European Equity Markets Volatility Spillover: Destabilizing Energy Risk is the New Normal

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Abstract

While energy risk is recognized as a new systemic risk, surprisingly little research has been done about the risk propagation of energy commodities across geographic regions. In this paper, we examine 24 countries of the European Economic Area (EEA) to address ongoing concerns about energy stability. In addition to traditional panel regressions, we also deploy the Diebold-Yilmaz volatility spillover index (2014) method for a focused network analysis. We also seek to differentiate in the cross-section across the core EU block, new EU countries joining after the 2004 enlargement, and others. In the last 20 years, the major sources of market volatility primarily emanated from economic or political uncertainty of a specific country, or group of countries, for example, from Greece during the sovereign debt crisis, from Central and Eastern European countries (CEEC) after the 2004 EU extension, and from Norway during the oil rout. Energy risks, measured by large oil and gas price shocks, have become major volatility providers since 2019, with increasing volatility risk arising from gas, a green labelled energy source. Lastly, we also show that market development plays a key role in equity market resilience, and that the less liquid CEEC markets with weakening currencies are more sensitive to oil and gas price shocks.

Keywords: *Climate risk, Energy systemic risk, Energy resilience, Europe, Economic stability, Spillover Index*
JEL Classification: G1, G15, Q4, Q5

1. Introduction

Energy prices and economic development have long been intertwined. On the one hand, low energy prices can fuel production, manufactory activity, and investment, while on the other hand, economic activity and growth can push up energy commodity prices at least in the short term because of the low elasticity of supply in oil and gas production. The tightly integrated relation between the economy and energy prices resulted in a development of two strands of research, one examining the impact of oil price on equity markets, primarily in the US and in major energy producing countries (Sadorsky, 1999; 2001), and the other analyzing the influence of equity market on oil and other commodity prices. The financialization of commodity trading, particularly in the oil market, has further enhanced the interconnectedness between the oil market and global stock markets (Ding et al., 2021).

Mensi et al. (2017) provide evidence of tail dependence between oil and four major stock market indices (S&P500, STOXX600, DJPI and TSX indexes) and suggest that changes in oil prices can significantly impact stock markets, and the oil price influence is non-liner and non-symmetric. Specifically, the authors document that stock market's response to oil price change is different in up and down-market conditions and varies based on the country's energy import dependance. The authors suggest that connectedness increased because more investors make decisions not only based on fundamental information in stock markets, but also on prevailing information in the oil markets. There is an extensive and growing literature on the influence of commodity prices on the equity market. The focus varies from the US market, major oil producing countries, key global equity exchanges, and specific regions or countries, such as BRICS and China. To our knowledge there are no extant studies which analyze European equity markets in relation to oil and gas prices.

As oil and gas prices impact economic activity, service, and manufacturing, it is critical to understanding the increasingly complex energy market, and the new sources of volatility, such as the financialization of commodity trading, cybersecurity threats (oil and gas, utility companies are primary targets in cyber-crime), pandemics, and political uncertainty.[1] In addition, new unknown uncertainties emerged from the onset of the pandemic and the supply interruption during the pandemic, rising geopolitical risks. Lastly, the growing tensions in Sudan, Israel, and on the South China Sea, and new armed conflicts have led to extremely volatile commodity prices that effect not only crude oil, natural gas, but also aluminum and nickel.[2]

The European Economic Area (EEA), with its ambitious net zero emission targets, has been at the forefront of the climate issue for years. Such initiatives are expected to not only have climate benefits with the reduced reliance on traditional energy sources, such as oil and coal, but also strengthen energy resilience through diversification and managing systemic risk arising from the price volatility of oil and gas. In 2022, the European Parliament (European Parliament, 2022) has agreed not to veto the designation of nuclear and gas energy sources as green, to encourage countries energy diversification. However, nuclear energy is not only impractical solution in the near future because of the minimum 5-8 years of construction period for new facilities, it also faces strong opposition from the people in Germany and France.

This study aims to examine the economic spillover effect of gas and oil during the ongoing green transformation. The role of gas prices is especially important now, with the green designation of gas resources coinciding with the increasing reliance of Europe on this form of energy. Specifically, we examine the implications of price and volatility of energy commodities on equity markets across Europe from 3/24/2003 to 12/31/2022, covering several political and economic turmoil events, and in the extreme three Russian conflict situations, such as the Georgian-Russian War (Council of Europe, 2008), Crimea Annexation, and the

[1] Ransomware attacks on utility firms: https://www.oilandgasiq.com/digital-transformation/articles/5-big-cyber-security-attacks-in-oil-and-gas; according to Statista there were 21 attacks on Oil and Gas companies in 2021.
[2] The extreme price movements in nickel in 2022, resulted in London Metal Exchange (LME) setting a price limit on Nickel contracts (Reuters, 2022a).

ongoing Russian-Ukrainian conflict since 2022 (Council of Europe, 2022). In the cross-section, we include all current and past EU countries and collaborators, except same smaller countries (e.g., Slovakia, Luxembourg, Iceland, Malta) because of data limitations. Our final sample comprises 24 unique European countries providing representative coverage for the EEA.

First, in panel regression setting, we examine the equity market performances for the sample countries, using MSCI index daily returns, and find that gas and oil prices systematically influence equity markets. We also examine MSCI index volatility in panel regressions. The results show that oil and gas are major volatility contributors and have been increasingly so over the years. More importantly, we find that countries with relatively underdeveloped exchanges or weak domestic currencies are more sensitive to energy shocks. In the final section, we deploy Diebold-Yilmaz's spillover index (Diebold and Yilmaz, 2014; 2023) to gain more insights into the spillover effect of energy prices in a closed network setting.

We provide network analysis for a number of subperiods, such as the year 2004 – EU enlargement, 2005-2008 – US Mortgage market run-up with the 2008 Global Financial Crisis, 2009-2012 – European Sovereign Debt Crisis, 2013-2015, 2016-2019, 2020, 2021, and 2022, to provide insights into the network changes with the yearly overview. Across the eight subperiod analysis, we find significant difference. During our sample period of 20 years, the primary sources of volatility were initially from economic or political uncertainty. Generally, the key source of volatility in the European equity markets was a specific country, or group of countries, for example, from Greece during the sovereign debt crisis, from Central and Eastern European countries (CEEC) after the 2004 EU extension, and from Norway during the oil rout. We also note that the volatility spillover effect of oil and gas potentially is an increasingly acute issue to consider.

Europe is taking a comprehensive approach to addressing climate change, with a focus on reducing emissions, promoting renewable energy, improving energy efficiency, and supporting sustainable practices in agriculture and other sectors. However, despite all these efforts, Europe remains heavily reliant on traditional energy sources. Before the COVID-19 pandemic, some of the most pressing climate risk issues in Europe were extreme weather events, rising sea levels, biodiversity loss, water scarcity and a decline in public health exacerbated by climate change. Overall, climate risk issues pose significant challenges to Europe and require urgent action to mitigate their impacts and build resilience. While most European countries are actively working to diversify energy resources, the primary sources are still gas and oil.

Overall, our study can be considered an extension of Mensi et al. (2017). We examine the oil price spillover to equity indices, with a larger sample coverage, and include gas in addition to oil as an energy commodity, as a proxy for the source of energy risk. Specifically, we provide three new unique contributions. Frist, we are the first to deploy the D-Y spillover index (Diebold and Yilmaz, 2014) in the EEA context to gain insights into the interconnectedness of European economies in response to economic, political, and energy shocks. Second, in addition to oil, we include natural gas (i.e., TTF) in the network model, in view of Europe's increasing gas dependency. Last, unlike extant D-Y Index applications, we also provide comprehensive panel regression analysis of the impact of the oil and gas price shocks on the equity market before focusing on the closed network model, presenting a more complete picture by allowing for additional, unidentified external factors in the model with fixed effects.

The remainder of the paper is structured as follows. Section 2 provides a review of studies examining energy prices and equity markets. Section 3 discusses the hypothesis development and the summary statistics of the data. Section 4 presents the results of the empirical analysis. Finally, Section 5 concludes.

2. Literature Review

The interconnectedness of the energy commodity market and the equity market has attracted much research attention. Earlier studies focus on the connection between oil prices and overall stock returns providing various conclusions. In the context of the US financial market, Kling (1985) suggests that falling stock markets are driven by rising crude oil prices. In contrast, Chen et al. (1986) show an insignificant relation between oil price changes and asset markets, while Jones and Gautam (1996) report a negative association between oil price changes and aggregate stock returns. Huang et al. (1996), on the other hand, examine the relation between oil futures and US stock returns and find insignificant relation between returns on commodity futures and aggregate equity market indexes. Sadorsky (1999) argues that a rise in oil prices leads to a fall in US stock returns and, in a follow up work, Sadorsky (2001) provides supporting evidence by including interest rates and foreign exchange rates as additional explanatory variables.

Apart from the extensive literature on the linkages between oil prices and stock returns (e.g., Cunado and de Gracia, 2003; El-Sharif et al., 2005; Kilian et al., 2009; Wang et al., 2013), a growing number of studies explore the volatility relation across the commodity markets (including oil) and the equity market. Mostly aggregated stock market indices are considered in evaluating the link between oil and stock market volatility in the USA (e.g., Arouri et al., 2011a; Phan et al., 2016) or in the context of major oil producing countries (Arouri et al., 2011b).

Despite extant studies on the spillover between crude oil and the stock market, there are relatively few studies into the interconnectedness of natural gas and financial markets. Ewing et al. (2002) analyze the volatility spillover between oil and natural gas markets using GARCH model, while Zhang et al. (2017) investigate the spillover effect of the stock market volatility index for crude oil and natural gas markets. Zhang et al. (2020) study the return and volatility spillover among the natural gas, crude oil, and electricity utility stock indices in North America and Europe. They find that, compared to natural gas, crude oil has a greater volatility spillover on electricity utility stock indices. Dai and Zhu (2022) document the return volatility spillover and the dynamic connectedness of WTI crude oil futures, natural gas futures, and the Chinese stock market indices. They show that there exists a high interdependence among all analyzed asset classes, and the total volatility spillover increased sharply during major crises.

The energy industry is vital to the world economy for a variety of purposes, including labor, transportation, warmth, and food. With the deepening financialization and integration of the commodity market, specific systemic risk is also present in the international energy market. Numerous papers have been written on systemic risk in this sector. Kerste et al. (2015) provide an indication of the need for a generalized regulation of OTC derivative transactions, as introduced by the European Market Infrastructure Regulation (EMIR). They argue that this sector carries a relatively high degree of systemic risk compared to the financial and other non-financial sectors. Reboredo (2015) concludes that oil price behavior provides market-based incentives to develop the green economy, but the incentives are asymmetric. When oil prices are high, the development of the green economy can be promoted through the fossil fuel market without the need to implement specific energy policies. On the contrary, when oil prices are low, the market provides inadequate incentives, and the development of the green economy will need to be supported by green energy policies. By quantifying three market risk measures (VaR, CoVaR, deltaCoVaR), Mensi et al. (2017) report strong evidence of asymmetric spillovers from oil to stock markets and vice versa in the short and long run horizons, in response to up and down risk. Finally, the market risk spillovers are asymmetric over time and investment horizons. In related studies, (Mensi et al., 2021a, 2021b) find that spillover contagion from oil price to the stock market is time-varying, sensitive to crisis, frequency dependent, and strongly pronounced during the global financial crisis. More recently, Costola and Lorusso (2022) and Lee et al., (2021) find that energy related systemic risks and geopolitical risks are connected.

3. Data and Empirical Hypotheses Development

3.1 Data and Summary Statistics

In this study, we examine the performance of the European Economic Area (EEA) economies from 3/24/2003 to 12/31/2022.[3] We collect daily MSCI country equity index data from Refinitiv where available for all EU member states and collaborator countries (e.g., Norway, Switzerland, and Liechtenstein), and the former EU member state, the UK. Since MSCI does not provide equity index information for Cyprus, Latvia, Luxemburg, Malta, Slovakia and Liechtenstein, these countries are dropped from our analysis, resulting in a sample of 24 countries, covering just about 500 million population out of the 513 million of the entire EEA based, or 97.4% of the population based on 2022 Eurostat numbers.

In addition, to extensive cross-sectional coverage, we also have extensive time-series coverage, spanning across almost 10 years, covering the EU enlargement with CEEC in 2004, the built up of the US mortgage bubble from 2005-2008, the 2008 Global Financial Crisis (GFC) and the 2010 European Sovereign Debt Crisis (ESDC). The sample period also includes the onset of the Covid19 pandemic in 2020, the recovery in 2021, and the start of the Russian-Ukraine conflict in 2022.

Our cross-country time-series panel data is unbalanced because of data limitations for some of the newer countries (e.g., countries formed from the former Yugoslavia) and smaller countries. In 2004 from the CEE region, only Hungary and Poland had continuous daily coverage from MSCI. We extend our coverage as data becomes available and include Bulgaria, Croatia, Romania, and Slovenia from 2008, Estonia from 2010, Czech Republic from 2013 and

[3] Our historical data coverage is limited because of our data access.

Lithuania from 2014, as data becomes available from MSCI. We also include daily domestic currency to EUR exchange rates from the European Central Bank (ECB), measured in the number of domestic currency equivalent to a EUR.

We complement our panel data of daily MSCI index value for 24 European countries with annual value for energy production and energy consumption from Eurostat (see Appendix A.2). From the Eurostat data, for each country, we calculate country specific energy (total energy, crude oil, natural gas) dependencies by the formula of: 1- (energy production/energy consumption). By the time of writing this article, Eurostat provides country specific energy production and consumption data only up to 2021. The 2022 energy dependence numbers were extrapolated using the last 5 years of the data, from 2017-2021, capturing the shift towards green alternatives.[4] Unfortunately, the energy dependence information is only available annually and the variable is rather sticky, effectively a consistent country characteristics at least during our sample period.

Last, we collect daily commodity price information. Similarly, to Wang et al. (2019), Corbet et al. (2020) and others, we use daily futures prices for commodities, oil, and gas. Daily exchange listed futures information collected on ICE Europe Brent Crude Oil (Brent) and the Dutch TTF Natural Gas (Natural Gas). Additionally, to control for the arrival of new information from different geographic market information, we also include daily Asia Pacific and the USA equity indices data from MSCI.

Overall, our final data contains daily energy commodity information on brent oil prices, TTF gas price in form of futures prices from Refinitiv Eikon, and daily MSCI index data for all 24 EEA countries, and daily EUR - domestic currency rates, and country energy dependence information. Variable definitions and summary statistics are presented in Table 1, Panel A.

[4] In case of the UK, Eurostat has stopped data coverage for the country in 2019 with Brexit, thus we extrapolate the 2020 - 2022 energy dependence numbers the previous 5 years of data, using a rolling window approach.

Ret1d and Ret5d are the key return measures based on each country's MSCI index value, calculated as the aggregate change. APlag1d, APlag5d, USlag1d and USlag5d are the previous 1 day and 5-day Asian Pacific and US market index returns, which are likely to influence the European market and included external controls.

[Table 1 about here]

Based on Table 1, it is important to note that, generally, market indices are well behaved, but there are outliers. The 1-day and 5-day market returns, Ret1d and Ret5d, with mean zero values, have rather wide ranges from -27% to 26%, and -37% to 42%, respectively, suggesting some extreme movement in some markets. For more insights about the distribution of the return variables, Table 1 Panel B provides summary statistics results by countries. It is also worth mentioning the extremely large price swings in gas (TTF) in 2022 after the start of the Russian conflict, when gas prices increased over 120% in five days temporarily.

3.2 Empirical Hypothesis Development

Empirically, the relation between energy prices, proxied by oil and gas prices, and economic growth (proxied by stock market performance) are intertwined. Economic growth and precautionary demand pressures drive energy prices up, given the relatively low elasticity of oil and gas supply where production adjustment is a slow process. On the other hand, oil and gas prices can impact the market and the economy in three ways, such as via (1) inflation, (2) consumer spending, and (3) volatility of market uncertainty.

First, higher oil prices can lead to inflation, as the costs of producing and transporting goods increase, and the costs are passed on to consumers. While traditionally higher prices are endogenous and driven by demand, supply shocks due to collusion of producers can also impact prices, as is the case with OPAC interventions in the energy market. Second, higher energy prices and higher volatility, especially when combined with market uncertainty (e.g., Russian

– Ukrainian conflict), can lead to reduced consumer spending as people spend more on energy bills and petrol and increased precautionary savings. Also, higher oil prices can dampen consumption because of higher production costs, lower return on investment, and lower disposable income. Third, if the oil and gas price induced market volatility, where rising oil prices signaling recessionary outlook, may trigger mass selloffs on the equity market. Overall, energy price shocks are expected to influence the equity markets by influencing investors' future outlook, companies' investment policies and thereby have a significant impact on the economy and the financial well-being of individuals and businesses.

While the energy risk spillover to equity markets is rather intuitive, it has only been tested empirically in a few studies. Given, the ongoing energy market turbulence as a result of the Russia-Ukraine conflict and rising tensions in the Middle East, understanding the energy risk spillover to European economies is of both academic and policy interest. We specifically examine equity market returns and equity market volatility relation with oil and gas price trends and volatility to test four empirical hypotheses. We have a baseline model with the following specification:

$$Ret_{c,t} = \alpha + \beta * \Delta Ener + \sum_{j=0}^{l} \gamma * \sum_{j=0}^{l} K + \varepsilon \qquad (1)$$

The dependent variables are the 1-day or 5-day future MSCI market index cumulative returns in a sample of 24 European countries from March 24, 2003, to December 31, 2022. The return is measured in percentages.

Our focal variables are energy price changes (*ΔEner*), proxied by changes in Brent and TTF. In the control vectors, we include country specific controls, lagged market performance, currency levels, and currency movements, and also control for the lagged market information from the US and Asia Pacific region. Our *FXprice* measures the number of local currencies equivalent of one EUR, and thus, the FX return variable is positive when the local currency depreciates.

Empirical Hypothesis 1: Energy prices (gas and oil) influence equity markets across Europe.

The alternative hypothesis is that energy prices are influenced by the market and or energy prices are irrelevant at the short term because energy price production and consumption can be forecasted at reasonable high accuracy, especially in the traditional oil and gas segment. The degree of market sensitivity may change over time, depending on the country's energy exposure and country development as suggested by Mensi et al. (2017). We address this cross-sectional variation in our second hypothesis.

Empirical Hypothesis 2: Energy prices (gas and oil) influence countries more with weak domestic currencies, since oil and gas contracts are predominantly settled in USD or EUR.

We test hypothesis 2, with the following specification in eq 2.

$$Ret_{c,t} = \alpha + \beta * \Delta Ener + \delta * Int + \gamma * En_{Shock} * Int + \sum_{j=0}^{l} \gamma * \sum_{j=0}^{l} K + \varepsilon \quad (2)$$

While forecasting equity market returns is not a primary concern for regulators and policy makers, country indices are key barometers of the economy and attract foreign direct investment. In addition to the return on the index, naturally the volatility of the index is also relevant for investors. High volatility in the market may deter investors from entering the market, as it may signal market instability or low liquidity, lack of depth in the market.

Empirical Hypothesis 3: Energy price shocks and volatility increase the market volatility of equity markets, and the effect is stronger in countries with weak domestic currencies.

We test the volatility implications with a similar model as the eq. 2., but we exchange the dependent variable for a 5-day market volatility measure, with the following specification:

$$Vol_{c,t} = \alpha + \beta * \Delta En + \delta * Int + \gamma * En_{Shock} * Int + \sum_{j=0}^{l} \theta * \sum_{j=0}^{l} K + \varepsilon \quad (3)$$

In equation 3, the dependent variable is the 5-day volatility in the MSCI index calculation as the differences of the maximum and minimum values during the 5-day period, scaled by the last day return. Specifically, the Vol_{5dhead} = ($maxMSCIIndex_{t,t+5}$ – $MinMSCIindex_{t,t+5}$) / $MSCIIndex_{t}$.

Our last hypothesis concerns with the variation of energy price shock impact and market ability to absorb, as follows:

Empirical Hypothesis 4: Energy price shocks influence conditional on other market uncertainties within system resulting from political and economic disturbances (election uncertainties, sovereign debt defaults).

Using daily data with Diebold-Yilmaz Spillover index, we test whether market sensitivity to energy shocks is consistent over time or whether economic and political uncertainty may be more relevant, especially in certain time periods.

In the next section, we test our first three empirical hypotheses in a panel regression setting, with 2-way fixed effect and allowing for the clustering of standard errors consistent with the literature to provide overall evidence about the influence of energy prices on equity markets. In the last section, we test the fourth hypothesis by presenting subsample network analysis with the D-Y Index for our network countries. In a recent review article of the D-Y index, Diebold and Yilmaz (2023) explain that the reason for the Diebold-Yilmaz connectedness measurement is its flexibility in adaptation. Its methodology is simple and attractive, combining traditional econometric modelling thinking with modern network and Big Data thinking. This allows for new possibilities in analysis. The measurement relies on variance decompositions, which are familiar and comfortable, and it establishes a new connection between the seemingly distinct VAR variance-decomposition literature and the network literature. The insight is that a variance decomposition can be viewed as a network. Therefore, network tools are effective in summarizing and visualizing connectedness as defined by variance decompositions, and they scale well to higher dimensions.

4. Empirical Analysis of Energy Risk in European Economies

In this empirical section in 3 parts, we test equity market implications of oil and gas price movements, specifically price changes and volatility of Brent (European oil price) and TTF. In Sections 4.1 and 4.2, in a panel dataset, covering 24 European countries, we examine MSCI Index returns and volatility, respectively. Last, in Section 4.3., we present network models of volatility spillovers for 8 sub-periods, from January 2004 to December 2022.

4.1 European Market Indices Return Analysis in Relation with Oil & Gas Returns

In Table 2, we start our regression analysis by examining the impact of MSCI market returns for 24 European countries. To investigate whether oil and gas prices have an influence on equity markets, we estimate Models 1A-3A with 1-day future returns on the MSCI equity index, and Models 1B-3B with 5-day returns. We find that the coefficients on the lagged 1- and 5-day oil price returns (Brentlag1dRet and Brentlag5dRet) are generally insignificant, except for a positive and significant coefficient on Brentlag5dRet in Models 2A and 2B, indicating a short-term market rally following oil price increases. However, the gas price change variables (TTFlag1dRet and TTFlag5dRet) are insignificant in both specifications in which they are included (Models 3A and 3B).

[Table 2 about here]

In Table 3, we further explore the relationship between MSCI index returns and oil prices in a subsample analysis. We find some evidence that the price of gas became more relevant to equity markets after 2013. Specifically, in the subsample analysis of 2003-2012, the coefficient estimate on Brentlag5dRet remains significant and positive in Table 3 Model 1A, consistent with the results in Table 2. However, this significance disappears in the later part of the sample period. On the other hand, the coefficient on the TTFlag5dRet variable is significant in the after-2013 subsample in Model 2B.

[Table 3 about here]

Overall, results from Tables 2 and 3 provide some weak evidence that oil and gas prices are relevant for the equity market performance in Europe during the 2003-2022 sample period. One potential explanation for the weak and insignificant results is that we also include lagged US market information in our regression analysis, which potentially already prices in some of the energy market information. Moreover, predicting returns is not the primary objective of this paper. Rather, we aim to demonstrate the economic and political importance of energy risk from an equity market perspective. Therefore, in the next sections, we focus on equity market volatility instead of returns.

4. 2 Analysis of the Relation Between European Market Indices Volatility and Oil & Gas Volatility

Table 4 examines the relationship between equity market volatility and oil and gas returns, as well as oil and gas price volatility. The dependent variable is the five-day volatility in the MSCI index value, and the explanatory variables are the five-day volatilities in oil and gas prices. Our findings show that, on average, oil price increases tend to be positive news for the equity market and reduce market volatility. However, oil price volatility tends to spill over to equity market volatility and has a significant positive relation with equity market volatility across all model specifications in Table 4.

[Table 4 about here]

Consistent with previous results, we do not find that gas prices influence equity market volatility. Nevertheless, we report a significant positive coefficient on the five-day gas price volatility measures (*TTFvol5d*), indicating a significant positive relation with equity market volatility. Thus, while the level of gas prices may not matter for the equity market, the uncertainty in gas prices does.

