

Sectoral and Regional Volatility Connectedness: The Case of
EU and US Indices

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Abstract

This paper investigates sectoral and regional volatility connectedness across 22 equity sector indices – 11 for the US and 11 for Europe over 09/10/2001 – 31/12/2024. Daily price series are converted into log returns which are used to extract volatility using univariate GARCH models. The Diebold and Yilmaz (2012) framework is applied to measure the total, directional and pairwise spillovers. Furthermore, the paper looks at the dynamic volatility spillovers, highlighting how trends shift between stable periods and crisis periods. This research quantifies the magnitude and direction of volatility spillovers, identifying key transmitters and receivers and analyses the evolution of systemic risk across four sub-periods: the post dot-com recovery, the Global Financial Crisis (GFC) and subsequent Eurozone sovereign debt crisis, the post-crisis monetary easing era, and the recent shocks of the COVID-19 pandemic and the Russia-Ukraine war.

The findings reveal a high degree of internal connectedness within both markets, however the key drivers of volatility differ. In the US, sectors like Consumer Staples and Materials are persistent net transmitters, whereas in the EU, Utilities and Financial services were the main transmitters. The cross-regional relationship is highly dynamic; while the US was the dominant net transmitter of shocks during the GFC, Europe became the primary source of volatility spillovers to the US during the 2022 energy and geopolitical crisis. However, although when both regions are combined the system is highly connected, the connectedness between the two markets is notably lower, with Europe acting as the net transmitter over the full sample. Cross-border spillovers are strongest within integrated industries.

The analysis shows that every major crisis led to a sharp increase in connectedness, both domestically and internationally confirming the contagion effects which diminishes the

benefits of cross-sector and cross-regional diversification. Furthermore, a structural shift after the GFC was established due to higher integration across markets.

Keywords: Volatility Connectedness; Financial Contagion; US-EU equity markets; Vector Autoregression; Financial Crisis.

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1. Introduction

Over the past two decades, the world has undergone several events, including the Dot Com Bubble, the Global Financial Crisis (GFC), the European Sovereign Debt Crisis, COVID-19 and the ongoing war between Russia and Ukraine. The US financial crisis, one of the most unanticipated events, struck the global financial system where financial institutions and several governments approached bankruptcy (Diebold and Yilmaz, 2014). Consequently, this led to a chain reaction on to Europe due to the interconnectivity of the global financial system leading to the European Debt Crisis.

As the financial landscape has undergone significant transformation, marked by an increase in integration and interdependence between aggregate stock markets, the benefit of diversification is reduced as financial markets are more prone to local and international shocks and events (Raddant and Kenett, 2021). Markowitz (1952) proposed, optimizing portfolios to maximize returns for a given risk, however, Markowitz (1999) explains the implications on diversification when the returns are correlated as “even with unlimited diversification” the presence of risk is still present. Hence, an importance in research on volatility transmission and understanding volatility spillovers and connectedness, both sectoral and geographical is key, not only to portfolio or investment managers but also to policymakers. Such insights guide fiscal and monetary policies in preventing or managing crises.

Given the increasing integration among the global economies driven by trade and financial linkages, volatility spillovers especially during periods of crises tends to rise with the consequences of financial stability (Shehzad et al., 2021). The post-dot-com recovery reconstructed capital growth sectors, while the GFC and European sovereign crisis

highlighted region-specific fragilities. More recently, the pandemic and the energy-price shock introduced new complexities. Building on the context of the United States and Europe, the two markets that dominate market capitalisation, are linked through trade and cross-border financing, yet they differ in monetary regimes and market structures. The US equity market is comparatively more technology and consumer oriented, while many European indices carry heavier weights in financials, industrial, energy and utilities.

This study contributes to the strand of literature on connectedness and spillover effects across US and EU sector indices. Volatility connectedness has been a subject of extensive study in finance with early works explored co-movements and contagion in international equity markets (Arshanapalli and Doukas, 1993), finding that shocks in one market could significantly impact others during crisis periods. Over time, researchers have developed more sophisticated methods to quantify these spillovers. A major advance was the Diebold and Yilmaz (DY) framework first proposed in 2009. This approach was later refined to measure directional spillovers identifying the transmitters and absorbers of volatility. Diebold and Yilmaz (2014) interpreted the spillover index in a network context where financial markets act as a connected web which have given rise to “connectedness” literature that applies the framework to various asset classes.

A vast body of empirical work has demonstrated that financial connectedness is not static but exhibits significant time variation, intensifying during periods of market stress (Balli et al., 2019; Baele, 2005; Mollah et al., 2016). The literature reveals that while the GFC was a crisis originating within the financial system, the COVID-19 pandemic which is a “black swan event” also triggered severe financial contagion (Veerendra Anchan et al., 2024). Another significant stream of research has uncovered the asymmetric nature of volatility spillovers (Xu et al., 2019 and Warshaw, 2020). While many studies have examined volatility transmission across national stock indices (treating each country’s market as a single entity), fewer have delved

into the sectoral composition of this transmission. Sector specific analysis can reveal whether certain industries act as a main transmitter of volatility. For example, research on the GFC demonstrated that financial institutions were tightly interconnected and transmitted risk globally (Diebold and Yilmaz, 2015). However, beyond the financial sector, less is known about how other sectors (e.g. technology, energy, etc.) contribute to cross-border linkages in an integrated economy. This study contributes to this area by analysing 22 sector indices across the US and EU and thus can identify which sectors serve as volatility transmitters and which are receivers.

