

$$TS(H) = \frac{\sum_{i,j=1,i\neq j}^{N} \tilde{\phi}_{ij}(H)}{\sum_{i,j=1}^{N} \tilde{\phi}_{ij}(H)} \times 100 = \frac{\sum_{i,j=1,i\neq j}^{N} \tilde{\phi}_{ij}(H)}{N} \times 100 \tag{3}$$

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

$$DS_{i\leftarrow j}(H) = \frac{\sum_{j=1,j\neq i}^{N} \tilde{\phi}_{ij}(H)}{\sum_{i,j=1}^{N} \tilde{\phi}_{ij}(H)} \times 100 = \frac{\sum_{j=1,j\neq i}^{N} \tilde{\phi}_{ij}(H)}{N} \times 100 \tag{4}$$

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

$$DS_{i\rightarrow j}(H) = \frac{\sum_{j=1,j\neq i}^{N} \tilde{\phi}_{ji}(H)}{\sum_{i,j=1}^{N} \tilde{\phi}_{ji}(H)} \times 100 = \frac{\sum_{j=1,j\neq i}^{N} \tilde{\phi}_{ji}(H)}{N} \times 100. \tag{5}$$

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 (4) from Equation (5) the net spillovers from variable i to all other variables j are obtained as

$$NS_i(H) = DS_{i\rightarrow j}(H) - DS_{i\leftarrow j}(H), \tag{6}$$

providing information on whether a variable is a receiver or transmitter of shocks in net terms. Put differently, Equation (6) provides summary information about how much each variable contributes to the volatility in other variables, in net terms.

Finally, the net pairwise spillovers can be calculated as

$$\begin{aligned} NPS_{ij}(H) &= \left(\frac{\tilde{\phi}_{ji}(H)}{\sum_{i,m=1}^{N} \tilde{\phi}_{im}(H)} - \frac{\tilde{\phi}_{ij}(H)}{\sum_{j,m=1}^{N} \tilde{\phi}_{jm}(H)}\right) \times 100 \\ &= \left(\frac{\tilde{\phi}_{ji}(H) - \tilde{\phi}_{ij}(H)}{N}\right) \times 100. \end{aligned} \tag{7}$$

The net pairwise volatility spillover between variables i and j is simply the difference between the gross volatility shocks transmitted from variable i to variable 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.

This study is based on the Diebold and Yilmaz (2012) approach. However, a key methodological innovation and contribution of the study is that, instead of using the generalised vector autoregressive framework, we adopt a structural vector autoregressive framework, as it allows for the identification of the oil price shocks. Thus, the choice of structural variance decomposition is predicated upon our empirical exercise. That is, to examine the effects of oil price shocks on stock market returns and volatility. In particular, we disaggregate oil price shocks based on the framework of Kilian and Park (2009). Essentially, with the use of a Structural VAR (SVAR) model, we distinguish between three types of oil price shocks; namely, supply–side shocks (SS), aggregate demand demand (ADS), as well as, oil specific demand shocks (OSS); and by including stock market returns (volatility) in the SVAR, we assess the effects of oil price shocks on stock market returns (volatility).

For the general case of a p^{th}–order Structural VAR model, we obtain the following standard representation:

$$\mathbf{A}_0\mathbf{y}_t = \mathbf{c}_0 + \sum_{i=1}^{p}\mathbf{A}_i\mathbf{y}_{t-i} + \varepsilon_t \tag{8}$$

where, $\mathbf{y}_t$ is a $[N \times 1]$ vector of endogenous variables. In this paper, N=4, containing world oil production, the global economic activity index, real oil price returns and the stock market returns (volatility) of the respective country, noting that the order of the variables is important. A_0 represents the $[N \times N]$ contemporaneous matrix, A_i are $[N \times N]$ autoregressive coefficient matrices, ε_t is a $[N \times 1]$ vector of structural disturbances, assumed to have zero covariance and be serially uncorrelated. The covariance matrix of the structural disturbances takes the following form:

$$E[\varepsilon_t\varepsilon_t'] = \mathbf{D} = \begin{bmatrix} \sigma_1^2 & 0 & 0 & 0 \\ 0 & \sigma_2^2 & 0 & 0 \\ 0 & 0 & \sigma_3^2 & 0 \\ 0 & 0 & 0 & \sigma_4^2 \end{bmatrix} \tag{9}$$

In order to get the reduced form of our structural model (8) we multiply both sides with $\mathbf{A}_0^{-1}$, such as that:

$$\mathbf{y}_t = \mathbf{a}_0 + \sum_{i=1}^{p}\mathbf{B}_i\mathbf{y}_{t-i} + \mathbf{e}_t \tag{10}$$

where $\mathbf{a}_0 = \mathbf{A}_0^{-1}\mathbf{c}_0$, $\mathbf{B}_i = \mathbf{A}_0^{-1}\mathbf{A}_i$, and $\mathbf{e}_t = \mathbf{A}_0^{-1}\varepsilon_t$, i.e. $\varepsilon_t = \mathbf{A}_0\mathbf{e}_t$. The reduced form errors $\mathbf{e}_t$ are linear combinations of the structural errors $\mathbf{e}_t$, with a covariance matrix of the form $E[\mathbf{e}_t\mathbf{e}_t'] = \mathbf{A}_0^{-1}\mathbf{D}\mathbf{A}_0^{-1'}$.

Imposing suitable restrictions on $\mathbf{A}_0^{-1}$ allows us to identify the structural disturbances of the model. In particular, we impose the following short-run restrictions:

$$\begin{bmatrix} e_{1,t}^{\Delta \text{Oil Production}} \\ e_{2,t}^{\text{Real Global Economic Activity}} \\ e_{3,t}^{\Delta \text{Real Oil Prices}} \\ e_{4,t}^{\text{Stock Market Returns (Volatility)}} \end{bmatrix} = \begin{bmatrix} \alpha_{11} & 0 & 0 & 0 \\ \alpha_{21} & \alpha_{22} & 0 & 0 \\ \alpha_{31} & \alpha_{32} & \alpha_{33} & 0 \\ \alpha_{41} & \alpha_{42} & \alpha_{43} & \alpha_{44} \end{bmatrix} \times \begin{bmatrix} \varepsilon_{1,t}^{SS} \\ \varepsilon_{2,t}^{ADS} \\ \varepsilon_{3,t}^{OSS} \\ \varepsilon_{4,t}^{SMR(SMV)} \end{bmatrix} \quad (11)$$

where SS is the supply–side shock, ADS is the aggregate demand shock, OSS is the oil specific demand shock, and SMR (SMV) is the stock market returns (volatility) shock.

The purpose of the short–run restrictions we impose on the model is to help us identify the underlying oil price shocks, similarly with Kilian and Park (2009). According to the restrictions for N=4, high adjustment costs forbid oil production to contemporaneously respond to changes in demand for oil. Furthermore, changes in the supply of oil are allowed to contemporaneously affect both global economic activity and the price of oil. In addition, given that it takes some time for the global economy to react to changes in the price of oil, global economic activity is assumed not to receive contemporaneous feedback from oil prices. However, changes in aggregate economic activity is expected to have a contemporaneous impact on oil prices and this is largely explained by the instantaneous response of commodities markets. Furthermore, it is understandable that oil price developments can be triggered by all types of shocks and in this regard all types of shocks are assumed to contemporaneously affect oil prices. Finally, stock market returns (volatility) respond contemporaneously to all aforementioned oil price shocks.

2.2. Data description

We collect monthly data of stock market indices for major oil–importing and oil– exporting countries, namely, Canada (S&P/TSX), China (SSE), ESP (IBEX35), France (CAC40), Germany (DAX30), Italy (FTSEITA), Japan (NIKKEI225), Norway (OSE), Russia (RTS) the UK (FTSE100) and the US (S&P500) from Datastream. The stock market indices series are converted into stock market returns using the first difference of the natural logarithms. The motivation for the choice of these countries stems from the literature. Specifically, empirical evidence shows that the impact of oil price changes (shocks) on a particular stock market depends on whether the country, that the market is operating in, is a net oil–importer or a net oil–exporter. For instance, Wang et al. (2013); Mohanty et al. (2011); Bjørnland (2009) claim that positive oil prices changes trigger positive responses for the stock markets of net oil–exporting countries, whereas the opposite stands true for the stock markets of the net oil–importers. Thus, in order to capture any possible heterogenous behaviour, our sample consists of the main net oil–importers and net oil–exporters of the world. In addition, we collect monthly data for oil prices, world oil production and the real global economic activity index (GEA), which are used for the estimation of the oil price shocks. Data for the Brent crude oil price and world oil production have been extracted from the Energy Information Administration, whereas the data for the real global economic activity index have been retrieved from Lutz Kilian's personal website (http://www-personal.umich.edu/∼lkilian/). The time period of study runs from 1995:09 until 2013:07. Oil prices and world oil production are expressed in log-returns. Furthermore, oil prices are transformed in real terms. Table 1 reports the descriptive statistics of the series.

[Insert Table 1 around here]

According to Table 1, all stock markets returns are positive on average, apart from Japan, where negative returns are recorded. Stock market returns exhibit some variability, as shown by the standard deviation, the minimum and the maximum values. In particular, stock market returns in Russia are the most volatile, while stock market returns in the US are the least volatile. With regard to oil price changes, we observe a positive mean value, with quite a high standard deviation. In addition, none of the series is normally distributed, as indicated by the skewness, kurtosis and the Jarque–Bera statistic. Finally, according to the ADF–statistic, all variables are stationary.

Figures 1 and 2 exhibit the evolution of the series during the sample period. All stock market returns exhibit some common troughs. To be more explicit, in all markets we notice the significant negative impact of the Great Recession of 2007–2009. In addition, we observe that for most European stock markets, a second important trough is observed during the first few months of the European debt crisis in 2010. Furthermore, stock market volatilities also exhibit common patterns. More importantly, we observe the peak of volatility during the period 2007–2009, signifying the turmoil that the Great Recession brought to these markets. However, a second peak in the European stock market volatilities is noticed during the early stages of the ongoing European debt crisis. Finally, the effects of the Great Recession are also evident on the changes of oil production, global economic activity, as well as, on oil price changes, where a significant decline is observed.

[Insert Figure 1 around here]

[Insert Figure 2 around here]

3. Empirical Results

3.1. Oil price shocks and stock market returns

3.1.1. Total spillovers between oil price shocks and stock market returns

The spillover effects between stock market returns and disaggregated oil price shocks within countries are presented in Table 2. According to these results we observe that on average the total spillover indices range between 18.7% (UK) and 25.8% (Norway), indicating a moderate interdependence between oil market shocks and stock market returns for most countries. On average, net spillovers for the whole sample reveal that stock market returns are net transmitters of shocks in Canada, China, Spain, Germany, Japan, Norway and in Russia, while in France, Italy, the UK and the US, stock market returns act as net receivers of spillover effects from oil price shocks (see, Table 2). Among oil price shocks, aggregate demand shocks are generally net transmitters (with the exception of China and Russia), while supply–side shocks and oil–specific demand shocks are generally on the receiving ends of spillovers (with the exception of Germany, Italy, Norway and the UK in terms of the former shocks, and of Canada and Spain in terms of the latter shocks). These results are in line with the literature that emphasises the importance of demand–side shocks, as opposed to supply–side shocks (see, among others, Baumeister and Peersman, 2013; Lippi and Nobili, 2012; Hamilton, 2009a,b).

[Insert Table 2 around here]

Despite the fact that Table 2 reveals some interesting patterns on the link between oil price shocks and stock market returns, we should not lose sight of the fact that during our sample period several economic, financial and geopolitical events took place, which impacted both the oil and the stock markets (e.g. the dot–com bubble in early the2000s, the war in Iraq in 2003, the Great Recession of 2007–2009, the ongoing European debt crisis of 2010 and Arab uprising which began in 2010 and was subsequently succeeded by a series of geopolitical events such as the Libyan civil war in 2011 and the Syrian unrest of 2013). Hence, the average values presented in Table 2 are not expected to hold for the whole time span. Thus, it would be valuable to examine how these spillovers evolve over time. Therefore we proceed with our analysis by presenting the total and net spillovers using 60–month rolling samples.[1]

The time–varying spillover indices are illustrated in Figure 3. As expected, total spillovers between in stock market returns shocks and oil price shocks behave rather heterogeneously over time and across countries. The range for the total spillover plots span from values as low as 45% to values as high as 80% in almost all countries, implying that total spillovers between oil price shocks and stock market returns do not remain constant; although a relative flat trend is observed at around 60% level. This is suggestive of the fact that throughout the sample period, regardless the economic or geopolitical conditions, spillovers between the oil price shocks and stock market returns are important.

Furthermore, spillovers seem to peak during periods of economic turbulence and geopolitical unrest, such as, the Great Recession, the 2nd war in Iraq and the Start of the Arab Spring. Nevertheless, the peaks which are observed during the Great Recession period are unprecedent only for the net oil–exporting countries. This result confirms the findings by Awartani and Maghyereh (2013) who reported that spillover effects between oil and GCC stock markets (net oil–exporters) peaked during the period of the Great Recession. Another interesting observation that can be made from Figure 3 is that a peak is observed in spillovers for Russia and China in 2012 (i.e. during the escalation of the Syrian Civil War), whereas for all other countries, spillovers either decline or fluctuate at relatively stable levels.

[Insert Figure 3 around here]

[1] It should be underlined that different forecast horizons (from 5 up to 15 months) and different window lengths (48 and 72) were also considered and the results were qualitatively similar (results are available from the authors upon request). Thus, we maintain that the results are not sensitive to the choice of the forecast horizon and/or the length of the rolling–windows.

3.1.2. Directional spillovers between oil price shocks and stock market returns

In an attempt to further disentangle the link between oil price shocks and stock market returns, we estimate model (1) using 60–month rolling windows and compute the time-varying directional spillovers from (to) each variable to (from) all others, as defined in equations (4)–(5). The directional spillovers from (to) each variable to (from) all others are presented in Figures 4 and 5, respectively.

[Insert Figures 4 and 5 around here]

Starting with the supply–side shocks (SS), we observe a structural break in their contribution to spillover effects in the post–2009 period. In particular, low spillover effects exist until 2009, whereas an increasing pattern in spillover effects deriving from oil–supply shocks is evident thereafter, reaching a peak towards the end of the Great Recession. Notably, the peak for all European countries of our sample is evident almost two years later, at the end of 2010, i.e. immediately after the outbreak of the Eurozone debt crisis. A similar behaviour (although from the reverse angle) is observed in terms of spillover effects towards the supply–side shocks. These spillovers exhibit a stable pattern at about 20% level until 2009 (where a peak in reached), while a decline is observed thereafter (at the levels of about 10-15%).

A structural break is also evident in the spillover effects from and to aggregate demand shocks (ADS). More specifically, spillovers from aggregate demand shocks are high until 2009 (at about 25-50% level), when these spillovers reach their peak, whereas a continued decline is observed in the post–Great Recession period (the only exception is Russia). In terms of the spillover effects to aggregate demand shocks we notice that they are volatile and heterogeneous among countries until 2009, whereas a stable and increasing pattern is noticeable thereafter.

Furthermore, spillover effects associated with oil–specific demand shocks (OSS) appear to decline remarkably during the peak years of the Great Recession with the exception of Japan. On the other hand, for all countries of our sample, the magnitude of spillover effects received by oil–specific demand shocks is relatively stable, at about 20%.

Considering spillover effects from stock market returns (SMR) shocks, we observe that they tend to fluctuate at the level of about 25% reaching, though, a trough in 2009 (although the reverse holds true for Russia). At the other end of the spectrum, stock market returns receive spillover effects at a rather stable pattern, reaching a spike at the heart of the Great Recession (with the exception of Italy).

In the section that follows, we provide additional information aiming to attain deeper knowledge of the evolution of spillover effects. To do so we concentrate on the net spillovers and net pairwise spillovers between oil price shocks and stock market returns.

