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Research paper

Energy Markets and EMEA Stocks: Asymmetric TVP-VAR Connectedness and Investment Strategies

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Abstract

This study examines the dynamic transmission of shocks between key energy markets and selected equity markets in the Europe, Middle East, and Africa (EMEA) region using an asymmetric time-varying parameter vector autoregression (TVP-VAR) framework. Our daily dataset includes Clean Energy, Natural Gas, Crude Oil, and Heating Oil and eleven EMEA stocks (Czech Republic, Hungary, Kuwait, Qatar, Saudi Arabia, Poland, UAE, Egypt, Greece, South Africa, and Turkey) spanning from May 1, 2015 to Dec 31, 2024. The analysis reveals a moderate Total Connectedness Index (TCI) under aggregate shocks, with spikes during major global disruptions such as oil and climate related crisis, the COVID-19 pandemic, Russia-Ukraine war, and the Iran Israel war. Positive shocks exhibit stronger spillovers, peaking at over 60% TCI, driven by synchronized recovery periods, while negative shocks show lower but significant connectedness. Clean Energy consistently emerges as a dominant net transmitter across all regimes, while Natural Gas and certain equity markets, such as the UAE and Greece, act as net receivers. Network visualizations highlight Qatar's prominence in positive shock regimes and Clean Energy's systemic role during downturns. These findings underscore the asymmetric nature of shock transmission, offering critical insights for portfolio diversification, hedging strategies, and systemic risk monitoring in a globally integrated financial environment.

Keywords: *TVP-VAR, Energy Market, EMEA Stocks, Connectedness, Investments strategies*

1. Introduction

Emerging markets are usually considered as fast-growing economies, which have high returns potential, but are also characterized by higher risks than the developed markets. These countries are industrialized and have dynamic financial and social systems and therefore have good investment prospects with a lot of challenges like political instability, regulatory uncertainties, environmental problems and market fluctuations. Investors are forced to go through these complexities to take advantage of the high potential returns that these dynamic economies offer. However, even though research on emerging market spillovers has been conducted so far, there is still a major gap in literature in the field of the relationship between the emerging markets and the energy markets. In Scopus database, it is observed that even though there are over 600 articles on emerging market spillovers, few studies have been done on the significant yet understudied spillover between the emerging markets and the energy markets and hence it is an area of future research.

The stock prices and volatility in the energy market have also been especially harsh in the last decade and there is an interconnection between the energy market and the stock prices. The increased volatility in the energy and stock exchange market has a major impact on the stability and development of the economy, especially, in the emerging markets (Mensi et al., 2023). The uncertainty in these markets has been aggravated by the crises that have been experienced, e.g. economic, financial, energy, political and epidemic crises and therefore it is a serious subject of study. The growing interdependence of global financial and energy markets underscores the importance of understanding how shocks are transmitted across asset classes and regions. The Europe, Middle East, and Africa (EMEA) region comprises countries from Africa, Europe (excluding Russia), and the Middle East, extending as far as Iran. The term EMEA is commonly used in business and financial contexts, particularly in North America. The EMEA (Europe, Middle East, and Africa) region comprises 116 countries and 12 territories, encompassing subregions such as Eastern, Northern, Southern, and Western Europe, Arabia, the Levant, Northern Africa, and Sub-Saharan Africa. Its strategic importance is underscored by historical trade routes, including the Suez Canal—constructed in 1869—which linked Europe to the Indian Ocean and East Asian markets. Additionally, the Pax Britannica facilitated British dominance in global maritime trade during the late 19th century.

Although the main theme of this study involves a sample of EMEA emerging markets, comprising of countries like Egypt, Greece, South Africa among others, there are fundamental energy-dependent economies like Nigeria and Russia that it does not cover. These countries are omitted due to the availability and/or utilization of data as well as the limitation of the study. Nevertheless, these countries have substantial contribution in the global energy market and mostly in oil and gas. It should be mentioned that the findings of this paper might carry certain significance beyond the current research itself, affecting other energy-based economies in the EMEA region, especially to those with a strong fossil fuel export market. The scope of the research may also be extended in future to include such major markets and others to understand to which extent these results hold true.

The region's economic resilience is reflected in recent figures from the World Bank, which projects a growth rate of 4.6 percent for 2024, slightly higher than the 4.4 percent recorded in 2023, despite ongoing challenges such as high debt levels, elevated interest rates, and persistent political uncertainties. As a region largely reliant on export-oriented economies, EMEA remains vulnerable to shifts in global trade dynamics. Trade growth is forecast to rise to 2.3 percent in 2024, compared to 2.1 percent in the previous year. However, external shocks—such as a 1 percent decline in GDP in the United States or China—could reduce regional growth by approximately 0.5 percent and 0.3 percent, respectively.

The role of emerging economies in achieving the global climate goal is also being appreciated. The programs such as the "Network to Mobilize Clean Energy Investment to the Global South" introduced at the World Economic Forum 2024 underline the necessity to increase investments in clean energy in developing countries (IEA, 2025). This will help in attracting huge capital to fast track the energy transition in nations such as India, Kenya, Nigeria and Egypt, which is an inevitable step towards closing the investment gap that has plagued most emerging economies in their bid to realize energy security (IEA, 2025). The energy transition requires more investment and a lot of emerging markets have substantial obstacles to financing the energy transition. They are not able to attain energy security since they cannot develop energy infrastructure due to the lack of capital and the difficulty of accessing advanced renewable technologies (Saleh & Hassan, 2024). Moreover, the export of the materials needed to produce renewable technologies, including solar panels and batteries, can be blocked, and this will delay the process of transforming such markets into energy resilience. This shows how the global energy systems are dependent on each other where the energy policies of the emerging markets are not only affected by the domestic policies, but the global supply chains and investment trends.

Besides macroeconomic and financial effects of energy shocks, there is a need to look at effects of energy shocks on financial reporting and risk accounting in firms. As an example, the volatility in energy prices may affect the cost allocation of firms especially in EMEA energy-intensive markets. Moreover, the changes energy shocks bring about might necessitate the need to revise risk management systems and financial statements to still incorporate the modifications that energy prices bring about as firms adjust their hedging arrangements. The inclusion of accounting insights into the research can add more economic impacts of energy jolt on the economy and especially the companies that belong to businesses that utilise energy intensely like the manufacturing and utility industries. Therefore, a future project may focus on finding out how energy price volatility affects the financial reporting and the risk accounting system of these companies operating within the EMEA region.

This study investigates the asymmetric spillovers between key energy markets—Clean Energy, Natural Gas, Crude Oil, and Heating Oil—and selected EMEA emerging equity markets as per MSCI classification, including the Czech Republic, Hungary, Kuwait, Qatar, Saudi Arabia, Poland, the United Arab Emirates (UAE), Egypt, Greece, and South Africa. Using an asymmetric time-varying parameter vector autoregression (TVP-VAR) framework, we analyze how positive and negative shocks propagate differently across these markets. Financial markets exhibit non-linear responses, with distinct spillover patterns during periods of optimism versus distress, such as the 2018 trade tensions, the COVID-19 pandemic, and the Russia-Ukraine conflict. By disaggregating shocks into aggregate, positive, and negative regimes, this study provides nuanced insights into the state-dependent nature of market interactions, emphasizing the systemic role of Clean Energy and the vulnerabilities of certain EMEA equity markets. These findings have critical implications for asset allocation, risk management, and policy formulation in this diverse and globally significant region.