In Table 5, we consider market development and test the impact of energy price volatility in conjunction with market development, using the local domestic currency trend as a proxy. Depreciating currencies (relative to EUR) tend to indicate economic weakness or uncertainty, making countries more likely to be "hit harder" by energy price shocks. We use the five-day change in the domestic currency exchange rate and interact it with the five-day gas price volatility and oil price volatility measures. Our findings show that in countries with depreciating local currencies, oil price and gas price volatility are associated with a larger market volatility impact. Moreover, the subsample analyses in Models 3B through 3D highlight that market volatility sensitivity is increasing over time, especially in vulnerable countries with weak domestic currencies.

[Table 5 about here]

In this sub-section, we show that while increases in gas and oil prices tend to reduce market volatility, oil and gas price volatility has a spillover effect and a significant positive relationship with equity market volatility. We find that the uncertainty in gas prices, rather than their level, is the driving force behind equity market volatility. These findings have important policy implications, particularly for countries vulnerable to energy price shocks.

In the next sub-section, we take a closer look at “our” network participants the 24 European Economies and examine their equity markets in conjunction with energy shocks in a closed network setting, with the DY spillover index method.

4.3 Application of the Diebold-Yilmaz Spillover Index in the Context of European Markets

In this section, we deploy the generalized version of the DY spillover index, introduced in Diebold and Yilmaz (2012). The D-Y model is based on a VAR method (Sims, 1980) with a major focus on the calculation of the Forecast Error Variance Decomposition (FEVD). We use the generalized VAR framework (e.g., Koop et al., 1996), where the FEVDs are invariant to the ordering of the variables, avoiding the ordering of the variables in the VAR model. Given the goal is to assess the magnitude of the volatility spillovers rather than identifying the causal effects of structural shocks, this appears to be the preferred choice in the present context (Diebold and Yilmaz, 2023).

Under the generalized VAR framework, we consider a covariance-stationary VAR (p) model with N-variable i.e., $Y_t = \sum_{t=1}^{p} \psi_i Y_{t-1} + e_t$, where $e_t \sim i.i.d(0, \Sigma)$ is a $N \times 1$ vector of residuals. The moving average representation of the VAR model takes the form of $Y_t = \sum_{j=0}^{\infty} A_j e_{t-j}$ where the $N \times N$ is a coefficient matrix. A_j follows a recursive pattern as $A_j = \psi_1 A_{j-1} + \psi_1 A_{j-2} + \cdots + \psi_p A_{j-p}$, where A_0 is an identity matrix and $A_j = 0$ for $j < 0$. Diebold and Yilmaz (2012) applies the generalized VAR framework to calculate the H-step-ahead generalized forecast error decompositions as follows:

$$\Phi_{ij}(H) = \frac{\sigma_{ii}^{-1} \sum_{h=0}^{H-1} \left(e_i' A_h \sum e_j\right)^2}{\sum_{h=0}^{H-1} (e_i' A_h \sum A_h' e_i)} \tag{4}$$

where σ_{ii} is the i element on the principal diagonal of Σ. Since the sum of each row of $\Phi_{ij}(H)$ is not equal to 1, each element of the matrix is normalized by summing the row as

$$\widetilde{\Phi}_{ij}(H) = \frac{\Phi_{ij}(H)}{\sum_{j=1}^{N} \Phi_{ij}(H)} \tag{5}$$

so that the decomposition including shocks in each market equals to unity, i.e., $\sum_{j=1}^{N} \widetilde{\Phi}_{ij}(H) = 1$ and the total decomposition of all variables sum to N, i.e., $\sum_{ij=1}^{N} \widetilde{\Phi}_{ij}(H) = N$. The total spillover index is computed as follows:

$$TS(H) = \frac{\sum_{ij=1, i \neq j}^{N} \widetilde{\Phi}_{ij}(H)}{N} \cdot 100 \tag{6}$$

The total spillover index explains the spillovers from all the assets to the total FEVD. The directional spillovers which measure the volatility spillover received by asset i from the universe of markets j is calculated as follows:

$$DS_{i\leftarrow j}(H) = \frac{\sum_{j=1,i\neq j}^{N} \widetilde{\Phi}_{ij}(H)}{N} \cdot 100 \quad (7)$$

and

$$DS_{i\rightarrow j}(H) = \frac{\sum_{j=1,i\neq j}^{N} \widetilde{\Phi}_{ji}(H)}{N} \cdot 100 \quad (8)$$

Finally, the net spillovers from one variable to another for a set of variables are calculated by taking the difference of eq. (7) and (8) as follows:

$$NS_i(H) = DS_{i\rightarrow j}(H) - DS_{i\leftarrow j}(H) \quad (9)$$

We analyze the volatility transmission of equity indices across Europe, USA, and Asia Pacific by investigating their spillover effects. Table 6 presents key volatility spillover results of our equity index universe, from the year 2004. This year is of particular interest because on May 1st, 2004, the European Union welcomed 10 new countries. At that time there were insufficient data for most of the freshly joined EU members (and we could only utilize Hungarian and Polish indices). There were no observations for TTF which started trading in 2005).

Diebold and Yilmaz (2014), investigating the interconnectedness of the financial system, they report a total spillover index of 78.3%, which they consider very high. In our case, the total volatility spillover index is also high, 78.8% in 2004, implying a very strong interconnectedness among the assets.

[Table 6 about here]

A network participant is either a net volatility transmitter (positive values in *Net* row) or receiver (negative values in *Net* row), based on the difference between emitted and absorbed volatilities. According to the net spillover indices, the US equity market return is the largest volatility receiver (-56.5%). Similarly, the Asian aggregate index (i.e., APAC in the graph) is a volatility receiver, while Norway is a volatility transmitter. BRENT has the strongest net positive effect (118.2%), suggesting that its volatility heavily impacts the domestic equity markets.

Using the connectedness table, it is also possible to construct a matrix containing the pairwise net directional connectedness of all pairs. Fig. 3 provides a visual representation of these relations in an informative network graph. An arrow from variable y_i to variable y_j denotes a positive net directional connectedness (in other words, variable y_i explains more of variable y_j than the reverse). The assets are grouped and color-coded as follows:

- Red: Core EU countries (CORE),
- Blue: PIIGS countries (PIIGS),
- Green: Countries joined the EU after 2004 (A2004)
- Purple: Ex EU countries and regions (EXEU)
- Grey: Brent crude oil benchmark (Brent)[5]

[Figure 3 about here]

The colors of the arrows indicate the group of the transmitter participant. Only those edges in the uppermost 5% considering the magnitude of the net spillover. Thicker arrows represent connections in the top 1%, which are the strongest pairwise spillover connections.

In Fig. 3, the grey-colored arrows dominate, which indicate that Brent is the primary volatility transmitter in the system in 2004. Out of the total 23 arrows, 14 are from this asset accounting for 61% of all edges. There are a few underlying reasons behind the high spillover ratio of Brent. Bildirici et al. (2015) point out that demand for oil increased drastically from rapidly developing countries such as China and India, which led to a rise in oil prices globally. Since 2003, the production of the Russian Yukos, a main Integrated Oil and Gas company, has been inconsistent because of legal challenges. This led to concerns about a potential supply shortage (and indeed Yukos went bankrupt in 2006) (Hanson, 2005). In addition, geopolitical

[5] TTF is represented with orange, however it started trading in 2005 thus not represented in the 2004 plot.

tensions, and armed conflicts, such as the Iraq War and terrorist attacks in the Middle East, also had an impact on the Brent benchmark price (Choi, and Shawkat, 2010).

In the next section, we partition our estimation time frame into seven additional subsets, depicted in Figure 4. We progressively introduce new network elements as data becomes accessible. Specifically, in the period 2005-2008 (refer to Table 7), we integrate TTF, and in the period 2009-2012 (refer to Table 8), we incorporate more countries, particularly CEEC and the Baltics, thus expanding our network, particularly the non-core EU group in the model. To gain a better understanding of specific disturbances such as the onset of the Covid19 pandemic in 2020, the recovery in Europe in 2021, and the commencement of the Russo-Ukrainian conflict in 2022, we examine the years 2020, 2021, and 2022, one by one.

[Figure 4 about here]

Several extant studies (Liow, 2015, Balli et al, 2015, Gamba-Santamaria et al, 2017) find that the total volatility spillover increases during crisis period. Our GFC and ESDC subperiod (2005 – 2008 and 2009 - 2012) show a total spillover increase of 85.47% and 85.65%, which is consistent with the earlier studies. Between 2005 and 2008 (Fig 4.a), Norway was the main volatility emitter, accounting for 57.1% of the total possible arrows. Park and Ratti, (2008) highlight that the volatility of Norwegian stocks is particularly sensitive to negative and positive oil price shocks. Between July 2008 and December 2008, Brent price fell from 146 USD/Bbl to 36 USD/Bbl which greatly affected the volatility of the Norwegian price index.

Although Norway remained an important volatility (12.8%) emitter, its dominance declined during 2009-2012, as Hungary (25.6%) and Poland (17.9%) emerged as major transmitters. A reason for the new volatility source from CEE countries is the lower stock market resilience against GFC shocks in CEEC compared to the eurozone economies as suggested by (Mihaljek, 2010). Austria (12.8%) is also a major volatility emitter during this period, likely due to the changes in political leadership and concerns over corruption, creating a climate of uncertainty and unpredictability.

Fernández-Rodríguez et al. (2015) and Mensi et al. (2018) report increased volatility spillover not just during the time of the GFC but also during the ESDC which affected Portugal, Italy, Ireland, Greece, and Spain (PIIGS). These countries were economically weaker and more vulnerable to financial instability than other countries in the Eurozone. Among the PIIGS countries, Greece was the closest to default, but it was bailed out. Although the European Sovereign Debt Crisis happened from 2009 to 2013, its effect reached the stock market later and hit Greece the most. From 2013 to 2015, Greece was the largest volatility emitter, accounts for 44% of the outgoing edges.

In June 2015, the Greek Government imposed capital controls which restricted the amount of money that could be withdrawn from banks and led to a significant decrease in liquidity and an increase in uncertainty in the financial markets (NPR, 2015, Kosmidou et al, 2020). Additionally, in January 2015, the far leftist Syriza party won the election in Greece. The actions of the new government, which included renegotiating Greece's debt and opposing austerity measures, created uncertainty and concern among investors, further fueling volatility in the stock market (BBC, 2015). Italy faced similar political uncertainty during 2013 – 2015, when it could not form a strong government (Chiaramonte, 2018). It was the second largest volatility transmitter during this time, accounting for 21% of the connections.

In the 2016 – 2019 period, Greece remained the most dominant volatility transmitter (54%), with TTF prices also in second place. One of the main reasons for the TTF price volatility was the oversupply of natural gas in the global market, particularly in the USA, putting downward pressure on prices. From 2016 to 2019, US natural gas production increased by 13% due to the shale gas revolution (EIA, 2022, Middleton et al, 2017). The expansion of the liquified natural gas (LNG) trade also contributed to the oversupply of natural gas worldwide, as LNG trade increased by 35% during this period (BP, 2022). Furthermore, tensions between Russia and Ukraine, two major natural gas producers, had led to supply disruption and price volatility (Zhiznin and Timokhov, 2019). It is noteworthy, that TTF mainly provides volatility towards the A2004 countries which are heavily reliant on natural gas imports from Russia and are therefore more vulnerable to fluctuations in gas prices.

The rapid spread of the COVID-19 had greatly increased uncertainty in both the financial and commodity markets, especially the energy market (Boqiang and Su, (2021); Zhang et al., 2020). Fig 4.e shows that all the arrows originate from Brent (57%) and TTF (43%). In the first half of the year, the pandemic led to a decrease in demand for oil and gas due to lockdowns and reduced economic activity. This decrease in demand caused a surplus in the market, which led to lower prices. In response to the decrease in demand, producers reduced their production levels, which ameliorated the oversupply (ACER, 2021, Reuters, 2022b). Both Brent and TTF have a U-shaped price graph. As economies began to reopen and activities started to pick up, the production cuts led to a tightening of the market and higher prices. Besides these common factors, the price war between Saudi Arabia and Russia over oil production levels led to a significant increase in oil supply and further contributed to the oversupply and lower prices (Iglesias and Rivera-Alonso, 2022). In reaction OPEC+ decided to cut production in May 2020 that helped stabilize the market and support higher prices in the second half of 2020 (Enerdata, 2020).

In 2021, the main sources of volatility transmission were still TTF (39%) and Brent (35%). Natural gas demand was driven by cold weather conditions which swept across Europe, in early 2021, leading to a surge in demand for natural gas for heating purposes. This increase in demand led to a supply shortage, and contributed to higher prices and volatility (IEA, 2021). The global LNG market continued to experience imbalances in supply and demand, which affected TTF prices. The COVID-19 pandemic disrupted the LNG market with production and delivery delays, leading to supply shortages (Chai et al, 2021). Furthermore, there were concerns about the possible disruptions of natural gas supplies from Russia, a large part of which were transported through Ukraine to Europe (Reuters, 2022c). The pandemic had less of an impact on Brent prices in 2021 compared to 2020, but it continued to affect the market. Variants of the virus and vaccination rollouts in different regions caused uncertainty in the demand for oil, which affected prices (CNBC, 2021). In April 2021, OPEC+ decided to gradually increase production in response to the improving market conditions, which put downward pressure on prices. However, in July 2021, OPEC+ decided to maintain current production levels, which supported prices (Reuters, 2021).

The unexpected Russian invasion of Ukraine created much uncertainty about unrestricted access to fossil commodities, especially to natural gas. The war in the first few months of 2022 raised concerns about the safety of Europe's gas supply and the unpredictability of gas prices. In the first quarter of 2022, the EU spent a projected €78 billion on gas imports, €27 billions of which came from Russia. The EU's net gas imports increased by 10% over this time, while imports of liquefied natural gas increased by 72% year over year (EC DG-Energy, 2020; 2022). At their peak in August 2022, European gas prices topped 345 euros/MWh because (1) Russia weaponized its natural gas exports in response to punitive EU sanctions, and (2) sky-high temperatures over the summer, drove up demand. Following that, however, unseasonably warm weather through winter in much of northwest Europe reduced demand for heating and allowed the continent to replenish its gas inventory. By the end of 2022, TTF price reverted to pre-war levels (CNBC, 2022). This extreme hike and drop within a year made TTF the main volatility transmitter (59%) in 2022. Besides TTF, Hungary (28%) and Poland (13%) are net volatility emitters. Silva et al. (2023) point out that from the European countries, Hungary and Poland have the largest trade exposure with countries at war (3.6% and 3.2% respectively). Our results are in line with Yousaf et al. (2022) and Silva et al. (2023) who claim that the equity markets of Hungary and Poland are the most sensitive to the Russia-Ukraine war.

5. Conclusion

In this study, we investigate the spillover effects of energy prices, specifically oil and gas prices, on equity markets in 24 European Economic Area (EEA) countries to contribute to ongoing policy debates about energy stability. Our sample period from 3/24/2003 to 12/31/2022, covering about 20-years, includes a number of political and economic crises across Europe and globally.

In panel regression analyses we examine gas and oil prices' influence on equity market returns and equity market volatility. Our results show that gas and oil prices have a weak impact on the equity markets in the sample countries. On the other hand, we do find that price volatility of oil and gas are major contributors to volatility in the equity markets, particularly in countries with relatively underdeveloped exchanges or weak domestic currencies. For a more focused analysis, we employ the D-Y spillover index method to perform network analysis for a number of subperiods over a 20-year sample period. We find significant differences in the sources of volatility across the subperiods, with the primary sources of volatility initially stemming from economic or political uncertainty. We also identify specific countries or groups of countries, such as Greece during the sovereign debt crisis, Central and Eastern European countries (CEEC) after the 2004 EU extension, and Norway during the oil rout, as key sources of volatility in the European equity markets. Interestingly, oil and gas price shocks have become direct primary volatility providers since 2019, with increasing volatility risk arising from gas, a green-labelled energy source, despite the ongoing efforts of diversification.

Overall, our study provides several unique contributions to the existing literature. First, we are the first to deploy the D-Y spillover index in the EEA context, providing insights into the interconnectedness of European economies in response to economic, political, and energy shocks. Second, we include natural gas (i.e., TTF) in addition to oil in our network model, acknowledging Europe's increasing gas dependency. Lastly, we provide comprehensive panel regression analysis of oil and gas price shocks to equity markets before focusing on a closed network model, addressing potential omitted variable biases and allowing for external factors.

Our findings have policy implications for managing the risks associated with energy price volatility in the European equity markets. Our results suggest that policymakers should consider the potential impact of energy shocks on countries with relatively underdeveloped exchanges or weak domestic currencies. Additionally, our study highlights the need for diversification in the energy mix to mitigate the risks associated with energy price volatility, particularly in light of Europe's increasing gas dependency. Finally, our study underscores the importance of maintaining an open and interconnected European economy to better manage the spillover effects of energy price shocks.

6. References

ACER, 2021, EU gas supply sourcing costs fell to record low in 2020 due mainly to COVID-19 gas demand reductions and record LNG deliveries, European Union Agency for the Cooperation of Energy Regulators, https://documents.acer.europa.eu/Media/News/Pages/EU-gas-supply-sourcing-costs-fell-to-record-low-in-2020-due-mainly-to-COVID-19-gas-demand-reductions-and-record-LNG-deliver.aspx [Accessed: 4/15/2023]

Arouri, M.E.H., Jouini, J., Nguyen, D.K., 2011a. Volatility spillovers between oil prices and stock sector returns: Implications for portfolio management. *Journal of International Money and Finance* 30, 1387–1405.

Arouri, M.E.H., Lahiani, A., Nguyen, D.K., 2011b. Return and volatility transmission between world oil prices and stock markets of the GCC countries. *Economic Modelling* 28, 1815–1825.

Balli, F., Hassan Rafdan Hajhoj, Syed Abul Basher, and Hassan Belkacem Ghassan. 2015. An analysis of returns and volatility spillovers and their determinants in emerging Asian and Middle Eastern countries. *International Review of Economics & Finance* 39, 311-325.

BBC, 2015, https://www.bbc.com/news/world-europe-31003070 [Accessed: 3/31/2023]

Bildirici, Melike E., and Tahsin Bakirtas. 2014. The relationship among oil, natural gas and coal consumption and economic growth in BRICTS (Brazil, Russian, India, China, Turkey and South Africa) countries. *Energy* 65, 134-144.

BP Statistical Review of World Energy, 2022. https://www.bp.com/content/dam/bp/business-sites/en/global/corporate/pdfs/energy-economics/statistical-review/bp-stats-review-2022-full-report.pdf [Accessed: 4/10/2023]

Chai, Jian, Xiaokong Zhang, Quanying Lu, Xuejun Zhang, and Yabo Wang. 2021. Research on imbalance between supply and demand in China's natural gas market under the double-track price system. *Energy Policy* 155, 112380.

Chen, N.F., Roll, R., Ross, S.A., 1986. Economic forces and the stock market. *Journal of Business* 59, 383–403.

Chiaramonte, Alessandro, Vincenzo Emanuele, Nicola Maggini, and Aldo Paparo, 2018. Populist success in a hung parliament: The 2018 general election in Italy. *South European Society and Politics* 23 (4), 479-501.

Choi, Kyongwook, and Shawkat Hammoudeh. 2010. Volatility behavior of oil, industrial commodity and stock markets in a regime-switching environment. *Energy Policy* 38 (8), 4388-4399.

CNBC, 2021, https://www.cnbc.com/2021/11/30/oil-markets-opec-and-allies-omicron-covid-variant.html [Accessed: 4/20/2023]

CNBC, 2022, https://www.cnbc.com/2022/12/29/european-natural-gas-prices-return-to-pre-ukraine-war-levels.html [Accessed: 2/11/2023]

Corbet, S., Goodell, J.W., Gunay, S., 2020. Co-movements and spillovers of oil and renewable firms under extreme conditions: New evidence from negative WTI prices during COVID-19. *Energy Economics* 92, 104978.

Costola, Michele, and Marco Lorusso, 2022. Spillovers among energy commodities and the Russian stock market. *Journal of Commodity Markets* 28, 100249.

Council of Europe, 2008. The consequences of the war between Georgia and Russia, Resolution 1633, https://assembly.coe.int/nw/xml/XRef/Xref-XML2HTML-en.asp?fileid=17681 [Accessed: 4/28/2023]

Council of Europe, 2023. Council of Europe will continue to support Crimea and all of Ukraine, says Secretary General, August 23, 2022, https://www.coe.int/en/web/portal/-/council-of-europe-will-continue-to-support-crimea-and-all-of-ukraine-says-secretary-general [Accessed: 4/28/2023]

Cunado, J., de Gracia, F.P., 2003. Do oil price shocks matter? Evidence for some European countries. *Energy Economics* 25, 137–154.

Dai, Z., Zhu, H., 2022. Time-varying spillover effects and investment strategies between WTI crude oil, natural gas and Chinese stock markets related to belt and road initiative. *Energy Economics* 108, 105883.

Diebold, F.X., Yilmaz, K., 2012. Better to give than to receive: Predictive directional measurement of volatility spillovers. *International Journal of Forecasting* 28, 57–66.

Diebold, F.X., Yilmaz, K., 2014. On the network topology of variance decompositions: Measuring the connectedness of financial firms. *Journal of Econometrics* 182, 119-134.

Diebold, F.X., and Yilmaz, K., 2023. On the past, present, and future of the Diebold–Yilmaz approach to dynamic network connectedness. *Journal of Econometrics* 234, 115-120.

Ding, Shusheng, Tianxiang Cui, Dandan Zheng, and Min Du. The effects of commodity financialization on commodity market volatility. *Resources Policy* 73 (2021): 102220.

EC DG-Energy, 2020. European Commission Directorate-General for Energy, EU quarterly gas reports, 1st quarter of 2020, https://energy.ec.europa.eu/data-and-analysis/market-analysis_en [Accessed: 2/3/2023]

EC DG-Energy, 2022. European Commission Directorate-General for Energy, EU quarterly gas reports, 1st quarter of 2022, https://energy.ec.europa.eu/data-and-analysis/market-analysis_en [Accessed: 2/3/2023]

EIA, 2022, https://www.eia.gov/energyexplained/natural-gas/where-our-natural-gas-comes-from.php [Accessed: 4/1/2023]

El-Sharif, I., Brown, D., Burton, B., Nixon, B., Russell, A., 2005. Evidence on the nature and extent of the relationship between oil prices and equity values in the UK. *Energy Economics* 27, 819–830.

Enerdata, 2020, https://www.enerdata.net/publications/daily-energy-news/opec-agrees-97-mbd-crude-oil-production-cut-may-june-2020.html [Accessed: 3/2/2023]

European parliament, 2022. EU parliament backs labelling gas and nuclear investments as green, by Kate Abnett, https://www.europarl.europa.eu/news/en/press-room/20220701IPR34365/taxonomy-meps-do-not-object-to-inclusion-of-gas-and-nuclear-activities

Eurostat, 2022. Energy dependence, https://ec.europa.eu/eurostat/web/energy/database [Accessed: 1/12/2023]

Ewing, B.T., Malik, F., Ozfidan, O., 2002. Volatility transmission in the oil and natural gas markets. *Energy Economics* 24, 525–538.

Fernández-Rodríguez, Fernando, Marta Gómez-Puig, and Simón Sosvilla-Rivero. 2015. Volatility spillovers in EMU sovereign bond markets. *International Review of Economics & Finance* 39, 337-352.

Gamba-Santamaria, Santiago, Jose Eduardo Gomez-Gonzalez, Jorge Luis Hurtado-Guarin, and Luis Fernando Melo-Velandia, 2017. Stock market volatility spillovers: Evidence for Latin America. *Finance Research Letters* 20, 207-216.

Hanson, Philip. Observations on the Costs of the Yukos Affair to Russia. 2005. *Eurasian Geography and Economics* 46 (7), 481-494.

Huang, R.D., Masulis, R.W., Stoll, H.R., 1996. Energy shocks and financial markets. *Journal of Futures Markets* 16, 1–27.

IEA, 2021, https://www.iea.org/reports/gas-market-report-q2-2021/gas-market-update-and-short-term-forecast [Accessed: 3/2/2023]

Iglesias, E. M., and D. Rivera-Alonso, 2022. Brent and WTI oil prices volatility during major crises and Covid-19. *Journal of Petroleum Science and Engineering* 211, 110182.

Jones, C.M., Kaul, G., 1996. Oil and the stock markets. *The Journal of Finance* 51, 463–491.

Kerste, M., M. Gerritsen, J., Weda, and B., Tieben. 2015. Systemic risk in the energy sector—Is there need for financial regulation? *Energy Policy* 78*,* 22-30.