From a regional perspective, few studies focus on the US and EU which makes the need for a regional pair analysis between the two said countries. Diebold and Yilmaz (2015) show spillover directions can shift over time, with the US leading during the subprime crisis and Europe taking over during its sovereign crisis. This insight motivates for a further examination of broader cross-section of the market: The study extends the analysis beyond financial institutions to multiple sectors and the inclusion of recent events is a notable contribution, as the pandemic and the European geopolitical crisis represent significant shocks that have not been fully examined in the connectedness literature.

This study employs Diebold and Yilmaz's (2012) connectedness approach to investigate the transmissions among sector indices. Finance literature has developed alternative measures for measuring spillover effect, such as the Granger causality network approach of Billio et al., (2012), the Multivariate GARCH (MGARCH) model of Engle and Kroner, (1995) and the conditional value at risk (CoVar) of Adrian and Brunnermeir (2016). The connectedness approach of Diebold and Yilmaz (2012) measures connectedness at different levels (pairwise and system-wide) and avoids challenges such as parameters identification. A rolling window analysis is produced to detect time-varying patterns that static full-sample analyses might

overlook, thus by utilising a dynamic approach the movement volatility spillovers during stress periods are captured.

The findings of this paper have important implications for several strands of the finance literature and for practical risk management. In terms of literature, the results will add to the evidence that financial integration could either share risks and potentially improve capital allocation, or, on the other hand, integration increases the probability that a disturbance in one market will spread to others, thereby weakening stability. Hence, by identifying key transmitters in the US-EU context, this thesis provides valuable information to systemic risk indicators.

The aim of this research is to address the above gaps and to measure the extent of volatility connectedness among major sectoral indices in the US and EU, both within each region and geographically. Secondly, is to determine which sectors and regions act as net transmitters of volatility, and which act as net receivers. This will shed light on the key drivers of volatility and the potential sources of systemic risk. Thirdly, is examining how volatility connectedness evolves over time and how it behaves during major financial crises and stress periods. The analysis will focus on five critical episodes: the post-dot com crash (early 2000s), the Global Financial crisis (2007-2009), the post-GFC recovery and European sovereign debt crisis (2010-2012), the COVID-19 pandemic (2020), and the Russia-Ukraine war outbreak (2022).

Furthermore, the paper investigates sectoral and regional effects in volatility transmission. This aims to determine whether cross-border volatility spillovers are primarily connected among equivalent sectors across regions (e.g. US-EU Financial index linkages). In essence, the study seeks to understand the degree of financial integration. Lastly, the objective would be to evaluate how the identified patterns of volatility spillovers affect the potential benefits

of international and cross-sector diversification as it will provide practical information to policymakers, market participants, asset managers and risk managers.

This study is structured as follows. Chapter 2 reviews theoretical and empirical literature on volatility spillovers and connectedness, including applications of the DY framework. Chapter 3 presents the methodology used in this study. Chapter 4 describes the data sources, the descriptive statistics for both returns and volatilities and the correlations between the indices across and within region. Chapter 5 presents and analyses the main empirical results of the study. Finally, Chapter 6 discusses the economic interpretation and policy implications of the findings, summarises the thesis's contribution, the study's limitations and suggests avenues for future research.

2. Literature Review

2.1 Introduction

There are three main types of studies which are relevant to this paper with respect to the research objectives. This chapter provides a review of the existing literature of volatility spillovers on a sectoral and geographical basis. Furthermore, volatility spillovers including spillovers for crisis-specific dynamics and financial connectedness is discussed. Finally, as this paper adopts the Diebold and Yilmaz (DY) framework, applications of such framework are outlined.

2.2 Financial Connectedness

We are moving into a more integrated world where financial integration is continuously increasing which brings about a higher correlation among financial markets (Gatfaoui, 2013, Claessens et al., 2012). Consequently, this increases the probability of increased frequency and intensity of contagion among national financial markets and cross-markets. Chen and Sun, (2023) highlighted the importance of considering non-linear and tail specific dynamics across global markets. Daily data ranging from 2007 to 2022 was used to examine the connectedness between the US and Chinese stock, bond, and foreign exchange markets using a quantile Granger causality framework which captures variations in spillover effects across different market conditions. The US financial market emerged as more central and dominant than China's, acting as both a transmitter and receiver of shocks, particularly in high-return environments.