3.1.3. Net spillovers between oil price shocks and stock market returns

By concentrating on net spillovers we can deduce whether one of the variables is either a net transmitter or a net receiver of spillover effects within a particular country. We thus proceed by examining the net spillover effects between stock market returns and oil price shocks. Initially, we concentrate on the nature (i.e. net transmitter or net recipient) of each one of the variables of interest in contrast with all other variables. The variable of interest is considered to be a net transmitter of spillover effects when the line lies within the positive upper part of each panel. Results are shown in Figure 6.

[Insert Figure 6 around here]

As can be seen in Figure 6, in the early period of our study and until the peak of the Great Recession, supply–side (SS) and oil–specific demand shocks (OSS) assume a net receiving role, whereas the reverse holds true for the aggregate demand shocks (ADS). From that point onward, the opposite roles are observed where supply–side and oil–specific demand shocks assume a net transmitting role for the largest part of this period (with the exception of Russia), whereas aggregate demand shocks (ADS) become net receivers. In addition, the net spillovers for the supply–side and oil–specific demand shocks are relatively low compared with these of the aggregate demand shocks. The latter shocks reach a peak in the net transmission of shocks during the Great Recession. Overall, these results suggest that aggregate demand shocks (ADS) are more important compared to supply–side (SS) and (OSS) oil–specific demand shocks, in terms of their magnitude. This is in line with Basher et al. (2012); Filis et al. (2011); Kilian and Park (2009), among others, who also find evidence in favour of the importance of aggregate demand shocks.

Turning to stock market returns (SMR) shocks, these appear to be relatively stable in terms of magnitude throughout the period of study. However, in most countries they seem to frequently switch between a net transmitting and a net receiving role.

The net spillover effects, defined in equation (6), have highlighted the importance of the aggregate demand shocks in this particular framework of study. However, we have not disentangled whether the net transmitting/receiving role of these spillover effects is related to stock market returns or to any of the remaining two oil price shocks. Thus, we need to extend our dynamic analysis in order to uncover the net spillovers between each of the oil price shocks and stock market returns, concentrating on net pairwise spillover effects, defined in equation (7), (see Figure 7). We should note that stock market returns are considered to be net transmitters (receivers) of spillover effects when the net spillovers receive negative (positive) values.

[Insert Figure 7 around here]

According to Figure 7, which reports the net pairwise spillover effects, stock market returns (SMR) shocks appear to be net transmitters of spillover effects to supply–side shocks (SS) throughout the pre–Great Recession period. The reverse picture is observed from 2009 onwards, when in most countries it is the supply–side shocks that assume the net transmitting role.

Pertaining to the relation between stock market returns (SMR) shocks and aggregate demand shocks (ADS), apparently, in the pre–Great Recession period, the latter, clearly transmit spillover effects to the former. With the exception of Russia, this pattern reaches a climax during the peak years of the Great Recession, while in the post–Great Recession period and up until 2012 stock market returns act as net recipients of spillover effects from aggregate demand shocks (although this does not hold for China, whose stock market returns shocks transmit spillover effects immediately after the Great Recession). Post–2012 stock market returns shocks clearly assume a net transmitting role with respect to aggregate demand shocks, for all countries.

Considering net spillover effects between stock market returns (SMR) shocks and oil–specific demand shocks (OSS), these appear to be rather low (with Russia being a notable exception) in the pre–Great Recession period, with the stock market being the net transmitter of shocks. Nevertheless, for most of the period after the 2009, stock market returns become net receivers of shocks from the oil–specific demand shocks. This holds for all countries apart from Russia.

On a final note, there is no clear-cut evidence of any substantial differences between net oil–exporting and net oil–importing countries. Nevertheless, Russia seems to exhibit a different behaviour, compared to its group.

3.2. Oil price shocks and stock market volatility

3.2.1. Total spillovers between oil price shocks and stock market realized volatility

Apart from investigating the various linkages between oil price shocks and stock market returns, our study further purports to explore the relation between oil price shocks and stock market uncertainty. We use realized volatility as our measure of current–looking volatility.[2]

Starting with Table 3, we observe that the total spillover indices range from 15.8% (China) to 21.3% (Italy). As in the case of stock market returns, this suggests that a moderate interdependence exists between disaggregated oil price shocks and realized volatility. The directional spillover effects indicate that realized volatility and aggregate demand shocks are the main transmitters, whereas the opposite holds true for supply–side and and oil–specific demand shocks. Nevertheless, on average, the stock market volatilities of Canada, China and the US seem to be at the receiving ends of spillovers during the period of the study.

[Insert Table 3 around here]

In order to be consistent with our analysis of the previous section, we also have to consider the evolution of spillovers across time. The cornerstone for the presentation of our empirical findings is again the crisis of 2007–2009 along with some major geopolitical events that took place during the sample period. The time–varying spillover indices for the realized volatility are illustrated in Figure 8.

[Insert Figure 8 around here]

[2]We have also explored the robustness of our results based on another backward–looking measure of volatility, namely, conditional volatility, and the results remain qualitatively very similar with these of the realized volatility. Thus, for the sake of brevity, these results are not presented, but are available upon request.

As with stock market returns, Figure 8 shows that the total spillover plots assume values as low as 45% and as high as 85%. This implies that quite a few peaks and troughs of total spillovers between oil price shocks and realized volatility can indeed be reported throughout the period of study. In particular, total spillover indices reach a peak at the heart of the Great Recession for all countries of our sample, although, this peak is not unprecedented. In truth, similar values can be reported in all countries, both during the pre– and the post–Great Recession period. For instance, we notice that the highest spillover effects for Russia appear in mid–2010 (e.g. during the start of Arab Spring), whereas for Italy and China, in 2005 and 2011, respectively. This suggests that the Great Recession triggered significant spillover effects among oil price shocks and stock market volatility; nonetheless, similar behaviour can be traced during other events, as well, (e.g. during the escalation of the Syrian Civil war between November 2011 and March 2012, and in February 2006, when the Nigerian military launched several raids against oil militants), at different time periods. Furthermore, there is no significant differences in the behaviour of these spillovers between net oil–importing and net oil–exporting countries.

Despite the fact that some interesting patterns are observed in the total spillover plots, it is the directional and net spillovers which will allow us to understand better the nature of the spillover effects among oil price shocks and stock market volatility.

3.2.2. Directional spillovers between oil price shocks and stock market realized volatility

In an attempt to further disentangle the link between oil market shocks and stock market realised volatility we focus on the time–varying directional spillovers from (to) each variable to (from) all others, as defined in equations (4) and (5). The directional spillovers from (to) each variable to (from) all others are presented in Figures 9 and 10, respectively.

[Insert Figures 9 and 10 around here]

Starting with the supply–side shocks (SS), these appear to contribute considerably in the years during the Great Recession for the oil–importing countries and during 2010–2011 for the oil–exporting countries. We notice, though, that some exemptions exist among the net oil–importing countries (i.e. China, Japan and the US), as a peak is reached in these countries immediately after the period of the Great Recession, resembling the spillover patterns of the net oil–exporting countries. By contrast, supply–side shocks receive spillover effects mainly in the pre–Great Recession period.

Turning to aggregate demand shocks (ADS), these contribute considerably to spillover effects in all other variables in the pre–Great Recession period. Furthermore, with the exception of Russia, the UK and the US, spillover effects generated by aggregate demand shocks attain a peak at the heart of the financial crisis. On the other hand, aggregate demand shocks appear to receive spillover effects throughout the period of study without following a stable path.

As far as the oil–specific demand shocks (OSS) are concerned, they seem to contribute more in the years that followed the Great Recession, while all other variables tend to instigate spillover effects to oil–specific demand shocks at a rather stable pace throughout the period of study, reaching a peak during the years of the Great Recession.

Considering the stock market realized volatility (SMRV) shocks, results regarding effects from this variable to all other variables seem to be country specific. Nonetheless, we note that in all European countries a peak is reached in the years immediately before the onset of the Great Recession. Turning to spillover effects exerted on stock market realized volatility, these appear to be rather stable (at about 10-20% level) throughout the period of study, reaching a peak at the heart of the Great Recession.

In the next section, we conclude the exposition of our results by considering net spillover and net pairwise spillover effects between stock market realized volatility and oil price shocks.

3.2.3. Net spillovers between oil price shocks and stock market realized volatility

Net spillovers between oil price shocks and stock market realized volatility are shown in Figure 11. Each variable of interest acts as a net transmitter of spillover effects when net spillovers receive positive values.

[Insert Figure 11 around here]

Figure 11 reveals that the supply–side shocks (SS) are mainly net recipients of spillover effects in the period which preceded the Great Recession. By contrast, in the years that followed the crisis, supply–side shocks switch to net transmitters. In point of fact, with only a few exceptions (i.e. Canada, China, Japan and Norway) the transition occurs in 2009. It is also worth mentioning that at the heart of the crisis all net oil–exporting countries of our sample, along with China, Japan and to a lesser extend the US, exhibit a trough. On the other hand, European countries appear to attain a peak for the same period.

As far as the aggregate demand shocks (ADS) are concerned, these act as net transmitters of spillover effects in almost all countries, for the largest part of our sample period. As a matter of fact, at the heart of the crisis a peak is reached. Apparently, though, in the post–2012 period, aggregate demand shocks switch to net recipients of spillover effects and this holds for all countries of our sample.

The reverse is true for oil–specific demand shocks (OSS). These shocks mainly assume a net receiving role, which appears to be quite persistent as it is evidenced throughout the period before and immediately after the crisis. This role reaches a trough for most countries at the heart of the crisis. In the post–2012 period, however, oil–specific demand shocks clearly assume a rather net transmitting role in all countries but China.

Regarding the stock market realized volatility (SMRV) shocks, in the period before the years of the Great Recession it assumes either roles, although specifically in the years immediately before the beginning of the crisis realised volatility clearly assumes a net transmitting role (with the exception of Japan and Russia). Furthermore, with the exception of Canada, Russia and the US, there is again a transition at the heart of the crisis in which realised volatility reaches a trough. Interestingly enough, in the post–2012 period realised volatility is mainly a net recipient of spillover effects and this holds for all countries but China and Russia.

Turning to pairwise net spillover effects, results are illustrated in Figure 12. Realized volatility is considered to be net transmitter (receiver) of spillover effects when the line lies within the negative lower (positive upper) part of each panel.

[Insert Figure 12 around here]

Focusing on the net oil–exporting countries we observe that the realized volatility is a net transmitter of spillover effects to supply–side (SS) and oil–specific demand shocks (OSS) until the peak years of the Great Recession. After 2009 the reverse relationship is observed as both supply–side and oil–specific demand shocks assume a net transmitting role. The aggregate demand shocks (ADS) appear to transmit spillover effects to realized volatility throughout the study period (Russia being the only exception). A change in this behaviour is observed in the post–2012 period when realized volatility assumes a net transmitting role.

The behaviour of the pairwise spillover effects between stock market realized volatility and supply–side shocks for the net oil–importing countries resembles that of the net oil–exporters. The same observation can be made for the oil–specific demand shocks, with the exception of China. Thus, overall, even for the oil–importing countries, realized volatility is a net transmitter of spillover effects to supply–side and oil–specific demand shocks until 2009, when the reverse behaviour preponderates. The relation between realized volatility and aggregate demand shocks is rather more heterogeneous. In most countries, realized volatility assumes a net receiving role which peaks during the years of the Great Recession. By contrast, in the post–2012 period, realized volatility mainly transmits spillover effects to aggregate demand shocks. Same notable exceptions include the Germany and the US stock market realized volatility which transmit spillover effects to aggregate demand shocks, both several years before and during the Great Recession period.

3.3. Robustness

Given that the realised volatility of stock market returns is regarded as a current–looking measure of volatility, we reiterate the analysis between oil price shocks and forward–looking volatility, with the later now being approximated by the implied volatility of stock market options. According to Koopman et al. (2005), implied volatility is more informational efficient and thus it could provide additional information on the spillover effects between oil price shocks and stock market volatility. Implied volatility represents the market's expectation of stock market volatility over the next 30–day period, and as such, can provide additional insights for market participants' expectations on the link between oil price shocks and stock market volatility.

As the availability of implied volatility indices is rather limited, and our econometric approach very data intensive, we restrict our analysis only to the stock market indices for which implied volatilities exist from the 1990s. In particular, the countries (implied volatility series) that fulfill these criteria are France (VCAC), Germany (VDAX), Japan (VXJ), the UK (VFTSE) and the US (VIX).

As shown in Figure 2, the implied volatility indices are highly correlated with the realised and conditional measures of volatility. It is also evident that the implied volatility measure is relatively smoother than the realised volatility one.

The results based on the implied volatility measure are presented in Table 4. This table reveals that the total directional spillover indices range within 20% (Germany) and 27.6% (the UK). These levels suggest that, for some countries, total spillovers are of greater magnitude when the implied volatility is considered than total spillovers based on realized volatility. Results again indicate a moderate interdependence among the variables of interest. The results for the directional spillovers, as well as the net spillovers are similar with these of the realized volatility reported in the previous section.

[Insert Table 4 around here]

The time–varying spillover effects are reported in Figure 13. Directional spillover effects (*FROM* and *TO*), net spillovers and net pairwise spillovers are shown in Figures 14, 15, 16 and 17, respectively.

[Insert Figure 13 around here]

[Insert Figures 14 around here]

[Insert Figures 15 around here]

[Insert Figure 16 around here]

[Insert Figure 17 around here]

According to Figures 13–17, one can clearly observe their similarity to the respective implied volatility spillover plots.

Overall, some important conclusions that can be extracted from the spillover effects among oil price shocks and stock market volatility (realized or implied). First, there are no notable differences among the historical and the forward–looking measures of volatility, suggesting that implied volatility does not provide any superior information compared to the realized and/or conditional volatility. Second, we notice that net oil–exporting countries tend to exhibit somewhat different patterns of spillover effects compared to the net oil–importing countries. Third, it is evident that spillover effects on three net oil–importers, namely, China, Japan and the US exhibit similar behaviour with these of the net–oil exporters.

So far, we have presented the results from the spillover effects between oil price shocks and stock market returns and volatilities in a descriptive way. In the next section, we provide an in-depth analysis of these findings, in an effort to better understand these spillover effects.

4. Discussion

In order to gain a clearer understanding of the aforementioned relations, we now proceed with the interpretation of the formerly reported results. For the sake of brevity, our discussion builds on the empirical findings relating to pairwise net spillover effects, ensuring though, that no important information is left out. In particular, we seek to identify which type of oil price shocks appears to be more important for the stock market, especially at times of recession or geopolitical turbulence. Neverthelss, country–specific analysis is also being reported, so as to trace the distinct dynamics of spillover effects emanating from oil price shocks to the stock market of each country in our sample. As formerly mentioned, the cornerstone of our analysis is the Great Recession of 2007–2009; whereas, recent economic and geopolitical developments (i.e. the post–2010 period) are also of major concern. On a final note, our discussion revolves around the net pairwise spillover results illustrated in Figures 7 and 12.

Prominent among our results is the fact that in the period before and during the Great Recession, aggregate demand shocks act mainly as net transmitters of spillover effects to stock market returns and volatility. On the other hand, oil–specific demand shocks appear to act as net transmitters of shocks in the post–Great recession period. It is worth mentioning again, though, that the spillovers from oil–specific demand shocks exhibit an increasing importance.

In close relation to this, authors such as (see, *inter alia* Basher et al., 2012; Filis et al., 2011; Kilian and Park, 2009), have already reported the increasing effects of the demand–side oil price shocks (but more importantly of the aggregate demand shocks) on stock market performance. In addition, our findings offer support to Degiannakis et al. (2014) who report that aggregate demand shocks affect stock market volatility.

The general consensus regarding this relationship is that positive aggregate demand shocks are regarded as positive news about economic activity and as such, trigger positive developments in the stock market. These positive developments are not only reflected by higher stock market returns (see, *inter alia*, Wang et al., 2013; Kilian and Park, 2009), but also by lower stock market volatility (Degiannakis et al., 2014). In this context, the fact that during the Great Recession aggregate demand shocks are primarily transmitting spillovers to stock market returns and volatility, reveals that the negative aggregate demand shocks observed during this period, trigger negative responses from the stock markets and increase uncertainty. Furthermore, Bloom (2009) from a different standpoint, provides additional evidence to support the argument that negative news about global economic activity are likely to increase volatility in the stock market.