Kilian, L., Park, C., 2009. The impact of oil price shocks on the US stock market. *International Economic Review* 50, 1267–1287.

Kling, J.L., 1985. Oil price shocks and stock market behavior. *The Journal of Portfolio Management* 12, 34–39.

Koop, G., Pesaran, M.H., Potter, S.M., 1996. Impulse response analysis in nonlinear multivariate models. *Journal of Econometrics* 74, 119–147.

Kosmidou, Kyriaki, Dimitrios Kousenidis, Anestis Ladas, and Christos Negkakis, 2020. Regulation of capital flows: Effects on liquidity and the role of financial reporting quality. *Journal of Economic Behavior & Organization* 175, 86-97.

Lee, Chi-Chuan, Chien-Chiang Lee, and Yong-Yi Li, 2021. Oil price shocks, geopolitical risks, and green bond market dynamics. *The North American Journal of Economics and Finance* 55, 101309.

Lin, Boqiang, and Tong Su. 2021. Does COVID-19 open a Pandora's box of changing the connectedness in energy commodities? *Research in International Business and Finance* 56, 101360.

Liow, Kim Hiang, 2015. Volatility spillover dynamics and relationship across G7 financial markets. *The North American Journal of Economics and Finance* 33, 328-365.

Mensi, W., S. Hammoudeh, S. J. H., Shahzadd, and M. Shahbaz , 2017. Modeling systemic risk and dependence structure between oil and stock markets using a variational mode decomposition-based copula method, *Journal of Banking & Finance* 75, 258-279.

Mensi, Walid, Ferihane Zaraa Boubaker, Khamis Hamed Al-Yahyaee, and Sang Hoon Kang, 2018. Dynamic volatility spillovers and connectedness between global, regional, and GIPSI stock markets. *Finance Research Letters* 25, 30-238.

Mensi, Walid, Juan C. Reboredo, and Andrea Ugolini, 2021a. Price-switching spillovers between gold, oil, and stock markets: Evidence from the USA and China during the COVID-19 pandemic. *Resources Policy* 73, 10221.

Mensi, Walid, Shawkat Hammoudeh, Xuan Vinh Vo, and Sang Hoon Kang, 2021b. Volatility spillovers between oil and equity markets and portfolio risk implications in the US and vulnerable EU countries. *Journal of International Financial Markets, Institutions and Money 75, 101457.*

Middleton, Richard S., Rajan Gupta, Jeffrey D. Hyman, and Hari S. Viswanathan, 2017. The shale gas revolution: Barriers, sustainability, and emerging opportunities. *Applied Energy* 199, 88-95.

Mihaljek, D., 2010. The spread of the financial crisis to central and eastern Europe: Evidence from the BIS data. *Money, Banking and Financial Markets in Central and Eastern Europe: 20 Years of Transition*, 5-31.

NPR, 2015, https://www.npr.org/sections/thetwo-way/2015/06/28/418276486/greece-tries-to-stanch-bank-run-ahead-of-looming-default [Accessed: 4/1/2023]

Park, Jungwook, and Ronald A. Ratti. Oil price shocks and stock markets in the US and 13 European countries. *Energy Economics* 30, no. 5 (2008): 2587-2608.

Phan, D.H.B., Sharma, S.S., Narayan, P.K., 2016. Intraday volatility interaction between the crude oil and equity markets. *Journal of International Financial Markets, Institutions and Money* 40, 1–13.

Reboredo, Juan C. 2015. Is there dependence and systemic risk between oil and renewable energy stock prices? *Energy Economics* 48, 32-45.

Reuters, 2021, https://www.reuters.com/business/energy/opec-seen-sticking-with-supply-plan-irans-oil-yet-return-2021-06-01/ [Accessed: 2/11/2023]

Reuters, 2022b, https://www.reuters.com/business/energy/oils-journey-worthless-pandemic-100-barrel-2022-02-24/ [Accessed: 4/10/2023]

Reuters, 2022c, https://www.reuters.com/markets/commodities/russian-gas-transit-via-ukraine-fell-25-2021-2022-01-04/ [Accessed: 4/20/2023]

Reuters, 2022a, https://www.reuters.com/business/lme-imposes-price-limits-first-time-after-nickel-crisis-2022-03-15/ [Accessed: 4/30/2023]

Sadorsky, P., 1999. Oil price shocks and stock market activity. *Energy Economics* 21, 449–469.

Sadorsky, P., 2001. Risk factors in stock returns of Canadian oil and gas companies. *Energy Economics* 23, 17–28

Silva, Thiago Christiano, Paulo Victor Berri Wilhelm, and Benjamin Miranda Tabak. 2023. Trade matters except to war neighbors: The international stock market reaction to 2022 Russia's invasion of Ukraine. *Research in International Business and Finance*, 101935.

Sims, C.A., 1980. Macroeconomics and reality. *Econometrica: Journal of the Econometric Society*, 1–48.

Wang, Y., Wu, C., Yang, L., 2013. Oil price shocks and stock market activities: Evidence from oil-importing and oil-exporting countries. *Journal of Comparative Economics* 41, 1220–1239.

Wang, X., Wang, Y., 2019. Volatility spillovers between crude oil and Chinese sectoral equity markets: Evidence from a frequency dynamics perspective. *Energy Economics* 80, 995–1009.

Yousaf, I., Patel, R., and L.Yarovaya. 2022. The reaction of G20+ stock markets to the Russia–Ukraine conflict black-swan event: Evidence from event study approach. *Journal of Behavioral and Experimental Finance* 35, 100723

Zhang, W., He, X., Nakajima, T., Hamori, S., 2020. How does the spillover among natural gas, crude oil, and electricity utility stocks change over time? Evidence from North America and Europe. *Energies* 13, 727.

Zhang, Y.J., Chevallier, J., Guesmi, K., 2017. De-financialization of commodities? Evidence from stock, crude oil and natural gas markets. *Energy Economics* 68, 228–239.

Zhiznin, S. Z., and V. M. Timokhov. 2019. Economic and geopolitical aspects of the Nord Stream 2 gas pipeline. *Baltic region* 11 (3), 25-42.

Table 1
Panel A. Summary Statistics for the Pooled Sample
The sample statistics are based on 24 EEA countries from March 24, 2003 to December 30, 2022. Cntrcd is a country indicator used here to show that the sample covers 24 unique countries. *Ret1d* and *Ret5d* are future 1-day and 5-day returns on the country' equity market, measured by the change in the country's MSCI Index. *Lad1dRet* and *Lag5dRet* are the country's own lagged equity market returns. *APlag1dRet*, *APlag5dRet*, and *USlag1dRet* and *USlag5dRet* are the lagged 1-day and 5-day MSCI index returns in Asia Pacific and in the USA, respectively. *Brentlag1dRet*, *Brentlag5dRet*, *TTFlag1dRet*, and *TTFlag5dRet* are the lagged 1-day and 5-day price changes in Brent oil contract and TTF gas contracts, respectively. *Engdep* is the country's energy dependence, or energy shortfall, measured as 1 – energy production/energy consumption. *TTFvol5d* and *Brentvol5d* are the 5-day extreme price volatility for gas and oil, measured as the difference between the last 5-day maximum price and minimum price, divided by the initial price, or the price 5-days ago. *LogFXprice*, is the natural logarithm of the forex rate, the number of domestic currency are needed to buy 1 EUR. *FXlag1dRet* and *FXlag5dRet* are the lagged 1-day and 5-day change in the forex rates for a country. [6]

Variables	Observations	Mean	Std. Dev.	25th perc	Median	75th perc	Min	Max
cntrcd	110740	12.7993	6.9245	7.0000	13.0000	19.0000	1.0000	24.0000
Ret1d	110740	0.0002	0.0165	-0.0070	0.0003	0.0079	-0.2711	0.2614
Ret5d	110740	0.0010	0.0370	-0.0159	0.0026	0.0199	-0.3773	0.4238
Lag1dret	110740	0.0002	0.0165	-0.0070	0.0003	0.0079	-0.2711	0.2614
Lag5dret	110740	0.0009	0.0370	-0.0160	0.0026	0.0199	-0.3773	0.4238
APlag1dRet	110740	0.0002	0.0109	-0.0051	0.0006	0.0060	-0.0862	0.0933
APlag5dRet	110740	0.0011	0.0250	-0.0116	0.0026	0.0155	-0.1784	0.1690
USlag1dRet	110740	0.0004	0.0120	-0.0039	0.0004	0.0055	-0.1212	0.1168
USlag5dRet	110740	0.0018	0.0241	-0.0085	0.0034	0.0141	-0.1836	0.1818
Brentlag1dRet	110740	0.0004	0.0232	-0.0104	0.0007	0.0113	-0.2440	0.2102
Brentlag5dRet	110740	0.0021	0.0516	-0.0235	0.0037	0.0291	-0.3470	0.5137
TTFlag5dRet	102343	0.0012	0.0404	-0.0123	0.0000	0.0118	-0.3199	1.0000
TTFlag5dRet	102377	0.0053	0.0895	-0.0318	-0.0024	0.0314	-0.4842	1.2162
Engdep	110740	0.4345	0.4009	0.3126	0.5067	0.6992	-1.0000	0.9119
TTFvol5d	102257	0.0643	0.0729	0.0232	0.0428	0.0774	0.0000	1.1026
Brentvol5d	110620	0.0442	0.0341	0.0239	0.0359	0.0550	0.0015	0.5000
LogFXprice	110740	0.8422	1.4229	0.0000	0.0000	1.5770	-0.4233	6.0653
FXlag5dRet	110740	0.0001	0.0056	0.0000	0.0000	0.0000	-0.0942	0.0991
FXlag1dRet	110740	0.0001	0.0056	0.0000	0.0000	0.0000	-0.0942	0.0991

[6] We also use interaction variables of the oil price change and the gas price change variables (e.g., brent1dlagret, brent5dlagret, ttf1dlagret, ttf5dlagret) are interacted with the country total energy dependence (Engdep) variable.

Table 1 continued

Panel B. Detailed summary statistics of the daily MSCI index returns by countries and the daily price changes in the commodity futures[7]

	Observations	Mean	Median	SD	Min	Max	Skewness	Kurtosis
Core EU countries								
Austria	4957	0.000	0.001	0.019	-0.153	0.143	-0.125	10.538
Belgium	4957	0.000	0.000	0.015	-0.180	0.142	-0.743	18.209
Germany	4957	0.000	0.000	0.015	-0.140	0.123	-0.027	11.313
Denmark	4957	0.001	0.001	0.014	-0.126	0.113	-0.157	9.727
Finland	4957	0.000	0.000	0.016	-0.115	0.123	-0.068	9.064
France	4957	0.000	0.000	0.015	-0.138	0.126	-0.010	12.154
Netherlands	4957	0.000	0.000	0.014	-0.114	0.111	-0.044	10.816
Sweden	4957	0.000	0.000	0.017	-0.138	0.151	0.104	9.781
PIIGS countries								
Spain	4957	0.000	0.000	0.016	-0.158	0.174	-0.029	13.382
Greece	4957	0.000	0.000	0.024	-0.222	0.187	-0.163	10.908
Ireland	4957	0.000	0.000	0.018	-0.140	0.136	-0.330	9.989
Italy	4957	0.000	0.000	0.017	-0.186	0.131	-0.330	12.458
Portugal	4957	0.000	0.000	0.015	-0.129	0.125	-0.112	10.439
Countries joined the EU after 2004								
Bulgaria	3756	0.000	0.000	0.016	-0.167	0.120	-1.000	15.169
Czech Republic	2609	0.000	0.000	0.013	-0.123	0.077	-0.738	11.902
Croatia	3756	0.000	0.000	0.013	-0.211	0.261	0.830	81.962
Estonia	3157	0.000	0.000	0.013	-0.123	0.138	0.064	15.662
Hungary	4957	0.000	0.000	0.022	-0.184	0.225	0.028	12.856
Lithuania	2273	0.000	0.000	0.010	-0.136	0.081	-1.326	28.257
Poland	4957	0.000	0.000	0.019	-0.162	0.153	-0.197	9.360
Romania	3756	0.000	0.000	0.018	-0.271	0.134	-1.168	24.183
Slovenia	3756	0.000	0.000	0.013	-0.119	0.099	-0.652	11.125
Ex-EU regions								
United Kingdom	4957	0.000	0.000	0.014	-0.132	0.130	-0.149	15.195
Norway	4957	0.000	0.001	0.019	-0.133	0.166	-0.244	10.099
United States	4957	0.000	0.000	0.012	-0.121	0.117	-0.283	16.260
Asia Pacific	4957	0.000	0.001	0.011	-0.086	0.093	-0.259	9.309
Commodities								
Brent	4957	0.000	0.001	0.023	-0.244	0.210	-0.202	13.030
TTF	4668	0.001	0.000	0.040	-0.320	0.614	2.877	39.431

[7] The panel is an unbalanced panel with shorter time coverage for the Central and Eastern European Countries (CEEC) because of data limitations.

Table 2.
MSCI Country Index Return Regression Analysis

The dependent variable is the future 1-day MSCI index return in Models 1A-3A and the future 5-day MSCI index return in Models 1B-3B, respectively. The explanatory variables are defined in Table 1. The sample period is from March 24, 2003, to December 30 2022, covering 24 EEA countries (see the complete list of countries in Table 2). The panel is an unbalanced panel with shorter time coverage for the Central and Eastern European Countries (CEEC) because of data limitations. The coefficient estimates with the corresponding robust t-statistics (in parentheses) are reported from panel regression, with time and country fixed effects, with clustered standard errors at time and country dimensions. ***, **, and *, indicate the statistical significance at the 1 percent, 5 percent, and 10 percent levels.

VARIABLES	(Model 1A) Ret1d	(Model 2A) Ret1d	(Model 3A) Ret1d	(Model 1B) Ret5d	(Model 2B) Ret5d	(Model 3B) Ret5d
Lag1DRet	-0.076***	-0.074***	-0.273***	-0.036	-0.035	-0.005
	(-3.35)	(-3.29)	(-14.20)	(-1.04)	(-1.01)	(-0.14)
Lag5DRet			0.281***			-0.046**
			(30.50)			(-2.49)
APlag1dRet	-0.170***	-0.166***	-0.100***	-0.044	-0.042	-0.058
	(-5.60)	(-5.54)	(-3.62)	(-0.63)	(-0.61)	(-0.78)
APlag5dRet	-0.011	-0.018	-0.175***	-0.143***	-0.146***	-0.125***
	(-0.62)	(-0.98)	(-9.31)	(-3.63)	(-3.69)	(-2.95)
USlag1dRet	0.214***	0.222***	0.291***	-0.107	-0.104	-0.121
	(6.17)	(6.43)	(8.62)	(-1.34)	(-1.30)	(-1.46)
USlag5dRet	0.206***	0.194***	0.064***	0.134***	0.129***	0.149***
	(9.38)	(9.11)	(4.30)	(2.93)	(2.93)	(3.16)
Brentlag1dRet	-0.003	-0.024*	-0.007	0.033	0.023	0.026
	(-0.28)	(-2.01)	(-0.60)	(1.03)	(0.70)	(0.73)
Brentlag5dRet		0.023***	0.009*		0.010	0.016
		(3.79)	(1.74)		(0.68)	(1.02)
TTFlag1dRet			-0.000			-0.010
			(-0.02)			(-0.51)
TTFlag5dRet			0.001			-0.009
			(0.21)			(-1.26)
Constant	0.001**	0.001**	-0.016***	0.012***	0.012***	0.021
	(2.32)	(2.45)	(-3.28)	(8.85)	(8.91)	(1.24)
Observations	110,740	110,740	102,292	110,740	110,740	102,292
R-squared	0.116	0.120	0.304	0.026	0.026	0.025

Table 3.
MSCI Country Index Regression Analysis, Subsample Results
The dependent variable is the future 1-day MSCI index return in Models 1A-3A and the future 5-day MSCI index return in Models 1B-3B, respectively. The explanatory variables are defined in Table 1. The sample is from March 24, 2003, to December 30 2012 in Models 1A and 1B, from January 1, 2013 to December 30 2019 in Models 2A and 2B, and from January 1, 2020 to December 30 2022 in Models 3A and 3B. The cross-sectional coverage is the same as in Tables 1 and 2, 24 EEA countries (see the complete list of countries in Table 2). The coefficient estimates with the corresponding robust t-statistics (in parentheses) are reported from panel regression, with time and country fixed effects, with clustered standard errors at time and country dimensions. ***, **, and *, indicate the statistical significance at the 1 percent, 5 percent, and 10 percent levels.

	(Model 1A)	(Model 2A)	(Model 3A)	(Model 1B)	(Model 2B)	(Model 3B)
VARIABLES	Ret1d	Ret1d	Ret1d	Ret5d	Ret5d	Ret5d
	Bef 2013	Aft 2013	Aft 2020	Bef 2013	Aft 2013	Aft 2020
Lag1DRet	-0.286***	-0.263***	-0.285***	-0.032	0.024	0.110
	(-11.27)	(-10.88)	(-8.50)	(-0.66)	(0.47)	(1.08)
Lag5DRet	0.292***	0.267***	0.294***	-0.053	-0.045*	0.034
	(27.59)	(21.71)	(15.80)	(-1.58)	(-1.97)	(0.76)
APlag1dRet	-0.090**	-0.087***	-0.153**	-0.058	-0.062	-0.145
	(-2.26)	(-2.95)	(-2.76)	(-0.52)	(-0.73)	(-0.88)
APlag5dRet	-0.221***	-0.129***	-0.151***	-0.166**	-0.070	-0.202**
	(-8.83)	(-6.88)	(-5.45)	(-2.51)	(-1.51)	(-2.19)
USlag1dRet	0.400***	0.180***	0.178***	-0.143	-0.098	-0.152
	(8.30)	(5.04)	(3.56)	(-1.13)	(-0.92)	(-0.95)
USlag5dRet	0.078***	0.046**	0.037	0.207**	0.094*	0.121
	(3.43)	(2.62)	(1.39)	(2.61)	(1.80)	(1.45)
Brentlag1dRet	-0.021	0.002	0.003	0.064	0.006	0.028
	(-0.90)	(0.15)	(0.13)	(1.04)	(0.13)	(0.36)
Brentlag5dRet	0.019*	0.005	0.011	0.004	0.024	0.040
	(1.86)	(0.90)	(1.06)	(0.13)	(1.34)	(1.43)
TTFlag1dRet	-0.010	0.004	0.003	-0.008	-0.009	-0.012
	(-1.05)	(0.58)	(0.46)	(-0.26)	(-0.41)	(-0.42)
TTFlag5dRet	0.005	-0.001	-0.002	0.020	-0.019**	-0.017
	(1.24)	(-0.44)	(-0.55)	(1.36)	(-2.17)	(-1.58)
Constant	-0.009	-0.000	0.000	-0.006	0.003**	0.003
	(-0.98)	(-0.38)	(0.19)	(-0.21)	(2.42)	(0.88)
Observations	40,030	62,262	18,792	40,030	62,262	18,792
R-squared	0.338	0.277	0.324	0.039	0.016	0.026

Table 4.
MSCI Country Index Volatility Regression Analysis with Oil and Gas Price Volatility
The dependent variable is the future 5-day MSCI index return volatility (i.e., Max MSCI Index level – Min MSCI Index level) MSCI indexlag5) in Models 1A-3A for the full sample, with model 3A specification replicated in Models 3B through 3D with various subsamples. The explanatory variables are defined in Table 1. The sample is from March 24 in 2003 to December 30 in 2012 in Models 1A through 3B, from January 1, 2013, to December 30 2019 in Models 3C, and from January 1, 2020 to December 30 2022 in Models 3D. The cross-sectional coverage is the same as in Tables 1 and 2, 24 EEA countries (details are in the Appendix). The panel is an unbalanced panel with shorter time coverage for the Central and Eastern European Countries (CEEC) because of data limitations. The coefficient estimates with the corresponding robust t-statistics (in parentheses) are reported from panel regression, with time and country fixed effects, with clustered standard errors at time and country dimensions. ***, **, and *, indicate the statistical significance at the 1 percent, 5 percent, and 10 percent levels.

	(Model 1A)	(Model 2A)	(Model 3A)	(Model 3B)	(Model 3C)	(Model 3D)
VARIABLES	mscivol5d	mscivol5d	mscivol5d	mscivol5d	mscivol5d	mscivol5d
				Bef 2013	Aft 2013	Aft 2020
Lag1DRet	-0.030	-0.034	-0.032	-0.041	-0.012	-0.011
	(-1.60)	(-1.64)	(-1.70)	(-1.43)	(-0.53)	(-0.24)
Lag5DRet	-0.070***	-0.074***	-0.068***	-0.055***	-0.074***	-0.068***
	(-5.95)	(-5.95)	(-5.67)	(-3.55)	(-4.69)	(-3.14)
APlag1dRet	0.008	-0.003	0.005	0.009	0.006	-0.001
	(0.20)	(-0.08)	(0.13)	(0.15)	(0.16)	(-0.01)
APlag5dRet	-0.002	-0.019	-0.001	-0.022	0.021	0.013
	(-0.08)	(-0.83)	(-0.04)	(-0.68)	(0.88)	(0.29)
USlag1dRet	0.004	-0.010	0.002	-0.004	0.012	0.018
	(0.09)	(-0.23)	(0.04)	(-0.07)	(0.22)	(0.22)
USlag5dRet	-0.051**	-0.068**	-0.049**	-0.067*	-0.041	-0.070
	(-2.34)	(-2.75)	(-2.18)	(-1.84)	(-1.58)	(-1.71)
Brentvol5d	0.106***		0.108***	0.207***	0.079***	0.103***
	(8.12)		(7.85)	(7.61)	(5.29)	(5.14)
Brentlag1dRet	-0.015		-0.015	-0.030	-0.011	-0.024
	(-0.91)		(-0.89)	(-0.86)	(-0.54)	(-0.68)
Brentlag5dRet	-0.033***		-0.036***	-0.043**	-0.031***	-0.040***
	(-4.47)		(-4.52)	(-2.71)	(-3.78)	(-3.05)
TTFvol5d		0.028***	0.021***	0.035***	0.015**	0.025***
		(5.36)	(3.93)	(3.58)	(2.25)	(3.22)
TTFlag1dRet		0.000	0.002	-0.000	0.004	0.007
		(0.05)	(0.28)	(-0.01)	(0.37)	(0.62)
TTFlag5dRet		-0.005	0.001	-0.009	0.004	0.004
		(-1.43)	(0.16)	(-1.18)	(0.92)	(0.78)
Constant	0.021***	0.019***	0.015***	0.011***	0.024***	0.029***
	(12.40)	(14.20)	(9.80)	(6.55)	(26.23)	(12.83)
Observations	110,596	102,232	102,232	40,004	62,228	18,768
R-squared	0.286	0.271	0.291	0.301	0.226	0.240

Table 5.
MSCI Country Index Volatility Regression Analysis with Oil and Gas Price Volatility and FX
Dependent variable is the extreme movement in EU countries MSCI index in 5 days.