2. Literature Review

Transmission of shocks between energy markets and emerging equity markets has attracted considerable attention as a result of the growing integration of financial systems around the world. Energy markets such as oil, natural gas and commodities affect emerging equity markets by affecting prices, macroeconomic interrelation and investor sentiment. Spillovers (including return, volatility and risk transmissions) play an important role in the study of portfolio diversification, risk management and economic policy in emerging economies, which tend to be more exposed to external shocks. The literature has progressed beyond the static models to dynamic and time-varying models that reflect asymmetries and crisis-related dynamics, which form a basis of analyzing market interactions between energy and equity.

Early research by Diebold and Yilmaz (2012) proposed the connectedness framework based on generalized forecast error variance decompositions (GFEVD), which allows measuring the directional spillovers between markets. Antonakakis et al. (2018) further generalized this strategy using the time-varying parameter vector autoregression (TVP-VAR) model, which allows dynamic spillover effects, which are especially relevant to the volatile energy markets interactions with equities. Baruník and Křehlík (2018) pointed to the asymmetry of spillovers, where positive and negative shocks have different effects, where positive shocks tend to enhance co-movements in emerging markets because of pro-cyclicality.

Oil price shocks are among the central areas of energy-equity spillover research. Demirer et al. (2020) investigated how oil shocks affect the sovereign bond market in emerging economies and concluded that demand-based oil shocks have a substantial effect on the financial markets other than equities, which is applicable to emerging markets that rely on energy sources. Mensi et al. (2018) have applied a wavelet method to study co-movements between BRICS stock markets and crude oil prices (WTI and Brent) and found strong low-frequency co-movements during the 2008 global financial crisis (GFC). It implies that oil price volatility increases the spillover to emerging equity markets in turbulent times. In the same vein, Mikhaylov (2018) used a FIGARCH model to investigate volatility spillover in oil-exporting economies such as Russia and Brazil, and identified unidirectional spillover between currency and stock markets, and long memory dynamics, which are compounded by structural breaks, which is an important insight in emerging markets that depend on energy exports.

The diversification and safe-haven characteristics of energy-related assets have also been well established. Bouri et al. (2020) compared Bitcoin, gold, and commodities with stock market indices, including emerging markets, through wavelet coherency as safe havens. They discovered that commodities, such as energy assets, have low correlation with equities, providing diversification advantages, especially at longer horizons, which is useful to emerging market investors. Bekiros et al. (2017) examined the role of gold in the BRICS markets, finding time-varying asymmetric dependence, where gold is a haven in times of crisis, which may be true of other energy commodities such as clean energy in emerging economies. Regional and global spillover dynamics are critical for understanding energy-equity interactions. Yarovaya et al. (2016) explored intra- and inter-regional spillovers across emerging and developed markets using stock indices and futures, finding that futures enhance information transmission, with stronger spillovers during crises. This is relevant for emerging markets with active futures markets. Li and Giles (2015) documented unidirectional volatility spillovers from the US to Asian emerging markets, with bidirectional spillovers during the Asian financial crisis, indicating that crisis periods amplify energy-equity linkages. Beirne et al.

(2010) confirmed global and regional spillovers in emerging markets, with variance spillovers prominent in emerging Europe, suggesting that energy price shocks may similarly drive volatility in other emerging regions.

In the context of specific emerging markets, Aloui and Hkiri (2014) used wavelet squared coherence to study co-movements in Gulf Cooperation Council (GCC) stock markets, finding increased dependence during the 2007–2008 GFC, particularly at higher frequencies, which implies short-term portfolio benefits. Majdoub and Mansour (2014) examined Islamic emerging markets (e.g., Indonesia, Qatar), finding weak correlations with the US market due to Shari'ah-compliant restrictions, which limit volatility spillovers and enhance diversification. These findings highlight the unique dynamics of energy-dependent emerging markets.

Volatility modeling is a key theme in spillover studies. Mensi et al. (2016) employed a DCC-FIAPARCH model to analyze US-BRICS spillovers, detecting long-memory volatility and dynamic correlations post-GFC, with Brazil, India, China, and South Africa showing recoupling with global markets. This underscores the sensitivity of emerging markets to energy-driven shocks. Bostanci and Yilmaz (2020) applied the Diebold-Yilmaz methodology to sovereign credit default swaps, noting high connectedness driven by emerging markets post-crisis, a pattern relevant to energy-exporting emerging economies.

Beyond equities, Ferreira and Gama (2007) found that sovereign debt rating downgrades generate negative spillovers to stock markets, with stronger effects in emerging markets, suggesting that energy price shocks may amplify credit risk spillovers. Economic policy uncertainty (EPU) also influences spillovers, as Tsai (2017) showed that China's EPU significantly affects contagion risk in emerging markets, while Europe's EPU drives volatility locally, highlighting the role of policy environments in energy-equity dynamics.

Forecasting models enhance spillover analysis. Kao et al. (2013) proposed a Wavelet-MARS-SVR model for stock price forecasting in emerging markets, demonstrating improved accuracy by capturing time-frequency dynamics, relevant for energy market spillovers. Lin et al. (2021) combined CEEMDAN and LSTM to forecast stock indices, showing superior performance in emerging markets, which could be applied to energy-equity interactions. Singh et al. (2010) and Lee et al. (2019) emphasized same-day effects and network indicators in global stock market spillovers, with regional influences dominating in emerging markets.

Currency dynamics also play a role. Lin (2012) found stronger co-movements between exchange rates and stock prices in Asian emerging markets during crises, driven by capital account dynamics, a pattern relevant for energy-exporting emerging markets. Aizenman et al. (2016) showed that open macro policies, like flexible exchange rates, increase sensitivity to center economies' shocks, affecting emerging markets' energy-equity linkages.

While Égert and Kočenda (2007) and Li (2007) found limited integration in Central and Eastern European and Chinese markets, respectively, they did not address energy-specific spillovers or asymmetries. Graham et al. (2012) highlighted varying co-movement strengths across emerging markets, underscoring the need for region-specific analyses. This study addresses these gaps by focusing on asymmetric spillovers between energy markets (including clean energy) and emerging equity markets, using a TVP-VAR framework to capture state-dependent dynamics during crises, building on the methodologies and findings of the reviewed literature.

Research on spillovers specifically involving EMEA economies remains limited, despite their economic significance as energy exporters and emerging markets. Shaik and Rehman (2023) examined the dynamic volatility connectedness of S&P ESG stock indices across regions, including the Middle East and Africa (MEA), from May 2010 to March 2021, using a DCC-GARCH model. They found that the MEA ESG index is a net shock transmitter to other regions, including the US and Asia-Pacific, with stronger bilateral correlations among US, Latin America, and Europe, but weaker links with MEA. This suggests that EMEA markets, particularly energy-driven economies like those in the Middle East, play a unique role in global ESG spillovers, with implications for portfolio diversification. However, their study focuses on ESG indices rather than energy markets directly, highlighting a gap in the literature on energy-specific spillovers in EMEA economies. Few other studies, such as Aloui and Hkiri (2014) and Majdoub and Mansour (2014), address EMEA markets (e.g., GCC and Islamic markets), but they primarily focus on equity market co-movements rather than energy-equity spillovers, underscoring the need for further research in this area.