Moreover, the fact that oil–specific demand shocks are transmitting shocks to the stock markets in the post–Great Recession period, relates to the recent events in Syria and Libya, which raised concerns about the geopolitical stability of Middle East. Typically, such events raise concerns about the future availability of oil triggering significant oil–specific demand shocks, which drive stock market returns (volatility) in lower (higher) levels.

Another interesting finding is that during the last few months of the Great Recession and thereafter, stock market returns and volatilities are net recipients of spillover effects from supply–side shocks, although these effects are not very pronounced. These findings are not in line with previous studies who have demonstrated the insignificant effects of supply–side shocks in stock markets (see, *inter alia* Degiannakis et al., 2014; Basher et al., 2012; Filis et al., 2011). The consensus is that supply–side shocks do not cause any effects in the stock markets given that OPEC's decision regarding changes in oil supply are anticipated by the markets. Nevertheless, a plausible explanation of our result regarding the effects of supply–side shocks on stock market returns and volatility could lie on the fact that recent disruptions of oil supply are not related to OPEC decisions, but are rather related to unplanned oil supply disruptions caused by the Arab uprising, the oil theft in Nigeria and the closure of Libya's ports. Such developments are expected to trigger negative responses from the financial markets (i.e. lower returns and increased volatility).

Next, we concentrate on the country–specific results. A general comment regarding the relations of interest is that we are able to point out specific differences not only between groups, but also, within groups of countries. In particular, we notice that, with the exception of China, Japan and the US, all remaining net oil–importing countries in our sample (i.e. the European countries) exhibit certain differences compared to their net oil–exporting counterparts. As noted earlier, these differences are mainly related to the time–varying features of the link between oil price shocks and the stock market.

Starting with the net oil–exporting countries, the empirical findings for Canada suggest that, during turbulent times, aggregate demand shocks play a key role in the transmission process of spillovers to the stock market. Specifically, during the years of the Great Recession - especially at the heart of the crisis - aggregate demand shocks appear to be significantly transmitted to both stock market returns and stock market volatility. This is somewhat expected given the aforementioned analysis in connection with the importance of aggregate demand shocks for the stock market. By contrast, aggregate demand shocks appear to be of a rather lesser importance during tranquil times. In fact, during the more recent years, it is the oil–specific demand and supply–side shocks which appear to be of greater importance. As previously noted, the importance of aggregate demand shocks for net oil–exporting countries has also been reported by Wang et al. (2013); however, this study provides additional evidence which accounts for the time–varying role of both oil–specific demand and supply–side shocks. Apergis and Miller (2009) also provide empirical evidence suggesting that oil–specific demand shocks mildly affect stock market returns in Canada without specifying though whether this influence relates to turbulent or tranquil periods. On a final note, it is important to emphasize that, during the years of the crisis, supply–side shocks were also on the transmitting end of spillovers to the Canadian stock market, although to a lesser extent compared to spillovers originating from aggregate demand shocks. This could potentially be explained on the basis of the importance of current availability of oil during periods of recession for net oil–exporting countries (see, among others, Antonakakis et al., 2014; Afonso and Furceri, 2010; Sturm et al., 2009), as well as, on the events that have taken place since the Great Recession in the Middle East.

As far as Norway is concerned, results are qualitatively very similar to those reported for Canada. However, both oil–specific demand and supply–side shocks seem to play a rather greater role in the Norwegian stock market in recent years. Jung and Park (2011) and Wang et al. (2013) also provide evidence of the persistent relation between the two demand–side shocks and the Norwegian stock market; nevertheless, this study suggests that supply–side shocks are also important at different time periods.

Turning to Russia, aggregate demand shocks appear to be important for stock market returns and volatility in the early stages of the Great Recession and until the peak years of the crisis. In addition, supply–side shocks are also important for both stock market returns and volatility, especially from the peak years of the crisis onwards. By contrast, oil–specific demand shocks do not appear to be important. This is in line with Antonakakis et al. (2014) who further subscribe to the belief that for net oil–exporting countries, both aggregate demand and supply-side shocks appear to be important during periods of economic downturn, while oil–specific demand shocks are likely to be more important during relatively even–tempered economic periods. This is true for Russia, although we cannot report any considerable spillover effects deriving from oil–specific demand shocks on the Russian stock market until the very recent years of our sample period. A potential explanation of the transition from aggregate demand shocks spillovers to supply–side shocks spillovers on the Russian stock market during the years of the Great Recession may lie in the work of Bhar and Nikolova (2010). These authors, put forward the argument (by referring to specific oil–related global disturbances such as the terrorist attack of September 11th 2001 and the 2003 war in Iraq) that, although on the eve of any oil price shock, concerns within the Russian economy are mainly demand driven. Eventually, at a later stage, Russia always acts as a resilient supplier of oil on every disturbing occasion; thereby raising concerns for future oil availability. In fact, Bhar and Nikolova (2010) provide historical evidence to support the argument that during such events, oil production within Russia has typically increased compared to production within other oil–producing countries. With regard to the prominence gained in recent years by spillover effects deriving from oil–specific demand shocks on the Russian stock market, authors such as Aleklett et al. (2010) explain that there have been considerations recently, regarding future oil production and thus oil availability within Russia; implying that a more targeted national policy regarding the security of future oil resources is rather essential. Reiterating a point made earlier, concerns regarding the future availability of oil in Russia (i.e. the resilient supplier) are likely to rise, especially in view of escalating upheaval in the Middle East.

Next, we concentrate on the net oil–importers, starting with the the Chinese stock market. We notice that during the years of the Great Recession, aggregate demand shocks are very important in the transmission process of shocks to both Chinese stock market returns and volatility; while clearly, supply–side shocks also assume a net transmitting role. Conversely, oil–specific demand shocks do not appear to be important throughout the years of the crisis. In turn, in the post–2012 period, oil–specific demand shocks appear to be important for Chinese stock market returns but not for stock market volatility. Considering that China is the world's second largest oil–importer (IEA, 2013), demand for oil can be a crucial factor affecting both stock market returns and volatility. Thus, the fact that Chinese stock market volatility is not receiving any spillover effects from oil–specific demand shocks in the post–2012 period is rather unexpected. It is worth mentioning though, that in recent years, authors such as Yuan et al. (2008), Zhang et al. (2009), as well as, Ma et al. (2012, 2011) raise concerns about the future availability of oil in China and stress the necessity for the formulation of appropriate governmental policies to secure oil reserves within the country, and shield the country against abrupt rises in the price of oil. Hence, potentially the Chinese stock market volatility does not currently react to oil–specific demand shocks anticipating that the new policy initiatives will be successfully implemented.

In Japan, aggregate demand shocks appear to be the dominant transmitters of spillovers to both stock market characteristics especially during the first years of the crisis; however, these shocks seem to be more important in the transmisison process of spillover effects to stock market volatility than to stock market returns. In addition, the same period is also characterised by the net transmitting role of oil–specific demand shocks. Empirical evidence related to the results presented in our study, can be found in the work of authors such as Abhyankar et al. (2013), who emphasize both the significant impact of aggregate demand shocks and the negative impact of oil–specific demand shocks on Japanese stock market returns. In addition, authors, such as Chang et al. (2013), emphasize that oil price shocks are, in general, key factors in explaining stock market volatility in Japan. Turning to the post–2012 period, spillover effects mainly originate from supply–side and oil–specific demand shocks. These results are expected given the evidence provided by Abhyankar et al. (2013) and Chang et al. (2013) and the aforementioned geopolitical events that have taken place during this period.

Spillover effects during the years of the Great Recession in the US are mainly transmitted from aggregate demand shocks, especially during the first years of the crisis. We should note however, that this transmission process appears to be more important for stock market returns. Our results suggest, though, that there is definitely a key role for supply–side and oil–specific demand shocks during the latter part of our study. Once again, even in the case of the US we observe the impact of the recent events in the Middle East in the stock market returns and volatility. Our findings are somewhat in line with the empirical evidence by Kilian and Park (2009), who argue that supply–side shocks are less important to the US stock market, compared to the two demand–side shocks. Nevertheless, in this study we point out that the importance of each oil price shock to stock market returns and volatility cannot be examined in a static environment as it clearly depends on events that take place at different time periods.

Finally, spillovers during the Great Recession in European countries are mainly originating from aggregate demand shocks. However, volatility in European stock markets appears to also be influenced by both supply–side and oil–specific demand shocks. It is worth noting that most existing studies on European stock markets concentrate on stock market returns (i.e. excluding stock market volatility) within a static framework in order to provide evidence that entails either a minimum or a negligible influence originating from supply–side shocks. From the few studies focusing on the stock market volatility in Europe, Degiannakis et al. (2014) provide specific evidence that it is aggregate demand shocks rather than the other two that mostly influence volatility in European stock markets. Apparently, though, at turbulent economic or geopolitical times, supply–side and oil–specific demand shocks are also important for the volatility of European stock markets given that these shocks act as transmitters of spillover effects too. Especially the net transmitting role of the oil–specific demand shocks to both stock market returns and volatility in European countries that is observed in the post–2012 period signifies the importance of the ongoing Middle East crisis to these stock markets.

In conclusion, our results suggest that aggregate demand shocks are the main transmitters of spillover effects to the stock markets during periods of economic turbulence, whereas supply–side and oil–specific demand shocks seem to transmit spillover effects during periods of geopolitical unrest. Our findings also indicate the importance of adopting a dynamic approach so as to capture the relevance of each type of shock and to trace similarities and differences between the various types of countries over time.

5. Conclusion

Attaining deeper understanding regarding the relationship between oil price shocks and the stock market appears to be of major concern to recent relevant literature. Contemporary research in this field typically breaks down into three main strands; that is, (i) the investigation of the effects of oil price shocks on the stock market considering the origin of the shock, (ii) the investigation of whether there exists a time-varying relationship between oil prices and the stock market, as well as, (iii) the investigation of potential spillover effects between the said markets.

In this respect, the main contribution of this study is that it combines all three aforementioned strands of related literature in order to investigate spillover effects between oil price shocks (i.e. shocks disaggregated by virtue of their origin) and 11 major stock markets of the world (including both stock markets of net oil-importing and of net oil-exporting countries), within a time-varying framework. The period of the study spans from September 1995 to July 2013. The employed methodology is the one proposed by Diebold and Yilmaz (2012), which in this study is being further extended by the application of a structural vector autoregressive framework that allows for the identification of the three different types of oil price shocks. It follows that this study adds to existing literature not only in terms of introducing new evidence regarding the relationship under investigation, but also, in terms of further exploiting existing econometric methods.

Furthermore, this study concentrates on two stock market characteristics; namely, stock market returns and stock market volatility. One of the major concerns of the authors is to also investigate whether consistent results regarding the behaviour of both stock market characteristics can indeed be obtained (whether, for example, a negative shock that triggers negative responses from stock market returns also creates higher stock market volatility). We employ both current (conditional and realised) and forward–looking (implied) measures of stock market volatility in order to investigate whether the forward–looking measure can indeed provide better information, as has been suggested by the literature.

The implementation of the specific econometric method allows for the investigation of spillover effects from three different angles. In particular, we are able to calculate total, directional, as well as, net spillover effects between oil price shocks and the stock market. Total and directional spillover effects, draw a broader picture of the relationship under investigation, providing information about the magnitude, the trend, as well as, the level of spillover effects either received or transmitted by each one of the variables of the study. Net spillover effects, on the other hand, provide specific information regarding the role of each variable under investigation throughout the period of study (i.e. net transmitter or net recipient of spillover effects). What is more, net spillover effects can be further specified in order to facilitate a pairwise investigation approach (i.e. net effects between variables).

Empirical findings suggest that considering both a time–varying framework of study and the disaggregation of oil price shocks by virtue of their origin is of cardinal importance. To be more explicit, we provide evidence that spillover effects indeed vary across time and that their direction and magnitude is closely related to global economic developments. Furthermore, we find that not all types of oil price shocks transmit spillover effects to the stock market at the same time, but rather, this also depends on the specific period under investigation. More specifically, considering net pairwise spillover effects, our evidence indicates that aggregate demand shocks appear to be net transmitters of spillover effects to the stock market during turbulent economic periods (e.g. during the years of the Great Recession), while both supply–side and oil–specific demand shocks act as net transmitters of spillover effects during periods characterised by intense global geopolitical unrest.

Results are also indicative of the fact that spillover effects may differ not only between the two groups of countries under investigation (i.e. net oil–importing and net oil–exporting countries) but also among the countries of each group. These differences can be partly attributed to the time-varying character of the relationship between oil price shocks and the stock market. What is more, we provide no evidence that the forward-looking measure of stock market volatility provides superior information compared to the current-looking measure.

Our findings are important to investors and portfolio managers who have positions to both the oil and stocks and thus need to adjust their holdings according to spillovers transmitted by both markets. In particular, investors should strongly consider the fact that different oil price shocks transmit different spillovers over different time periods that result in different correlations within a portfolio comprising investments in both markets. For instance, spillovers from aggregate demand shocks tend to strengthen the co–movement of the two markets, while spillovers from both supply–side and oil–specific demand shocks entail negative correlation. These results are also important to investors who participate in the options market given that volatility is the key component of option pricign. Thus, they need to be aware of the time–varying nature of potential spillovers that oil price shocks transmit to stock market volatility.

An exciting avenue for future research may include the examination of spillover effects between oil price shocks and industrials sectors rather than aggregate stock indices. Aggregate stock market indices may mask the individual characteristics of the industrial sectors. Finally, spillover effects between oil price shocks and other financial assets (e.g. exchange rates) and commodity price indices (e.g. gold or food), which form part of investment portfolios, is an interesting area for further research.

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Figure 1: Oil production growth, oil returns, general economic activity & stock market returns

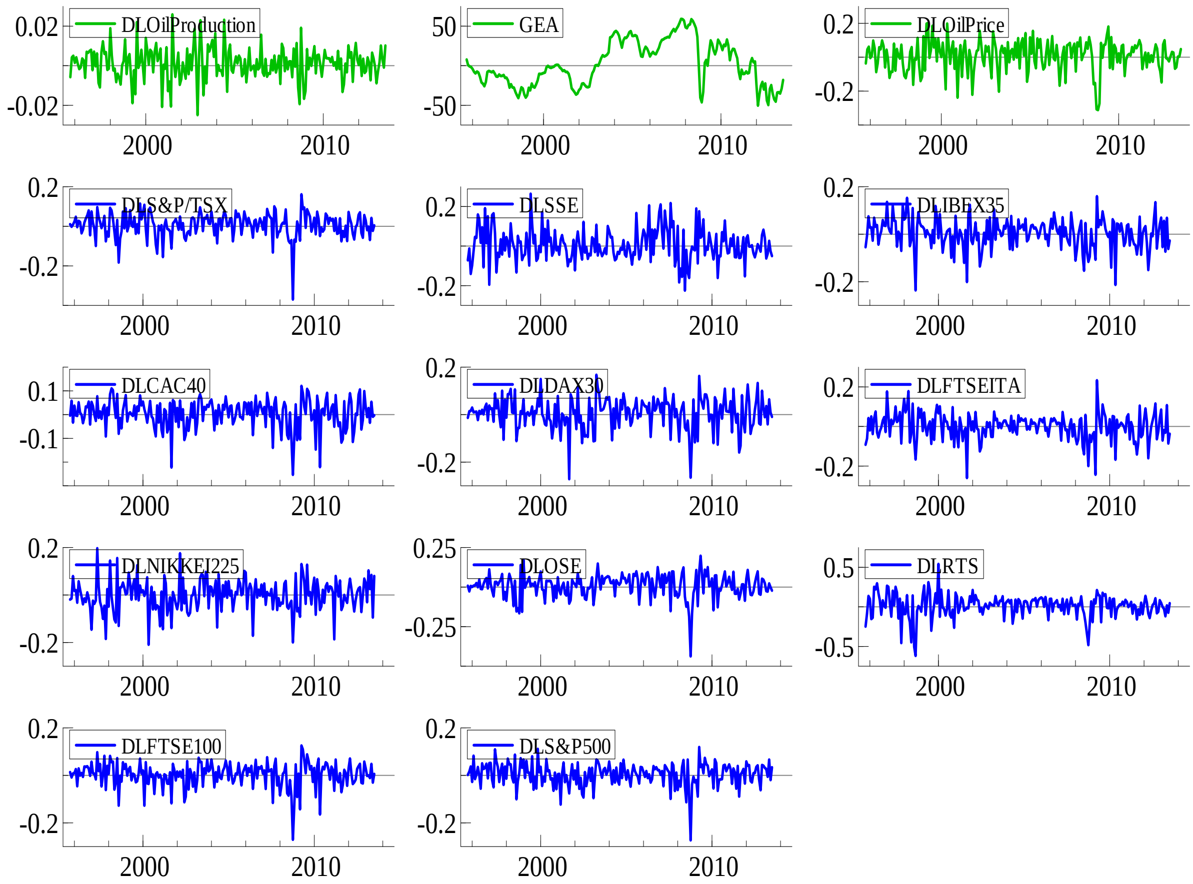


Figure 2: Stock market returns' realised volatility, conditional volatility & implied volatility