	(Model 1)	(Model 2)	(Model 3A)	(Model 3B)	(Model 3C)	(Model 3D)
VARIABLES	mscivol5d	mscivol5d	mscivol5d	mscivol5d	mscivol5d	mscivol5d
				Bef 2013	Aft 2013	Aft 2020
Lag1DRet	-0.031	-0.034	-0.033*	-0.040	-0.013	-0.015
	(-1.62)	(-1.66)	(-1.73)	(-1.39)	(-0.60)	(-0.34)
Lag5DRet	-0.067***	-0.071***	-0.065***	-0.053***	-0.070***	-0.060**
	(-5.37)	(-5.28)	(-5.09)	(-3.22)	(-4.11)	(-2.75)
APlag1Ret	0.007	-0.004	0.005	0.009	0.004	-0.003
	(0.19)	(-0.10)	(0.11)	(0.15)	(0.12)	(-0.05)
AP5dLagRet	-0.002	-0.020	-0.002	-0.022	0.021	0.014
	(-0.12)	(-0.86)	(-0.08)	(-0.69)	(0.93)	(0.32)
USlag1dRet	0.005	-0.010	0.003	-0.004	0.014	0.020
	(0.12)	(-0.23)	(0.06)	(-0.06)	(0.26)	(0.25)
USlag5dRet	-0.050**	-0.069**	-0.049**	-0.068*	-0.041	-0.074*
	(-2.32)	(-2.78)	(-2.18)	(-1.85)	(-1.61)	(-1.83)
Brentvol5d	0.105***		0.107***	0.206***	0.077***	0.100***
	(8.17)		(7.89)	(7.63)	(5.36)	(5.10)
FXlag5d*Brentvol	2.033***		1.704***	0.126	2.574***	2.555***
	(3.96)		(3.90)	(0.11)	(4.64)	(4.21)
FXlag1dsret	-0.030	-0.036	-0.039	0.001	-0.081*	-0.165**
	(-0.51)	(-0.59)	(-0.63)	(0.01)	(-1.94)	(-2.23)
FXlag5dsret	-0.069*	0.007	-0.102**	0.067	-0.168***	-0.269***
	(-1.86)	(0.21)	(-2.43)	(1.01)	(-2.99)	(-3.27)
Logfxprice	-0.003	-0.002	-0.003	0.006	0.004	0.046*
	(-0.81)	(-0.68)	(-0.95)	(0.51)	(0.76)	(1.72)
Brentlag1dret	-0.015		-0.016	-0.030	-0.012	-0.026
	(-0.93)		(-0.90)	(-0.86)	(-0.58)	(-0.74)
Brentlag5dret	-0.031***		-0.035***	-0.043**	-0.029***	-0.038***
	(-4.35)		(-4.44)	(-2.71)	(-3.64)	(-2.92)
TTFvol5d		0.027***	0.021***	0.036***	0.014**	0.024***
		(5.34)	(3.91)	(3.61)	(2.19)	(3.12)
FXlag5d*TTFvol		0.727***	0.584**	-0.640*	0.723***	0.865***
		(2.95)	(2.43)	(-1.79)	(2.89)	(3.32)
TTFlag1dret		0.000	0.002	-0.000	0.004	0.007
		(0.06)	(0.29)	(-0.01)	(0.39)	(0.66)
TTFlag5dret		-0.006	0.000	-0.009	0.003	0.003
		(-1.57)	(0.04)	(-1.19)	(0.74)	(0.62)
Constant	0.023***	0.021***	0.018***	0.007	0.021***	-0.012
	(8.58)	(7.29)	(6.44)	(0.76)	(4.22)	(-0.51)
Observations	110,596	102,232	102,232	40,004	62,228	18,768
R-squared	0.286	0.271	0.291	0.301	0.229	0.246

Table 6.

Volatility spillover summary table for MSCI equity indices of our sample EEA countries, US equity index, APAC equity index, and Brent one month ahead future prices during the period of 1/1/2004 and 12/31/2004

	AUT	BEL	DEU	DNK	FIN	FRA	GBR	NLD	SWE	ESP	GRC	IRL	ITA	PRT	HUN	POL	NOR	USA	APAC	Brent	From
AUT	18.0	4.1	4.9	4.2	4.8	3.9	3.0	4.0	7.2	4.7	4.0	1.9	3.1	2.3	5.7	2.7	7.7	1.4	2.5	10.0	82.0
BEL	4.6	9.8	8.0	4.0	7.3	6.6	4.1	6.0	8.5	6.5	3.4	2.0	4.4	3.7	3.4	2.2	5.7	1.4	1.2	7.3	90.2
DEU	3.9	5.6	12.3	3.5	7.4	7.6	3.6	7.4	10.5	6.8	3.2	1.6	4.8	2.6	3.2	1.8	5.2	1.4	1.3	6.4	87.7
DNK	5.6	4.6	5.1	10.9	5.7	4.2	3.4	4.4	7.5	5.3	4.7	2.4	2.9	4.2	4.5	2.2	6.0	2.0	1.0	13.6	89.1
FIN	2.0	2.6	3.2	1.6	56.7	2.5	2.5	2.5	5.1	2.2	1.3	1.2	1.5	1.8	3.2	1.4	2.7	0.9	0.4	4.7	43.3
FRA	4.1	5.9	9.8	3.5	7.9	9.5	3.8	7.6	9.6	6.9	3.2	1.3	4.8	2.6	3.3	1.6	5.4	1.4	1.0	6.9	90.5
GBR	3.7	5.0	6.6	3.4	9.7	5.4	10.4	5.6	7.1	5.3	2.9	2.1	3.7	3.0	5.2	2.8	8.5	1.7	1.3	6.8	89.6
NLD	4.1	5.6	9.9	3.7	8.0	7.9	4.1	9.8	8.7	6.6	3.4	1.5	4.7	2.7	3.1	1.3	6.0	1.6	1.2	6.2	90.2
SWE	4.3	4.6	7.5	3.5	7.9	5.3	2.6	4.6	22.5	4.4	3.2	2.0	3.3	3.2	2.9	2.1	5.5	1.5	1.9	7.5	77.5
ESP	4.6	5.7	8.3	4.0	6.0	6.4	3.9	5.9	8.1	12.4	4.0	1.7	4.7	3.2	3.6	1.9	6.0	1.8	1.3	6.7	87.6
GRC	4.2	3.5	3.9	4.0	4.8	3.0	3.1	3.2	5.6	5.0	23.3	2.6	2.4	2.9	5.9	3.0	8.1	2.2	1.4	8.0	76.7
IRL	3.5	3.5	4.1	3.2	6.6	2.3	3.3	2.9	8.7	3.1	4.6	17.1	2.1	4.2	5.9	3.2	8.1	2.1	2.6	8.8	82.9
ITA	4.3	5.5	8.6	3.6	5.5	6.6	4.1	6.2	8.1	7.4	3.2	1.5	8.6	3.3	4.0	2.7	6.7	1.5	1.1	7.6	91.4
PRT	3.3	5.1	3.7	4.9	8.1	3.1	2.8	3.3	8.2	4.2	4.1	3.1	2.8	16.1	4.5	3.1	5.3	1.8	1.2	11.7	83.9
HUN	4.7	2.0	2.4	2.6	5.4	1.9	2.2	2.1	5.2	2.5	3.4	1.4	1.5	1.9	36.1	3.7	7.4	1.5	2.9	9.3	63.9
POL	2.9	2.1	2.4	2.5	3.6	1.7	2.0	1.7	6.6	2.8	3.9	2.1	1.4	2.2	6.2	32.8	8.1	2.2	2.4	10.1	67.2
NOR	4.1	3.0	3.6	3.3	5.2	3.0	4.3	3.6	6.6	3.8	3.6	2.5	2.7	2.5	4.2	4.1	28.3	2.1	1.9	7.8	71.7
USA	4.4	3.2	4.3	4.1	7.1	3.0	3.4	4.1	8.2	3.8	3.7	2.0	2.2	2.7	4.5	1.7	8.2	15.5	1.3	12.8	84.5
APAC	4.7	2.7	3.8	2.2	3.4	1.8	1.6	2.5	8.5	2.8	2.2	2.3	1.3	1.8	8.7	3.6	9.2	1.7	24.1	11.1	75.9
BRENT	1.8	0.9	0.9	1.0	2.5	0.8	0.7	0.8	2.1	0.6	1.8	1.0	0.5	1.2	3.5	1.3	2.6	0.8	0.7	74.8	25.2
To	74.8	75.0	100.9	62.6	116.9	77.0	58.5	78.1	140.0	84.5	63.7	36.1	54.8	51.9	85.4	46.3	122.4	30.9	28.5	163.1	77.6
Net	-7.3	-15.2	13.2	-26.4	73.6	-13.5	-31.2	-12.1	62.5	-3.1	-13.0	-46.8	-36.7	-32.0	21.4	-20.9	50.7	-53.6	-47.3	137.8	

Table 7.

Volatility spillover summary table for MSCI equity indices of our sample EEA countries, US equity index, APAC equity index, and Brent and TTF one month ahead future prices during the period of 1/1/2005 and 12/31/2008

	AUT	BEL	DEU	DNK	FIN	FRA	GBR	NLD	SWE	ESP	GRC	IRL	ITA	PRT	HUN	POL	NOR	USA	APAC	Brent	TTF	From
AUT	10.7	3.7	4.5	5.3	4.0	5.0	5.3	4.9	6.1	5.0	3.9	5.8	4.2	3.2	5.3	4.9	10.8	2.4	1.0	3.0	1.1	89.3
BEL	5.0	14.8	3.9	4.4	4.4	4.8	4.7	6.7	5.3	4.7	4.0	6.5	3.9	3.2	4.2	4.2	8.1	1.8	1.2	2.5	1.9	85.2
DEU	4.9	3.2	7.7	4.8	5.1	6.3	5.5	5.4	6.8	5.9	3.8	4.8	5.1	2.9	5.6	5.5	9.2	1.9	1.0	3.1	1.4	92.3
DNK	5.6	3.8	4.4	8.8	4.5	5.2	5.1	4.9	6.3	4.9	4.3	5.9	4.3	3.4	5.4	5.4	10.7	1.6	1.2	3.0	1.3	91.2
FIN	4.7	4.4	5.0	4.6	10.5	5.6	5.1	5.2	7.1	5.0	3.8	5.4	4.4	2.9	5.1	5.2	8.9	1.5	1.1	3.0	1.7	89.5
FRA	5.4	3.9	5.8	5.0	5.2	6.9	5.7	5.8	7.0	5.9	3.7	5.5	5.2	3.1	5.2	4.8	9.3	1.7	1.0	2.7	1.2	93.1
GBR	5.8	3.8	5.3	5.1	4.9	6.0	7.4	5.6	6.5	5.6	3.8	6.0	4.8	3.2	5.3	4.9	9.3	1.8	1.0	2.7	1.2	92.6
NLD	5.2	5.6	5.1	4.8	4.9	6.0	5.5	7.7	6.7	5.6	3.4	6.1	4.8	3.1	5.0	4.4	9.2	1.7	1.0	2.7	1.4	92.3
SWE	4.9	3.7	4.9	4.9	5.5	5.6	5.2	5.2	10.8	5.2	3.6	5.7	4.5	2.9	4.9	5.0	9.9	1.7	1.0	3.2	1.7	89.2
ESP	5.3	3.6	5.6	4.9	4.9	6.1	5.6	5.4	6.7	7.8	4.2	5.9	5.1	3.4	5.2	4.9	8.9	1.7	1.1	2.6	1.4	92.2
GRC	5.1	4.3	4.2	5.1	4.3	4.6	4.6	4.4	5.4	4.9	11.0	6.1	3.9	3.6	5.6	6.0	8.7	1.5	1.5	3.5	1.7	89.0
IRL	5.0	4.3	3.5	4.6	4.4	4.5	4.7	4.6	5.8	4.6	4.0	17.4	3.6	3.3	4.3	4.3	8.8	1.8	1.1	3.1	2.4	82.6
ITA	5.4	3.7	5.7	5.1	4.8	6.2	5.5	5.6	6.7	6.0	3.9	5.4	6.6	3.4	5.4	4.7	9.1	1.8	1.0	3.0	1.1	93.4
PRT	5.7	4.1	4.4	5.4	4.4	5.2	5.1	5.0	5.8	5.6	4.5	6.8	4.8	7.4	5.1	4.7	8.6	1.5	1.2	3.1	1.7	92.6
HUN	5.5	2.7	4.2	4.5	3.3	4.2	4.3	4.4	4.7	4.1	3.4	4.5	3.6	2.8	19.5	7.2	9.2	1.8	1.2	3.3	1.8	80.5
POL	4.6	3.4	4.2	4.5	4.1	4.2	4.3	4.1	5.0	4.1	4.2	4.4	3.5	2.6	8.5	15.7	8.7	1.5	1.3	4.2	3.1	84.3
NOR	5.4	3.5	4.2	5.2	4.2	4.7	4.6	4.5	6.2	4.2	3.6	5.2	3.8	2.6	5.5	5.2	19.0	1.8	1.1	3.7	2.0	81.0
USA	5.8	4.0	4.9	4.5	3.3	4.6	5.1	5.1	5.5	4.4	3.5	5.7	4.0	2.2	4.7	4.0	11.2	9.6	0.9	4.9	2.2	90.4
APAC	4.9	4.3	4.3	5.1	4.0	4.6	4.8	5.0	5.1	5.2	4.2	5.8	3.8	2.9	6.1	5.7	9.7	2.7	5.2	4.3	2.4	94.8
Brent	3.5	3.1	3.1	3.3	3.1	3.2	3.4	3.8	4.9	3.1	2.8	4.1	3.1	2.3	4.5	4.8	8.5	1.9	0.9	27.2	5.5	72.8
TTF	0.3	0.4	0.3	0.3	0.4	0.3	0.3	0.3	0.5	0.3	0.3	0.4	0.2	0.2	0.7	0.8	0.8	0.1	0.2	1.5	91.5	8.5
To	97.8	73.7	87.6	91.2	83.6	96.7	94.3	95.7	114.0	94.4	72.8	106.0	80.5	57.2	101.5	96.5	177.5	34.1	20.8	62.9	38.1	84.6
Net	8.5	-11.5	-4.7	0.0	-5.9	3.6	1.6	3.4	24.8	2.1	-16.2	23.4	-12.9	-35.4	21.1	12.3	96.5	-56.3	-74.0	-9.9	29.6	

Table 8.

Volatility spillover of MSCI equity indices of our sample EEA countries, US equity index, and APAC equity index, as well as Brent and TTF one month ahead future prices during the period of 1/1/2009 and 12/31/2012

	AUT	BEL	DEU	DNK	FIN	FRA	GBR	NLD	SWE	ESP	GRC	IRL	ITA	PRT	BGR	HRV	HUN	POL	ROU	SVN	NOR	USA	APAC	Brent	TTF	From
AUT	12.3	3.1	5.0	2.6	4.7	5.1	2.5	4.0	5.8	5.7	5.2	3.6	6.4	3.1	0.6	0.6	7.9	6.8	3.6	0.8	6.0	0.9	0.5	1.8	1.9	87.7
BEL	6.5	5.8	5.4	2.8	4.9	6.0	2.9	4.8	5.8	6.4	5.2	4.1	6.7	3.5	0.6	0.7	7.5	6.5	2.7	0.7	5.7	1.0	0.4	1.8	1.7	94.2
DEU	6.5	3.4	7.4	2.7	5.5	6.7	3.1	4.9	6.7	6.1	4.7	3.8	7.4	3.0	0.6	0.4	7.0	6.6	2.3	0.6	5.9	1.3	0.5	1.9	1.0	92.6
DNK	6.4	3.1	5.0	7.6	5.2	5.0	2.6	4.1	6.7	4.7	6.0	3.9	5.7	3.0	0.8	0.6	6.9	6.7	3.1	0.8	6.6	1.0	0.5	2.2	1.8	92.4
FIN	6.3	3.1	5.6	2.9	10.0	5.7	2.6	4.2	6.7	5.7	4.9	3.7	7.0	3.2	0.7	0.5	7.1	6.7	2.4	0.8	5.7	1.1	0.5	1.8	1.3	90.0
FRA	6.5	3.7	6.4	2.6	5.5	7.2	3.0	4.9	6.3	7.0	4.9	4.0	7.9	3.4	0.6	0.4	6.9	6.2	2.3	0.6	5.7	1.2	0.4	1.7	1.0	92.8
GBR	6.1	3.4	5.9	2.7	5.0	5.9	5.2	4.5	7.0	5.4	4.7	4.2	6.6	2.8	0.6	0.4	6.8	6.7	2.7	0.6	7.0	1.3	0.6	2.5	1.5	94.8
NLD	6.5	3.7	6.1	2.8	5.2	6.4	3.0	6.0	6.4	6.3	5.1	3.9	7.4	3.4	0.6	0.4	7.1	6.4	2.3	0.7	6.0	1.2	0.4	1.8	1.2	94.0
SWE	6.5	3.0	5.6	3.0	5.6	5.5	3.1	4.3	11.3	5.0	4.1	3.7	6.1	2.7	0.5	0.4	6.8	7.1	2.9	0.7	7.0	1.3	0.5	2.1	1.4	88.7
ESP	6.5	3.5	5.3	2.2	4.8	6.2	2.4	4.3	5.0	12.0	5.8	3.9	8.8	4.1	0.6	0.4	7.2	5.8	2.4	0.7	4.4	1.0	0.3	1.5	1.1	88.0
GRC	4.5	2.1	3.2	2.3	3.0	3.2	1.5	2.8	3.3	4.1	36.8	2.8	4.1	2.8	1.0	0.3	5.4	5.0	3.0	0.8	3.5	0.6	0.5	1.3	2.3	63.2
IRL	6.0	3.1	4.7	3.0	4.4	5.1	2.8	3.9	5.5	5.4	5.4	13.3	5.7	2.9	0.6	0.4	6.3	6.2	2.6	0.6	6.0	1.1	0.5	2.2	2.4	86.7
ITA	6.7	3.3	5.8	2.4	5.4	6.4	2.7	4.6	5.7	8.0	4.9	3.8	10.5	3.8	0.6	0.5	7.1	6.0	2.1	0.7	5.4	1.2	0.4	1.6	0.8	89.5
PRT	6.5	3.5	4.8	2.6	5.0	5.5	2.3	4.2	5.2	7.6	6.9	3.7	7.5	7.3	0.7	0.6	7.4	6.1	2.9	0.8	5.0	0.9	0.3	1.4	1.4	92.8
BGR	5.4	2.1	3.4	2.7	3.9	3.0	1.5	2.6	4.6	3.8	8.2	2.5	4.6	2.3	15.7	2.0	6.4	5.9	4.2	1.4	5.0	1.1	1.0	3.7	3.2	84.3
HRV	6.1	2.3	2.6	2.0	2.7	2.5	1.4	2.2	3.7	3.0	3.9	2.0	3.3	1.9	1.3	24.1	6.5	9.5	3.8	1.2	5.0	0.7	0.7	2.9	4.7	75.9
HUN	6.5	2.8	4.3	2.4	4.1	4.4	2.2	3.6	4.9	5.1	4.6	3.4	5.5	2.8	0.7	0.6	19.4	8.1	3.3	0.8	5.3	0.9	0.5	2.0	2.1	80.6
POL	6.5	2.8	4.8	2.4	4.7	4.7	2.5	3.7	6.1	4.9	4.8	3.5	5.5	2.8	0.6	0.7	9.4	14.4	3.1	0.7	6.1	0.9	0.5	1.9	2.2	85.6
ROU	6.2	2.2	2.9	2.4	3.1	2.9	1.8	2.4	4.4	3.3	5.8	2.7	3.5	2.2	0.8	0.6	6.3	5.7	26.5	1.2	5.6	1.0	0.7	2.8	3.3	73.5
SVN	6.1	2.7	3.9	3.1	4.5	3.8	1.8	3.2	4.8	4.1	8.4	3.3	5.0	2.7	1.6	1.3	6.9	6.3	5.5	8.4	5.2	1.1	0.8	2.7	2.8	91.6
NOR	6.8	3.0	5.2	2.9	4.9	5.1	3.2	4.1	7.0	4.5	4.3	3.9	5.9	2.7	0.6	0.6	7.1	6.9	3.1	0.7	11.9	1.1	0.5	2.3	1.8	88.1
USA	5.8	2.7	5.5	2.6	5.0	5.1	3.1	4.2	6.8	4.8	4.5	4.1	6.4	2.4	0.7	0.7	5.7	6.0	3.6	0.6	6.0	7.2	0.8	3.9	2.1	92.8
APAC	5.9	2.5	5.0	2.7	4.8	4.1	2.4	3.5	5.5	4.2	7.8	3.7	5.4	2.5	1.3	0.8	6.8	7.3	4.2	0.9	5.7	1.9	4.7	3.6	2.9	95.3
Brent	5.0	2.1	3.6	2.5	3.4	3.1	2.5	2.8	4.2	3.1	4.6	2.8	4.1	1.7	0.8	1.0	5.9	6.6	4.3	0.8	6.1	1.6	0.9	22.6	4.1	77.4
TTF	3.0	1.1	1.6	1.2	1.3	1.3	1.0	1.4	2.8	1.3	4.5	2.2	1.2	0.8	0.5	0.6	4.7	5.5	1.8	0.5	3.3	0.4	0.5	1.9	55.6	44.4
To	144.8	68.2	111.5	61.2	106.4	112.6	57.4	89.1	130.6	119.3	129.2	83.1	137.5	66.3	17.9	15.5	162.6	156.5	74.2	18.4	133.2	25.7	12.9	53.1	49.7	85.5
Net	57.1	-26.1	18.9	-31.2	16.4	19.8	-37.4	-5.0	41.9	31.3	66.0	-3.6	48.0	-26.5	-66.4	-60.4	82.0	71.0	0.7	-73.2	45.1	-67.1	-82.4	-24.3	5.3	

Table 9.

Volatility spillover of MSCI equity indices of our sample EEA countries, US equity index, and APAC equity index, as well as Brent and TTF one month ahead future prices during the period of 1/1/2013 and 12/31/2015