Camera and Gioffré (2024) in their study on financial contagion and financial lockdowns outline financial contagion as a phenomenon in economies with weak fundamentals which allows shocks to spread easily. The authors tie the process of contagion to economic activity

with a variety of assumptions. Financial firms, which are considered as the main players in the economy, are split into financially healthy and financially distressed firms. They explain that the spread of a financial shock in an economy depends on the financial vulnerability of healthy firms and the effectiveness of institutions tasked with developing policy interventions that enable economic recovery. When both conditions are unfavourable the economy is considered to have weak fundamentals. The model used by the authors specifically emphasises the importance of restoring the financial health of distressed firms rather than allowing them to fail or go bankrupt, since distressed firms continue to operate and present a threat of contagion for the financial system. Similarly, Forbes and Rigobon (2002) and Pericoli and Sbracia, (2001) outline contagion as a significant increase in cross-market linkages following a shock, a structural shift that cannot be explained by economic fundamentals alone.

Raddant and Kenett (2021) explain the importance of measuring connectedness as the authors describe financial markets as a double-edged sword. Due to being more interlinked, financial markets can either absorb shocks which leads to greater robustness or worsen the spread of shocks and consequently create greater fragility. Their analysis identifies the United States and Germany as central nodes within the global equity network, underlining their pivotal roles in market interdependence. Notably, the industrials, materials, and financial sectors emerge as the dominant links of global connectivity, with the influence of the energy and materials sectors showing a market increase over the sample period. The study highlights the heterogeneity in connectivity over time and across individual stocks, indicating that network linkages are not static but evolve with changes in volatility and asset-specific characteristics.

Connectedness indices have also been examined as crisis predictors. Minoiu et al., (2014) outline that the degree of connectedness can also serve as an early warning indicator for

systemic banking crisis. The authors state that higher levels of a country's own connectedness captured by the intensity of its financial ties in the global banking network are associated with an increased probability of crisis. Their results show that a rise in a country's own financial connectedness, especially when accompanied by a fall in the connectedness of its neighbours, significantly increases the likelihood of a crisis. This asymmetry suggests that interconnectedness can signal fragility rather than resilience under certain structural configurations.

2.3 Volatility Spillovers

Volatility is taken to mean as the measure of the rate of fluctuations in the price of a security over time. An increase in volatility will bring about higher fluctuations in a particular asset's price, hence it deviates from the mean, while low volatility will have no or little movement in the financial instrument's price. Volatility of financial markets and understanding how it spreads has become a primary focus of research since the emergence of the conditional heteroscedasticity models of Engle (1982) and Bollerslev (1987). Nelson (1991) recognised that volatility propagates in an asymmetric manner which was formalised in an exponential Generalised Autoregressive Conditional Heteroscedasticity (GARCH).

Antonakakis et al., (2018) and Barunik et al., (2016) demonstrate sector-specific patterns in volatility spillovers, highlighting the financial sector's pivotal role due to its sensitivity to credit and liquidity conditions. Such sector specific analyses provide insights into how systemic risks originate and propagate through financial systems, especially in the context of EU-US market interactions. These studies argue that sectors like financials, technology, and energy exhibit pronounced volatility connectedness, given their global reach and integration in cross-border trading activities.

Regional differences in volatility transmission have also been rigorously examined. For instance, Greenwood-Nimmo et al., (2016) provide evidence that volatility spillovers between the US and EU are asymmetric, frequently dominated by shocks originating in US markets. Their findings highlight the dominant position of US markets in global financial interconnectedness, suggesting that volatility shocks originating in US indices, such as the S&P 500 tend to have a substantial impact on European markets. This is confirmed by Diebold and Yilmaz (2016) and Bekaert et al., (2014) finding that US markets act as net transmitter of volatility shocks to Europe.

More extensive research has focused on the implications of macroeconomic events and policy actions for volatility connectedness. For example, Ehrmann et al. (2011) and Claeys and Vasicek (2014) have assessed the effects of monetary policy interventions, particularly during crises on volatility spillovers between the EU and the US. Their analyses confirm that accommodative monetary policies, such as quantitative easing implemented by the European Central Bank (ECB) and the US Federal Reserve (FED), have substantial spillover effects, reducing volatility in domestic markets but occasionally amplifying cross-border volatility transmission.

Recent advancements in econometric techniques, such as time-varying parameter VAR model (TVP-VAR), improves the analysis of volatility spillovers by capturing their dynamic nature more effectively and recognizing the role of time in sectoral relationships. Gabauer and Gupta (2018) utilise TVP-VAR which allows for precise attribution of uncertainty shocks across types and borders, demonstrating that some uncertainties propagate more globally than others. The study shows that monetary policy uncertainty is the primary driver of both domestic and international spillovers, followed by fiscal, currency market, and trade policy uncertainties.

2.3.1 Volatility Spillovers for Crisis-Specific Dynamics

Empirical literature also points to specific events where volatility spillovers intensify during financial crises, making it crucial to understand how crisis dynamics specifically influence volatility transmission. Crises increase volatility because market players become more uncertain, and risk aversion rises sharply. In such times, investor sentiment is high which causes prices to fluctuate. The GFC is a prime example of increased volatility spillovers. Diebold and Yilmaz (2012) demonstrated that volatility spillovers across global financial markets peaked during the GFC, driven by interconnected financial institutions and market panic. Their spillover indices revealed sharp increases in volatility transmission, particularly from the US financial sector to other markets globally.