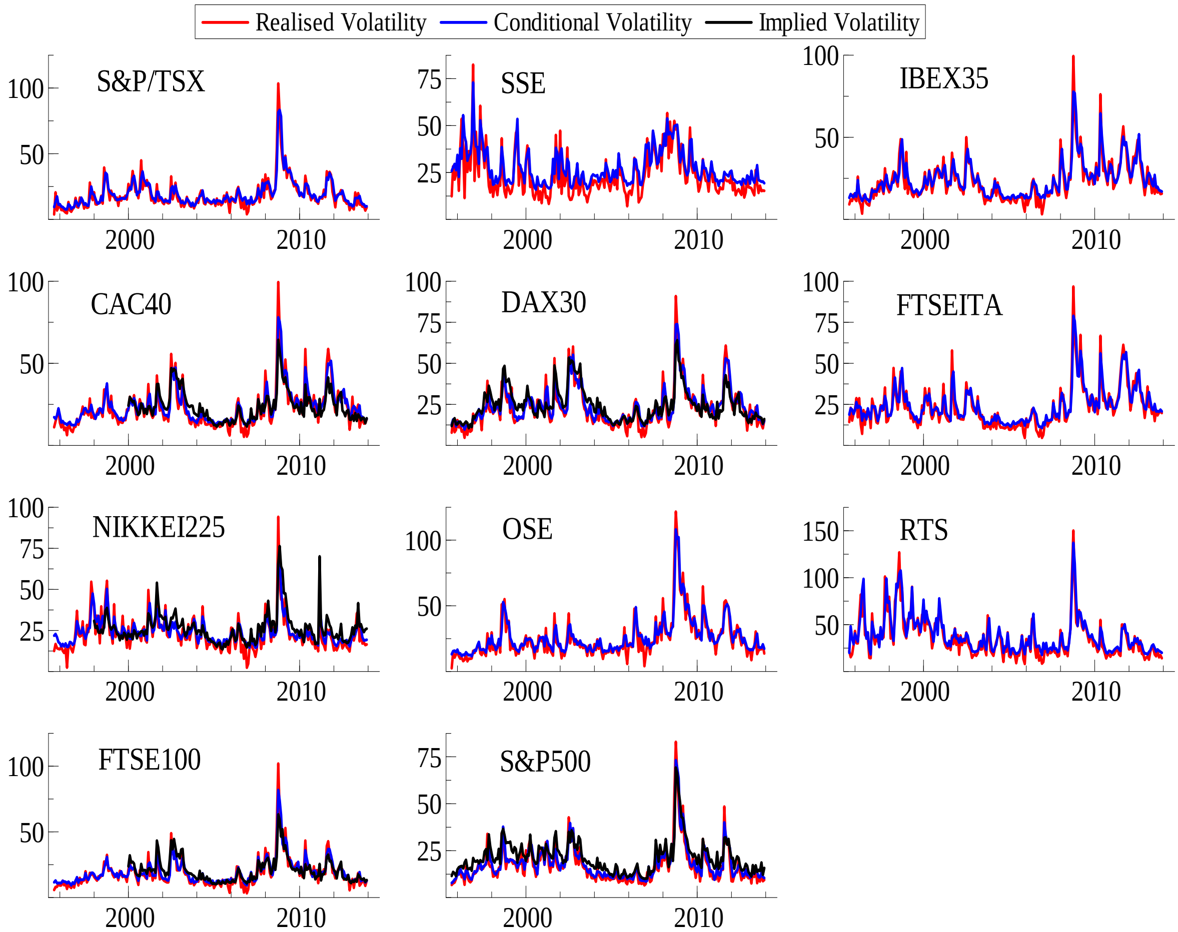
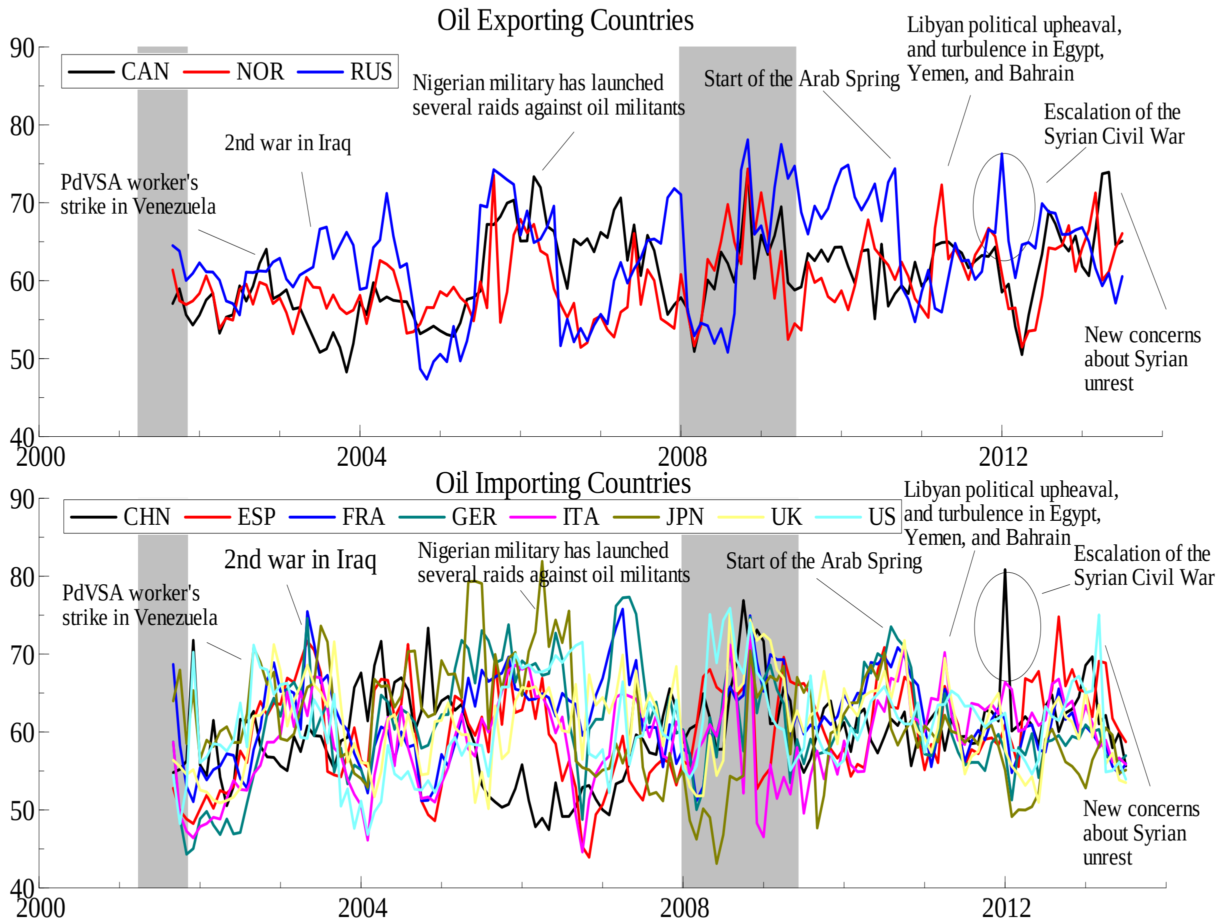


Figure 3: Total spillovers between oil price shocks and stock market returns



Note: Shading denotes US recessions as defined by the NBER.

Figure 4: Directional spillovers *FROM* oil price shocks and stock market returns to all others

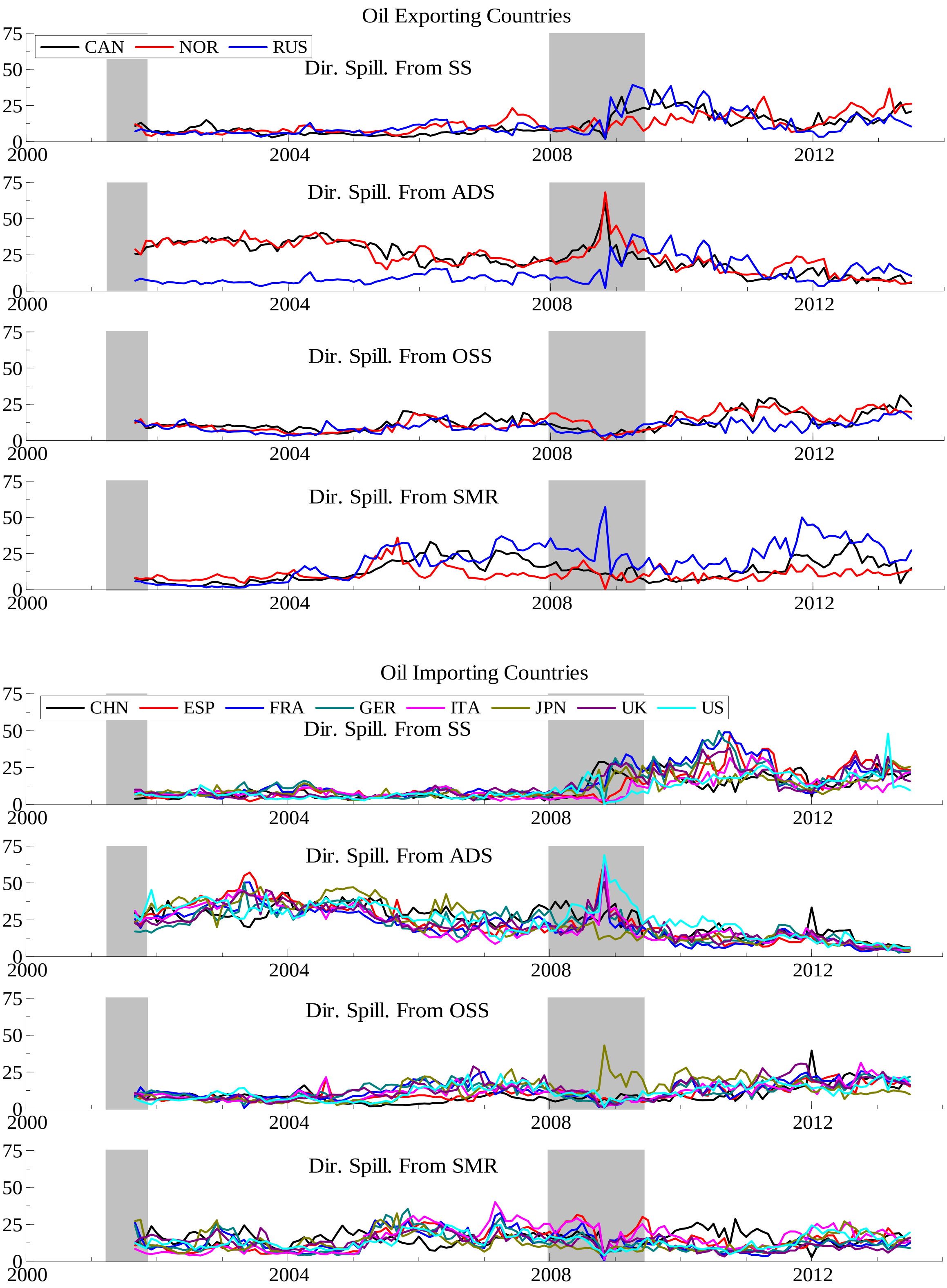


Figure 5: Directional spillovers *TO* oil price shocks and stock market returns from all others