3. Data and Methodology

3.1 Data

The data employed in this research is targeted at examining the association between EMEA emerging markets equity and energy markets. We have taken the data of 2015-2024 and represented countries of various regions: EMEA (Czech Republic, Hungary, Kuwait, Qatar, Saudi Arabia, Poland, UAE, Egypt, Greece, South Africa, and Turkey), and the research also contains the data on clean energy and fossil fuel market with such variables as S&P Global Clean Energy Transition Index, S&P GSCI Natural Gas, S&P GSCI Crude Oil, and S&P GSCI Heating Oil. All the information was retrieved on Bloomberg that is a credible and comprehensive database to analyze. The provided data has served as a good foundation to investigate the relationship between the returns of equity in the EMEA emerging markets and the performance of the clean energy and fossil fuel industries. The details of the selected countries and energy proxies used in the analysis are presented in Table 1.

Table 1: Proxies under study

MSCI_EMERGING MARKETS	TICKERS	ENERGY MARKETS	TICKERS
EMEA		**CONSTITUENTS**	
Czech Republic	PX	Clean Energy	SPGTCLEN
Hungary	IDX	Natural Gas	SPGSNG
Kuwait	BKP	Crude Oil	SPGSCL
Qatar	QSI	Heating Oil	SPGSHO
Saudi Arabia	TASI		
Poland	WIG20		
United Arab Emirates	FTFADGI		
Egypt	EGX30		
Greece	ATG		
South Africa	FTSE		
Turkey	MITR00000PTR		

3.2 Methodology

3.2.1 Asymmetric Spillover Measure

A recent advancement in financial market connectedness research is the inclusion of asymmetric spillovers, recognizing that positive (good) and negative (bad) news may affect financial assets differently. Financial markets often exhibit asymmetries in response to positive and negative shocks, where negative shocks might cause larger and more persistent movements than positive shocks.

In order to measure asymmetric connectedness, we apply the TVP-VAR based connectedness approach based on positive and negative absolute returns to recover.

Data regarding the complex processes of transmitting volatility. The study relies on the methodology of Antonakakis et al. (2020). Specifically, the study estimates a TVP-VAR that is proposed by the Bayesian information criterion (BIC) that can be described as follows:

$$Z_t = B_t z_{t-1} + u_t \qquad u_t \sim N(0, \Sigma_t) \tag{1}$$

$$vec(B_t) = vec(B_{t-1}) + v_t \qquad v_t \sim N(0, R_{t-1}) \tag{2}$$

where zt, zt-1 and ut are k × 1 dimensional vector in t, t − 1, and the corresponding error term, respectively. Bt and Σt are k × k dimensional matrices that show the time-varying VAR coefficients and the time-varying variance-covariances while vec(Bt) and vt are k2 × 1 dimensional vector and Rt is a k2 × k2 dimensional matrix.

As the idea of the generalized forecast error variance decomposition (GFEVD) proposed by Koop et al. (1996) and Pesaran and Shin (1998) is based on the Wold representation theorem, we must convert the TVP-VAR model to a TVP-VMA process in the form of the following equality:

$$Zt = \sum_{i=1}^{p} B_{it} z_{t-i} + ut = \sum_{j=0}^{\infty} A_{jt} u_{t-j} \tag{3}$$

The (scaled) GFEVD normalizes the (unscaled) GFEVD, $\psi_{ij,t}^{g}(H)$, so that each row would sum up to unity. Hence, $\psi_{ij,t}^{g}(H)$ represents the influence variable j exerts on variable i in terms of its forecast error variance share which is defined as the pairwise directional connectedness from j to i. This indicator is computed by,

$$\psi_{ij,t}^{g}(H) = \frac{\Sigma_{ii,t}^{-1} \Sigma_{t=1}^{H-1} (\iota_i' A_t \Sigma_t \iota_j)^2}{\Sigma_{j=1}^{k} \Sigma_{t=1}^{H-1} (\iota_i' A_t \Sigma_t \iota_j)^1} \qquad \psi_{ij,t}^{g}(H) = \frac{\psi_{ij,t}^{g}(H)}{\Sigma_{j=1}^{k} \phi_{ij,t}^{g}(H)} \tag{4}$$

with $\sum_{j=1}^{k} \psi_{ij,t}^{g}(H) = 1$, $\sum_{i,j=1}^{k} \psi_{ij,t}^{g}(H) = k$, H stands for the forecast horizon, and At corresponds to a selection vector with unity on the i-th position and zero otherwise.

First, we consider the situation where variable i passes its shock to all the other variables j and this is referred to as total directional connectedness TO others and is defined as

$$C_{i \to j,t}^{g}(H) = \Sigma_{j=1, j \neq i}^{k} \psi_{ji,t}^{g}(H) \tag{5}$$

Second, we compute the shock variable I am getting from variables j denoted as total directional connectedness FROM others and is referred to as:

$$C_{i \leftarrow j,t}^{g}(H) = \Sigma_{j=1, i \neq j}^{k} \psi_{ji,t}^{g}(H) \tag{6}$$

Subtracting the total directional connectedness TO others by the total directional connectedness FROM others gives the NET total directional connectedness, which can be taken as the effect variable i have on the network under analysis.

$$C_{i,t}^{g}(H) = C_{i \to j,t}^{g}(H) - C_{i \leftarrow j,t}^{g}(H) \tag{7}$$

The total connectedness index (TCI) calculates the market interconnectedness and is constructed by

$$C_{t}^{g}(H) = \frac{\Sigma_{i,j=1, i \neq j}^{k} \psi_{ji,t}^{g}(H)}{\Sigma_{i,j=1}^{k} \psi_{ji,t}^{g}(H)} = \frac{\Sigma_{i,j=1, i \neq j}^{k} \psi_{ji,t}^{g}(H)}{k} \tag{8}$$

The greatest issue with this measure is that the definition of what actually means high interconnectedness is subjective. According to Monte Carlo simulations Chatziantoniou and Gabauer (2021) have demonstrated that the own variance shares are by construction always greater or equal to all cross variance shares hence TCI is in the range $[0, \frac{k}{k-1}]$ rather than [0, 1]. Therefore, the TCI needs to be modified in the following way to enhance interpretability,

$$C_{t}^{g}(H) = \left(\frac{k}{k-1}\right) \frac{\Sigma_{i,j=1, i \neq j}^{k} \psi_{ji,t}^{g}(H)}{k} \tag{9}$$

$$= \frac{\Sigma_{i,j=1, i \neq j}^{k} \psi_{ji,t}^{g}(H)}{k-1} \qquad 0 \leq C_{t}^{g}(H) \leq 1 \tag{10}$$

Last but not least, the TCI has been demonstrated to be decomposed into the pairwise connectedness index (PCI) of the interconnectedness between two variables i and j (Gabauer, 2021):

$$C_{ijt}^{g}(H) = 2\left(\frac{\psi_{ij,t}^{g}(H) + \psi_{ji,t}^{g}(H)}{\psi_{ii,t}^{g}(H) + \psi_{ij,t}^{g}(H) + \psi_{ji,t}^{g}(H) + \psi_{jj,t}^{g}(H)} \right) \qquad 0 \leq C_{ijt}^{g}(H) \leq 1 \tag{11}$$

This metric ranges between [0, 1] illustrating the degree of bilateral interconnectedness across variable i and j which is masked by the TCI.