Akca and Ozturk (2015) gathered data between six major markets including the US, UK, Germany, Spain, Turkey and Greece and adopted the model developed by Diebold and Yilmaz (2009) to measure spillover index. Results illustrate that with the effect of the 2008 financial crisis; spillover indices increased around 55% and the six markets are highly correlated during times of crisis and the shock transmission is extremely strong. Germany had the highest net spillover as it generates the highest volatility spillovers to other countries.

Similarly, the Eurozone sovereign debt crisis from 2010-2012 led to significant regional volatility spillovers. Alter and Beyer (2014) highlighted how sovereign credit risk in countries like Greece, Spain and Italy rapidly spread volatility to other European markets. Banking sectors became critical transmission channels, increasing volatility across borders.

Emerging markets are also prone to crisis-driven volatility spillovers. The taper tantrum of 2013, when the US Federal Reserve announced potential tightening of monetary policy, triggered significant volatility spillovers to emerging economies. The proposed policy of

reducing the rate of FED asset purchases represented a negative shock to investors' expectations and as a result depressing the price of bonds. Eichengreen and Gupta (2015) noted that emerging markets experienced sharp volatility spikes due to sudden reversals in capital flows. Countries with high external debt and weaker financial frameworks faced more substantial volatility spillovers, illustrating how external policy shocks can destabilise emerging markets.

Sharif et al., (2020) examined the time-frequency connectedness between the recent COVID-19 outbreak, crude oil price volatility shock, geopolitical risk and economic policy uncertainty. They use US data across these variables during the early months of the pandemic. The authors apply a continuous wavelet transform and wavelet coherence to assess time-frequency co-movements. Results show that COVID-19 shocks have a particularly strong effect on geopolitical risk and economic policy uncertainty at low frequency, indicating persistent long-term impacts. Oil prices exert the strongest influence on US stock market volatility across both short and long frequencies.

COVID-19's impact on geopolitical risk exceeds its impact on economic policy uncertainty, implying that pandemic related geopolitical concerns overshadow economic uncertainty. Costa et al., (2021) in their studies of sectoral connectedness in the US with reference to COVID-19, saw an increase in volatility connectedness of almost 20% when compared to pre-crisis. Zhang et al., (2020) highlight that during the COVID outbreak, international stock markets became highly correlated in their volatility movements as investors worldwide reacted to the uncertainty.

The Russia-Ukraine conflict has catalysed governments to examine policy design in response to domestic economic uncertainties. U, Lin and Wang (2024), show how the Russia-Ukraine war creates significant volatility spillovers across the stock market, currency market,

commodity market and energy market. They find a sharp rise in total volatility spillovers at the beginning of the conflict and indicate the investor sentiment on the shock from the war will be substantial. Consequently, the Russian Ruble delivered a significant volatility shock to all other markets due to various Russian banks being restricted from accessing the SWIFT international payment system. Complementing these findings, Li et al., (2024) show that post-invasion volatility connectedness across a set of global markets rises much more than return spillovers, with equities and foreign exchange acting as the primary transmitters. The authors further document that investor attention to the war significantly amplifies volatility spillovers.

Similarly, Banerjee et al., (2024) study the risk spillover across geopolitical risk, stocks, bonds, forex, gold and energy markets from crisis and long-term perspectives. By employing a time-varying vector autoregression the authors capture the geopolitical risk to each market segment over time. The entire risk spillover network is caused by short-term risk spillovers, visible in the wartime period. The risk linkage among markets grew substantially, forming a risk connectedness with geopolitical risk as the risk transmitter and gold as the risk receiver. Importantly to note in geopolitical events, geopolitical risk becomes a risk spillover transmitter in financial markets which intensifies cross-risk spillovers.

2.4 Empirical Literature on Sectoral Volatility Connectedness

Sectoral volatility connectedness examines how volatility moves between different economic sectors, some of them being finance, energy, technology or healthcare. Understanding sector-specific volatility will help investors, regulators and businesses make informed decisions.

Choi et al., (2021) examine volatility connectedness across 11 Australian Securities Exchanges (ASX) sector indices involving crisis and non-crisis periods by applying the

Diebold and Yilmaz spillover index framework. The Finance sector was found to be the largest provider of volatility spillovers in the Australian sector market, and the Information Technology and Telecommunications Services Sectors are recipients of risk spillovers.

As outlined earlier in the paper, the TVP-VAR model has gained prominence to account for evolving sectoral relationships. For instance, Umar et al., (2023) show that in Eurozone equity networks the core markets are major shock transmitters while newer peripheral markets are more on the receiving end. Maurya et al., (2025), utilised this framework to analyse the degree of sectoral connectedness in the Indian stock market finding that the service sector was the largest transmitter of volatility while the fast-moving consumer goods (FMCG) was lowest transmitter. Pan et al. (2023) extends the TVP-VAR connectedness index by employing a nonparametric causality-in-quantiles test to measure the effect of global geopolitical risk on the dynamic volatility connectedness within China's sectoral stock markets. Global geopolitical risk was found to have varying degrees of causal effects on the net volatility spillovers in all sectors of Chinese stock market.