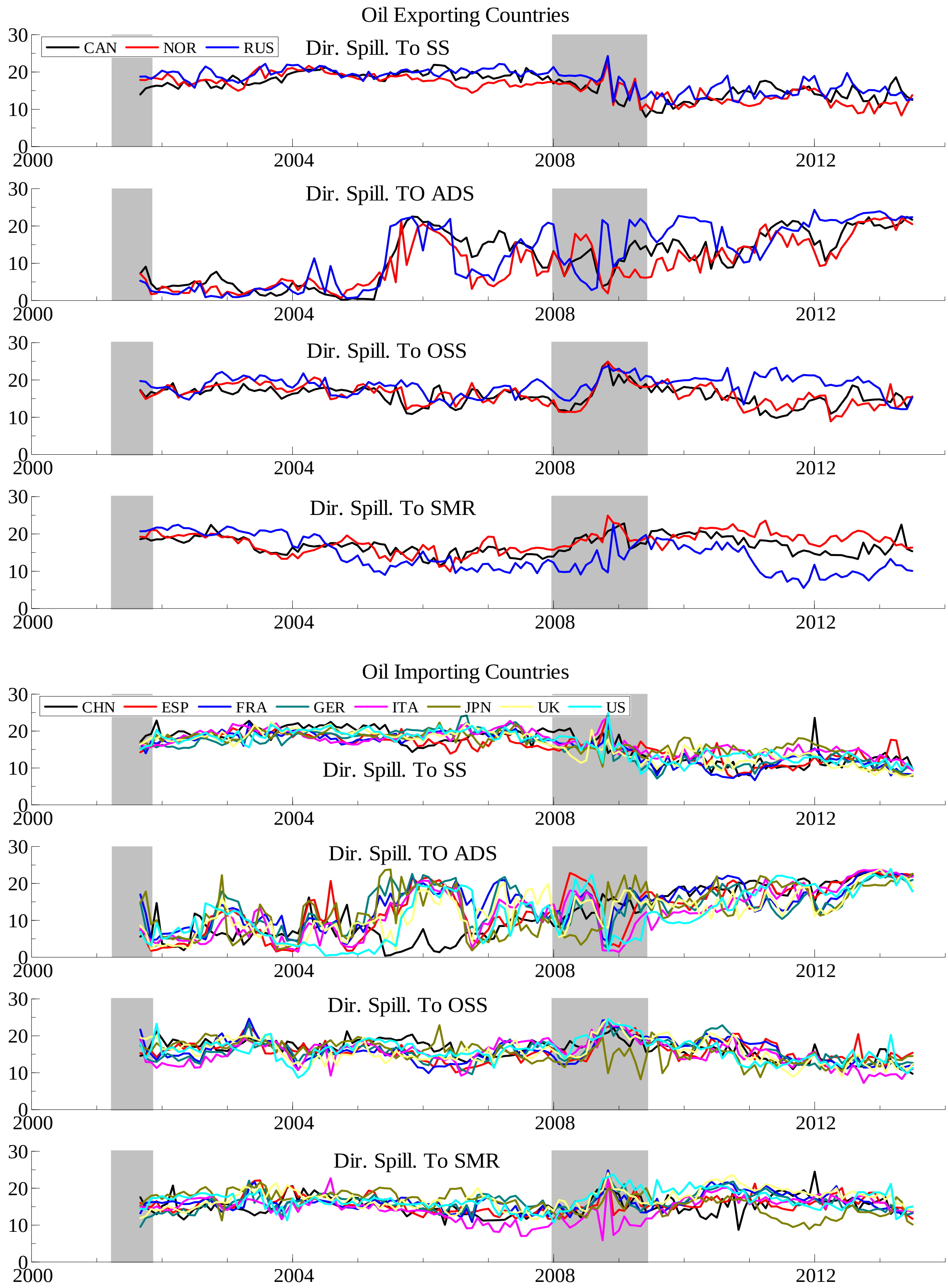


Figure 6: Net spillovers of oil price shocks and stock market returns

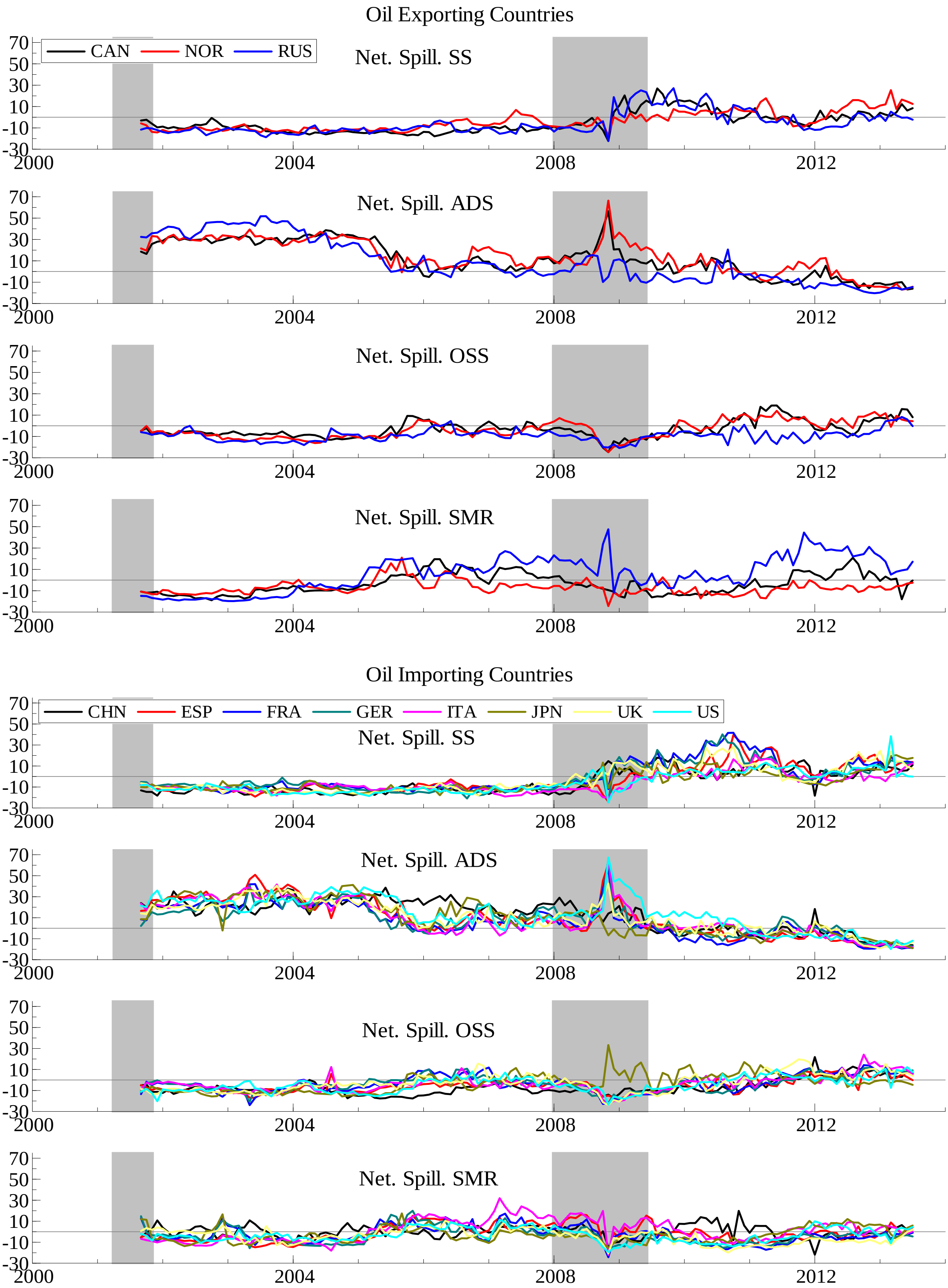


Figure 7: Net pairwise spillovers between oil price shocks and stock market returns

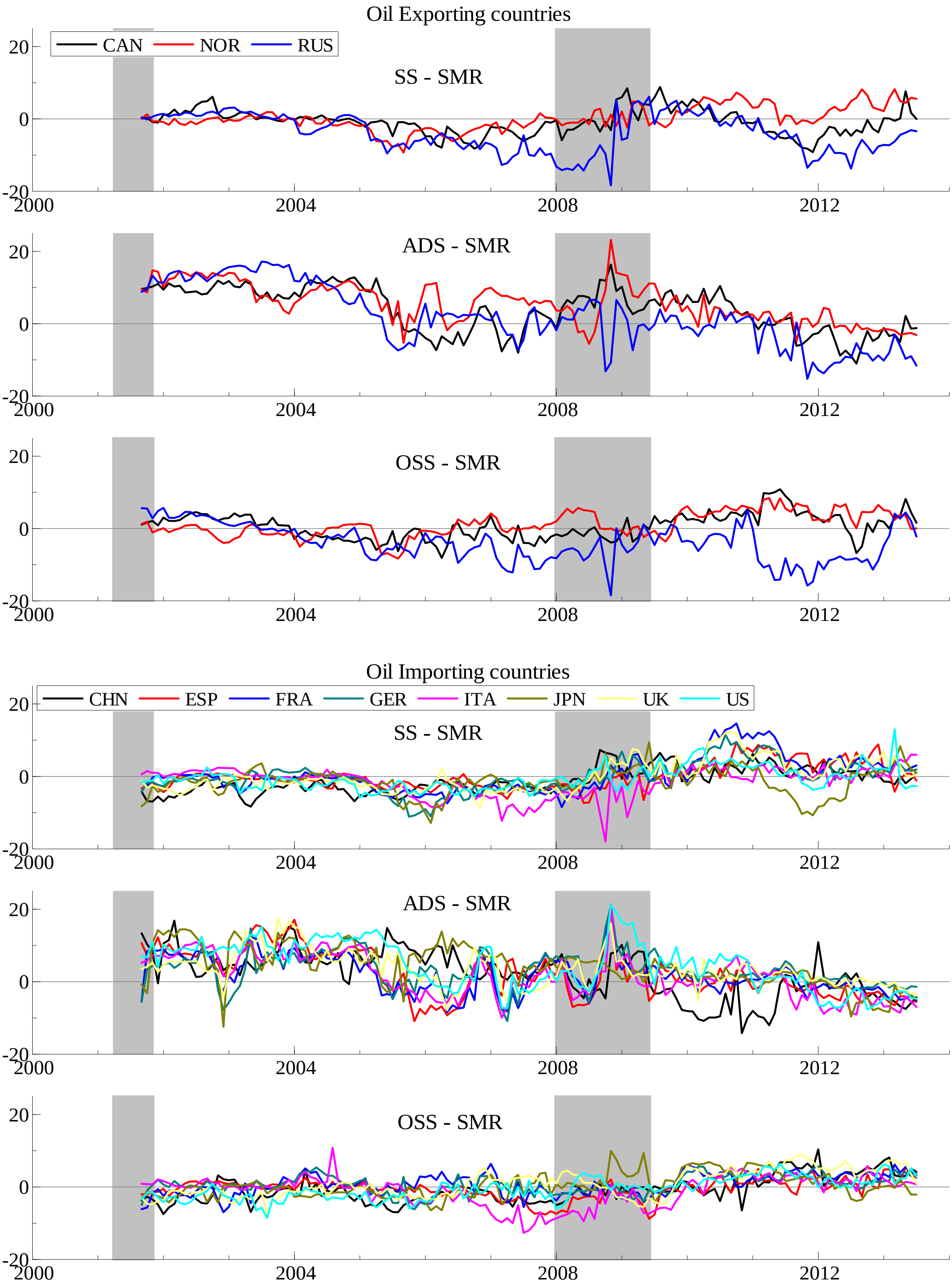
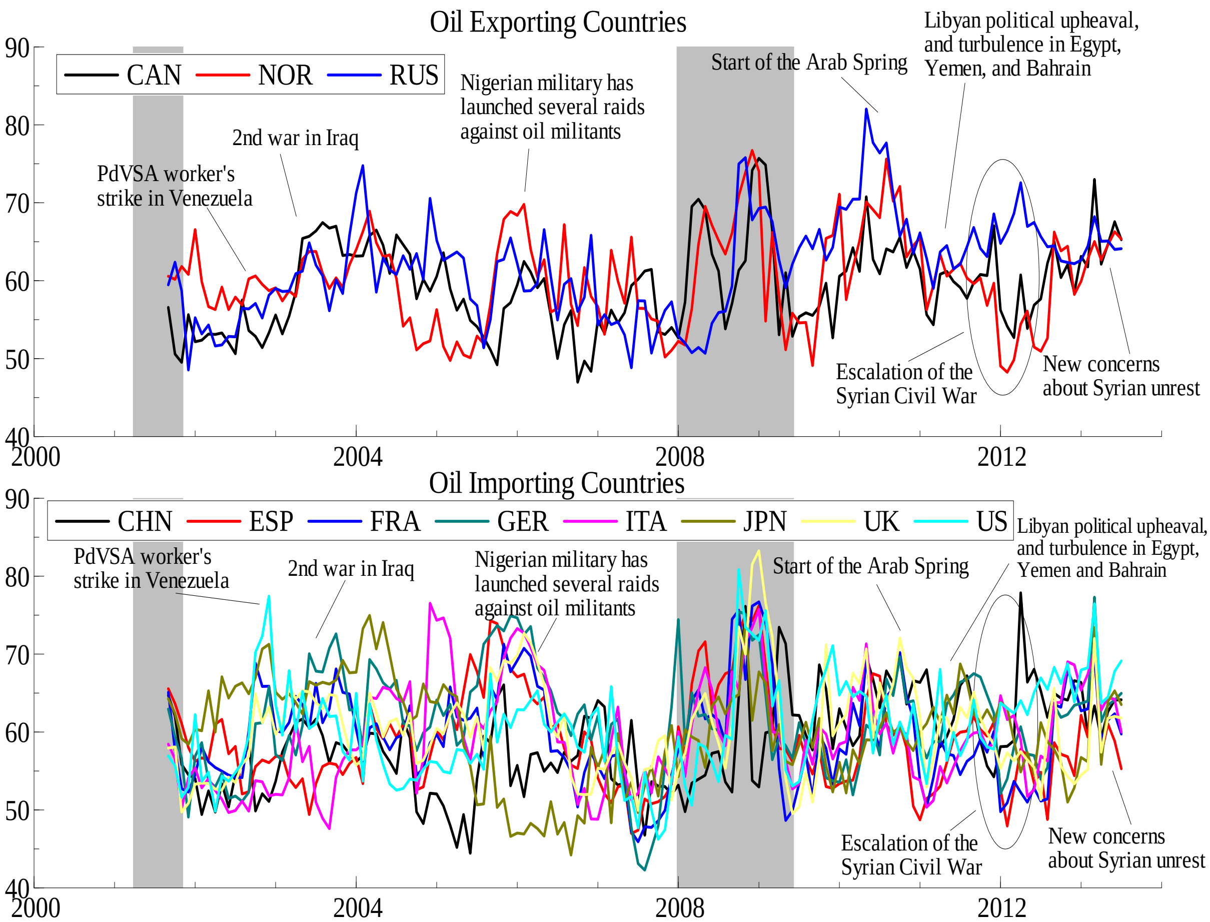


Figure 8: Total spillovers between oil price shocks and stock market realised volatility



Note: Shading denotes US recessions as defined by the NBER.

Figure 9: Directional spillovers *FROM* oil price shocks and stock market realised volatility to all others

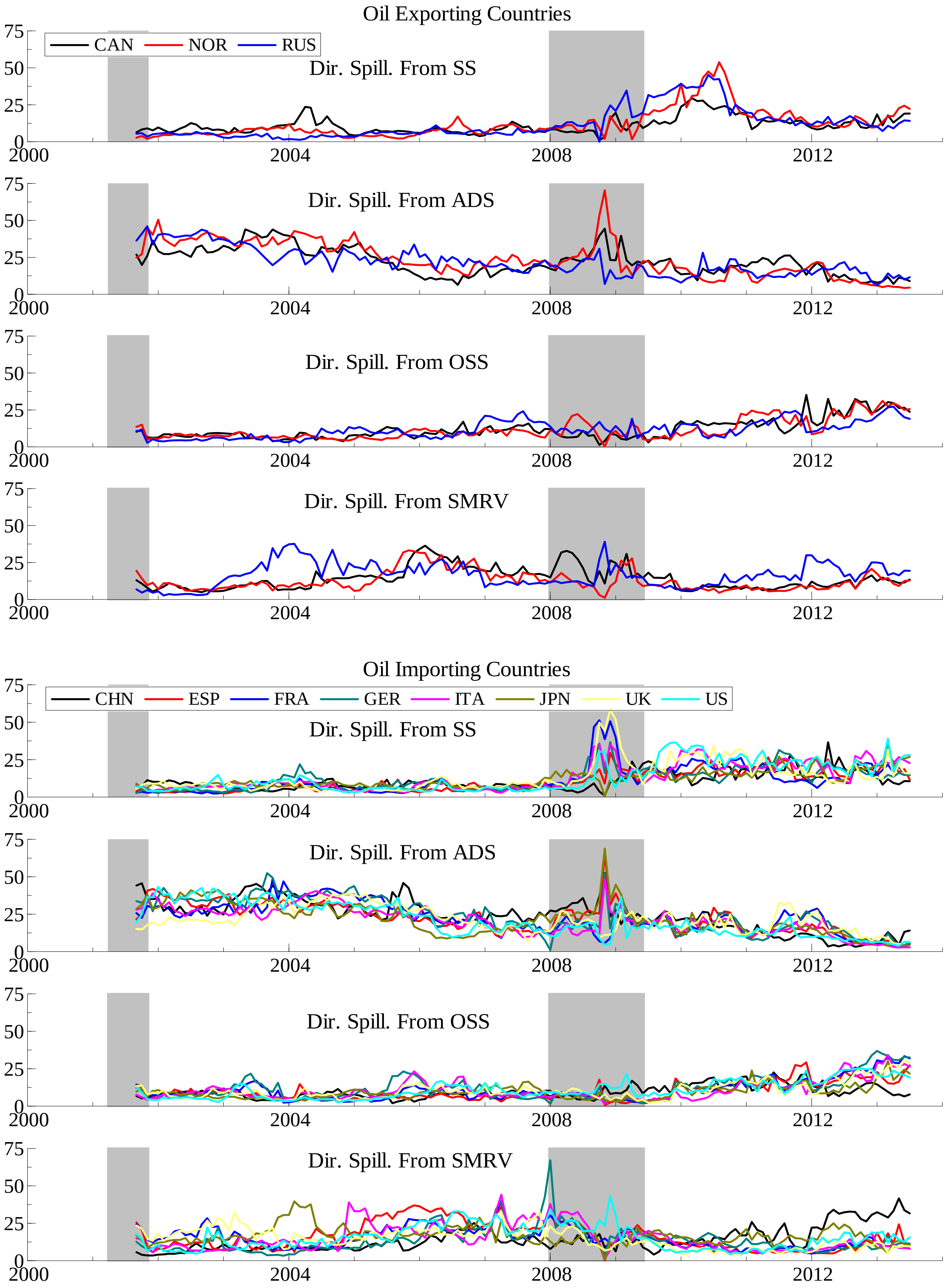


Figure 10: Directional spillovers *TO* oil price shocks and stock market realised volatility from all others