4. Results and Analysis

4.1 Overall Interpretation of TCI for EMEA and Energy Markets (2012-2024)

Time-Varying Total Connectedness Index (TCI) measures the interconnectedness between the EMEA equity markets and the four major energy markets (Crude Oil, Heating Oil, Natural Gas, and Clean Energy). The TCI gives the investors a good idea of the likelihood of these markets moving in the same direction particularly during a crisis or when the world is volatile. A low TCI is an indication of reduced interconnectedness, that is, the energy and equity markets are less likely to move together or in opposite directions, which is positive in terms of portfolio diversification. Conversely, a large TCI is an indicator of greater interconnectedness, i.e., the two markets have a greater chance of moving together, hence the risk of both markets falling or rallying at the same time. This interdependence is particularly important to investors who want to optimize their portfolios by reducing risk in high volatility periods or by ensuring that returns are maximized when markets move in the same direction.

In 2012-2016, the TCI was rather moderate, with the highest level of approximately 20 in the oil price crisis of 2014. This was a time when the world experienced a sudden fall in oil prices and this was majorly caused by over-supply of oil in the market caused by factors like the U.S. shale oil. Although this affected the energy markets, the equity markets did not respond in an absolutely coordinated manner. The moderate TCI implied that the investors were able to diversify their portfolios, having energy and equity assets without risking high chances of simultaneous falls or surges.

In 2017, the TCI demonstrated moderate growth, which could be caused by the rise of interest in climate change and a transition to cleaner energy sources, which impacted both energy and equity markets. The TCI increased slowly and was far below 25 indicating moderate interconnectedness between energy and equity markets.

The COVID-19 crisis (2020-2021) was characterized by a sharp decline in the TCI to less than 10 in early 2020, which signified a strong decoupling of the energy and equity markets. The pandemic caused a worldwide economic lockdown that resulted in a loss of energy demand, especially oil, and the equity markets were not spared. The sharp fall in the TCI meant that the movements of the two markets had little influence on each other during this time and this was an opportunity that the investors could use to diversify and lower the risk. Nonetheless, in 2021, the TCI rose to almost 30 indicating a rebound and reconnection between energy and equity markets as governments issued stimulus packages, and economies gradually reopened.

In 2022, with the geopolitical tensions, the Russia-Ukraine war, the TCI was at a level slightly lower than 15, which indicates that the two markets were closer, although not as close as in 2021. There was a lot of volatility in this period, especially in the energy markets, although the equity markets did not respond in perfect tandem, giving some scope to diversification. By 2024, the TCI had once more dropped below 10, indicating a time of decoupling between the energy and equity markets despite the geopolitical tensions, including the Iran-Israel conflict. This meant that there was another chance of diversification since the two markets were not likely to be moving in the same direction.

4.2 Good News (Positive Shocks)

Between 2012 and mid-2018, the TCI was less than 25, indicating that there was low interconnectedness between the energy and equity markets in reacting to positive shocks (good news). This time was characterized by favorable trends in the world economy and energy markets, and these processes did not result in a high level of synchronization of the two markets. This reduced interconnectedness could have been exploited by investors who could have diversified their portfolios by including both energy and equity assets where the markets did not move in unison.

The TCI jumped drastically in mid-2018 to early 2019, reaching almost 60, which means that there was a time of high positive interconnectedness. TCI was boosted by synchronized global growth, economic recovery and an increasing demand of oil. Energy and equity markets responded more to good news as a result of positive news, and the TCI indicated the increased correlation. This brought opportunities and risks to investors. Although the returns could have been higher through joint rallies in both markets, the high interconnectedness also implied high exposure to the risk of both markets moving in the same direction in case of a negative shock. This higher correlation meant that investors needed to rebalance their portfolios to deal with this, and may have decreased their exposure to the most volatile assets or markets.

As of 2020, in the COVID-19 pandemic, the TCI dropped below 10, indicating that the energy and equity markets had decoupled. The pandemic led to extreme declines in energy demand, especially oil, and equity markets were disrupted as well. The good news about government stimulus packages and vaccine distribution did not lead to a major spillover effect on energy markets since the sectors were affected by the crisis very differently. This made a great portfolio diversification opportunity, since low TCI meant that investors could minimize risk by investing in markets that were not moving in the same direction.

The TCI was less than 10 in 2022, at the time of the Russia-Ukraine war, indicating that, although the news about energy security and government actions to stabilize supply was positive, the energy and equity markets did not react synchronously. This further decoupling implied that investors could enjoy the benefits of diversification since positive shocks in one market were not followed by rallies in the other. On the same note, the TCI by the year 2024 was 25, despite the Iran Israel conflict, which shows moderate level of interconnectedness. Although geopolitical tensions affected the energy market, the equity markets were not affected similarly, which gave investors the opportunity to adjust their portfolio and concentrate on diversification to control risk.

4.3 Bad News (Negative Shocks)

Interconnectedness has been found to be stronger in the reaction of the TCI to negative shocks (bad news). The TCI was at its highest in 2014, when the oil price crisis took place, indicating that although the energy market was highly affected by the declining oil prices, the equity markets did not show the same degree of reaction. The moderate TCI indicated that the negative shocks in energy sector were not always spilling over to the equity markets to enable investors to diversify their investments. The Total Connectedness Index (TCI) for aggregate, positive, and negative spillovers is illustrated in Fig.1.

Nevertheless, the COVID-19 crisis in 2020 witnessed the TCI plummet to 5, indicating a robust decoupling of the energy and equity markets as a reaction to the adverse global shock. The pandemic caused a huge decline in energy demand, especially oil, and equity markets were significantly affected in other areas. The low TCI emphasized that, although there was a lot of bad news, the markets were not moving in the same direction, which presents a chance of diversification since the two markets were moving at different directions. Investors would have been able to minimize the risk of energy markets and concentrate on the sectors that are not as vulnerable to the adverse impact of the pandemic.

The TCI climbed to almost 40 in 2021, as the world recovered in unison against the pandemic. The increase in the TCI meant that there was more spillover of negative shocks across markets. This high degree of interconnectedness increased the possibility of both energy and equity markets experiencing a decline at the same time. This increased the risks of investors since the two markets were more prone to simultaneous falls in reaction to bad news. This therefore required cautious portfolio management to accommodate the increased risk of the two markets moving in the same direction.

The TCI reached its highest level in 2022, at the time of the Russia-Ukraine war, at a value of slightly less than 15, which means that the markets of energy and equity are becoming more interconnected. The war led to major energy market disruptions especially in Europe and equity markets were also volatile due to inflation and other economic forces. Even though TCI was greater than it was during the pandemic, it was still less than 20, which indicates that although negative shocks in the energy sector affected equity markets, the correlation was not as strong as in 2021. Although there was a higher possibility of concurrent downturns, opportunities of diversification still existed, particularly to investors who concentrated on markets or sectors that were less vulnerable to energy price changes.