Thubdimphun and Saelee (2023) examined volatility spillovers within 11 sectors of Thailand's stock markets. In contrary to previous studies, where the financial sector was the main transmitter of volatility specifically during crisis periods, the authors found that during COVID period, the petrochemical and chemical sector was the main transmitter while the finance and security sector was the main receiver. This implies that the COVID crisis could be different to a financial crisis. Likewise, Laborda and Olmo (2021) show that during the COVID period, the energy sector became a unique transmitter of volatility shocks through the system. Conversely, Dang et al., (2024) explore the sectoral expected uncertainty connectedness in emerging markets across different frequencies and quantiles, using the quantile time-frequency which integrates Chatziantoniou et al.'s (2022a) time-frequency decomposition and quantile-based spillover measurement. Consumer Cyclical was found

to be one of the greatest risk transmitters both in the short and long term, while Communications and Networking and Healthcare were the largest risk absorbers at the median level.

Meanwhile, Barunik et al., (2017) show the dynamic volatility spillovers among US stock sectors using the realized variance and semi-variance and the spillover index of Diebold and Yilmaz (2012, 2014). In their study, Mensi et al., (2021) found that the consumer services and the consumer goods sectors were the largest net transmitters of volatility to the other markets. The negative semi-variance had more effects on total volatility spillovers than positive semi-variance.

Under good volatility, sectors including Financials, Materials, Oil and Gas, REIT, Technology and Utilities act as net receivers while under bad volatility, Oil and Gas become a net transmitter outlining the asymmetric behaviour. Similarly, Dang et al., (2023) study volatility across sectors in Vietnam's stock market, finding that food, fisheries, and oil and gas were found to play a role as risk transmitters.

2.5 Empirical Literature on Regional Volatility Connectedness

Regional volatility and the understanding of financial shocks across countries and regions have become a central focus as events in one part of the world will affect markets globally. Early studies provided initial evidence of cross-market volatility transmission. Hamao et al., (1990) found that volatility shocks in the US and UK stock markets carried over to Japan's market during the 1987 crash period. Similarly, King et al., (1994) showed that major national stock markets became more interlinked in terms of volatility during global turmoil, suggesting the presence of contagion effects.

These works established that volatility is not country specific, but it correlates across borders, specifically during periods of financial stress. Subsequent research focused on regional volatility spillovers with more advanced techniques. For example, Eun and Shim (1989) examined volatility spillovers between the US and European equity markets finding that the US market influenced European indices and vice versa, although the US tended to be a net transmitter. This was consistent with the view that the US equity market often acts as a leader in global finance.

Within Europe, studies have documented substantial intra-regional volatility connectedness. Kanas (1998) tested volatility spillovers across the three largest European stock markets (London, Frankfurt and Paris) finding asymmetric spillovers in almost all the markets. The introduction of the Euro and harmonisation of financial regulations contributed to more synchronised market movements. The European experience during the Eurozone sovereign debt crisis offers a significant example of regional risk contagion. Alter and Beyer (2014) find that volatility in sovereign debt market quickly spilled over into equity markets across Europe and beyond. Their results underline the role of country-level financial health in shaping broader regional volatility patterns.

Similarly, Mensi et al., (2018) focuses their studies on the connectedness among the global (MSCI world index), regional (S&P 500, stoxx600 and P1DOW) and GIPSI (Greece, Ireland, Portugal, Spain, Italy) stock markets. The authors use the ADCC-GARCH model, finding evidence of asymmetric conditional correlations among markets. Specifically, Europe and Asia/Pacific regional markets along with Spain and Greek markets were the net receivers of shocks from other markets, while the remaining GIPSI markets and both global and regional US markets were the net transmitters of shocks to other markets.

Empirical evidence suggests that while financial markets around the world are interconnected, regional and domestic factors often dominate cross-region influences. Yarovaya et al., (2016) analyse 21 stock markets spanning Asia, Europe, the Americas and Africa, and conclude that markets are typically more affected by local and intra-regional volatility shocks than by inter-regional contagion. In other words, volatility transmission is usually strongest within the same region, whereas spillovers regarding cross-region are comparatively weaker.

In terms of specific regional dynamics, the US market often emerges as a key volatility transmitter in the global network. Bekiros (2014a); Wang et al., (2018); Beraich et al., (2022) consistently show the US as a net exporter of volatility. Europe, while highly interconnected internally, is also influenced by US volatility shocks though it can generate its own region-specific volatility events. Significant events in Europe such as the Eurozone sovereign debt crisis have been shown to create volatility effects on to the US (Brighton and Lebioda, 2012), although the magnitude is typically smaller than US to Europe spillovers. Other regions (Asia, Latin America), show growing connectedness, particularly as markets mature and globalise, but their impact on Europe and US volatility remains smaller by comparison (Tissaoui and Zaghdoudi, 2020).

Thangamuthu et al., (2022) studied the asymmetry and volatility spillover from stock market indexes of five major nations including United States (S&P 500), China (SSE), Germany (DAX), Australia (ASX 200) and Japan (NIKKEI 225) to the Indian stock market (Sensex). The authors apply EGARCH frameworks to capture asymmetric spillover dynamics and outline that before COVID-19, negative significant volatility spillover was evident, however, after COVID, positive and significant return spillovers emerge from all markets except DAX.