	AUT	BEL	DEU	DNK	FIN	FRA	GBR	NLD	SWE	ESP	GRC	IRL	ITA	PRT	BGR	CZE	EST	HRV	HUN	POL	ROU	SVN	NOR	USA	APAC	Brent	TTF	From
AUT	16.8	3.6	4.9	2.1	4.2	4.8	2.0	3.5	3.4	5.5	6.1	3.3	7.6	5.5	2.8	2.2	1.3	1.1	3.6	4.0	1.3	1.5	3.2	1.0	0.7	2.4	1.9	83.2
BEL	5.2	10.6	6.1	2.4	4.4	6.5	3.2	5.4	4.0	6.6	3.5	3.9	7.2	5.2	3.2	2.0	1.2	0.8	3.4	3.5	1.3	1.4	3.5	0.9	0.7	2.1	1.5	89.4
DEU	6.0	5.2	10.1	2.4	4.7	7.3	3.2	5.9	4.4	6.2	3.8	4.1	8.2	4.9	2.4	1.6	1.1	0.8	3.3	4.0	1.2	1.3	3.1	0.9	0.6	1.7	1.8	89.9
DNK	4.6	3.6	4.3	15.5	4.0	3.7	2.3	3.7	4.4	4.1	8.1	3.6	4.7	4.1	3.7	2.3	1.4	0.9	3.4	4.1	1.5	1.5	3.4	0.9	0.9	2.9	2.4	84.6
FIN	6.3	4.4	5.5	2.7	10.8	5.5	3.0	4.6	4.5	5.6	5.3	3.8	7.5	5.2	2.9	1.7	1.3	0.8	2.7	3.7	1.5	1.7	3.4	1.0	0.8	2.2	1.8	89.2
FRA	5.7	5.4	7.2	2.1	4.7	8.9	3.4	5.9	4.3	7.5	3.7	4.1	9.4	5.3	2.5	1.4	1.1	0.7	3.0	3.5	1.1	1.2	3.1	0.9	0.6	1.7	1.7	91.1
GBR	4.5	4.9	5.9	2.2	4.5	6.3	8.5	5.6	4.5	5.5	4.5	4.1	7.0	5.4	2.5	1.4	1.1	0.7	2.3	3.7	1.0	1.2	4.9	1.7	0.9	3.4	1.8	91.6
NLD	5.3	5.6	7.2	2.5	4.9	7.3	3.6	8.5	4.5	6.6	3.7	4.0	8.4	5.1	2.4	1.2	1.1	0.7	3.0	3.5	1.2	1.5	3.4	1.0	0.6	1.7	1.7	91.5
SWE	5.4	4.3	5.7	3.2	4.8	5.8	3.3	4.8	10.9	5.3	4.4	3.1	6.8	4.3	2.8	2.0	1.3	0.8	3.1	4.7	1.4	1.4	4.6	1.0	0.9	2.2	1.8	89.1
ESP	5.7	4.7	5.2	1.9	4.0	6.3	2.4	4.4	3.3	13.3	4.4	3.7	10.9	6.0	2.8	1.6	1.6	0.8	3.3	3.4	1.0	1.4	2.8	0.9	0.6	1.8	1.9	86.7
GRC	1.1	0.7	0.6	0.6	0.6	0.5	0.2	0.3	0.3	0.8	79.8	0.9	1.1	1.0	1.6	0.7	0.8	0.4	0.6	0.8	0.5	0.5	1.1	0.4	0.2	2.6	1.4	20.2
IRL	4.8	4.1	4.6	2.4	3.5	4.8	2.5	3.7	2.6	5.2	7.7	16.6	6.1	5.1	3.4	1.8	1.2	1.1	3.5	2.5	1.3	1.4	2.9	0.9	0.8	2.6	3.1	83.4
ITA	6.0	3.9	5.4	1.8	4.0	6.0	2.3	4.3	3.4	8.1	4.9	3.5	17.1	6.0	2.8	1.5	1.4	0.8	3.4	3.1	1.2	1.5	2.6	0.8	0.5	1.3	2.4	82.9
PRT	5.1	3.4	3.8	1.9	3.1	4.0	2.1	3.2	2.3	5.5	7.6	3.5	7.0	19.9	3.1	1.7	1.5	1.1	3.0	3.1	1.3	1.6	3.7	0.8	0.7	2.6	3.6	80.1
BGR	3.6	2.6	1.7	2.1	1.9	1.8	0.8	1.3	1.5	2.9	4.4	2.5	3.1	2.6	41.8	1.8	1.5	1.7	4.0	2.2	2.6	3.5	1.9	0.6	0.8	2.0	2.9	58.2
CZE	4.5	2.9	2.7	2.2	2.3	2.6	1.3	1.8	2.6	3.4	9.3	2.7	4.0	3.1	4.2	19.4	2.3	1.2	5.0	6.8	2.0	2.0	3.6	0.8	1.3	2.7	3.4	80.6
EST	3.2	2.7	2.6	2.0	2.1	2.3	1.0	1.7	1.9	3.3	10.1	2.2	3.8	3.3	5.0	2.8	23.3	2.1	2.9	3.1	2.4	2.5	2.5	0.8	0.8	4.5	5.1	76.7
HRV	4.8	2.7	2.5	2.3	2.1	2.5	1.0	1.8	1.9	3.0	9.9	3.7	4.6	3.8	5.4	2.9	3.3	17.6	3.6	3.5	3.1	3.0	2.8	0.9	1.0	2.6	3.8	82.4
HUN	4.8	2.9	3.1	2.0	2.3	2.9	1.1	2.3	2.3	3.6	6.5	3.3	4.8	3.3	3.2	2.7	1.7	1.4	27.5	5.6	1.9	1.8	2.3	0.6	0.8	2.1	3.3	72.5
POL	4.7	3.2	4.0	2.3	3.2	3.7	2.1	2.9	3.8	3.9	3.7	2.5	4.7	3.2	3.0	3.7	1.2	1.0	5.6	23.9	2.3	1.7	3.1	0.7	0.9	2.6	2.3	76.2
ROU	4.1	3.4	2.8	2.1	2.9	2.5	1.3	2.4	2.2	2.7	6.8	3.0	3.7	2.8	5.8	2.9	2.3	2.2	4.7	4.7	18.8	4.7	2.8	0.8	0.9	2.8	4.1	81.2
SVN	4.1	2.9	2.2	2.0	2.6	2.2	1.1	1.9	1.9	3.1	6.4	3.5	4.3	3.0	7.0	2.1	2.5	2.0	4.0	3.6	4.2	22.8	2.4	0.9	0.8	2.8	3.9	77.2
NOR	4.2	3.3	3.6	2.0	3.2	3.7	3.0	3.2	3.9	3.8	8.5	2.8	4.8	5.5	3.1	2.1	1.6	1.0	2.1	3.2	1.1	1.4	19.4	1.2	0.8	5.2	2.2	80.6
USA	4.5	3.6	4.2	2.0	3.7	4.1	3.7	3.9	3.2	3.8	8.6	3.5	5.3	5.2	3.3	1.5	1.4	1.1	2.1	3.1	1.5	2.0	4.3	10.4	1.7	5.6	2.7	89.6
APAC	4.2	3.8	3.8	2.5	3.4	3.8	3.2	3.3	3.9	4.1	6.3	3.6	5.3	4.7	4.2	2.3	2.0	1.1	3.3	3.8	2.1	1.9	5.0	3.1	9.3	3.8	2.1	90.7
Brent	1.9	1.4	1.4	0.9	1.1	1.3	1.3	1.5	1.1	1.5	13.9	1.1	1.6	2.3	2.0	1.2	1.5	0.9	1.2	1.6	0.9	1.0	3.5	1.5	0.5	47.7	4.4	52.3
TTF	0.9	0.6	0.7	0.7	0.6	0.5	0.2	0.4	0.4	0.4	3.3	0.6	0.8	1.4	2.0	0.6	0.9	1.0	1.4	0.9	1.3	1.1	0.6	0.2	0.2	2.2	76.0	24.0
To	115.1	89.8	101.7	53.3	82.9	102.7	54.4	83.8	76.4	111.6	165.1	80.4	142.8	107.1	87.2	49.5	39.7	28.2	81.5	89.7	42.2	45.3	80.3	25.3	19.7	70.3	69.4	77.6
Net	31.9	0.4	11.7	-31.2	-6.2	11.5	-37.2	-7.7	-12.7	24.9	144.9	-2.9	59.9	27.0	29.1	-31.1	-37.0	-54.2	8.9	13.5	-39.0	-31.9	-0.4	-64.3	-71.1	18.0	45.4	

Table 10.

Volatility spillover of MSCI equity indices of our sample EEA countries, US equity index, and APAC equity index, as well as Brent and TTF one month ahead future prices during the period of 1/1/2016 and 12/31/2019

	AUT	BEL	DEU	DNK	FIN	FRA	GBR	NLD	SWE	ESP	GRC	IRL	ITA	PRT	BGR	CZE	EST	HRV	HUN	LTU	POL	ROU	SVN	NOR	USA	APAC	Brent	TTF	From
AUT	15.9	2.6	4.0	2.0	2.2	3.9	3.3	2.5	2.9	6.2	12.3	3.2	7.4	3.2	1.6	1.4	0.5	0.8	3.0	0.8	5.1	1.8	1.0	3.6	1.0	0.6	3.1	4.1	84.1
BEL	4.6	11.5	4.5	2.6	2.4	4.9	3.3	3.7	3.2	5.8	10.1	4.2	6.8	3.2	1.6	1.4	0.6	0.8	2.5	0.9	4.3	1.8	0.9	3.6	1.2	0.7	3.0	6.1	88.5
DEU	5.2	3.4	8.1	2.5	3.0	6.1	4.3	4.3	4.4	6.8	10.7	4.3	8.1	3.4	0.8	1.1	0.4	0.7	2.5	0.7	4.7	1.1	0.7	3.9	1.2	0.6	2.5	4.4	91.9
DNK	3.5	2.8	3.5	13.4	1.9	3.5	2.7	2.7	2.5	4.4	14.0	3.5	5.5	3.0	1.5	2.0	0.5	1.1	3.0	0.8	4.4	1.4	1.2	4.2	0.9	0.8	4.5	7.0	86.6
FIN	5.1	2.9	4.7	2.7	9.9	4.4	3.2	3.3	4.8	4.9	11.3	4.2	6.3	3.2	1.3	1.5	0.6	1.0	2.5	0.9	4.8	1.4	1.0	4.2	1.3	0.6	3.1	5.1	90.2
FRA	5.0	3.6	5.9	2.3	2.7	7.5	4.7	4.4	4.0	7.5	10.8	4.6	8.7	3.9	0.9	1.1	0.3	0.6	2.4	0.6	4.6	1.3	0.6	4.1	1.1	0.6	2.3	3.9	92.5
GBR	4.9	2.6	4.8	2.1	1.9	5.4	9.0	3.7	3.6	7.4	13.9	4.5	8.2	3.7	0.8	1.2	0.4	0.7	2.6	0.5	4.6	1.2	0.6	4.4	1.1	0.7	2.7	2.9	91.0
NLD	4.4	3.7	5.8	2.6	2.7	6.1	4.6	6.4	3.8	7.0	11.4	4.3	7.7	3.5	0.9	1.2	0.4	0.6	2.4	0.7	4.3	1.5	0.8	3.8	1.4	0.6	2.8	4.8	93.6
SWE	4.8	2.8	5.1	2.5	3.6	4.9	3.9	3.3	9.2	5.2	11.2	4.4	6.8	3.2	0.9	1.3	0.4	0.8	2.5	0.7	4.9	1.3	0.7	5.1	1.3	0.6	3.1	5.9	90.8
ESP	5.2	2.8	4.5	2.0	1.5	5.1	4.2	3.5	2.5	12.7	14.0	3.7	10.4	3.8	1.0	1.4	0.4	0.8	2.9	0.5	4.6	1.4	0.8	3.6	0.8	0.6	2.7	2.7	87.4
GRC	2.7	1.2	1.9	1.8	0.6	2.0	2.1	1.5	1.2	4.2	51.2	1.8	5.2	1.9	0.9	1.4	0.3	0.7	2.2	0.5	3.9	1.0	0.7	2.6	0.4	0.6	3.1	2.4	48.8
IRL	4.2	3.0	4.3	2.6	2.3	4.6	4.2	3.2	3.5	5.9	14.6	11.8	7.1	2.8	1.0	1.2	0.5	0.7	2.5	0.7	4.5	1.4	0.9	3.3	1.1	0.5	2.9	4.8	88.3
ITA	5.2	2.6	4.5	2.0	1.6	4.8	3.7	3.1	2.7	8.7	14.5	3.5	16.8	3.6	0.9	1.2	0.3	0.7	2.4	0.5	4.3	1.2	0.8	3.3	0.9	0.5	3.4	2.7	83.2
PRT	4.1	2.6	3.7	2.4	1.8	4.2	3.5	2.8	2.5	6.4	13.0	2.9	7.0	12.4	1.2	1.4	0.6	0.9	2.9	0.6	5.3	1.3	1.2	4.5	0.9	0.8	4.3	4.9	87.6
BGR	2.7	1.7	1.5	2.4	0.9	1.2	0.8	0.9	0.9	1.9	9.0	1.6	2.7	2.4	30.6	2.0	1.9	1.8	2.6	1.2	4.8	1.8	2.4	1.8	0.9	0.7	5.2	11.7	69.4
CZE	3.5	2.0	2.2	2.4	1.4	2.2	2.0	1.6	1.4	4.3	17.2	2.2	5.6	3.2	2.7	13.0	1.2	1.4	4.0	1.4	6.1	2.2	1.6	3.4	0.8	0.9	5.7	4.6	87.0
EST	2.2	1.7	1.6	2.7	1.1	1.3	1.2	1.3	0.8	2.3	9.4	2.0	2.4	2.0	2.8	1.8	32.0	2.1	3.2	2.0	5.6	2.0	3.2	2.2	1.0	0.7	4.3	5.5	68.0
HRV	3.0	1.8	1.9	2.4	1.4	1.6	1.5	1.2	1.2	2.8	9.7	1.6	3.5	2.9	4.9	1.9	3.0	15.6	3.7	1.6	5.3	2.5	3.0	2.3	0.8	0.7	6.6	11.9	84.4
HUN	3.8	1.8	2.6	2.1	1.2	2.4	2.2	1.8	1.9	4.2	12.8	2.1	4.6	3.1	1.7	2.3	1.0	1.2	20.7	0.9	7.6	2.3	1.4	2.9	0.9	0.8	3.3	6.3	79.3
LTU	3.4	2.3	2.0	2.8	1.7	1.9	1.4	1.5	1.8	2.8	10.6	2.1	3.6	3.0	3.4	2.6	2.7	1.7	3.9	13.8	5.8	2.0	2.8	2.9	1.5	1.0	5.0	10.1	86.2
POL	4.0	2.2	3.1	2.0	1.7	3.0	2.5	2.1	2.6	4.4	11.4	2.8	4.6	3.2	1.6	2.0	1.0	1.0	5.0	1.0	21.2	1.7	1.4	3.5	0.8	0.9	3.2	6.3	78.8
ROU	2.8	1.7	1.3	1.9	0.8	1.6	0.9	1.1	0.6	2.7	7.4	1.4	3.2	2.4	1.6	1.2	1.0	1.3	2.4	1.2	3.8	42.6	1.5	1.8	1.0	0.5	4.1	6.3	57.4
SVN	2.0	1.5	1.5	2.8	1.1	1.3	0.9	1.0	0.6	2.4	8.4	1.7	3.0	3.2	3.4	1.7	2.1	1.7	4.0	1.5	5.2	1.7	23.7	2.3	0.6	0.7	6.8	13.3	76.4
NOR	4.1	2.5	3.8	2.7	2.4	4.0	3.5	2.6	4.0	5.2	13.4	3.2	6.1	3.8	1.3	1.5	0.4	0.7	2.5	0.7	5.0	1.7	0.8	13.2	1.0	0.9	4.8	4.3	86.8
USA	3.0	2.6	3.6	2.0	1.7	3.5	2.6	3.3	2.8	4.0	6.5	3.3	5.7	2.2	1.3	0.8	0.5	0.6	1.7	1.1	3.8	3.1	0.9	2.4	16.0	0.9	6.3	14.1	84.0
APAC	3.2	2.5	3.0	2.5	1.2	3.0	2.6	2.4	1.9	3.9	13.6	2.1	5.4	3.4	2.2	1.7	0.6	1.0	2.6	1.2	5.2	1.8	1.8	4.2	3.0	9.2	6.8	7.9	90.8
Brent	1.3	1.1	1.2	1.7	0.7	1.1	0.8	0.9	0.9	1.8	7.5	1.1	2.9	1.6	1.2	0.9	0.3	0.5	0.7	0.5	2.2	1.6	1.1	2.0	0.8	0.8	53.9	9.2	46.1
TTF	0.3	0.3	0.2	0.5	0.2	0.2	0.1	0.2	0.2	0.2	1.2	0.4	0.3	0.3	0.5	0.1	0.1	0.2	0.5	0.2	0.6	0.4	0.4	0.3	0.2	0.1	2.0	89.8	10.2
To	98.0	62.1	86.4	60.7	45.8	88.1	70.6	63.9	63.0	123.1	300.0	76.6	148.5	78.9	43.7	39.4	21.9	25.8	73.1	23.7	125.2	44.0	34.3	86.0	27.7	18.3	107.5	172.9	78.9
Net	13.9	-26.4	-5.4	-25.9	-44.3	-4.4	-20.5	-29.8	-27.8	35.7	251.3	-11.7	65.4	-8.8	-25.7	-47.6	-46.2	-58.6	-6.2	-62.5	46.4	-13.4	-42.0	-0.9	-56.3	-72.5	61.4	162.7	

Table 11.
Volatility spillover of MSCI equity indices of our sample EEA countries, US equity index, and APAC equity index, as well as Brent and TTF one month ahead future prices during the period of 1/1/2020 and 12/31/2020

	AUT	BEL	DEU	DNK	FIN	FRA	GBR	NLD	SWE	ESP	GRC	IRL	ITA	PRT	BGR	CZE	EST	HRV	HUN	LTU	POL	ROU	SVN	NOR	USA	APAC	Brent	TTF	From
AUT	7.6	5.1	4.4	0.9	2.6	4.7	3.4	2.3	3.6	4.6	3.7	2.4	6.0	2.7	2.6	1.9	0.5	0.8	4.0	1.1	3.6	1.9	1.4	4.8	1.9	0.4	13.1	8.1	92.4
BEL	5.4	7.9	4.7	1.2	2.7	4.9	3.9	2.5	4.1	4.4	4.1	2.6	6.0	2.5	2.2	1.5	0.6	0.8	3.8	1.2	4.1	2.0	1.1	5.1	1.9	0.5	11.7	7.0	92.1
DEU	4.9	5.1	6.3	1.2	3.0	5.3	3.9	3.0	4.6	4.6	3.2	3.0	6.7	3.2	1.9	1.9	0.4	0.7	4.4	1.0	4.3	2.1	1.2	4.9	1.9	0.4	11.1	6.1	93.7
DNK	2.3	4.0	4.4	4.4	2.4	4.0	2.9	3.0	3.9	3.2	4.3	2.5	5.0	3.6	1.6	1.4	0.3	0.7	3.6	1.1	5.5	2.1	1.6	4.4	1.6	0.5	9.6	16.2	95.6
FIN	4.7	4.8	5.0	1.3	4.4	4.7	3.7	2.8	4.6	4.3	4.5	3.0	5.8	3.0	2.2	1.6	0.3	0.7	4.3	1.2	4.4	2.2	1.3	5.4	2.3	0.4	11.1	6.0	95.6
FRA	5.3	5.4	5.4	1.3	2.9	5.9	4.1	2.8	4.5	5.0	3.7	2.8	6.8	3.1	1.9	1.9	0.4	0.7	4.3	0.9	4.2	2.1	1.2	5.1	1.9	0.4	10.7	5.4	94.1
GBR	4.7	5.2	5.0	1.2	2.8	5.1	5.5	2.8	4.3	4.8	4.1	2.9	6.4	3.1	2.0	1.9	0.4	0.6	4.1	0.8	4.1	2.4	1.1	5.0	2.0	0.5	10.7	6.3	94.5
NLD	4.0	4.7	5.3	1.5	3.0	4.7	3.8	4.0	4.4	3.9	3.7	3.0	6.3	3.6	2.2	1.7	0.3	0.7	4.1	1.0	4.1	2.1	1.3	4.9	2.1	0.5	11.2	7.9	96.0
SWE	4.6	5.2	5.3	1.3	3.2	5.1	4.0	2.9	5.6	4.3	3.1	3.1	6.3	3.1	1.9	1.5	0.3	0.8	4.3	1.0	4.2	2.1	1.2	5.6	2.0	0.5	11.8	5.9	94.4
ESP	5.2	4.8	4.8	1.2	2.7	5.0	3.9	2.5	3.8	6.2	4.3	2.3	6.8	3.2	2.3	1.9	0.3	0.7	3.8	0.9	4.4	2.1	1.2	4.7	2.0	0.4	11.9	6.7	93.8
GRC	3.2	4.0	3.4	1.4	2.3	3.4	3.0	2.2	2.3	3.9	14.5	1.9	4.7	2.9	2.6	1.9	0.5	0.7	3.4	0.8	5.0	2.2	1.4	4.9	2.6	0.5	14.2	6.2	85.6
IRL	4.6	4.9	5.0	1.2	3.0	4.7	3.8	2.8	4.2	3.9	4.7	4.9	6.0	3.0	2.4	1.7	0.5	0.8	4.3	1.1	4.1	2.3	1.5	5.0	2.4	0.5	11.2	5.5	95.1
ITA	4.6	4.8	5.0	1.2	2.6	5.0	3.8	2.8	4.1	4.9	3.5	2.6	8.1	3.5	2.5	1.7	0.3	0.8	3.6	0.9	4.1	2.0	1.3	4.9	1.9	0.4	13.5	5.8	92.0
PRT	3.2	3.8	4.7	1.6	2.5	4.3	3.4	3.0	3.8	3.9	4.1	2.6	6.6	6.5	2.8	1.5	0.4	0.8	3.6	1.0	4.6	1.9	1.4	4.9	1.9	0.5	13.4	7.5	93.5
BGR	2.8	3.0	2.7	0.8	1.9	2.7	2.2	2.2	2.2	2.6	5.0	1.9	4.8	3.3	10.2	1.2	0.5	1.1	3.0	1.3	3.2	1.9	1.9	4.1	2.6	0.6	24.3	6.3	89.8
CZE	4.2	3.6	4.2	1.1	2.3	3.9	3.0	2.4	2.9	4.0	5.5	2.4	5.6	3.1	2.9	4.0	0.5	1.0	4.3	1.2	4.3	2.6	1.8	4.4	2.1	0.5	14.2	8.2	96.0
EST	2.9	3.5	2.9	1.3	1.8	3.0	2.2	1.9	2.2	2.9	5.5	1.8	4.6	3.1	4.4	1.4	3.8	1.0	3.4	1.5	3.9	2.5	2.0	4.1	2.3	0.6	19.2	10.5	96.2
HRV	3.4	3.5	3.4	1.3	1.9	3.3	2.3	2.3	2.8	3.2	5.1	2.0	5.6	3.7	4.7	1.5	0.6	2.1	3.5	1.4	4.7	1.8	2.0	4.5	2.2	0.5	18.4	8.4	97.9
HUN	3.9	4.1	4.3	1.2	2.4	4.0	3.2	2.5	3.4	3.6	4.4	2.4	5.5	3.0	3.0	1.9	0.4	0.8	8.5	0.9	5.2	2.6	1.4	4.7	2.2	0.4	13.7	6.6	91.5
LTU	3.6	3.9	3.5	1.0	2.4	3.2	2.1	2.1	2.9	3.1	4.4	2.3	5.2	3.2	4.2	1.6	1.2	1.4	3.8	5.1	4.6	2.3	2.2	4.3	2.4	0.6	17.6	5.9	94.9
POL	3.4	4.0	4.4	1.6	2.5	3.9	3.3	2.5	3.4	4.0	5.0	2.6	5.5	3.4	2.2	1.7	0.4	0.8	4.5	1.1	8.8	2.4	1.4	4.6	1.8	0.5	13.6	6.6	91.2
ROU	3.5	4.3	4.1	1.2	2.4	4.1	3.5	2.3	3.3	3.8	4.5	2.5	5.3	2.9	2.5	2.1	0.6	0.8	4.8	1.3	4.7	5.7	1.7	4.7	2.0	0.6	13.6	7.4	94.3
SVN	3.0	2.8	3.5	1.3	1.9	2.9	2.2	2.1	2.3	2.7	5.1	2.1	4.7	3.1	3.4	1.5	0.6	1.0	3.2	1.3	3.8	2.4	4.7	3.9	2.1	0.5	19.2	12.7	95.3
NOR	4.5	5.1	4.7	1.3	2.9	4.6	3.7	2.7	4.3	4.1	4.2	2.4	6.0	3.1	2.1	1.7	0.4	0.7	4.0	1.0	4.3	2.1	1.2	7.1	2.1	0.5	11.9	7.1	92.9
USA	3.2	4.5	4.1	1.2	2.3	3.8	3.4	2.7	3.1	3.5	6.0	2.5	5.7	3.4	3.4	1.2	0.6	0.8	4.0	1.0	4.0	2.0	1.6	5.3	5.1	0.6	17.0	4.2	95.0
APAC	3.4	4.1	3.8	1.3	2.1	3.7	2.9	2.4	3.3	3.0	4.1	2.2	5.3	3.0	3.3	1.4	0.5	0.9	3.7	1.2	4.0	2.1	1.6	5.1	2.5	1.8	15.0	12.4	98.2
Brent	2.2	2.7	2.4	0.8	1.6	2.6	2.4	1.6	2.2	2.1	3.3	1.8	3.6	1.9	2.8	1.0	0.2	0.4	2.4	0.5	2.1	1.7	1.2	3.7	2.2	0.4	45.9	4.7	54.2
TTF	0.8	0.7	1.4	0.5	0.7	1.0	0.6	0.8	1.0	0.8	0.4	0.6	1.1	0.7	0.5	0.5	0.1	0.2	0.5	0.3	0.6	0.4	0.3	0.8	0.2	0.1	2.5	81.9	18.1
To	101.5	111.6	111.6	32.3	64.4	107.4	84.5	65.7	91.5	98.9	113.3	64.3	147.8	81.1	70.6	42.7	12.0	20.9	100.6	28.2	110.1	56.4	38.5	123.8	54.8	12.6	365.3	201.3	89.8
Net	9.1	19.4	17.9	-63.3	-31.1	13.3	-10.0	-30.3	-3.0	5.1	27.7	-30.8	55.9	-12.3	-19.2	-53.3	-84.2	-77.0	9.1	-66.7	18.9	-37.9	-56.8	30.9	-40.2	-85.6	311.1	183.2	

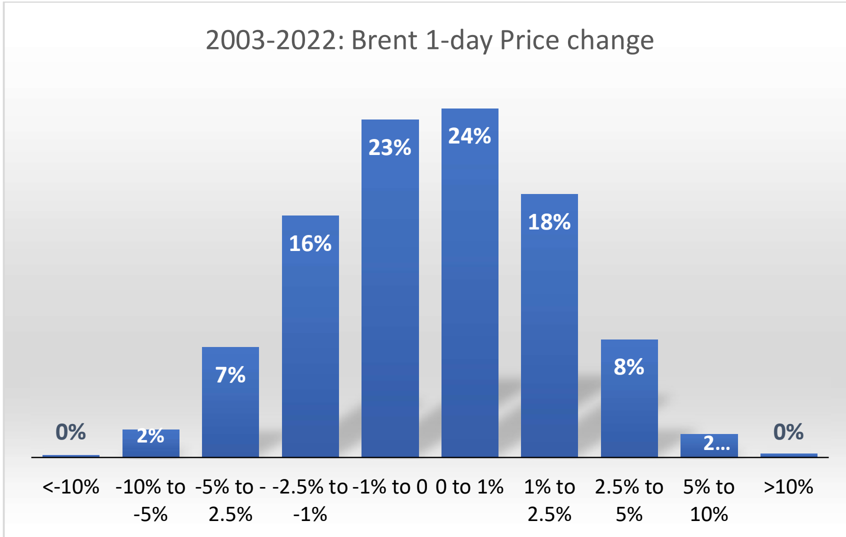
Table 12.