By 2024, as geopolitical tensions continue to brew because of the Iran-Israel conflict the TCI dropped back under 10, signaling a dip back to less interconnectedness between energy and equity markets. The decoupling between the two markets again provided sources of diversification since bad shocks in energy markets did not translate to the same bad shocks in equity markets. This low TCI was an indication that investors were able to invest in both energy and equity assets to diversify their portfolios and control risk better.

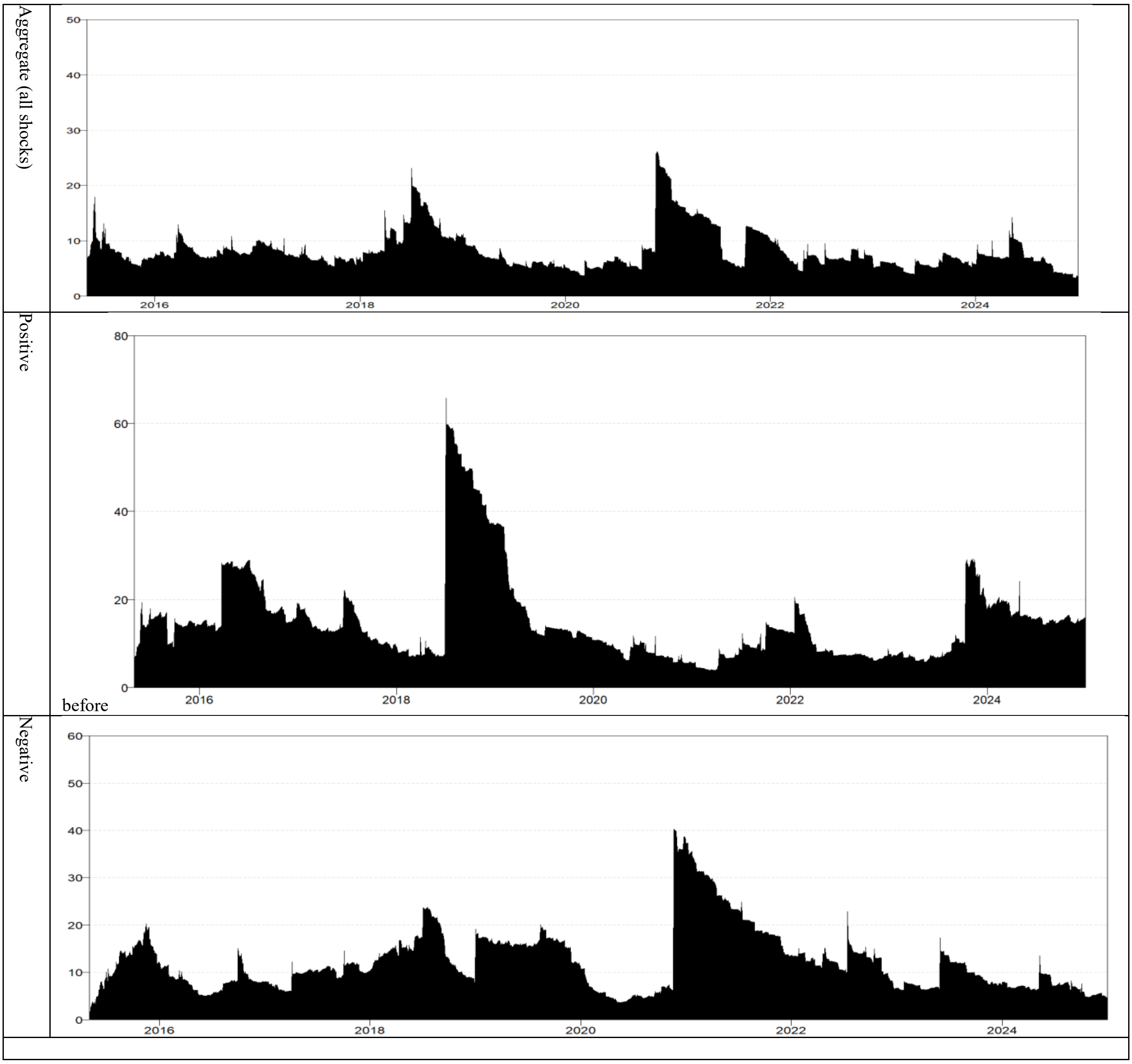


Fig 1: The Total Connectedness Index (TCI) represents the level of interconnectedness between the EMEA equity markets and key energy markets, including Clean Energy, Natural Gas, Crude Oil, and Heating Oil. The TCI is measured during aggregate shocks, positive shocks, and negative shocks. Significant TCI spikes correspond to major global disruptions such as the COVID-19 pandemic (2020), the Russia-Ukraine war (2022), and the Iran-Israel conflict (2024). Each spike highlights a period of heightened systemic risk, where energy and equity markets are more likely to move in tandem

Source: Author's own calculations

The asymmetric connectedness tables (see table 2) present the results of the generalized forecast error variance decompositions (GFEVD) derived from a time-varying parameter vector autoregression (TVP-VAR) model. This model is employed to examine the dynamic spillover effects between key energy markets namely Clean Energy, Natural Gas, Crude Oil, and Heating Oil and selected equity markets from the EMEA region, including the Czech Republic, Hungary, Kuwait, Qatar, Saudi Arabia, Poland, the United Arab Emirates (UAE), Egypt, Greece, and South Africa. The analysis is disaggregated into three distinct regimes: aggregate shocks (Panel A), positive shocks (Panel B), and negative shocks (Panel C), each providing directional spillover metrics in terms of "TO", "FROM", and net connectedness indicators.
In the context of aggregate shocks (Panel A), the Total Connectedness Index (TCI) is measured at 8.70%, signifying a moderate level of integration wherein most variables are largely influenced by their own shocks rather than by cross-market transmission. Clean Energy emerges as the predominant net transmitter (net +3.77), indicating its substantial role in propagating information to other markets. Conversely, Natural Gas and Heating Oil exhibit net receiver positions, with net spillover values of -1.20 and -1.68, respectively, suggesting their susceptibility to external shocks. Among the equity markets, Hungary and Poland function as moderate net transmitters, whereas the UAE assumes a net receiver position (-2.04), reflecting a higher degree of dependence on external market dynamics.
Under positive shock conditions (Panel B), the system-wide connectedness intensifies markedly, with the TCI increasing to 15.79%. This elevated interdependence suggests that market linkages become stronger during periods of optimism or favorable conditions. Qatar emerges as the most significant net transmitter (net+12.92), followed by Crude Oil (+5.29) and South Africa (+7.10), highlighting their prominent roles in disseminating positive spillovers. In contrast, markets such as Natural Gas, the UAE, and Saudi Arabia remain net receivers, indicating that they are more reactive to positive shocks rather than exerting influence. These results underscore an asymmetric transmission mechanism, where certain markets—particularly those related to energy act as catalysts during favorable conditions, while others exhibit a passive response pattern.
In the case of negative shocks (Panel C), the TCI registers at 13.03%, denoting a high, albeit slightly lower, level of system-wide spillover compared to the positive shock regime. Clean Energy continues to assert a dominant influence, with a net spillover of +8.51, suggesting its strategic relevance and potential role as a stabilizing asset during downturns. Hungary also assumes a net transmitter role (+2.60), potentially reflecting its policy framework or structural resilience during stress periods. On the other hand, Natural Gas (-2.24), Greece (-2.05), and South Africa (-1.83) are identified as significant net receivers, indicative of their heightened vulnerability to adverse market conditions. This reinforces the asymmetric nature of the system, wherein certain assets and markets become more fragile and reliant on external information during negative regimes.
In summary, the findings from the asymmetric connectedness analysis reveal that Clean Energy consistently serves as a dominant net transmitter across all regimes, highlighting its influential position within the broader financial and energy ecosystem. Natural Gas, by contrast, functions persistently as a net receiver, denoting its sensitivity to external developments. Equity markets such as Qatar and South Africa exhibit strong responses to positive shocks, while others, including Greece, Egypt, and South Africa, are more adversely affected by negative shocks. The asymmetries across the three regimes underscore the non-linear and state-dependent nature of market interactions, providing critical insights for portfolio diversification, systemic risk assessment, and the formulation of macroprudential policies.