As emerging markets have become more integrated into the global economy, their connectedness with developed markets has increased. Balli et al., (2015) focus on emerging markets and find that countries with more open financial systems tend to experience stronger spillovers. This implies that when barriers to capital flows are low, shocks travel faster and further, making these markets especially sensitive during periods of stress. The results show the dominance shocks in term of variance ratios of US shocks with the Asian markets particularly on the smaller markets, however, those emerging markets with greater market capitalisation, the influence of US shocks becomes weaker. Secondly the variance ratios of European spillovers were found to be less than 10% except for Bangladesh. The variance ratios of Japanese market spillovers were found to be closer to US spillover effects.

2.6 Applications of the Diebold and Yilmaz Framework

The Diebold and Yilmaz framework has become a standard tool to quantify volatility connectedness across financial markets. Originally introduced by Diebold and Yilmaz (2009), this approach defines a “spillover index” based on forecast error variance decompositions from VAR models. By using variance decompositions, it captures how much of one asset’s volatility can be attributed to shocks from others, providing intuitive measures of total and directional connectedness.

A crucial innovation in their 2012 methodology was employing a generalised VAR framework which is invariant to variable ordering. This enabled directional spillover measures for each market. This refined framework has been widely adopted in both academic research and risk management. By the 2014 paper, the framework was extended to interpret results as a network with measures of net direction and pairwise connectedness. Researchers often implement it in a rolling window analysis to track how connectedness evolves through time, which is especially useful for detecting periods of contagion.

The earliest of the framework focused on global equity markets. For example, the original Diebold and Yilmaz study applied the spillover index to international stock indices and found significant return and volatility spillovers among global equities. Subsequent research has extended this to many contexts and the connectedness framework has been widely used for measuring linkages among stock market indices, sector indices, credit markets, commodities and even cryptocurrencies. Studies have analysed connectedness within regions such as Eurozone equities and East Asian markets as well as across regions.

As outlined earlier in previous sections, a consistent finding in these applications is the identification of key net transmitters, usually large developed markets and net receivers which are the smaller or emerging markets (Prasad et al., 2018). For instance, (Izunna et al., 2023) show developed markets as persistent net transmitters of return and volatility shocks, with emerging and African markets as net receivers. Many others have looked at stock index spillovers in regions like Europe, Asia and Latin America (see Diebold and Yilmaz, 2015; Hou and Li, 2020; Choi, 2022; Son et al., 2023).

Another area of application is examining spillovers between different asset classes or markets. For instance, Manicaro (2023) analyse connectedness between equity indices and credit default swaps spreads across, US, UK, EU and Japan, finding that cross-asset volatility spillovers were relatively low in normal but spiked during crisis periods, with equity markets generally transmitting more volatility to credit markets. In the commodity space, DY based studies have assessed how oil price volatility spills into stock markets. Maghyereh et al., (2016) provide evidence of volatility connectedness between crude oil and equity markets using implied volatility indices linking the oil volatility index and stock volatility index.

Other work has extended this to multiple commodities and financial assets. One study of Gulf countries examined spillovers among oil gold and equity markets, which was found useful for cross-hedging and portfolio risk management (Maghyereh et al., 2017). More recently, the method has been brought to a new financial area like cryptocurrencies. Ji et al., (2018) apply the DY approach to major cryptocurrency markets and find dynamic connectedness patterns in volatility among crypto assets.

The Diebold and Yilmaz framework provides clear evidence of these markets that are connected and linked in terms of volatility. Practitioners and policymakers have also adopted variants of this framework for monitoring purposes, for instance central banks have looked at financial network spillover metrics to gauge contagion risk among banks or markets.

3. Methodology

3.1 Introduction

This chapter provides an analysis and describes the theory and the methodology used in this research to study the connectedness and spillovers mechanisms between the indices under study at both sectoral and regional level.

3.2 Volatility Clustering in Financial Time Series

A foundational step in analysing financial time series is to account for their empirical properties usually referred to as stylised facts. Volatility clustering describes the tendency for periods of high volatility and low volatility to occur in clusters. In practical terms, large price changes, regardless of their direction, tend to be followed by further large changes, while small changes are followed by small changes.

The presence of time-varying volatility is a phenomenon known as conditional heteroscedasticity which introduces a more sophisticated modelling approach. The Autoregressive Conditional Heteroscedasticity (ARCH) model, introduced by Engle (1982) and the Generalised ARCH (GARCH) by Bollerslev (1986) which suggested introducing a lagged conditional variance to the ARCH model were developed specifically to capture these dynamics. These models treat volatility not as a constant, but as a variable that evolves over time based on past information.

3.3 Diebold-Yilmaz Connectedness Framework

The study of interconnectedness within the financial system requires a framework that can capture the complex, dynamic and directional nature of shock transmission. Diebold and

Yilmaz (2012) developed a framework that provides such a structure moving beyond simple correlations to offer a better understanding on systemic risk and interdependence. The transmission of shocks is represented by weighted, directed edges enabling the identification of systemically important institutions, the primary channels of shock transmission and the overall resilience of the financial system to adverse events.