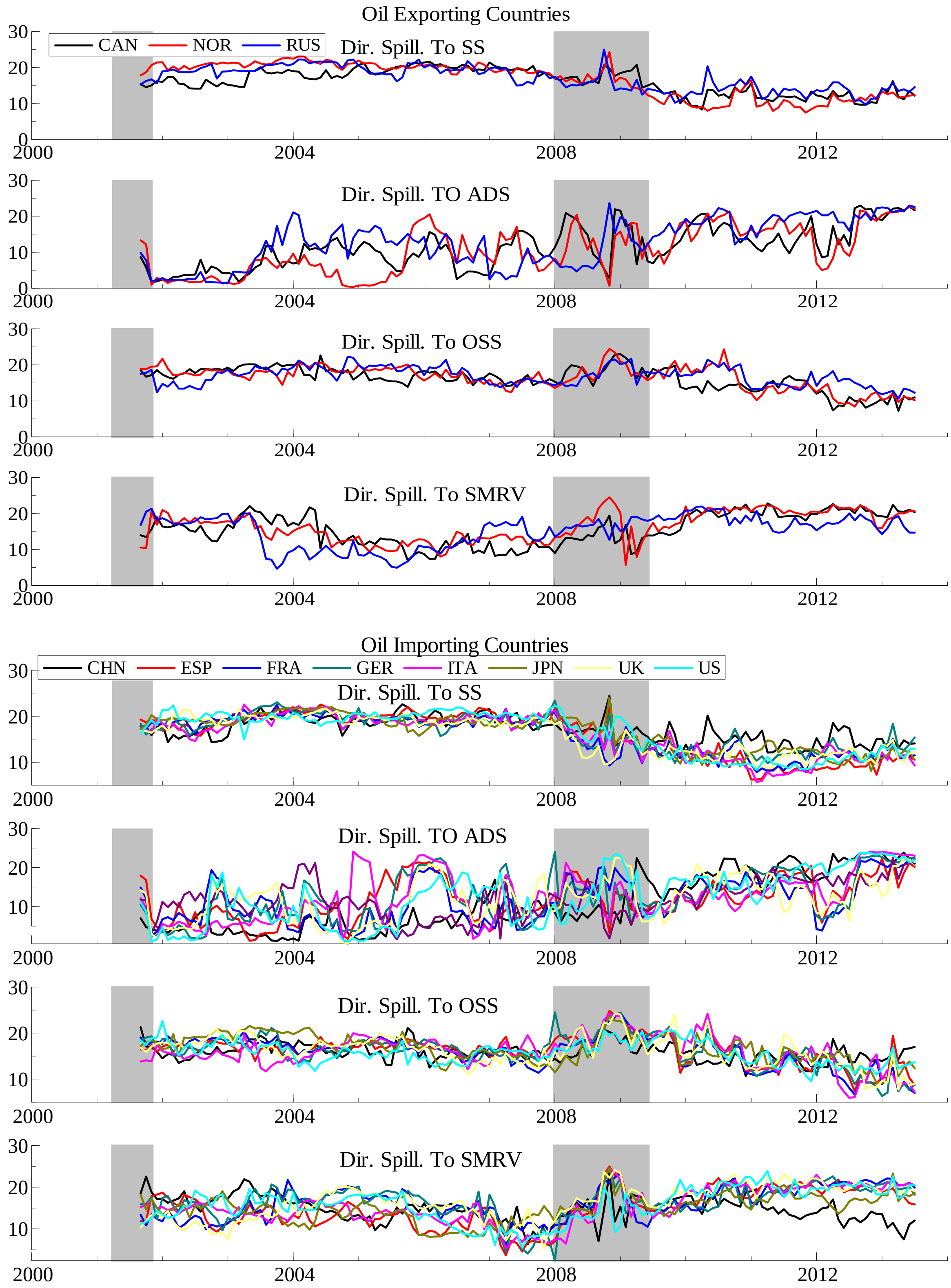


Figure 11: Net spillovers of oil price shocks and stock market realised volatility

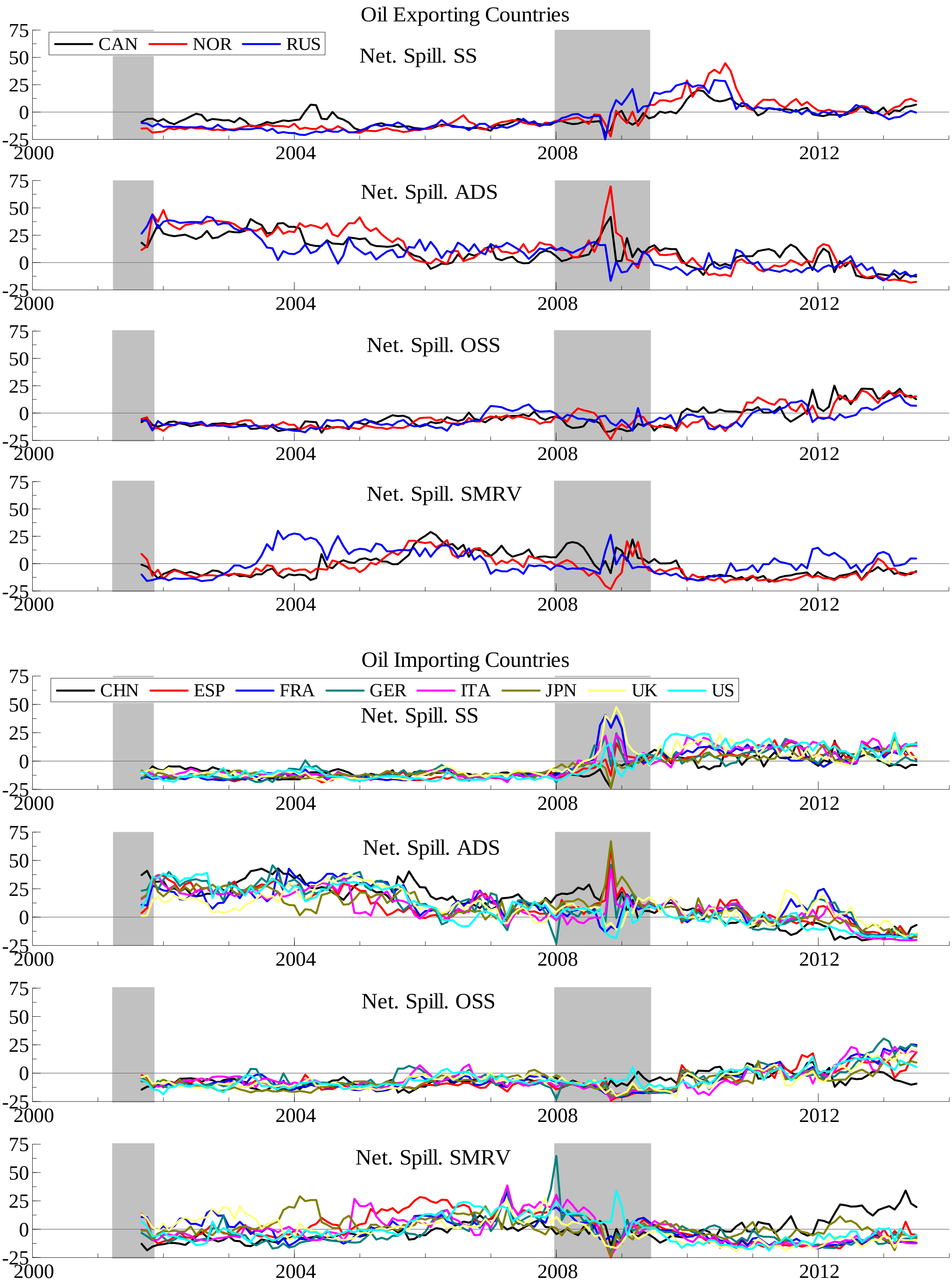


Figure 12: Net pairwise spillovers between oil price shocks and stock market realised volatility

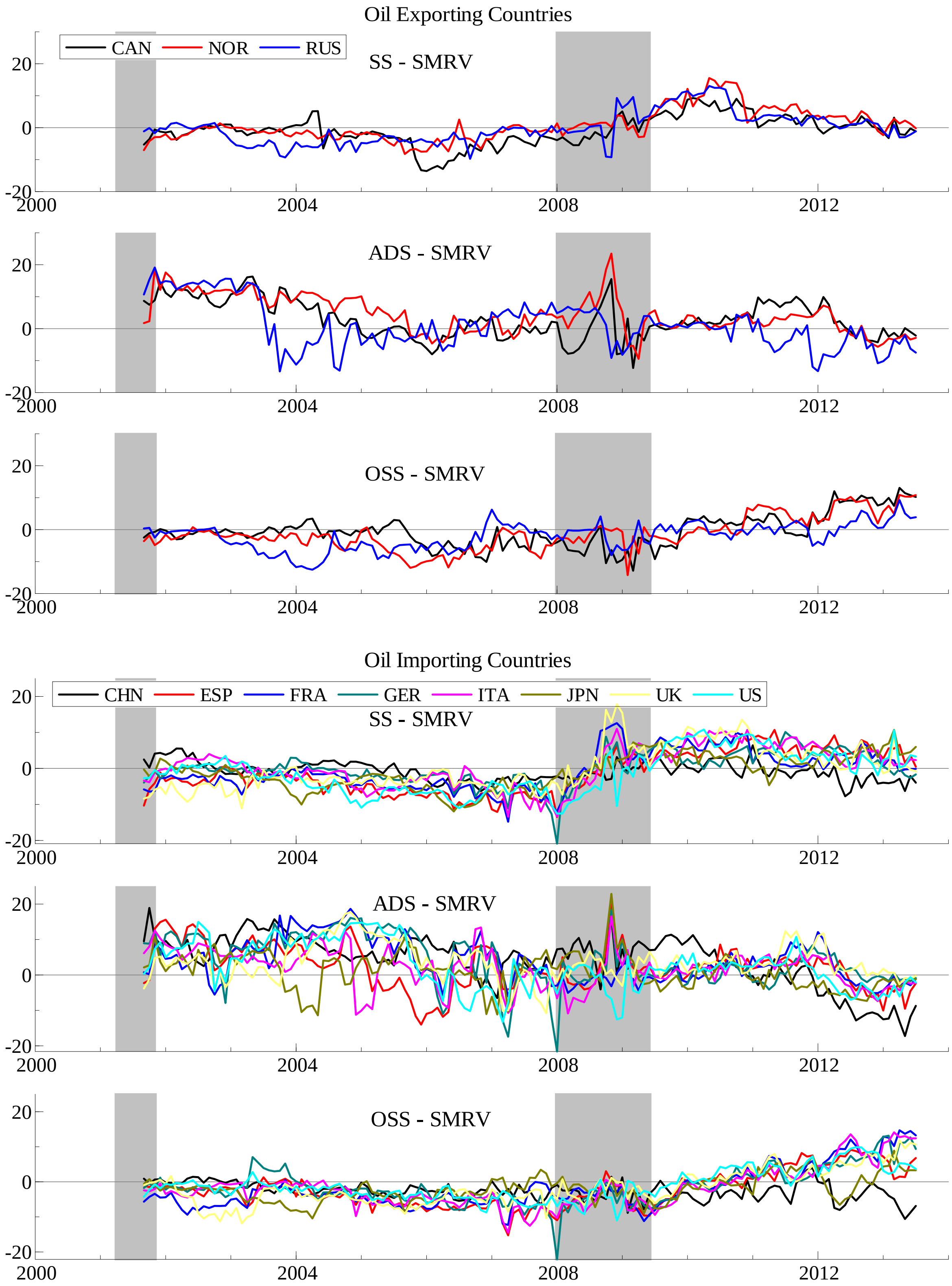
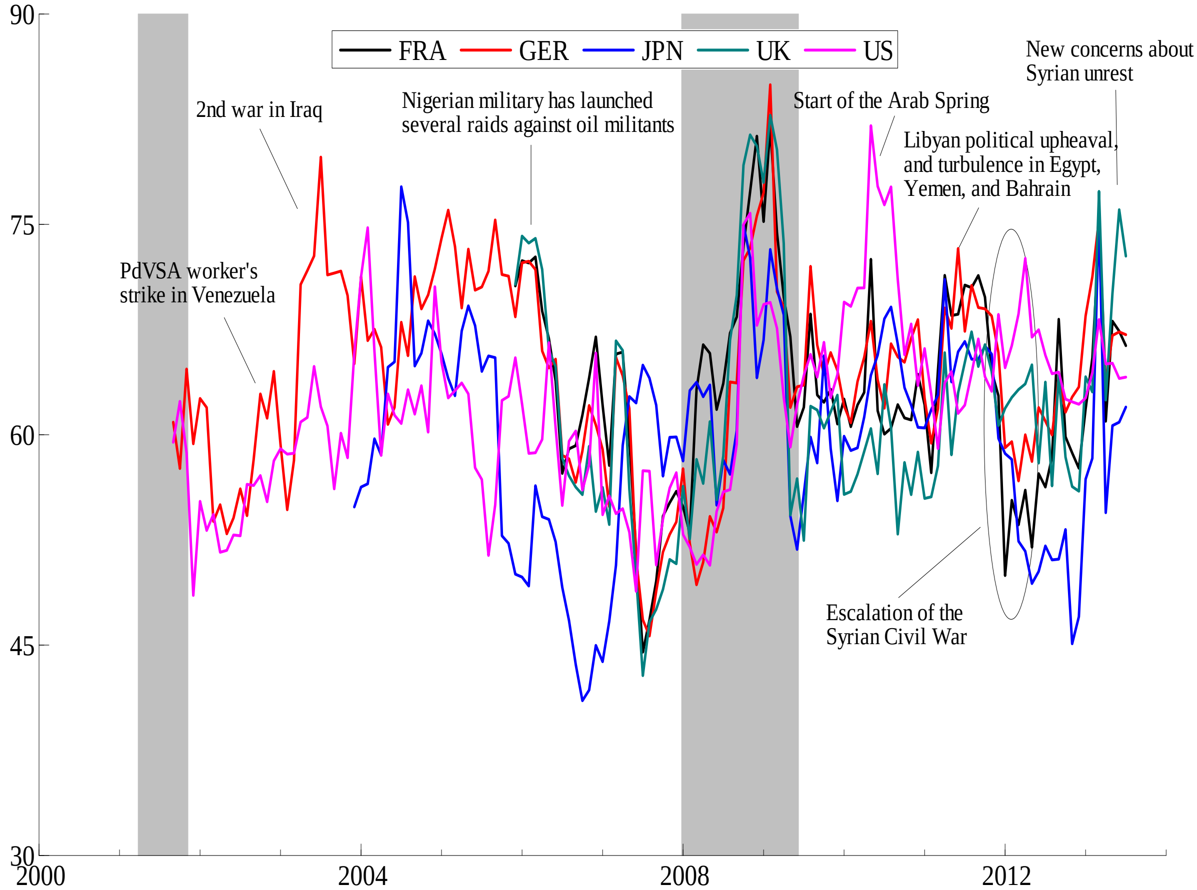


Figure 13: Total spillovers between oil price shocks and stock market implied volatility



Note: Shading denotes US recessions as defined by the NBER.