Table 2: Asymmetric spillovers between energy and EMEA equity markets

	Clean Energy	Natural Gas	Crude Oil	Heating Oil	Czech Republic	Hungary	Kuwait	Qatar	Saudi Arabia	Poland	UAE	Egypt	Greece	South Africa	FROM
Clean Energy	95.23	0.24	0.34	0.13	0.30	0.07	1.03	0.24	0.28	0.55	0.35	0.17	0.18	0.91	4.77
Natural Gas	0.67	90.19	0.64	0.37	0.53	1.22	1.22	0.81	0.80	0.77	0.30	0.63	0.88	0.96	9.81
Crude Oil	0.38	0.49	91.89	1.42	0.34	0.93	0.54	0.49	0.71	0.39	0.31	1.52	0.31	0.29	8.11
Heating Oil	1.81	0.57	1.42	91.74	0.19	0.17	1.09	1.12	0.36	0.50	0.28	0.18	0.44	0.13	8.26
Czech Republic	0.25	0.44	0.80	0.28	93.71	0.48	0.27	0.19	0.80	0.37	1.08	0.17	0.87	0.29	6.29
Hungary	0.43	0.94	0.63	0.14	0.45	90.73	1.30	1.53	0.88	1.38	0.28	0.34	0.77	0.20	9.27
Kuwait	1.48	1.08	0.60	0.78	0.28	1.75	89.47	0.87	0.58	0.52	0.41	0.87	0.66	0.65	10.53
Qatar	0.26	1.14	0.70	1.10	0.16	1.51	0.76	91.64	0.57	0.45	0.52	0.30	0.42	0.44	8.36
Saudi Arabia	0.35	0.54	0.63	0.24	0.83	0.84	0.63	0.66	92.31	0.94	0.76	0.51	0.62	0.13	7.69
Poland	0.23	0.89	0.34	0.41	0.45	1.54	0.41	0.33	0.77	91.95	0.72	0.51	0.29	1.17	8.05
United Arab Emirates	0.46	0.49	0.36	0.77	1.13	0.36	0.32	0.53	1.24	0.71	92.02	0.26	1.15	0.19	7.98
Egypt	0.33	0.46	1.54	0.22	0.59	0.38	0.92	0.52	0.37	0.47	0.35	92.34	1.07	0.46	7.66
Greece	0.70	1.12	0.36	0.57	0.81	0.77	0.60	1.17	0.66	0.50	0.44	0.90	90.44	0.97	9.56

South Africa	1.18	0.22	0.59	0.13	0.32	0.29	1.29	0.16	0.23	1.11	0.14	0.37	0.80	93.18	6.82
TO	103.77	98.80	100.84	98.32	100.09	101.06	99.84	100.23	100.56	100.62	97.96	99.06	98.89	99.95	cTCI/TCI
NET	3.77	-1.20	0.84	-1.68	0.09	1.06	-0.16	0.23	0.56	0.62	-2.04	-0.94	-1.11	-0.05	8.70/8.08
	Clean Energy	**Natural Gas**	**Crude Oil**	**Heating Oil**	**Czech Republic**	**Hungary**	**Kuwait**	**Qatar**	**Saudi Arabia**	**Poland**	**UAE**	**Egypt**	**Greece**	**South Africa**	**FROM**
Clean Energy	93.64	0.44	0.28	0.10	0.60	0.31	0.79	1.48	0.26	0.66	0.34	0.49	0.29	0.33	6.36
Natural Gas	0.38	83.54	1.39	0.66	0.43	0.82	1.31	1.71	0.95	1.02	1.63	1.65	0.94	3.56	16.46
Crude Oil	0.95	1.21	87.17	2.54	1.04	0.31	1.32	0.67	0.90	0.65	0.55	0.64	1.18	0.86	12.83
Heating Oil	0.51	2.10	3.15	86.82	0.42	0.41	1.23	1.58	0.49	0.17	1.15	0.37	0.60	0.99	13.18
Czech Republic	0.60	0.52	1.84	0.51	86.20	1.20	1.20	3.54	0.72	0.57	0.69	0.53	0.68	1.21	13.80
Hungary	0.49	0.67	1.76	0.19	1.17	85.50	1.45	2.42	0.59	0.93	0.61	1.05	1.22	1.96	14.50
Kuwait	0.48	2.68	1.48	1.14	0.86	1.22	81.63	0.97	1.20	1.47	1.63	2.15	0.97	2.12	18.37
Qatar	0.52	1.08	1.15	0.63	1.14	1.12	1.07	84.24	1.73	1.91	1.81	1.25	0.78	1.56	15.76
Saudi Arabia	0.27	1.18	1.80	0.68	0.89	0.73	1.79	3.10	82.99	0.83	1.48	1.08	1.22	1.95	17.01
Poland	0.61	1.26	1.10	0.22	0.55	0.88	0.59	2.14	1.03	84.77	1.06	1.43	0.26	4.11	15.23
United Arab Emirates	0.56	1.39	1.40	0.51	1.42	0.51	0.68	4.47	1.20	0.87	82.77	0.47	1.96	1.80	17.23
Egypt	0.32	1.56	0.24	0.36	0.76	0.76	1.92	2.46	0.72	1.16	0.57	85.55	1.53	2.08	14.45
Greece	0.56	1.20	1.54	0.22	0.47	1.11	0.71	2.45	1.15	0.27	0.39	0.87	87.18	1.89	12.82
South Africa	0.17	0.73	0.98	0.50	0.94	1.52	1.62	1.68	1.34	3.54	1.48	1.07	1.74	82.67	17.33
TO	100.06	99.56	105.29	95.07	96.89	96.39	97.31	112.92	95.29	98.82	96.16	98.61	100.54	107.10	cTCI/TCI
NET	0.06	-0.44	5.29	-4.93	-3.11	-3.61	-2.69	12.92	-4.71	-1.18	-3.84	-1.39	0.54	7.10	15.79/14.67
	Clean Energy	Natural Gas	Crude Oil	Heating Oil	Czech Republic	Hungary	Kuwait	Qatar	Saudi Arabia	Poland	UAE	Egypt	Greece	South Africa	FROM
Clean Energy	91.62	0.38	0.77	0.32	1.14	0.60	0.76	0.23	0.91	0.22	0.89	0.41	1.19	0.55	8.38
Natural Gas	2.03	86.30	0.65	1.04	0.46	1.51	1.39	1.89	1.22	0.49	0.54	0.79	1.04	0.63	13.70
Crude Oil	1.12	0.38	92.18	0.90	0.51	0.43	0.79	0.29	0.32	0.47	0.87	0.76	0.55	0.42	7.82
Heating Oil	0.49	0.90	0.96	89.16	0.21	0.46	0.85	2.07	0.49	0.49	1.47	0.56	1.70	0.20	10.84
Czech Republic	1.60	0.45	0.49	0.31	90.56	0.53	0.57	0.54	1.99	0.30	1.26	0.29	0.89	0.21	9.44