The idea of the DY framework is the idea that connectedness can be quantified by assessing the contribution of shocks in one variable to the future uncertainty of other variables in the system. This is achieved using forecast error variance decomposition which gives the proportion of the movements in variables due to their 'own' shocks versus shocks to the other variables (Brooks, 2008). This variance decomposition shows the H-step ahead forecast error variance of a variable i , is decomposed into proportions attributable to shocks originating from itself and from every other variable j in the system.

The study builds connectedness measures from the variance decomposition matrix of a vector-autoregressive approximating model. In particular, consider a covariance-stationary N-variable VAR(p), $x_t = \sum_{i=1}^p \Phi_i x_{t-i} + \varepsilon_t$ where $\varepsilon \sim (0, \Sigma)$. The moving average representation $x_t = \sum_{i=0}^{\infty} A_i \varepsilon_{t-i}$ where the N x N coefficient matrices A_i follow the recursion $A_i = \Phi_1 A_{i-1} + \Phi_2 A_{i-2} + \dots + \Phi_p A_{i-p}$ with A_0 being the N x N identity matrix and $A_i = 0$ for $i < 0$. The moving average representation is key to understand how shocks propagate through the system as it expresses the current value of each variable as a weighted sum of current and past shocks, thereby revealing the system's dynamic structure.

Following the calculation of variance decompositions orthogonal innovations and identification schemes like Cholesky factorisation is required. This approach orthogonalises the error terms, allowing the forecast error variance to be attributed to a set of uncorrelated

‘structural’ shocks however the variance decompositions are highly sensitive to the ordering of the variables in the VAR model which makes them unattractive. To overcome the order-dependency of the Cholesky approach, Diebold and Yilmaz (2012) adopt the Generalised Forecast Error Variance Decomposition (GFEVD) developed by Koop et al., (1996) and Pesaran and Shin (1998). The GFEVD approach does not require orthogonalisation of the shocks, hence produces results that are invariant to the ordering of the variables.

3.4 Generalised Forecast Error Variance Decomposition (GFEVD)

The GFEVD framework is used as it allows for correlated shocks, however it accounts for them properly. The H-step ahead GFEVD component denoted $\theta_{ij}^g(H)$, which measures the contribution of a shock in sector j to the forecast error variance of sector i , is represented by:

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

where Σ is the variance matrix for the error vector \mathcal{E} , σ_{jj} is the standard deviation of the error term for the j th equation, e_i is the selection vector with one as the i th element and zeros elsewhere. A_h are the infinite moving average coefficient matrices.

Since the generalised shocks are not orthogonal, the sum of contributions to the forecast error variance does not necessarily sum to 1 (i.e. $\sum_{j=1}^N \theta_{ij}^g(H) \neq 1$), hence, this is normalised by:

$$\tilde{\theta}_{ij}^g(H) = \frac{\theta_{ij}^g(H)}{\sum_{j=1}^N \theta_{ij}^g(H)} .$$

By construction, $\sum_{j=1}^N \tilde{\theta}_{ij}^g(H) = 1$ and $\sum_{i,j=1}^N \tilde{\theta}_{ij}^g(H) = N$.

Although the total volatility spillover index enables us to understand how much of the shocks spill over across different variables the generalised VAR provides information about the direction of volatility spillovers. $\tilde{\theta}_{ij}^g(H)$ provides a measure of pairwise directional connectedness from j to i at horizon H : $C_{i \leftarrow j}(H)$.

The directional connectedness is calculated by using the normalised elements of the generalised variance decomposition matrix. There are two versions of directional spillovers: the 'from' and 'to'. The directional volatility spillovers received by sector i from all other sectors j is measured as:

$$C_{i \leftarrow \bullet}(H) = \frac{\sum_{j=1, j \neq i}^N \tilde{\theta}_{ij}^g(H)}{\sum_{i,j=1}^N \tilde{\theta}_{ij}^g(H)} \times 100 = \frac{\sum_{j=1, j \neq i}^N \tilde{\theta}_{ij}^g(H)}{N} \times 100.$$

Similarly, the directional spillovers transmitted by sector i to all other sectors j is measured as:

$$C_{\bullet \leftarrow i}(H) = \frac{\sum_{j=1, j \neq i}^N \tilde{\theta}_{ji}^g(H)}{\sum_{i,j=1}^N \tilde{\theta}_{ji}^g(H)} \times 100 = \frac{\sum_{j=1, j \neq i}^N \tilde{\theta}_{ji}^g(H)}{N} \times 100.$$

The directional spillovers provide a decomposition of the total spillovers to those coming from (or to) a particular sector. Hence, the net total directional connectedness for sector i is measured by:

$$C_i(H) = C_{\blacksquare \leftarrow i}(H) - C_{i \leftarrow \blacksquare}(H)$$

A positive value indicates that the sector is a net transmitter of shocks, while a negative value indicates it is a net receiver. The equation above provides information on each sector on how much it contributes to the volatility in other sectors in net terms. It is also of importance to measure the net pairwise total connectedness ($C_{ij}(H) = C_{i \leftarrow j}(H) - C_{j \leftarrow i}(H)$) as it shows the net spillover effect between any two sectors. This is measured as:

$$C_{ij}(H) = \left(\frac{\tilde{\theta}_{ji}^g(H)}{\sum_{i,k=1}^N \tilde{\theta}_{ik}^g(H)} - \frac{\tilde{\theta}_{ij}^g(H)}{\sum_{j,k=1}^N \tilde{\theta}_{jk}^g(H)} \right) \times 100$$

$$= \left(\frac{\tilde{\theta}_{ji}^g(H) - \tilde{\theta}_{ij}^g(H)}{N} \right) \times 100$$

In simple terms the net pairwise total connectedness between sector i and j is the difference between the gross volatility shocks transmitted from sector i to sector j and those transmitted from j to i .