Figure 14: Directional spillovers *FROM* oil price shocks and stock market implied volatility to all others

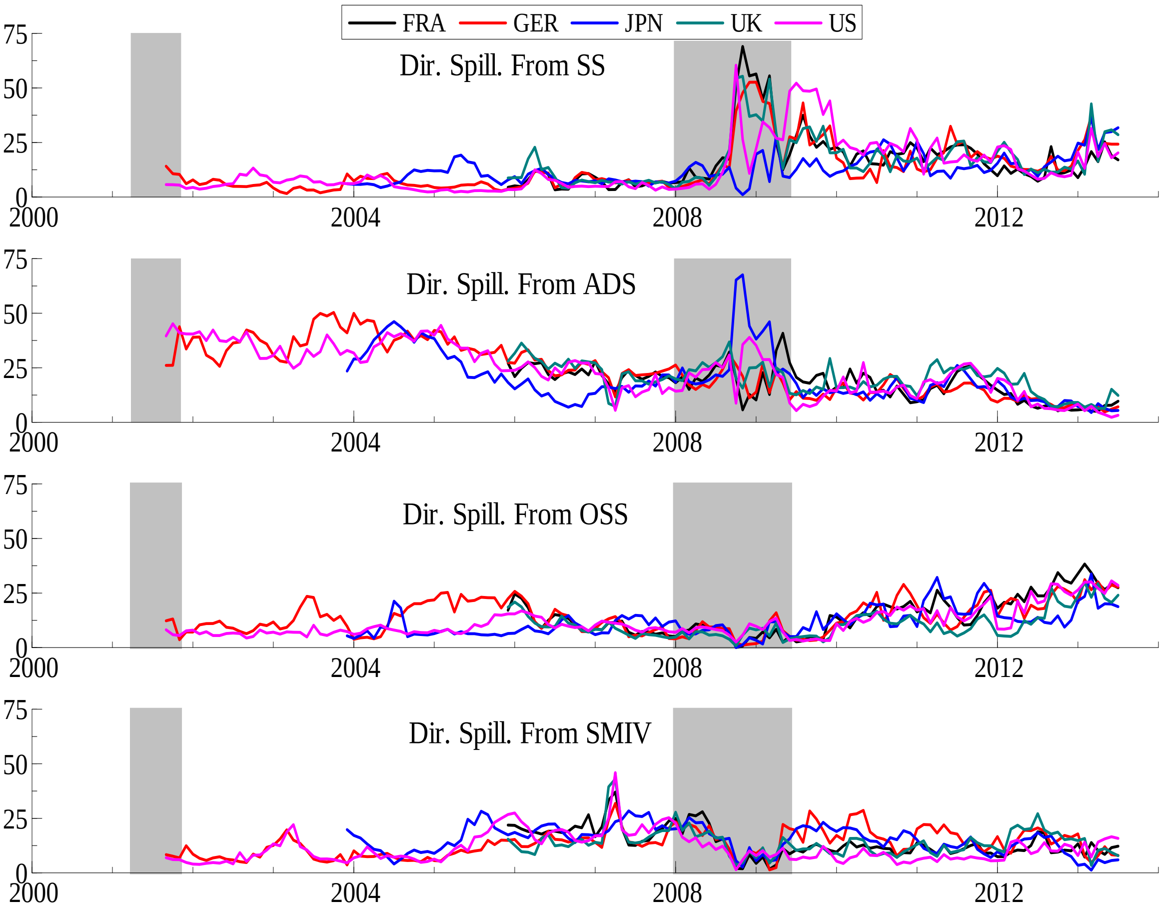


Figure 15: Directional spillovers *TO* oil price shocks and stock market implied volatility from all others

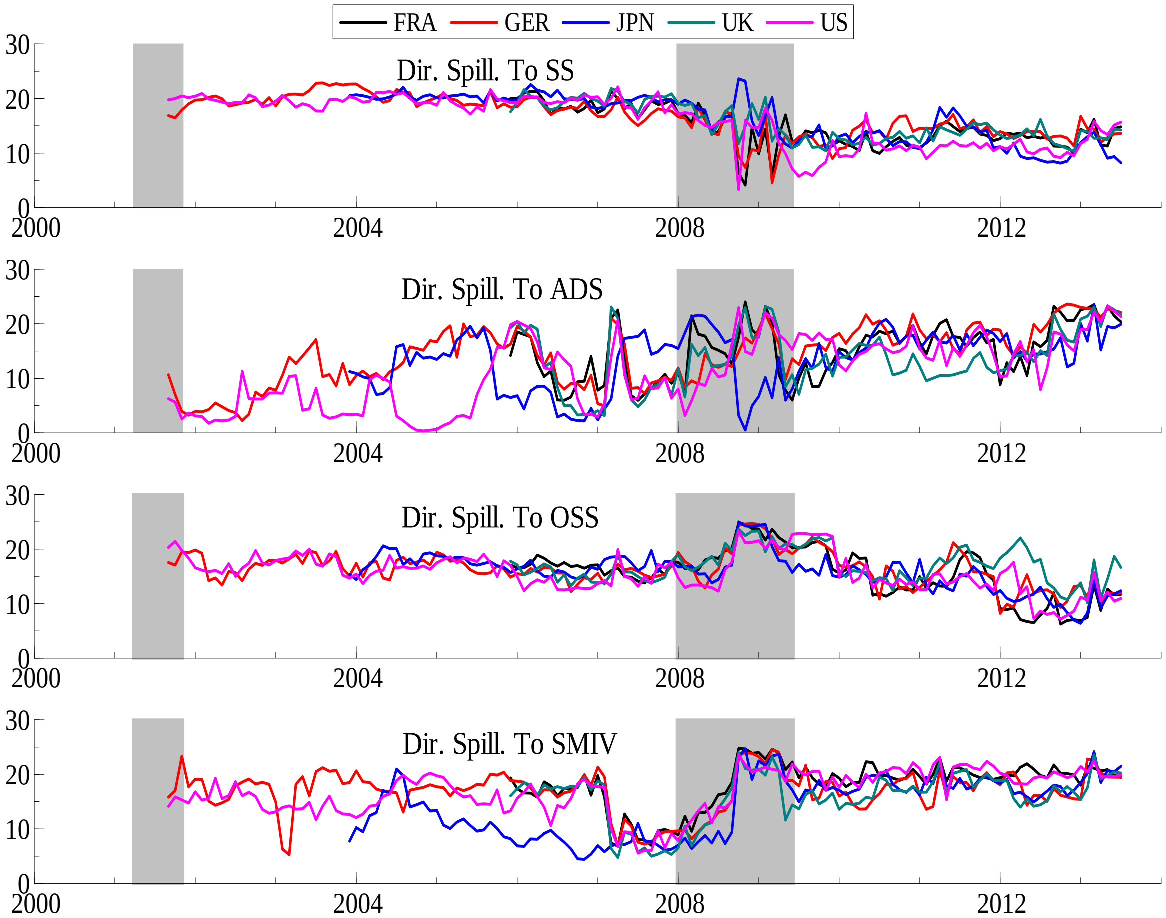


Figure 16: Net spillovers of oil price shocks and stock market implied volatility

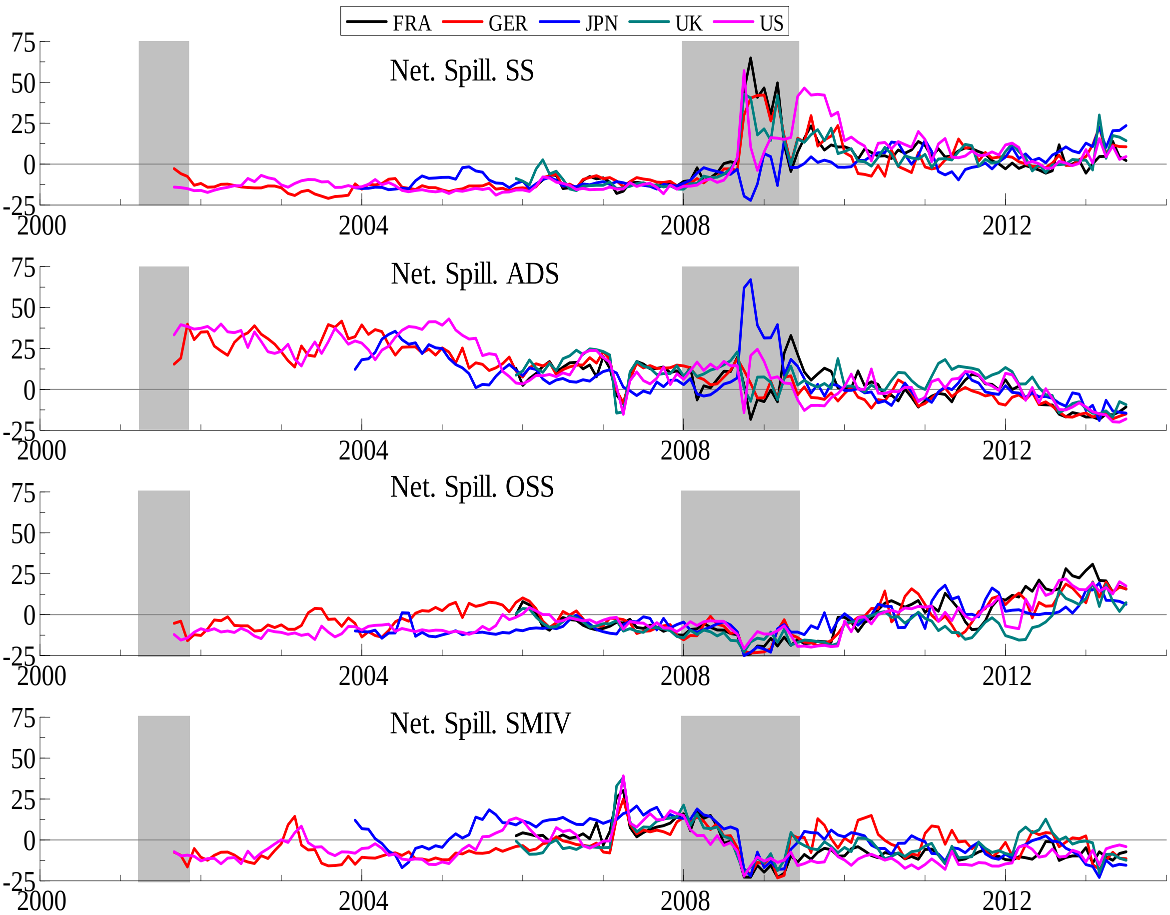


Figure 17: Net pairwise spillovers between oil price shocks and stock market implied volatility

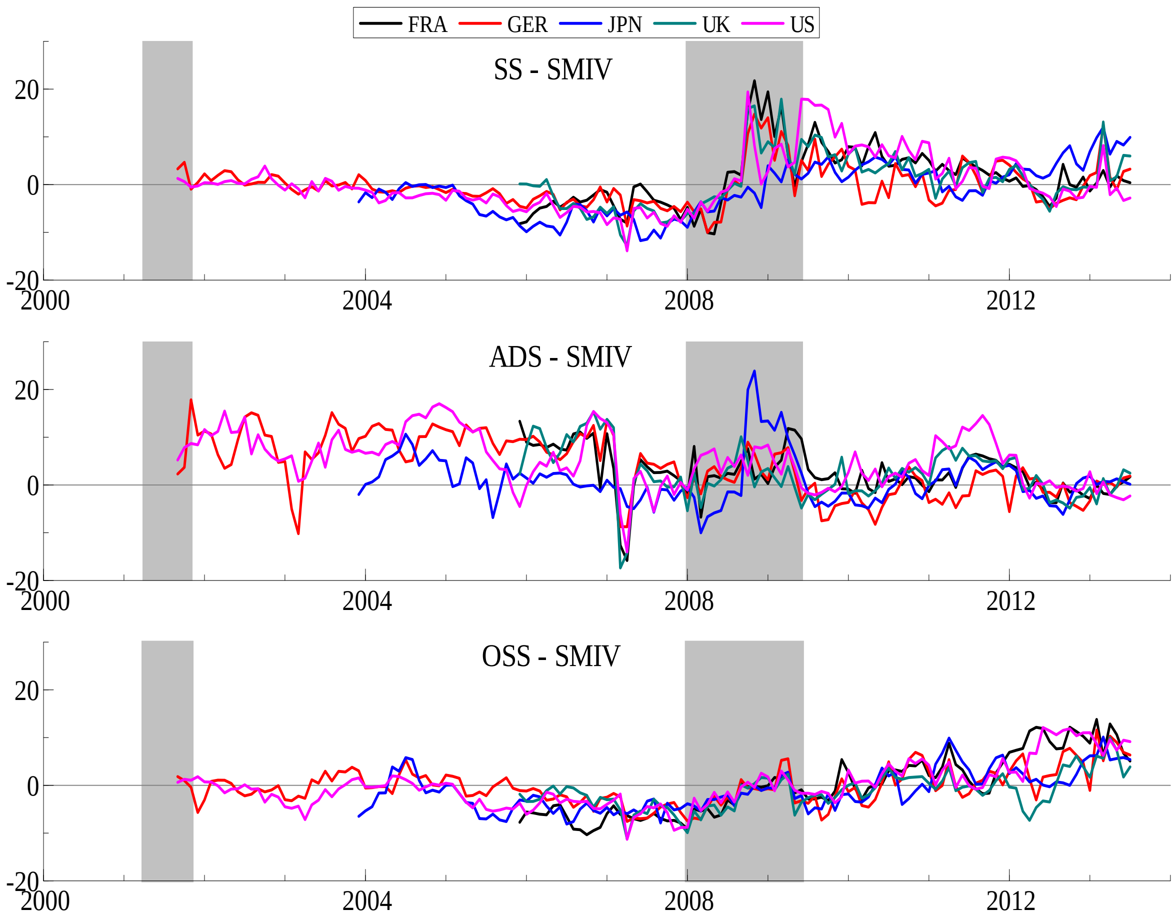


Table 1: Descriptive statistics, 1995:09 − 2013:07

Series	Obs	Mean	Std	Min	Max	Skewness	Excess Kurtosis	Jarque-Bera	ADF
$\Delta \ln$(S&P/TSX)	214	0.0060	0.0599	-0.3695	0.1612	-1.4062**	6.5226**	449.88***	-12.10**
$\Delta \ln$(SSE)	214	0.0061	0.0821	-0.2244	0.2642	0.3352*	0.4194	5.5767	-13.55**
$\Delta \ln$(IBEX35)	214	0.0037	0.0639	-0.2361	0.1595	-0.6319**	1.1885**	26.838**	-13.64**
$\Delta \ln$(CAC40)	214	0.0035	0.0610	-0.2533	0.1205	-1.0182**	1.9321**	70.265**	-13.34**
$\Delta \ln$(DAX30)	214	0.0059	0.0670	-0.2714	0.1674	-0.7328**	1.6925**	44.693**	-13.32**
$\Delta \ln$(FTSEITA)	214	0.0002	0.0663	-0.2597	0.2328	-0.4310**	1.6908**	32.119**	-13.89**
$\Delta \ln$(NIKKEI225)	214	-0.0010	0.0663	-0.2089	0.1965	-0.2930	0.8285*	9.1839*	-14.99**
$\Delta \ln$(OSE)	214	0.0079	0.0742	-0.4369	0.1972	-1.2884**	5.3154**	311.13**	-11.72**
$\Delta \ln$(RTS)	214	0.0122	0.1431	-0.6173	0.5408	-0.8889**	3.4226**	132.63**	-12.02**
$\Delta \ln$(FTSE100)	214	0.0027	0.0519	-0.2704	0.1255	-1.2230**	3.4775**	161.18**	-13.91**
$\Delta \ln$(S&P500)	214	0.0049	0.0478	-0.2729	0.1189	-1.1524**	4.5503**	231.99**	-14.39**
$\Delta \ln$(OIL PRICE)	214	0.0087	0.0898	-0.3110	0.2007	-0.7755**	1.0657**	31.574**	-11.93**
$\Delta \ln$(OIL PROD)	214	0.0012	0.0080	-0.0249	0.0259	-0.0877	1.0379**	9.8796**	-15.05**
GEA	215	2.1896	27.674	-50.300	59.100	0.2286	-0.9843**	10.502**	-2.993*
S&P/TSXRV	214	18.662	11.523	3.8878	103.42	3.2010**	16.880**	2987.7**	-5.625**
SSERV	214	23.920	11.704	7.0870	82.426	1.4583**	2.7164**	145.61**	-8.594**
IBEX35RV	214	23.389	12.714	3.2046	99.467	1.9250**	6.6881**	545.90**	-6.133**
CAC40RV	214	22.681	12.319	5.3115	99.453	2.1910**	7.9025**	748.46**	-5.788**
DAX30RV	214	23.325	12.549	4.7649	90.901	1.7591**	4.7469**	320.02**	-5.885**
FTSEITARV	214	23.446	12.934	4.6273	96.709	1.8891**	5.6263**	421.02**	-6.263**
NIKKEI225RV	214	23.152	10.558	2.3874	94.151	2.1821**	9.6313**	1024.9**	-8.408**
OSERV	214	25.092	16.134	2.5305	121.67	2.5882**	9.4901**	1071.2**	-5.429**
RTSRV	214	35.848	21.490	8.1671	150.17	1.8686**	5.0095**	358.06**	-6.213**
FTSE100RV	214	18.753	11.131	3.3155	101.96	2.9811**	15.506**	2529.7**	-6.091**
S&P500RV	214	17.442	10.105	6.5368	82.923	2.6828**	4.5503**	231.99**	-5.677**
S&P/TSXCV	214	19.382	10.327	7.62	83.330	3.2923**	15.620**	2574.2**	-3.904**
SSECV	214	27.692	9.4193	15.9	72.890	1.3310**	2.0001**	99.315**	-5.800**
IBEX35CV	214	24.430	10.989	10.83	77.720	1.7970**	4.7329**	316.38**	-4.550**
CAC40CV	214	23.572	10.390	12.28	77.990	2.1600**	6.6607**	564.61**	-4.187**
DAX30CV	214	24.287	10.951	9.76	73.850	1.7473**	3.9558**	249.59**	-4.362**
FTSEITACV	214	24.660	11.154	10.61	78.900	1.8456**	4.5224**	305.28**	-4.592**
NIKKEI225CV	214	24.246	7.745	14.54	68.170	2.2301**	7.8911**	736.03**	-5.773**
OSECV	214	26.345	14.153	11.68	108.12	2.7971**	10.813**	1327.7**	-3.791**
RTSCV	214	39.010	19.942	17.8	137.10	1.8442**	4.0907**	271.78**	-4.990**
FTSE100CV	214	19.506	9.5082	9.38	81.900	2.9814**	13.460**	1941.6**	-4.442**
S&P500CV	214	18.125	9.1764	7.78	73.230	2.7666**	11.337**	1425.6**	-4.495**
VCAC	163	24.206	9.2617	11.483	64.330	1.4167**	2.5517**	101.77**	-3.923**
VDAX	214	24.842	10.168	10.580	64.110	1.4276**	1.8293**	80.492**	-3.641**
VXJ	187	26.428	9.5090	13.580	76.350	2.4537**	7.9706**	613.29**	-5.530**
VFTSE	163	21.286	9.3322	10.294	63.260	1.7085**	3.8682**	186.47**	-4.060**
VIX	214	21.616	8.6736	10.050	69.250	2.1415**	7.2211**	493.42**	-3.945**

Note: ADF denotes Augmented Dickey Fuller tests with 5% and 1% critical values of -2.88 and -3.46, respectively. * and ** indicate significance at 5% and 1% level, respectively.