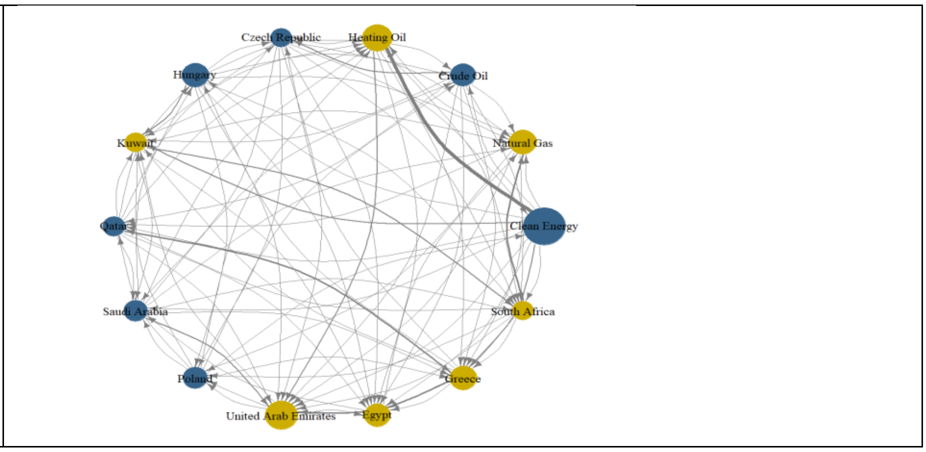
Hungary	2.35	0.98	0.19	0.45	0.49	83.97	3.84	0.63	1.58	2.41	0.72	0.81	0.60	0.98	16.03
Kuwait	2.46	1.29	0.57	0.79	0.56	4.35	81.49	1.30	1.08	3.17	0.57	0.69	0.96	0.71	18.51
Qatar	0.38	1.55	0.62	1.93	0.62	0.89	1.07	87.84	0.63	0.20	1.72	0.89	0.71	0.96	12.16
Saudi Arabia	1.11	0.92	0.19	0.46	1.79	1.84	1.55	0.65	87.18	1.49	1.04	0.70	0.85	0.22	12.82
Poland	0.44	0.51	0.26	0.31	0.39	2.53	3.11	0.23	0.79	88.73	1.00	0.51	0.53	0.65	11.27
United Arab Emirates	1.07	0.62	0.70	2.50	1.01	1.65	0.36	2.01	0.84	1.11	85.08	0.27	2.17	0.61	14.92
Egypt	1.45	1.02	0.71	0.40	0.40	1.28	0.95	0.85	0.31	0.65	0.63	90.23	0.65	0.48	9.77
Greece	1.53	1.68	0.51	1.98	0.82	1.05	1.04	0.64	0.90	0.77	2.07	0.40	85.70	0.92	14.30
South Africa	0.85	0.78	1.05	0.18	0.16	1.51	1.04	0.33	0.32	0.59	0.53	1.63	0.40	90.64	9.36
TO	108.51	97.76	99.85	100.71	99.12	102.60	98.81	99.51	98.56	101.09	98.41	98.95	97.95	98.17	cTCI/TCI
NET	8.51	-2.24	-0.15	0.71	-0.88	2.60	-1.19	-0.49	-1.44	1.09	-1.59	-1.05	-2.05	-1.83	13.03/12.09

4.4 Network connectedness

To further explore the asymmetries in shock transmission dynamics, network visualizations based on the TVP-VAR-derived connectedness measures are constructed across three regimes aggregate (all shocks), positive shocks, and negative shocks. These network graphs illustrate the directional spillovers among energy markets and EMEA equity markets, where node size reflects the net directional connectedness (larger nodes indicating stronger transmitters), node color indicates net transmitter (blue) or receiver (yellow), and edge thickness captures the magnitude of directional spillovers between markets.

In the aggregate network (all shocks, see fig 2), Clean Energy emerges as the central transmitter, as evidenced by its large node size and multiple thick outbound connections—particularly to markets such as South Africa, Natural Gas, and the United Arab Emirates. Other markets, including Hungary and Crude Oil, also act as modest net transmitters, though their influence is considerably lower. Several equity markets, notably Egypt, Greece, and South Africa, are positioned as net receivers, characterized by smaller node sizes and inbound-directed edges. The structure suggests a moderately connected system with Clean Energy as a systemic driver of spillovers under general market conditions.