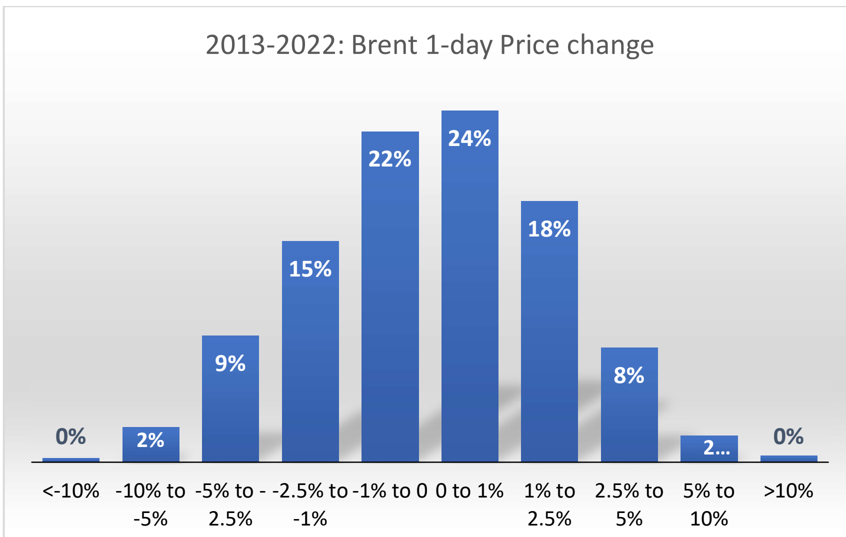
Volatility spillover of MSCI equity indices of our sample EEA countries, US equity index, and APAC equity index, as well as Brent and TTF one month ahead future prices during the period of 1/1/2021 and 12/31/2021

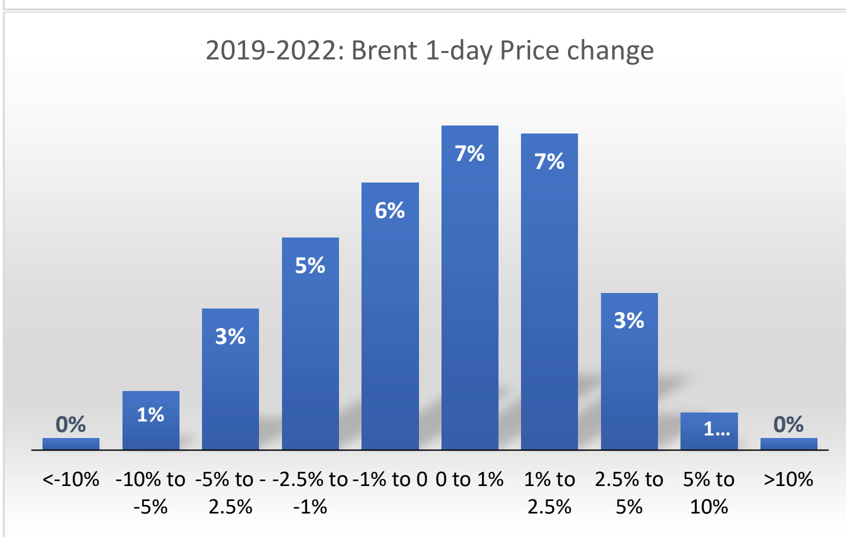
	AUT	BEL	DEU	DNK	FIN	FRA	GBR	NLD	SWE	ESP	GRC	IRL	ITA	PRT	BGR	CZE	EST	HRV	HUN	LTU	POL	ROU	SVN	NOR	USA	APAC	Brent	TTF	From
AUT	16.7	3.1	1.6	1.5	1.9	2.7	1.2	3.0	5.3	4.3	3.6	4.3	3.2	0.2	1.9	0.3	0.4	3.1	0.9	4.2	1.1	0.3	4.4	5.6	0.5	0.5	5.7	18.6	83.4
BEL	6.6	10.6	3.7	1.8	2.7	4.4	2.3	4.7	5.9	5.8	4.1	5.5	4.4	0.4	1.0	0.6	0.5	4.0	1.1	5.3	1.2	0.7	5.3	5.4	0.8	1.0	5.7	4.7	89.4
DEU	4.3	3.7	8.2	2.2	4.3	5.1	5.4	6.8	4.6	3.5	4.1	6.6	2.8	0.4	1.0	0.6	0.6	4.5	0.9	5.9	0.6	0.4	5.0	4.9	1.0	0.6	7.8	4.3	91.8
DNK	4.7	2.6	3.1	20.1	3.2	2.2	5.2	4.5	3.2	4.4	2.7	2.9	3.6	0.5	0.9	0.8	0.4	4.0	0.8	7.8	1.2	0.7	2.4	3.3	1.5	0.7	7.5	5.3	79.9
FIN	5.4	3.1	4.3	2.8	10.5	3.8	4.2	6.9	3.9	3.8	3.2	5.3	4.6	0.6	1.4	0.7	0.7	4.4	1.6	6.7	1.0	1.0	4.0	5.2	1.3	0.9	6.0	2.7	89.5
FRA	6.7	4.4	5.5	1.5	4.1	7.5	3.5	5.9	6.4	4.1	3.8	7.3	3.2	0.6	1.4	0.7	0.4	4.0	1.0	5.4	0.7	0.6	5.4	5.7	1.1	0.6	7.5	1.4	92.6
GBR	4.4	2.4	4.8	3.8	4.3	3.2	15.4	6.4	3.5	3.8	2.7	3.9	3.3	0.6	1.1	1.1	0.5	4.3	0.8	5.1	0.5	0.7	3.6	4.1	1.7	0.8	8.5	4.8	84.6
NLD	5.3	3.1	4.7	2.1	4.3	3.8	4.4	13.0	3.4	3.6	3.8	4.7	3.8	0.6	1.1	0.8	0.4	4.6	1.0	5.3	1.0	1.0	4.5	6.3	0.8	0.8	7.8	4.0	87.0
SWE	9.1	4.4	3.5	1.2	2.6	4.8	2.2	3.4	11.6	5.0	3.8	6.8	3.9	0.6	1.6	0.8	0.5	4.0	0.8	4.6	0.8	0.6	5.3	5.1	0.9	0.5	6.8	5.0	88.4
ESP	6.4	3.8	2.4	2.2	2.1	2.8	3.2	3.5	5.1	18.0	2.5	4.7	4.2	0.3	1.7	0.5	0.5	5.7	0.7	4.0	1.9	0.8	4.0	4.6	0.9	0.8	6.2	6.8	82.0
GRC	6.2	3.4	3.3	2.1	2.9	2.7	2.7	5.3	3.9	4.1	14.8	5.0	5.2	0.7	1.6	0.8	0.6	3.2	1.2	5.1	0.9	0.8	5.2	5.5	0.9	0.8	6.1	5.3	85.2
IRL	6.8	3.9	5.0	1.1	3.5	5.2	2.5	5.1	6.4	4.4	4.5	11.6	2.6	0.4	1.2	0.8	0.4	3.2	0.8	4.5	0.9	0.3	5.4	5.9	0.7	0.5	7.8	4.8	88.4
ITA	4.6	3.4	2.1	2.3	3.1	2.2	2.0	3.7	4.2	6.0	4.1	3.2	24.2	1.0	1.4	1.1	0.9	2.4	1.8	4.8	1.4	0.8	4.0	4.3	0.6	1.0	4.3	5.2	75.8
PRT	3.1	0.9	0.6	1.8	0.8	0.9	1.3	2.2	1.0	4.1	2.7	1.2	3.0	45.8	0.8	1.2	0.4	1.5	1.7	2.7	1.6	1.4	1.0	1.8	0.6	0.3	3.6	12.1	54.2
BGR	6.6	1.4	1.5	2.2	2.0	1.6	2.1	2.5	2.6	4.5	3.3	2.5	3.1	1.5	17.1	0.6	0.5	5.4	1.0	3.7	1.3	0.7	1.8	4.2	0.8	0.9	8.4	16.6	82.9
CZE	1.0	0.6	0.7	0.4	0.4	1.0	0.9	2.8	1.0	2.2	0.5	1.0	1.5	1.3	0.6	37.3	0.4	1.5	2.2	2.1	1.2	0.3	0.7	2.3	0.1	2.0	21.3	12.8	62.7
EST	4.3	2.3	1.5	2.4	3.1	1.0	1.3	2.6	2.5	6.3	3.6	2.9	6.9	1.0	1.4	1.3	7.1	4.6	1.7	5.2	2.0	0.6	2.0	2.6	0.6	0.8	4.7	23.7	92.9
HRV	5.8	1.6	2.0	2.1	1.7	1.7	2.3	2.5	3.6	6.0	2.5	2.8	2.9	0.9	1.8	0.4	0.8	23.2	0.9	4.5	1.5	0.4	2.4	3.0	0.8	0.6	8.5	12.9	76.8
HUN	3.2	2.2	2.0	1.0	3.5	2.4	1.0	4.0	1.7	4.9	6.3	3.2	4.1	2.0	0.9	5.2	0.9	2.4	21.7	7.0	1.7	0.9	2.6	4.0	0.2	0.7	6.3	4.0	78.3
LTU	5.2	2.5	2.7	1.9	2.1	2.1	1.5	3.2	3.1	3.5	3.0	3.3	2.2	0.3	0.8	1.1	0.4	3.5	0.8	19.9	1.6	0.9	3.7	3.8	0.5	0.6	9.1	17.1	80.1
POL	3.0	1.4	0.8	1.8	1.3	0.8	1.1	2.4	1.3	4.4	2.1	1.8	2.7	2.5	0.8	1.1	0.5	2.9	1.2	3.3	11.4	1.8	1.9	3.1	0.3	0.6	5.3	38.6	88.7
ROU	3.3	1.4	1.2	2.4	3.4	1.4	1.5	4.5	1.8	5.0	3.1	1.9	5.1	1.5	1.7	2.6	0.9	3.8	2.9	5.3	3.5	20.7	3.9	5.9	0.5	1.1	6.3	3.8	79.3
SVN	7.3	3.7	3.9	1.8	3.2	4.0	2.8	5.2	5.1	4.0	4.9	5.6	4.0	0.5	1.3	0.4	0.4	2.8	0.8	5.8	0.8	0.8	9.9	7.6	0.9	0.8	6.4	5.7	90.1
NOR	6.4	2.8	2.5	1.1	2.3	2.8	1.6	4.7	3.6	4.1	2.7	4.1	3.2	0.6	1.5	0.6	0.4	3.4	1.2	4.7	1.4	0.9	5.4	18.9	0.8	1.2	10.9	6.5	81.1
USA	5.0	3.0	3.4	3.1	3.5	3.0	4.5	4.3	5.0	5.0	3.2	3.3	3.3	1.8	1.3	0.6	0.4	6.5	0.6	7.7	0.6	0.8	4.3	4.5	7.8	1.5	9.1	3.1	92.2
APAC	5.1	2.9	2.5	2.1	2.5	2.4	3.4	4.3	4.4	3.9	3.7	3.4	2.9	1.7	1.1	1.1	0.4	3.5	0.6	5.9	0.9	1.1	4.6	4.9	2.3	7.4	10.9	10.1	92.6
Brent	3.2	1.2	1.6	1.2	0.9	1.5	1.2	1.9	2.5	2.5	1.6	2.4	1.6	0.5	0.8	0.7	0.2	3.6	0.4	3.2	0.9	0.1	2.1	3.7	0.6	1.4	53.4	5.3	46.6
TTF	0.7	0.2	0.1	0.5	0.1	0.1	0.2	0.1	0.2	0.2	0.5	0.2	0.1	0.2	0.3	0.1	0.0	0.5	0.2	0.4	0.2	0.1	0.2	0.3	0.1	0.0	0.3	94.0	6.1
To	133.3	69.6	70.8	50.0	69.5	69.7	65.0	106.3	95.2	113.3	86.0	99.7	91.5	22.9	32.2	26.5	13.1	97.2	29.2	130.0	32.2	19.2	95.1	117.6	21.6	21.9	198.6	245.2	79.4
Net	49.9	-19.8	-21.0	-30.0	-20.0	-22.9	-19.6	19.2	6.8	31.3	0.8	11.3	15.7	-31.3	-50.7	-36.2	-79.8	20.4	-49.1	50.0	-56.4	-60.1	5.0	36.6	-70.6	-70.7	152.0	239.1	

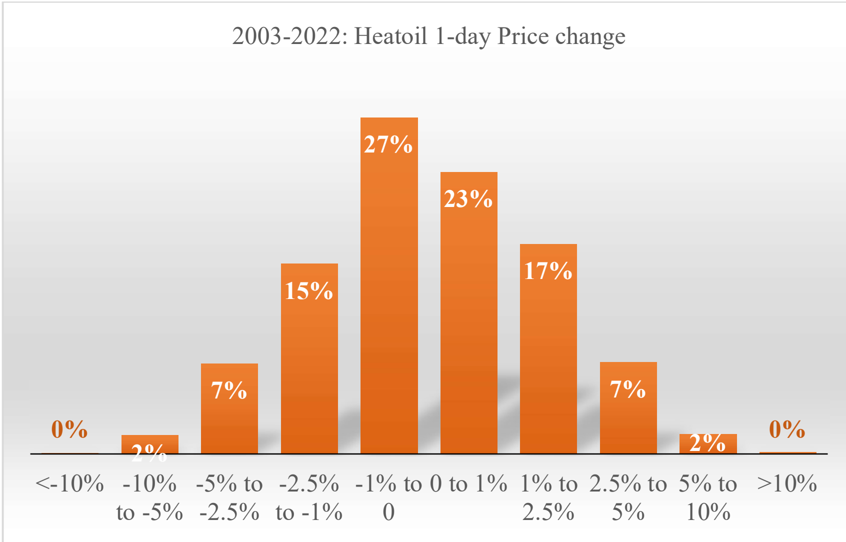
Table 13.
Volatility spillover of MSCI equity indices of our sample EEA countries, US equity index, and APAC equity index, as well as Brent and TTF one month ahead future prices during the period of 1/1/2022 and 12/31/2022

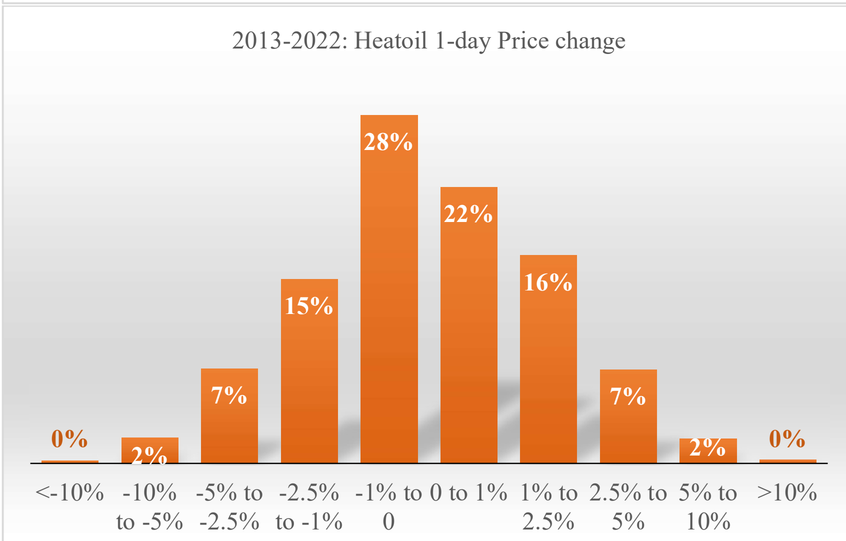
	AUT	BEL	DEU	DNK	FIN	FRA	GBR	NLD	SWE	ESP	GRC	IRL	ITA	PRT	BGR	CZE	EST	HRV	HUN	LTU	POL	ROU	SVN	NOR	USA	APAC	Brent	TTF	From
AUT	10.9	2.0	3.6	0.7	2.7	3.0	3.0	3.6	2.4	2.4	3.1	4.1	0.9	0.9	2.3	0.6	0.7	8.7	1.9	8.9	1.1	2.2	1.9	1.6	0.7	0.2	0.9	25.3	89.1
BEL	6.3	3.9	4.7	1.5	3.2	3.9	4.8	4.9	3.2	2.4	4.3	5.0	1.0	0.8	2.5	0.9	0.6	6.1	1.5	8.7	0.9	1.4	2.5	1.2	1.6	0.2	0.5	21.7	96.1
DEU	6.6	2.6	6.2	1.1	3.1	4.5	5.8	5.5	3.4	2.3	5.1	5.6	0.9	0.8	1.9	0.9	0.6	6.5	1.4	8.7	1.2	1.6	2.4	1.3	1.3	0.1	0.5	18.2	93.8
DNK	3.5	2.7	3.6	14.5	3.2	3.6	6.2	7.2	2.5	1.5	5.5	3.9	1.6	1.6	1.4	0.5	0.8	3.4	1.0	7.3	0.8	0.6	2.1	3.3	3.6	0.6	1.1	12.5	85.5
FIN	6.4	2.3	4.2	1.3	5.2	3.4	4.1	5.8	2.8	2.2	4.1	4.5	1.0	0.7	2.4	0.8	0.8	6.5	1.4	8.7	1.0	1.6	2.3	2.1	1.2	0.3	0.5	22.5	94.8
FRA	6.1	2.5	5.2	1.3	2.9	4.9	5.5	4.9	3.3	2.3	4.8	5.4	0.9	0.8	1.8	0.8	0.7	7.3	1.4	8.4	1.1	1.6	2.5	1.2	1.3	0.2	0.5	20.4	95.1
GBR	5.3	2.8	5.9	1.8	3.2	4.8	10.6	6.7	3.0	2.2	5.7	5.3	1.1	0.9	1.9	1.0	0.7	6.9	1.3	7.7	0.9	1.2	2.4	1.3	2.6	0.3	0.5	12.1	89.4
NLD	5.4	2.6	5.3	2.2	4.0	4.1	6.6	9.9	2.9	2.3	5.6	4.9	0.8	1.0	1.6	0.8	0.7	4.9	1.3	9.0	0.9	1.1	2.4	2.2	2.2	0.3	0.5	14.5	90.1
SWE	6.3	2.6	4.8	1.1	2.9	4.0	4.1	4.4	5.1	2.4	4.4	5.8	1.0	0.8	2.2	0.7	0.7	7.1	1.5	9.2	1.2	1.6	2.9	1.8	1.3	0.2	0.4	19.8	94.9
ESP	6.0	1.7	2.9	0.7	2.4	2.5	2.9	3.4	2.3	8.5	3.0	3.4	0.6	1.2	2.5	0.9	0.7	8.9	1.7	8.5	1.0	2.1	1.7	1.8	0.9	0.3	0.9	26.7	91.5
GRC	5.6	2.2	4.7	1.7	2.9	4.0	5.6	5.5	3.0	2.3	8.3	4.5	0.6	0.9	1.5	0.7	0.8	8.0	1.5	8.3	0.9	1.4	2.3	1.5	1.8	0.2	0.6	18.8	91.7
IRL	6.7	2.5	5.1	1.0	3.0	4.2	4.6	4.6	3.7	2.2	4.3	7.2	0.9	0.7	2.2	0.8	0.6	6.1	1.4	8.6	1.0	1.5	2.7	1.6	1.1	0.1	0.4	21.3	92.8
ITA	5.8	2.4	3.7	2.5	3.4	3.1	3.8	4.5	3.2	1.5	3.2	4.5	8.1	1.4	2.3	0.6	1.3	4.9	1.7	7.4	1.5	1.5	3.2	3.6	3.1	0.3	0.7	17.0	91.9
PRT	4.7	1.0	2.3	1.2	1.7	1.9	2.9	3.9	1.5	2.4	3.0	2.4	0.7	7.6	1.9	1.2	0.9	7.2	2.2	9.0	1.0	2.1	1.2	1.4	1.4	0.3	1.5	31.8	92.4
BGR	4.9	1.8	2.8	0.7	3.2	2.1	2.8	3.2	2.1	1.5	2.5	3.1	0.5	0.8	17.4	0.9	1.1	9.3	1.7	10.5	1.6	2.4	1.9	1.4	1.1	0.3	1.9	16.4	82.7
CZE	4.6	1.3	2.5	0.7	3.0	1.9	2.3	3.4	1.6	1.9	2.0	2.4	1.0	1.2	2.5	7.1	0.7	6.5	2.2	6.6	1.3	2.6	1.0	0.9	1.0	0.3	1.1	36.5	92.9
EST	4.2	1.1	2.7	0.9	2.4	2.6	2.5	3.2	2.0	1.5	2.8	3.0	0.7	1.4	2.7	0.4	4.6	8.6	1.8	8.8	2.2	1.8	2.0	1.9	2.4	0.4	0.5	30.9	95.4
HRV	6.7	1.3	2.5	0.4	2.1	2.1	2.4	2.7	1.7	2.6	2.7	2.4	0.6	1.0	2.9	0.5	0.9	24.5	2.4	10.2	1.0	2.8	1.2	1.0	0.8	0.2	0.6	20.0	75.5
HUN	5.7	1.4	2.7	0.7	2.1	2.1	2.5	3.3	1.9	2.4	3.2	3.0	0.6	1.2	2.5	1.0	0.8	10.5	3.8	9.4	1.1	2.9	1.9	1.1	0.8	0.2	0.5	30.9	96.2
LTU	5.7	1.8	3.6	0.9	2.7	3.0	3.2	4.3	2.6	2.7	3.9	3.8	0.6	1.0	2.7	0.6	0.8	8.5	1.8	16.9	1.2	2.2	2.2	1.8	0.9	0.3	0.7	19.8	83.1
POL	4.9	1.1	2.5	0.5	2.2	1.9	1.9	2.8	1.9	1.5	1.9	2.4	0.6	0.9	2.0	1.0	1.0	8.6	1.6	7.0	7.5	2.5	1.0	0.7	1.2	0.2	0.5	38.4	92.5
ROU	7.5	1.4	3.0	0.6	2.8	2.3	2.8	4.0	1.8	2.7	3.0	2.8	0.8	1.2	3.1	0.6	0.8	7.7	2.3	11.2	1.6	11.4	1.9	1.5	1.5	0.6	1.1	18.0	88.7
SVN	6.3	2.4	4.3	1.1	3.2	4.0	4.2	4.5	3.8	2.4	4.6	5.5	1.3	0.6	2.3	0.6	0.9	4.4	1.8	9.3	0.7	1.7	5.4	3.5	1.6	0.2	0.4	19.2	94.6
NOR	5.7	1.2	2.6	2.0	3.8	2.2	2.1	4.5	2.8	2.4	2.7	4.4	1.8	0.8	2.8	0.5	1.1	2.6	1.3	8.1	0.5	1.1	4.3	20.0	1.8	0.6	1.7	14.7	80.1
USA	3.2	1.9	4.0	1.7	2.2	3.3	7.1	5.8	2.5	0.6	4.1	3.9	0.8	1.3	2.1	0.4	1.3	5.6	1.2	7.5	1.6	0.9	2.3	2.5	18.7	0.5	1.4	11.9	81.3
APAC	4.0	1.3	3.3	1.1	2.8	2.7	5.1	4.5	2.0	1.4	3.0	2.9	1.1	1.6	2.3	0.6	1.3	5.5	1.4	6.9	2.4	2.5	1.6	2.4	6.2	3.8	1.9	24.4	96.2
Brent	3.6	0.5	1.2	0.3	1.5	1.1	1.2	2.0	0.8	1.3	0.9	1.5	0.3	0.9	3.1	0.7	0.8	4.9	1.0	4.3	1.4	1.6	0.6	1.7	1.0	0.2	17.8	43.9	82.2
TTF	1.7	0.4	0.7	0.3	0.8	0.7	0.7	1.2	0.6	0.6	0.7	0.9	0.3	0.3	0.5	0.2	0.3	2.3	0.7	3.3	0.5	1.0	0.5	0.3	0.4	0.1	0.2	80.2	19.8
To	143.3	48.7	94.4	29.9	73.3	78.8	100.6	114.2	65.0	53.6	94.0	101.3	22.7	26.6	59.7	19.1	22.3	177.6	42.2	221.7	31.3	47.3	54.5	46.4	44.8	7.7	21.8	607.5	87.5
Net	54.2	-47.4	0.6	-55.5	-21.5	-16.3	11.1	24.1	-29.9	-37.9	2.2	8.5	-69.2	-65.8	-22.9	-73.8	-73.1	102.2	-54.1	138.6	-61.2	-41.3	-40.1	-33.6	-36.5	-88.4	-60.4	587.7	0.0