Table 2: Oil price shocks and stock market returns, spillover table (1995:09 – 2013:07)

	CAN					**CHN**				
	From (j)					*From (j)*				
To (i)	SS	ADS	OSS	SMR	From others	SS	ADS	OSS	SMR	From others
SS	78.6	6.4	7.7	7.3	21.4	84.0	7.4	6.0	2.6	16.0
ADS	2.2	78.2	3.3	16.4	21.8	1.9	57.6	3.3	37.2	42.4
OSS	6.1	7.9	76.4	9.7	23.6	6.8	7.2	78.0	7.9	22.0
SMR	7.8	8.8	15.9	67.5	32.5	3.2	2.0	4.8	89.9	10.1
Contr. to others	16.1	23.0	26.9	33.4	Tot. Spillover	12.0	16.7	14.0	47.7	Tot. Spillover
Contr. incl. own	94.7	101.2	103.2	100.9	Index=24.8%	95.9	74.3	92.1	137.7	Index=22.6%
Net spillovers	-5.3	1.2	3.3	0.9		-4	-25.7	-8	37.6	
	ESP					**FRA**				
	From (j)					*From (j)*				
To (i)	SS	ADS	OSS	SMR	From others	SS	ADS	OSS	SMR	From others
SS	81.6	7.2	6.4	4.8	18.4	81.8	6.4	6.6	5.2	18.2
ADS	2.1	85.2	4.4	8.3	14.8	2.6	82.2	3.9	11.4	17.8
OSS	6.0	6.8	80.7	6.4	19.3	6.3	7.6	79.8	6.3	20.2
SMR	8.8	7.6	2.6	81.0	19.0	7.7	7.4	8.4	76.5	23.5
Contr. to others	16.9	21.6	13.3	19.5	Tot. Spillover	16.6	21.4	18.9	22.9	Tot. Spillover
Contr. incl. own	98.6	106.8	94.1	100.5	Index=17.9%	98.4	103.6	98.7	99.4	Index=19.9%
Net spillovers	-1.5	6.8	6	0.5		-1.6	3.6	-1.3	-0.6	
	GER					**ITA**				
	From (j)					*From (j)*				
To (i)	SS	ADS	OSS	SMR	From others	SS	ADS	OSS	SMR	From others
SS	83.6	5.9	6.0	4.5	16.4	82.1	6.3	6.9	4.7	17.9
ADS	2.5	83.1	3.8	10.6	16.9	2.8	87.1	5.3	4.8	12.9
OSS	6.9	7.7	78.7	6.7	21.3	6.0	6.9	79.9	7.2	20.1
SMR	9.2	7.0	4.0	79.9	20.1	11.9	8.5	4.6	74.9	25.1
Contr. to others	18.6	20.6	13.8	21.8	Tot. Spillover	20.7	21.7	16.9	16.7	Tot. Spillover
Contr. incl. own	102.2	103.6	92.5	101.7	Index=18.7%	102.8	108.7	96.8	91.6	Index=19.0%
Net spillovers	2.2	3.7	-7.5	1.7		2.8	8.8	-3.2	-8.4	
	JPN					**NOR**				
	From (j)					*From (j)*				
To (i)	SS	ADS	OSS	SMR	From others	SS	ADS	OSS	SMR	From others
SS	83.4	5.1	5.5	5.9	16.6	82.9	9.2	6.6	1.3	17.1
ADS	2.9	81.2	5.6	10.3	18.8	2.6	77.2	5.4	14.8	22.8
OSS	6.3	6.9	79.8	7.0	20.2	6.5	9.8	79.6	4.1	20.4
SMR	3.9	9.1	4.8	82.2	17.8	7.8	4.3	1.8	86.1	13.0
Contr. to others	13.0	21.1	16.0	23.2	Tot. Spillover	18.8	51.9	10.5	22.0	Tot. Spillover
Contr. incl. own	96.5	102.4	95.8	105.4	Index=18.3%	90.8	139.1	83.6	86.5	Index=25.8%
Net spillovers	-3.6	2.3	-4.2	5.4		1.7	29.1	-9.9	9	
	RUS					**UK**				
	From (j)					*From (j)*				
To (i)	SS	ADS	OSS	SMR	From others	SS	ADS	OSS	SMR	From others
SS	77.7	11.1	5.2	6.1	22.3	82.9	7.6	6.6	2.9	17.1
ADS	2.3	76.7	2.9	18.1	23.3	2.5	88.6	3.8	5.1	11.4
OSS	8.5	9.2	71.3	10.9	28.7	6.6	7.5	79.3	6.5	20.7
SMR	1.4	4.0	1.6	93.0	7.0	9.4	8.2	7.9	74.6	25.4
Contr. to others	18.0	18.7	20.8	23.3	Tot. Spillover	18.5	23.3	18.3	14.6	Tot. Spillover
Contr. incl. own	99.9	103.6	96.5	100.1	Index=20.2%	101.4	111.9	97.6	89.1	Index=18.7%
Net spillovers	-4.3	-4.6	-7.9	16.3		1.4	11.9	-2.4	-10.8	
	US									
	From (j)									
To (i)	SS	ADS	OSS	SMR	From others					
SS	79.9	7.7	6.4	6.0	20.1					
ADS	2.5	91.2	4.0	2.3	8.8					
OSS	6.6	8.6	76.6	8.2	23.4					
SMR	9.5	9.1	6.6	74.8	25.2					
Contr. to others	18.6	25.4	17.0	16.4	Tot. Spillover					
Contr. incl. own	98.5	116.6	93.7	91.2	Index=19.4%					
Net spillovers	-1.5	16.6	-6.4	-8.8						

Note: Spillover indices, given by Equations (2)-(6), calculated from variance decompositions based on 12-step-ahead forecasts.

Table 3: Oil price shocks and stock market realised volatility, spillover table (1995:09 – 2013:07)

	CAN					**CHN**				
	From (j)					*From (j)*				
To (i)	SS	ADS	OSS	SMRV	From others	SS	ADS	OSS	SMRV	From others
SS	79.0	8.1	7.3	5.6	21.0	82.4	7.6	6.0	4.0	17.6
ADS	2.0	89.4	4.1	4.5	10.6	2.6	92.3	3.6	1.5	7.7
OSS	6.9	8.4	75.3	9.5	24.7	5.1	10.1	80.7	4.0	19.3
SMRV	4.5	4.2	10.9	80.3	19.7	10.2	6.0	2.6	81.3	18.7
Contr. to others	13.4	20.8	22.4	19.5	Tot. Spillover	17.9	23.7	12.2	9.4	Tot. Spillover
Contr. incl. own	92.4	110.2	97.6	99.8	Index=19.0%	100.4	116.0	92.9	90.7	Index=15.8%
Net spillovers	-7.6	10.2	-2.3	-0.2		0.3	16.0	-7.1	-9.3	
	ESP					**FRA**				
	From (j)					*From (j)*				
To (i)	SS	ADS	OSS	SMRV	From others	SS	ADS	OSS	SMRV	From others
SS	81.8	6.7	6.9	4.6	18.2	81.2	7.3	6.9	4.5	18.8
ADS	2.8	76.2	3.6	17.4	23.8	2.7	85.5	2.5	9.3	14.5
OSS	6.5	7.1	74.9	11.4	25.1	6.7	8.6	72.4	12.3	27.6
SMRV	2.4	3.7	7.4	86.5	13.5	8.3	5.9	6.0	79.8	20.2
Contr. to others	11.7	17.5	17.9	33.5	Tot. Spillover	17.6	21.8	15.4	26.2	Tot. Spillover
Contr. incl. own	93.5	93.7	92.8	120.0	Index=20.1%	98.8	107.3	87.8	106.0	Index=20.2%
Net spillovers	-6.5	-6.3	-7.2	20		-1.2	7.3	-12.2	6	
	GER					**ITA**				
	From (j)					*From (j)*				
To (i)	SS	ADS	OSS	SMRV	From others	SS	ADS	OSS	SMRV	From others
SS	82.2	7.0	6.8	4.0	17.8	83.5	6.9	6.5	3.1	16.5
ADS	2.5	88.3	2.7	6.4	11.7	3.7	74.9	3.8	17.6	25.1
OSS	7.0	8.2	72.9	11.9	27.1	6.3	6.4	76.6	10.8	23.4
SMRV	9.3	6.7	4.4	79.6	20.4	6.0	6.2	7.8	80.0	20.0
Contr. to others	18.8	22.0	14.0	22.2	Tot. Spillover	16.0	19.5	18.2	31.4	Tot. Spillover
Contr. incl. own	101.0	110.3	86.9	101.8	Index=19.3%	99.5	94.3	94.7	111.4	Index=21.3%
Net spillovers	1.0	10.3	-13.1	1.8		-0.5	-5.6	-5.2	11.4	
	JPN					**NOR**				
	From (j)					*From (j)*				
To (i)	SS	ADS	OSS	SMRV	From others	SS	ADS	OSS	SMRV	From others
SS	78.4	7.5	5.8	8.3	21.6	82.5	7.5	6.6	3.4	17.5
ADS	1.7	90.0	2.7	5.6	10.0	2.2	86.9	3.8	7.2	13.1
OSS	7.7	9.9	73.4	9.0	26.6	6.2	7.4	71.5	15.0	28.5
SMRV	3.5	8.5	6.3	81.7	18.3	6.9	4.8	8.4	79.9	20.1
Contr. to others	12.9	25.9	14.8	22.9	Tot. Spillover	15.3	19.6	18.8	25.6	Tot. Spillover
Contr. incl. own	91.3	115.9	88.3	104.6	Index=19.1%	97.8	106.5	90.3	105.5	Index=19.8%
Net spillovers	-8.7	15.9	-11.8	4.6		-2.2	6.5	-9.7	5.5	
	RUS					**UK**				
	From (j)					*From (j)*				
To (i)	SS	ADS	OSS	SMRV	From others	SS	ADS	OSS	SMRV	From others
SS	82.5	8.3	7.3	1.9	17.5	82.1	7.6	6.8	3.5	17.9
ADS	2.5	85.9	4.2	7.4	14.1	2.7	86.6	3.0	7.7	13.4
OSS	6.0	6.1	76.8	11.1	23.2	6.2	8.3	72.9	12.6	27.1
SMRV	2.8	2.8	2.8	91.6	8.4	10.2	5.3	6.9	77.6	22.4
Contr. to others	11.3	17.2	14.2	20.5	Tot. Spillover	19.1	21.2	16.8	23.7	Tot. Spillover
Contr. incl. own	93.8	103.1	91.0	112.1	Index=15.8%	101.2	107.8	89.7	101.3	Index=20.2%
Net spillovers	-6.2	3.1	-9.0	12.1		1.2	7.8	-10.3	1.3	
	US									
	From (j)									
To (i)	SS	ADS	OSS	SMRV	From others					
SS	78.4	7.8	7.7	6.1	21.6					
ADS	2.4	88.2	4.0	5.5	11.8					
OSS	6.9	7.9	78.1	7.0	21.9					
SMRV	11.4	4.4	10.2	73.9	26.1					
Contr. to others	20.7	20.1	21.9	18.6	Tot. Spillover					
Contr. incl. own	99.1	108.3	100.0	92.6	Index=20.4%					
Net spillovers	-0.9	8.3	0.0	-7.5						

Note: Spillover indices, given by Equations (2)-(6), calculated from variance decompositions based on 12-step-ahead forecasts.

Table 4: Oil price shocks and stock market implied volatility, Spillover table

	FRA					GER				
	From (j)					*From (j)*				
To (i)	SS	ADS	OSS	SMIV	From others	SS	ADS	OSS	SMIV	From others
SS	81.2	9.5	7.1	2.2	18.8	84.6	6.6	7.0	1.9	15.4
ADS	2.6	91.8	4.0	1.6	8.2	3.1	90.7	4.1	2.1	9.3
OSS	9.6	11.1	68.9	10.4	31.1	6.3	7.5	73.1	13.1	26.9
SMIV	25.7	7.9	5.6	60.8	39.2	14.5	8.9	5.1	71.5	28.5
Contr. to others	37.9	28.6	16.6	14.2	Tot. Spillover	23.9	23.0	16.2	17.1	Tot. Spillover
Contr. incl. own	119.1	120.4	85.5	75.0	Index=24.3%	108.5	113.7	89.2	88.6	Index=20.0%
Net spillovers	19.1	20.4	-14.5	-25.0		8.5	13.7	-10.7	11.4	
	JPN					**UK**				
	From (j)					*From (j)*				
To (i)	SS	ADS	OSS	SMIV	From others	SS	ADS	OSS	SMIV	From others
SS	77.5	7.7	7.4	7.4	22.5	76.6	10.3	7.3	5.8	23.4
ADS	1.8	90.1	3.8	4.3	9.9	3.6	91.5	3.8	1.1	8.5
OSS	6.7	9.7	79.6	4.0	20.4	8.8	11.4	67.5	12.3	32.5
SMIV	8.8	25.9	10.4	54.9	45.1	31.9	8.5	5.5	54.1	45.9
Contr. to others	17.4	43.3	21.6	15.7	Tot. Spillover	44.2	30.2	16.6	19.2	Tot. Spillover
Contr. incl. own	94.9	133.3	101.2	70.6	Index=24.5%	120.8	121.8	84.1	73.3	Index=27.6%
Net spillovers	-6.5	-6.3	-7.2	20		-1.2	7.3	-12.2	6	
	US									
	From (j)									
To (i)	SS	ADS	OSS	SMIV	From others					
SS	80.7	7.4	7.9	4.0	19.3					
ADS	2.6	90.7	4.3	2.4	9.3					
OSS	6.0	8.2	75.7	10.0	24.3					
SMIV	8.2	9.8	10.8	71.2	28.8					
Contr. to others	16.8	25.5	23.0	16.5	Tot. Spillover					
Contr. incl. own	97.5	116.1	98.7	87.7	Index=20.4%					
Net spillovers	-0.9	8.3	0.0	-7.5						

Note: Spillover indices, given by Equations (2)-(6), calculated from variance decompositions based on 12-step-ahead forecasts.