Aggregate Network connectedness



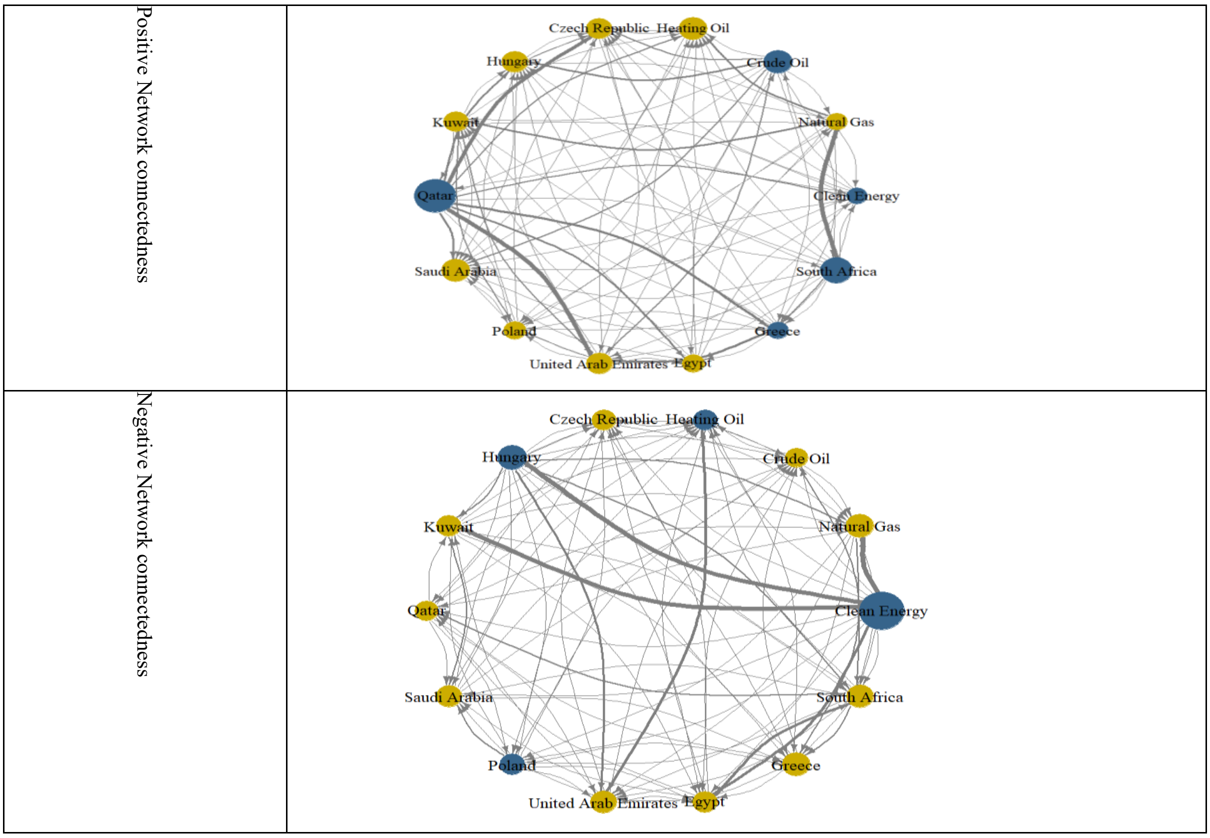


Fig 2: Network Visualizations of Spillovers in EMEA Markets

Source: Author's own calculation

Caption: This figure presents network visualizations of spillovers between energy markets and EMEA equity markets, divided into three regimes: aggregate shocks, positive shocks, and negative shocks. The node size reflects the net directional connectedness, with larger nodes indicating stronger transmitters of shocks. The color of the nodes indicates whether the market is a net transmitter (blue) or receiver (yellow). Edge thickness represents the magnitude of spillovers, illustrating how markets react to different types of shocks. Key events such as the COVID-19 pandemic, Russia-Ukraine war, and geopolitical tensions are highlighted as critical points that influence interconnectedness across the markets.

Under the positive shock regime (see fig 2), the network exhibits a distinctly different topology with heightened asymmetry. Qatar assumes the role of the most significant net transmitter, indicated by its disproportionately large node and numerous thick directional links to several equity markets, including Poland, UAE, Greece, and Egypt. This suggests that during periods of favorable market sentiment or economic optimism, Qatar-based equity dynamics exert substantial influence across the broader system. Crude Oil and South Africa also exhibit transmitter characteristics in this regime, whereas Hungary, Kuwait, and UAE serve predominantly as net receivers. The greater node centralization and thicker interconnections point to an increased degree of systemic spillovers during positive market phases, reflecting a pro-cyclical amplification of shocks.

In contrast, the negative shock network (see fig 2) is structurally more concentrated, with fewer dominant nodes leading to the transmission of adverse shocks. Clean Energy once again emerges as the most influential transmitter, underscoring its asymmetric role as both a systemic stabilizer and a conduit of volatility during downturns. The network highlights strong transmission pathways from Clean Energy to South Africa, Greece, and Egypt, all of which appear as prominent net receivers. Hungary also functions as a transmitter in this regime, possibly reflecting underlying structural or policy-based resilience during periods of distress. The comparatively sparser edge structure and localized transmission in the negative shock network suggest that adverse events result in selective, rather than widespread, systemic contagion.

Overall, these asymmetric connectedness networks underscore the differentiated behavior of markets depending on the nature of the shocks. Clean Energy consistently assumes a leading role in transmitting both positive and negative shocks, highlighting its increasing systemic relevance. In contrast, equity markets such as Greece, Egypt, and South Africa consistently appear as shock absorbers across regimes, indicating their heightened sensitivity to external influences. These findings provide critical insights into market structure, vulnerability mapping, and the importance of accounting for shock asymmetry when formulating investment, risk management, or macroprudential strategies. Our results align with previous studies (e.g., (Alshater et al., 2023; Anwer et al., 2022; Apergis et al., 2017; Baruník et al., 2016; BenSaïda, 2019; Hung, 2022), confirming the presence of asymmetric connectedness where negative (bad) volatility spillovers dominate during crisis periods and vary across time and frequency

5. Conclusion and Implications

This paper finds that the transmission of shocks between energy and EMEA equity markets is very asymmetric whereby positive shocks produce greater spillover effects than negative ones. The Time-Varying Total Connectedness Index (TCI) shows that there is an asymmetric relationship between energy and equity markets to both positive and negative shocks. In negative news periods, the TCI tended to be low, which means that the markets were less interconnected, and investors had more diversification possibilities. Conversely, when there were positive shocks, the TCI increased, which indicated greater interconnectedness and the risk of the two markets moving in the same direction increased. This asymmetry implies that during times of low interconnectedness (negative news) investors should take advantage of diversification opportunities and during times of high interconnectedness (positive news) investors should be more cautious in their portfolio and adjust their portfolios to control the risks and not concentrate in both markets. Clean Energy is always a system driver, whereas Natural Gas and equity markets such as Greece and the UAE are more vulnerable to external shocks. The leading role of Qatar in positive shock regimes and the robustness of Hungary in the negative regimes demonstrate the state-dependent nature of EMEA markets.

Our empirical findings are in strong alignment with the growing body of literature emphasizing asymmetric connectedness and time-varying volatility spillovers across global financial and commodity markets. Similar to Alshater et al. (2023), who identified persistent downside volatility spillovers in the global IT sector using a W-TVP-VAR framework, our results also highlight the dominance of negative spillovers during crisis episodes. This asymmetry is further supported by Baruník et al. (2016) and BenSaïda (2019), who demonstrated that bad volatility—arising from negative shocks—has a more substantial and longer-lasting impact than good volatility across U.S. and G7 markets, respectively. Consistent with Anwer et al. (2022), our study also reveals that spillover effects are not only asymmetric but also intensified during financial crises, especially in the short-run, reflecting heightened investor anxiety and herding behavior.

Our findings additionally echo Hung (2022), who observed significant nonlinear and directional return spillovers among traditional and digital asset classes, where the connectedness patterns were notably stronger during the COVID-19 pandemic. The evidence of partial dominance of bad over good volatility is also consistent with Apergis et al. (2017), who documented asymmetric volatility transmission in Australian electricity markets using high-frequency data, noting that such asymmetries reflect strategic behavior and market power. Overall, the confluence of our results with these studies underscores the critical importance of accounting for asymmetric, dynamic, and frequency-dependent connectedness patterns to better understand the complex interplay of shocks across financial and commodity markets.

As an additional perspective against which to locate the results of the present paper, the qualitative input of experts in the relevant industry and the case analysis of energy and equity markets can be useful. There is a risk that expert interviews with stakeholders in the energy sector will be valuable in giving us the insight of how volatility in energy prices affects the decision-making at a firm level (mainly in relation to investment, risk management as well as hedging). Arguably, real-life examples depicting how the equity markets can react to energy-related shocks can be found through a case study (Egypt or South Africa). Such qualitative considerations would go beyond making this research study more practically relevant but would also help in gaining a more in-depth explanation of the systemic risk that energy market disruptions present.

The implications of these findings for investors and policymakers are important. To diversify the portfolio, the dominance of Clean Energy implies that it should be added to it as a stabilizing asset, especially in the event of a decline. The susceptibility of markets such as Natural Gas and Greece to adverse shocks explains the importance of specific hedging measures. These insights can be used by policymakers to develop macroprudential tools that consider asymmetric spillovers to improve financial stability in the EMEA region. In future studies, this analysis may be expanded to include more asset classes or investigate how policy interventions can help reduce systemic risk.

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