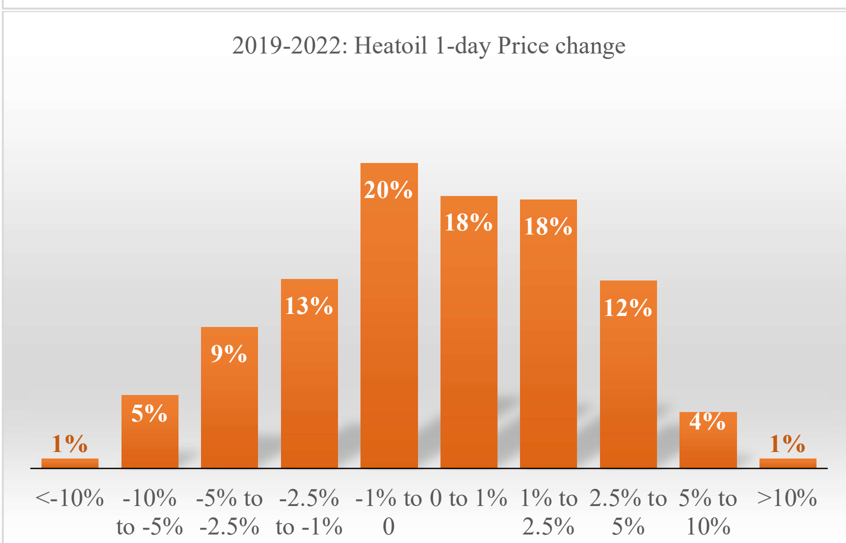

2003-2022: Brent 1-day Price change
0%
2%
7%
16%
23%
24%
18%
8%
2...
0%
<-10%
-10% to -5%
-5% to - 2.5%
-2.5% to -1%
-1% to 0
0 to 1%
1% to 2.5%
2.5% to 5%
5% to 10%
>10%

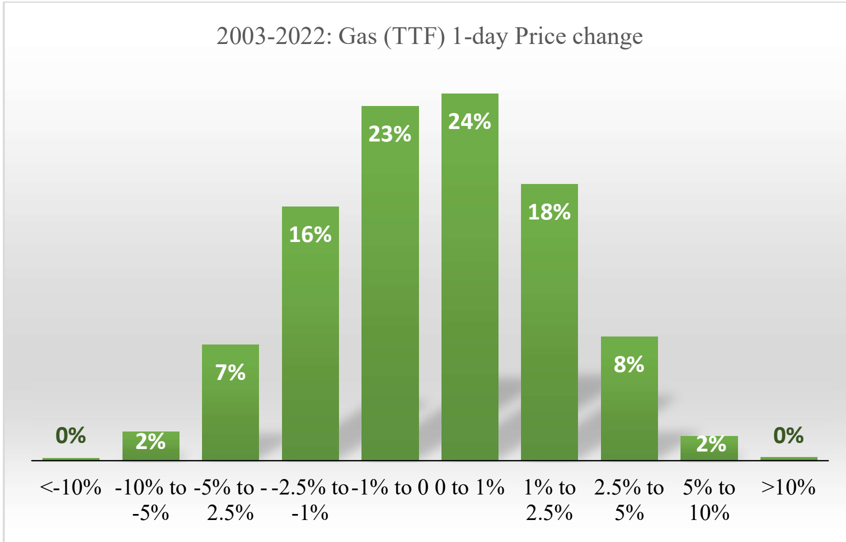

2013-2022: Brent 1-day Price change
0%
2%
9%
15%
22%
24%
18%
8%
2...
0%
<-10%
-10% to -5%
-5% to - 2.5%
-2.5% to -1%
-1% to 0
0 to 1%
1% to 2.5%
2.5% to 5%
5% to 10%
>10%

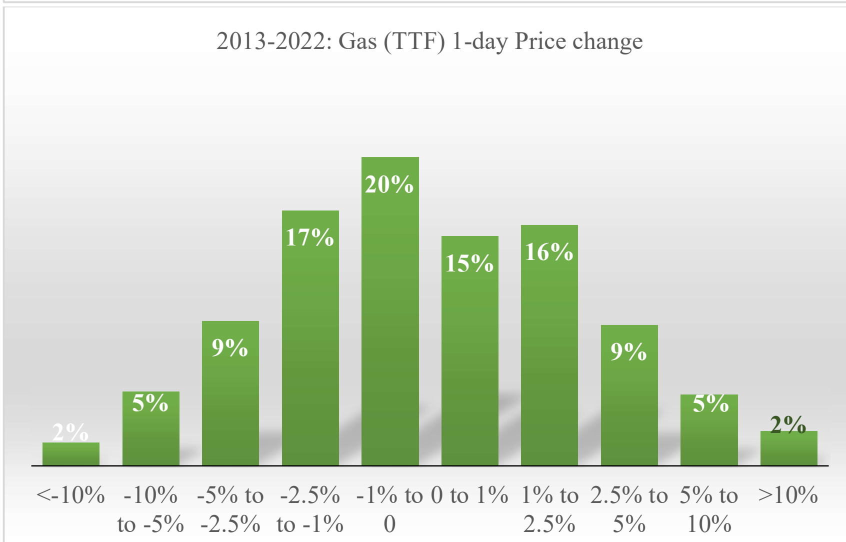

2019-2022: Brent 1-day Price change
0%
1%
3%
5%
6%
7%
7%
3%
1...
0%
<-10%
-10% to -5%
-5% to - 2.5%
-2.5% to -1%
-1% to 0
0 to 1%
1% to 2.5%
2.5% to 5%
5% to 10%
>10%

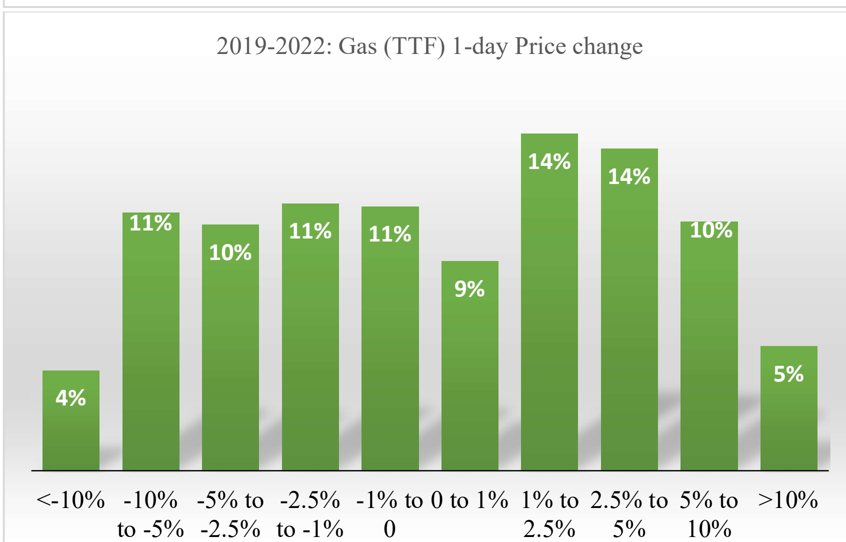

2003-2022: Heatoil 1-day Price change
0%
2%
7%
15%
27%
23%
17%
7%
2%
0%
<-10%
-10% to -5%
-5% to -2.5%
-2.5% to -1%
-1% to 0
0 to 1%
1% to 2.5%
2.5% to 5%
5% to 10%
>10%


2013-2022: Heatoil 1-day Price change
0%
2%
7%
15%
28%
22%
16%
7%
2%
0%
<-10%
-10% to -5%
-5% to -2.5%
-2.5% to -1%
-1% to 0
0 to 1%
1% to 2.5%
2.5% to 5%
5% to 10%
>10%


2019-2022: Heatoil 1-day Price change
1%
5%
9%
13%
20%
18%
18%
12%
4%
1%
<-10%
-10% to -5%
-5% to -2.5%
-2.5% to -1%
-1% to 0
0 to 1%
1% to 2.5%
2.5% to 5%
5% to 10%
>10%


2003-2022: Gas (TTF) 1-day Price change
0%
2%
7%
16%
23%
24%
18%
8%
2%
0%
<-10%
-10% to -5%
-5% to -2.5%
-2.5% to -1%
-1% to 0
0 to 1%
1% to 2.5%
2.5% to 5%
5% to 10%
>10%


2013-2022: Gas (TTF) 1-day Price change
2%
5%
9%
17%
20%
15%
16%
9%
5%
2%
<-10%
-10% to -5%
-5% to -2.5%
-2.5% to -1%
-1% to 0
0 to 1%
1% to 2.5%
2.5% to 5%
5% to 10%
>10%


2019-2022: Gas (TTF) 1-day Price change
4%
11%
10%
11%
11%
9%
14%
14%
10%
5%
<-10%
-10% to -5%
-5% to -2.5%
-2.5% to -1%
-1% to 0
0 to 1%
1% to 2.5%
2.5% to 5%
5% to 10%
>10%

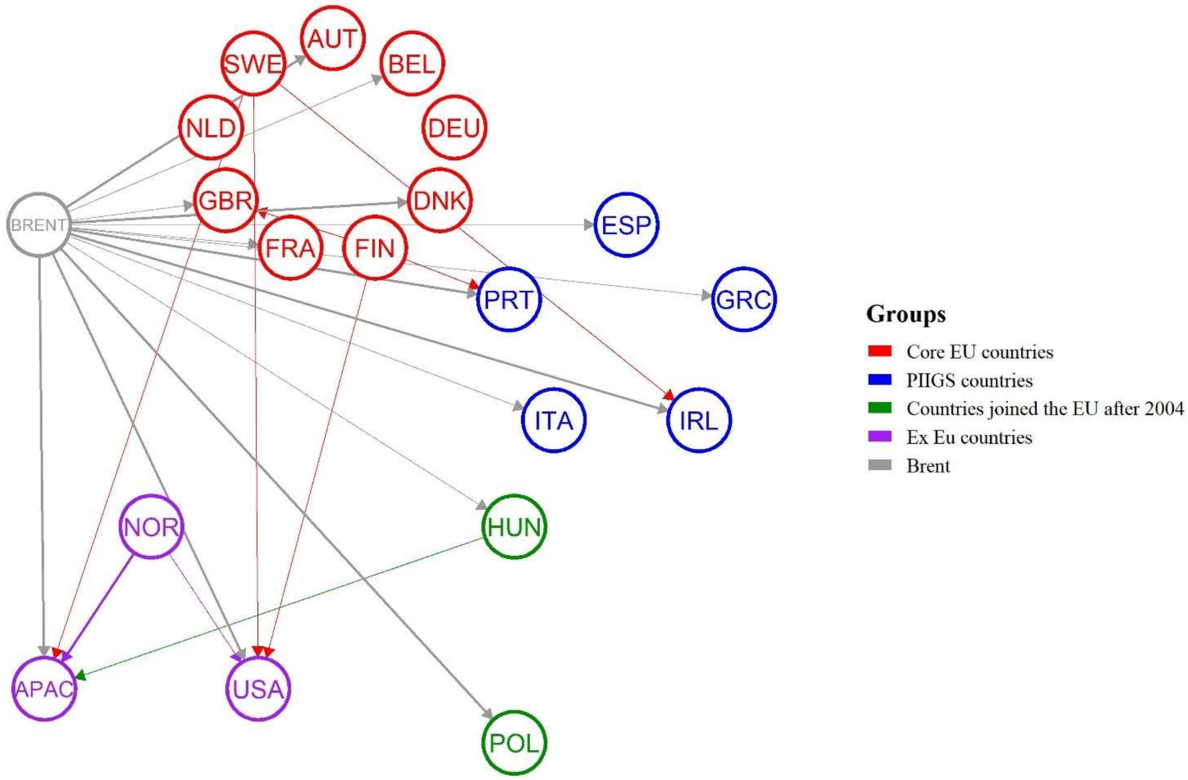
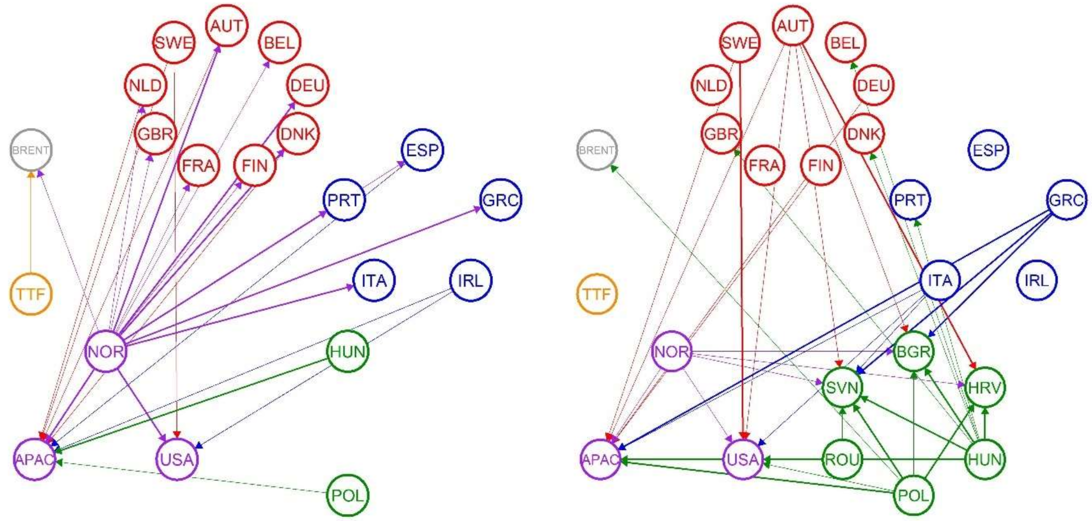
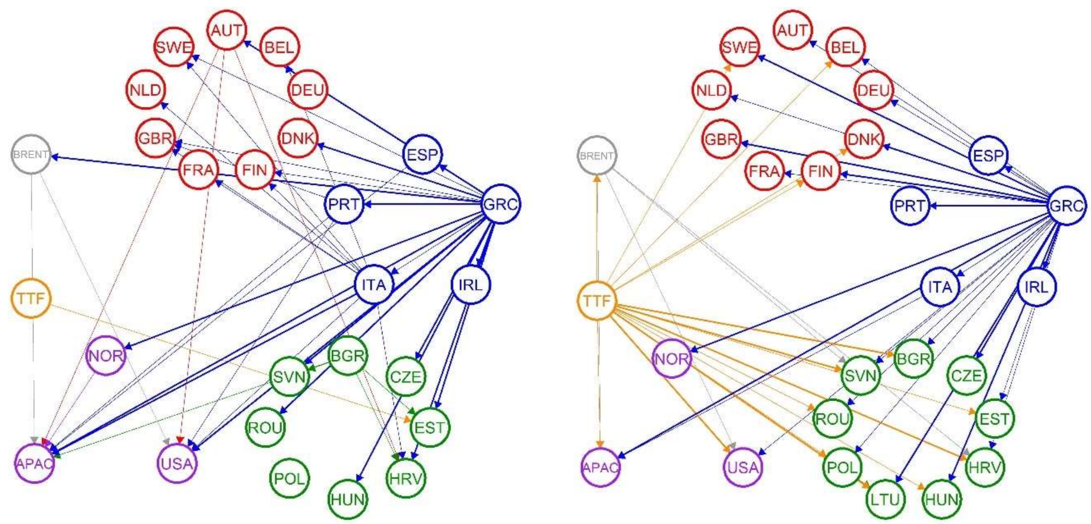


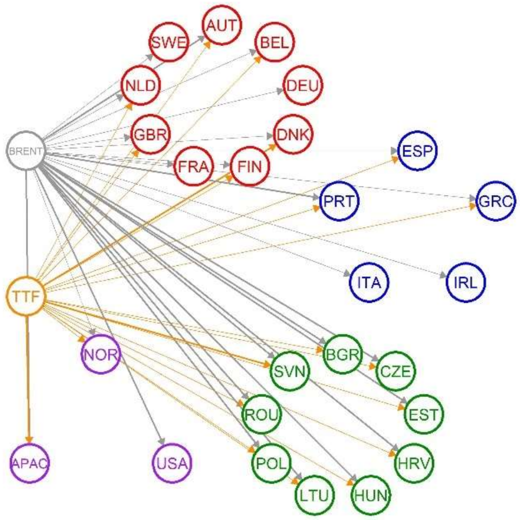
Fig. 3. Static volatility interconnectedness network during the period of 1/1/2004 and 12/31/2004 Note: An arrow between two nodes indicates the direction of the spillover, and the color of the arrow indicates the industry sector of the asset from which it originates from. Thinner lines represent the strongest 5% of connections, while thicker lines show the uppermost 1% of connections. For the figure, we use Lag=3 and H=10 model inputs. The figure is prepared using the Diebold and Yilmaz (2014) Spillover index method.



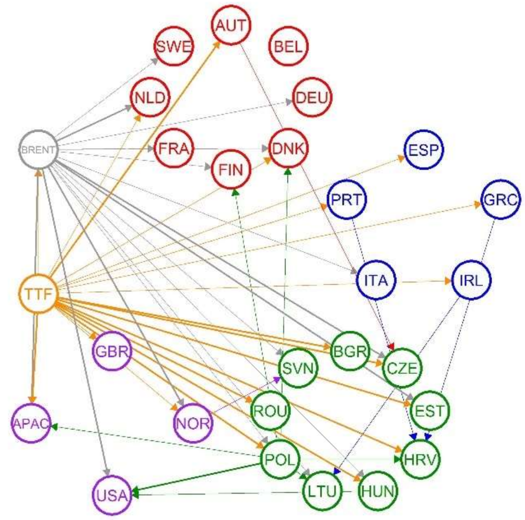
a) 2005 - 2008 b) 2009 - 2012



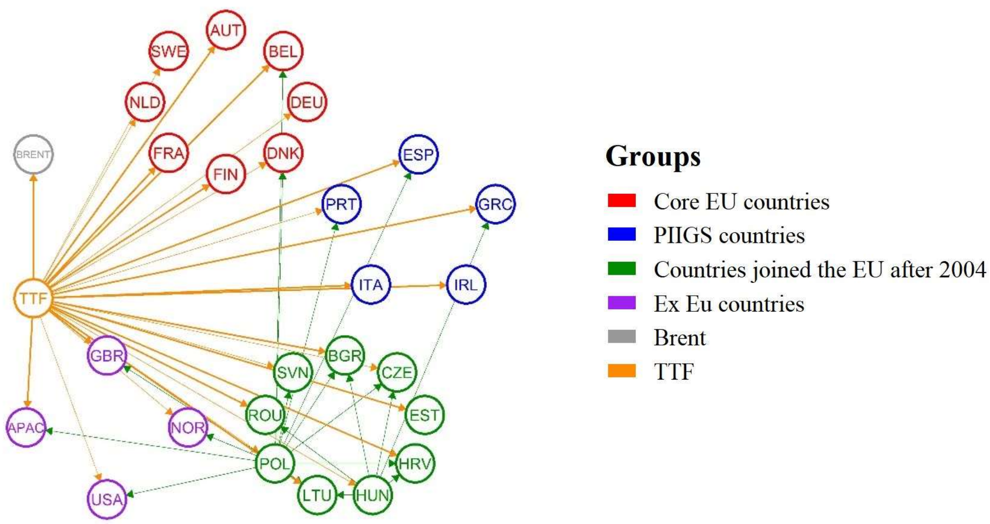
c) 2013 - 2015 d) 2016-2019



e) 2020



f) 2021



g) 2022

Fig. 3. Static volatility interconnectedness network during various periods.

Note: An arrow between two nodes indicates the direction of the spillover, and the color of the arrow indicates the industry sector of the asset from which it originates from. Thinner lines represent the strongest 5% of connections, while thicker lines show the uppermost 1% of connections. For the figure, we use Lag=3 and H=10 model inputs. The figure is prepared using the Diebold and Yilmaz (2014) Spillover index method.

Appendix

A. Table 1
Pearson Pairwise Correlation Analysis of Key Variables with Statistical Significance

+	lag1dret	ret1d	leadret5d	lag5dret	mscivol5d	apret1d	aplag1ret	apret5dlead	ap5dlagret	usalag1dret	usalag5dret
lag1dret	1.0000										
ret1d	0.0215	1.0000									
	0.0000										
leadret5d	-0.0256	-0.0036	1.0000								
	0.0000	0.2369									
lag5dret	0.4499	0.4428	-0.0251	1.0000							
	0.0000	0.0000	0.0000								
mscivol5d	-0.1066	-0.1045	-0.1360	-0.1974	1.0000						
	0.0000	0.0000	0.0000	0.0000							
apret1d	0.2907	0.4055	-0.0209	0.3234	-0.0946	1					
	0.0000	0.0000	0.0000	0.0000	0.0000						
aplag1ret	0.4054	-0.0014	-0.0258	0.3237	-0.0880	0.0426	1.0000				
	0.0000	0.6398	0.0000	0.0000	0.0000	0.0000					
apret5dlead	0.0176	0.1634	0.6213	0.0930	-0.1448	0.0147	-0.0162	1.0000			
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000				
ap5dlagret	0.2902	0.1648	-0.0342	0.6211	-0.1607	0.4418	0.4662	-0.0162	1.0000		
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000			
usalag1dret	0.4106	0.2082	-0.0284	0.2663	-0.0805	0.5205	0.2189	0.0080	0.3045	1.0000	
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0076	0.0000		
usalag5dret	0.2752	0.2862	0.0186	0.6063	-0.1767	0.3746	0.3786	0.1094	0.6810	0.3779	1.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	

A. Table 1 continued

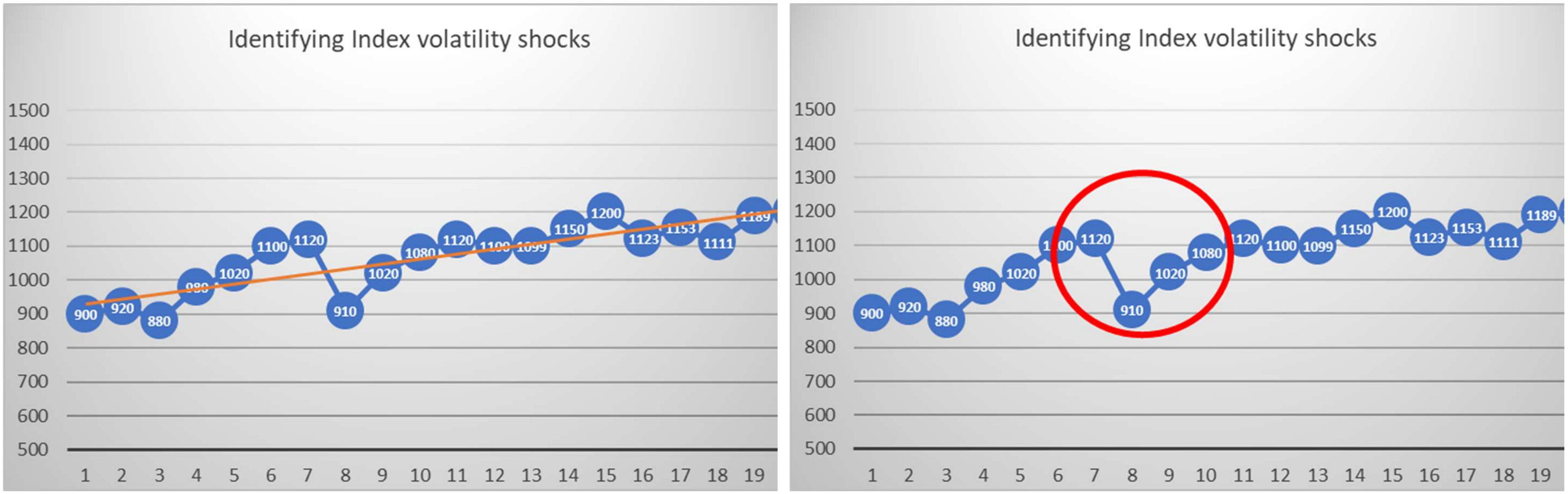
	ret1d	leadret5d	mscivol5d	brent_1dlagret	brent_5dlagret	ttf_1dlagret	ttf_5dlagret	totengdep2
ret1d	1.0000							
leadret5d	-0.0036	1.0000						
	0.2369							
mscivol5d	-0.1045	-0.1360	1.0000					
	0.0000	0.0000						
Brentlag1dRet	0.0392	0.0060	-0.0675	1.0000				
	0.0000	0.0475	0.0000					
Brentlag5dRet	0.1447	0.0214	-0.1204	0.4331	1.0000			
	0.0000	0.0000	0.0000	0.0000				
TTFlag1dRet	-0.0022	-0.0174	0.0028	0.1178	0.0572	1.0000		
	0.4793	0.0000	0.3679	0.0000	0.0000			
TTFlag5dRet	-0.0250	-0.0186	0.0071	0.0492	0.1259	0.4296	1.0000	
	0.0000	0.0000	0.0229	0.0000	0.0000	0.0000		
EngDept	-0.0048	-0.0102	0.0018	0.0004	0.0011	0.0018	0.0034	
	0.1073	0.0007	0.5572	0.8874	0.7181	0.5714	0.2724	1.0000

B. Table 2. Countries energy dependence from Eurostat

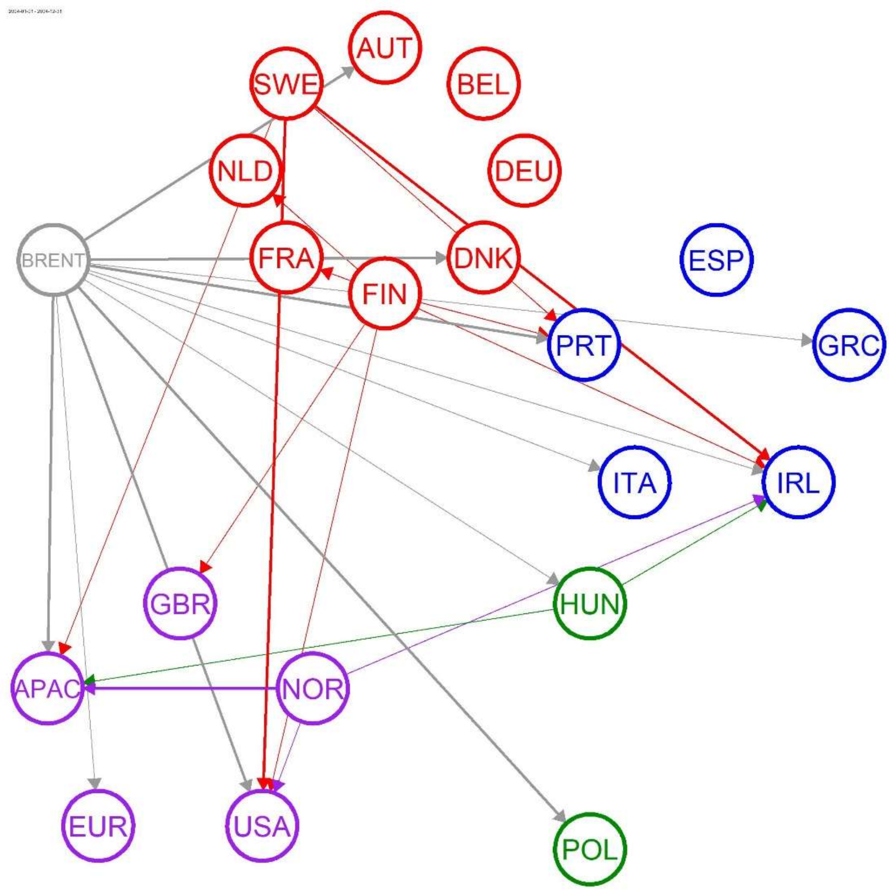
	2010	2012	2014	2016	2018	2020	2010	2012	2014	2016	2018	2020
	(terajoules)						(gigajoules per capita)					
EU	38 620 472.5	36 581 771.1	33 493 699.7	35 338 521.0	35 453 549.1	31 723 849.5	87.642	83.036	75.626	79.448	79.455	70.920
Belgium	2 244 919.0	1 940 718.2	2 056 342.3	2 000 888.0	2 192 366.4	1 627 327.6	207.1	175.2	183.9	176.9	192.3	141.2
Bulgaria	329 547.7	304 653.9	262 294.6	286 326.8	242 145.9	216 376.5	44.4	41.6	36.2	40.0	34.3	31.1
Czechia	497 973.8	454 552.5	532 826.2	551 784.4	642 492.9	616 146.0	47.6	43.3	50.7	52.3	60.6	57.6
Denmark	- 176 561.6	- 52 555.2	49 455.3	74 594.3	87 289.9	299 620.4	- 31.9	- 9.4	8.8	13.1	15.1	51.5
Germany	8 705 584.2	8 391 354.1	8 347 526.1	8 268 339.5	7 274 032.7	7 628 898.6	106.4	104.5	103.4	100.6	87.9	91.7
Estonia	44 656.4	85 686.1	47 447.1	24 681.8	22 220.9	32 913.8	33.5	64.7	36.1	18.8	16.8	24.8
Ireland	579 368.9	503 035.0	495 325.9	434 124.7	418 327.4	416 504.0	127.3	109.6	106.8	91.9	86.6	83.9
Greece	921 649.1	935 016.2	754 838.4	857 464.3	816 194.7	793 415.8	82.9	84.3	69.1	79.5	76.0	74.0
Spain	4 498 554.0	4 535 439.6	3 924 280.0	3 962 014.2	4 181 780.6	3 339 540.0	96.8	96.9	84.4	85.3	89.6	70.6
France	5 472 149.2	5 265 698.0	5 121 875.0	4 966 539.4	5 069 969.2	3 895 979.0	84.6	80.7	77.4	74.5	75.6	57.9
Croatia	182 349.6	178 324.6	153 488.1	186 649.4	190 726.4	190 384.3	42.4	41.7	36.1	44.5	46.5	46.9
Italy	6 343 666.2	5 647 889.8	4 671 948.7	5 164 721.3	5 006 289.9	4 258 679.5	107.2	95.1	76.9	85.1	82.8	71.4
Cyprus	124 091.0	110 818.1	96 541.2	110 068.4	112 394.7	99 815.2	151.5	128.6	112.5	129.7	130.1	112.4
Latvia	98 134.8	119 595.1	86 473.4	92 372.0	98 735.2	76 165.1	46.3	58.5	43.2	46.9	51.0	39.9
Lithuania	245 661.2	238 772.8	162 647.8	248 526.1	217 009.0	174 863.5	78.2	79.5	55.3	86.0	77.3	62.6
Luxembourg	190 534.8	182 294.7	171 271.3	167 528.3	178 475.1	154 097.9	379.5	347.3	311.6	290.7	296.5	246.1
Hungary	661 953.8	536 876.7	586 701.8	620 644.7	717 939.3	505 796.7	66.1	54.1	59.4	63.1	73.4	51.8
Malta	99 309.0	91 798.1	88 596.8	93 981.6	133 072.9	112 715.8	239.9	219.9	206.3	208.7	279.7	219.1
Netherlands	1 756 298.2	1 581 627.3	865 658.7	1 909 414.1	2 076 588.8	1 644 658.7	106.0	94.5	51.4	112.5	120.9	94.5
Austria	984 961.4	1 018 675.2	860 021.4	926 438.8	916 695.5	1 034 183.0	117.9	121.2	101.1	106.5	103.9	116.2
Poland	1 449 726.2	1 343 299.9	1 148 920.0	1 291 134.4	1 952 894.6	1 833 575.5	38.1	35.3	30.2	34.0	51.4	48.3
Portugal	816 528.8	798 025.7	655 206.0	742 712.5	720 482.4	626 050.6	77.2	75.7	62.8	71.8	70.0	60.8
Romania	288 702.8	317 167.4	273 891.3	297 710.5	348 982.6	343 636.6	14.2	15.8	13.7	15.1	17.9	17.8
Slovenia	157 908.0	156 793.4	148 836.2	155 506.4	152 367.9	105 654.5	77.1	76.3	72.2	75.3	73.7	50.4
Slovakia	460 700.9	415 750.1	393 964.0	396 035.3	423 327.6	400 542.8	85.5	76.9	72.7	73.0	77.8	73.4
Finland	771 882.3	688 842.9	703 330.3	745 480.2	655 973.3	546 124.2	144.2	127.5	129.0	135.9	119.0	98.8
Sweden	870 222.7	791 621.0	833 991.8	762 839.5	604 773.3	750 184.0	93.2	83.5	86.5	77.4	59.8	72.6
Iceland	32 002.9	33 622.3	35 578.6	45 076.6	53 230.8	30 648.0	100.8	105.2	109.2	135.6	152.8	84.2
Norway	-7 768 612.7	-7 130 940.3	-6 846 877.0	-7 409 925.5	-7 682 024.9	-7 041 569.2	-1,599.1	-1,430.2	-1,340.4	-1,422.1	-1,450.6	-1,311.9
United Kingdom	2 648 426.3	3 554 301.6	3 502 967.6	2 839 291.0	2 893 915.8	:	42.4	56.0	54.4	43.4	43.7	:

https://ec.europa.eu/eurostat/databrowser/view/nrg_bal_c/default/table?lang=en [Accessed March 15, 2023]

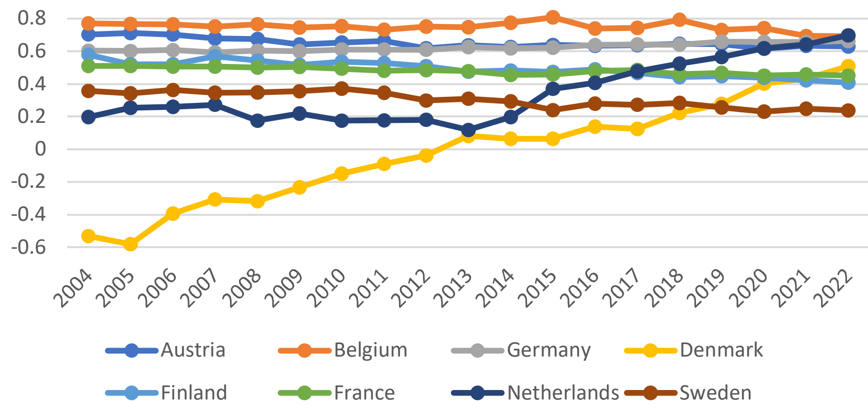
Appendix B Figures



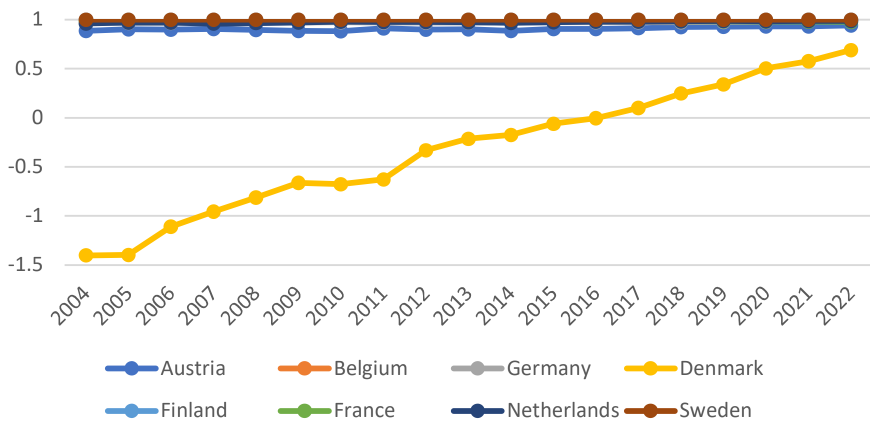
B. Figure 1.
Simulation for the excess volatility measure



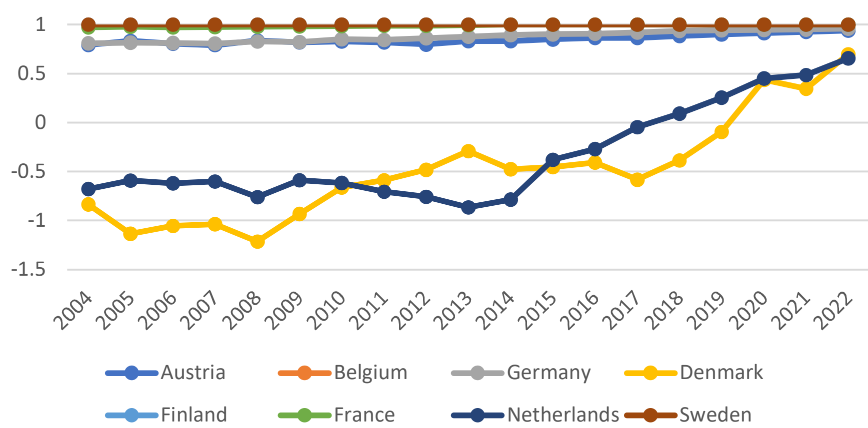
B. Figure 2: Spillover volatility network model



a) Total energy dependencies

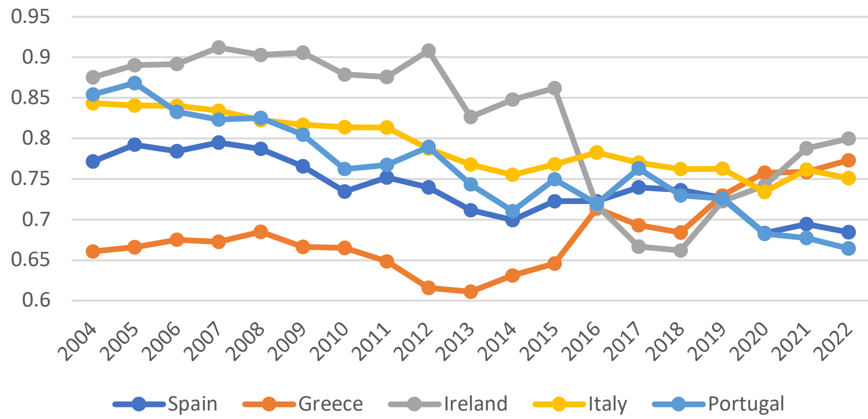


b) Crude oil dependencies

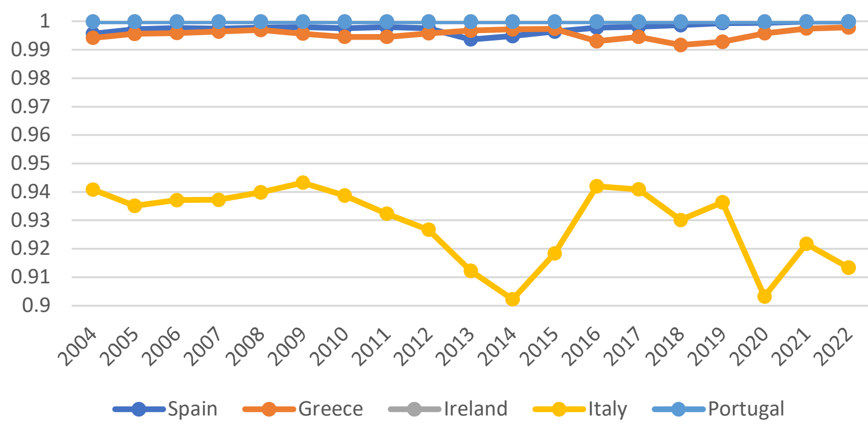


c) Natural gas dependencies

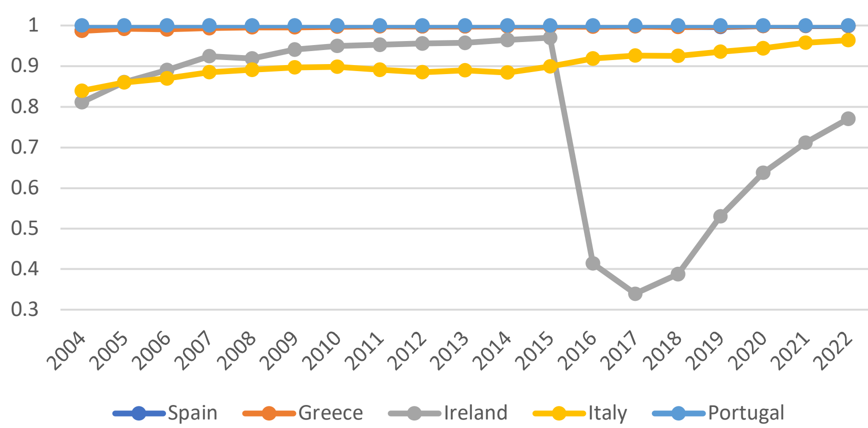
B. Fig 3A. Energy dependencies of Core European Union Countries



a) Total energy dependencies

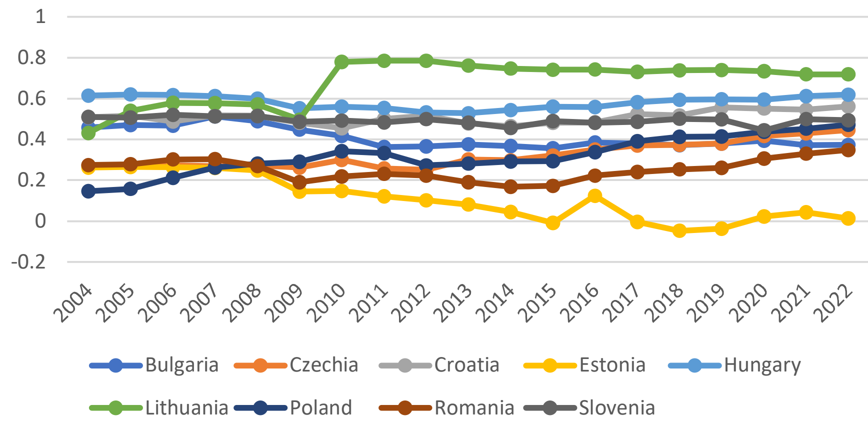


b) Crude oil dependencies

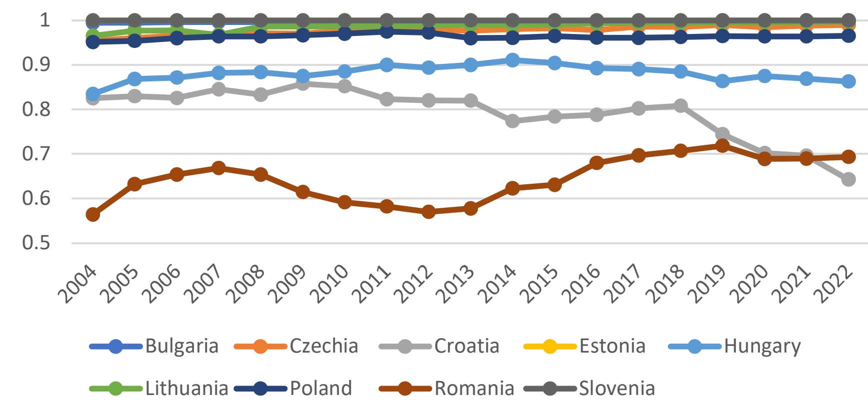


c) Natural gas dependencies

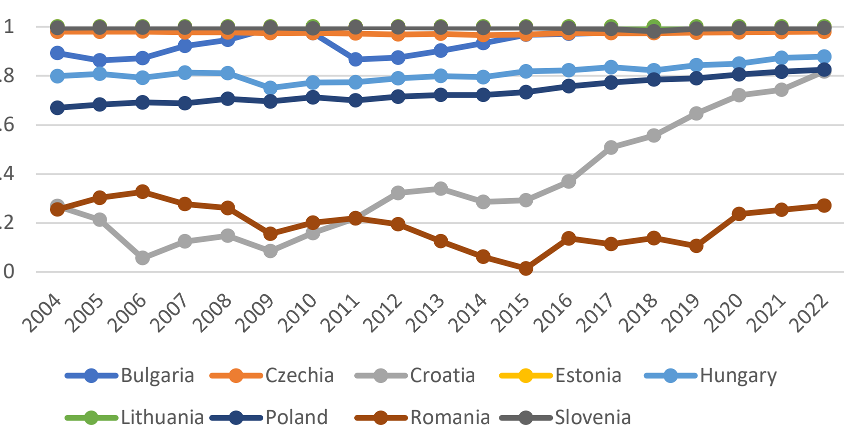
B. Fig. 3B. Energy dependencies of PIIGS Countries



a) Total energy dependencies

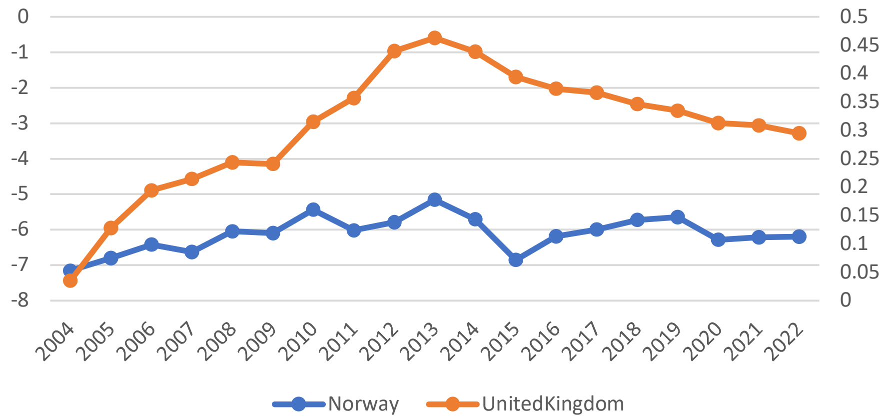


b) Crude oil dependencies

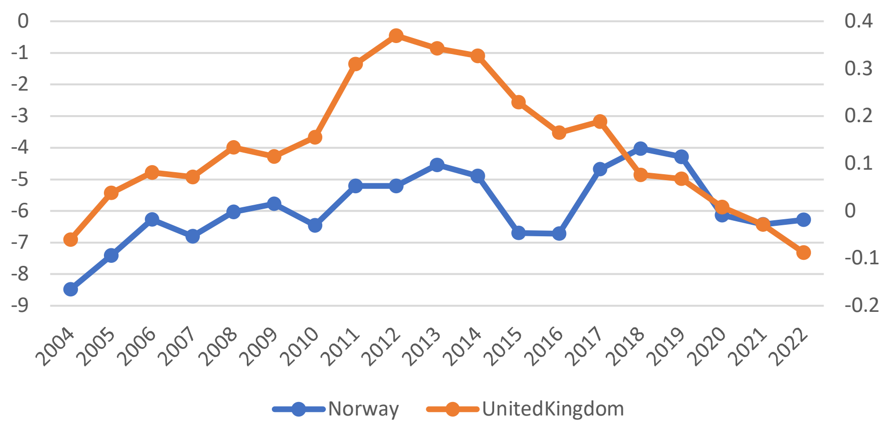


c) Natural gas dependencies

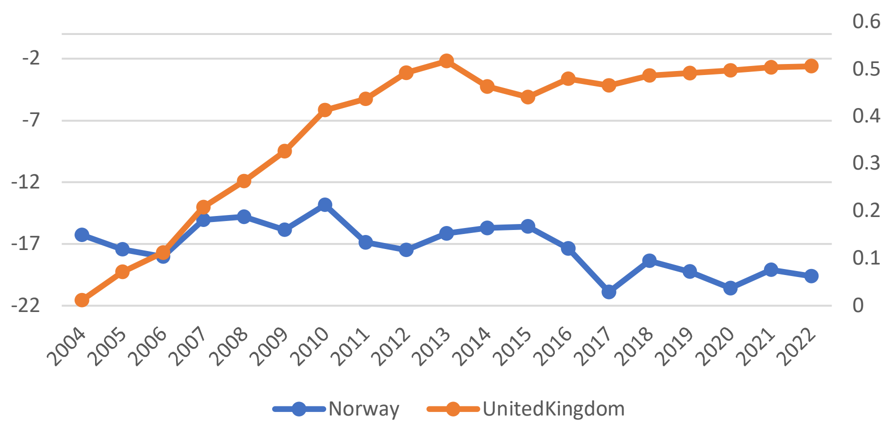
B. Fig. 3C. Energy dependencies of countries that joined EU after 2004



a) Total energy dependencies



b) Crude oil dependencies



c) Natural gas dependencies

B. Fig. 4. Energy dependencies of Norway and the United Kingdom

Norway's negative energy dependency (1- production/consumption) depicted on the left axis, while the United Kingdom's energy dependency depicted on the right axis.