Finally, the total connectedness is measured as:

$$C(H) = \frac{\sum_{i,j=1}^N \tilde{\theta}_{ij}^g(H)}{\sum_{i,j=1}^N \tilde{\theta}_{ij}^g(H)} \times 100 = \frac{\sum_{i,j=1}^N \tilde{\theta}_{ij}^g(H)}{N} \times 100.$$

This summarises the average contribution of spillovers from all other variables to the total forecast error variance of the system as developed by Diebold and Yilmaz (2012).

3.5 The Connectedness Table

Variable	x_1	x_2	...	x_N	From Others
x_1	$\theta_{11}^g(H)$	$\theta_{12}^g(H)$	...	$\theta_{1N}^g(H)$	$\sum_{j=1}^N \theta_{1j}^g(H), j \neq 1$
x_2	$\theta_{21}^g(H)$	$\theta_{22}^g(H)$	...	$\theta_{2N}^g(H)$	$\sum_{j=1}^N \theta_{2j}^g(H), j \neq 2$
\vdots	\vdots	\vdots	\ddots	\vdots	\vdots
x_N	$\theta_{N1}^g(H)$	$\theta_{N2}^g(H)$	...	$\theta_{NN}^g(H)$	$\sum_{j=1}^N \theta_{Nj}^g(H), j \neq N$
To others	$\sum_{i=1}^N \theta_{i1}^g(H)$ $i \neq 1$	$\sum_{i=1}^N \theta_{i2}^g(H)$ $i \neq 2$	...	$\sum_{i=1}^N \theta_{iN}^g(H)$ $i \neq N$	$\frac{\sum_{i,j=1}^N \tilde{\theta}_{ij}^g(H)}{N}$

Table 3.1: Connectedness table schematic (Source: Diebold and Yilmaz, 2014)

The equations above can be summarised in Table 3.1. The upper left of the $N \times N$ block refers to the variance decomposition matrix, which is denoted by $\theta^g = \theta_{ij}^g(H)$. The diagonal element of $\theta^g(H)$ outline the effect of own-variance shocks whilst the off-diagonal entries represent a measure of the shocks arising from other variables. These are referred to as pairwise directional connectedness. The pairwise directional connectedness from j to i can be denoted as $C_{i \leftarrow j}^H = d_{ij}^H$. Normally, $C_{i \leftarrow j}^H \neq C_{j \leftarrow i}^H$ leading to pairwise directional connectedness measures sum to $N^2 - N$. The sum of the off-diagonal elements gives the

share of the H-step forecast error variance of variable i due to shocks coming from other variables. The sum of cells labelled ‘from’ and ‘to’ in the table above measure total directional connectedness measures. Hence, there are $2N$ total directional connectedness measures. The net total directional connectedness for variable i is defined as: $C_i^H = C_{i \leftarrow \bullet}^H - C_{\bullet \leftarrow i}^H$, making the net total directional connectedness sum to N . Finally, the total off-diagonal entries in $\theta^g(H)$ measures total connectedness in the system.

3.6 The Approximating Model

This study uses a VAR(1) approximating model using the Schwartz Information Criterion (SIC). Hence the approximating model is represented by:

$$X_{t,US,EU} = \Phi_1 X_{t-1,US,EU} + \epsilon_t$$

where X_t is a $N \times 1$ vector of the conditional volatility series at time t . Φ_1 are $N \times N$ coefficient matrices for the lag taken and ϵ_t is an $N \times 1$ vector of serially uncorrelated shocks with a zero mean. It is crucial to clarify that while the model structure is held constant, the model’s parameters are unique to each market. The $N \times N$ coefficient matrix Φ_1 and the $N \times N$ error covariance matrix are estimated independently for each calculation (*being US sector indices, EU sector indices and the combined US-EU sector indices*).

For instance, the parameter matrix $\Phi_{1,US}$ is estimated using the conditional volatilities for the 11 US indices while $\Phi_{1,EU}$ is estimated using the conditional volatilities for the 11 EU indices. For the combined sectors both the conditional volatilities are estimated.

3.7 Model Specification: The GARCH (1,1) Process

For its parsimony and proven effectiveness in modelling financial data this study employs the GARCH(1,1) specification. The model is applied individually to each asset's return series (which results in having a Univariate GARCH) and is defined by two primary equations which are the conditional mean and the conditional variance.

The conditional mean equations, models the return of an asset i at time t , denoted $r_{i,t}$, as a function of a constant mean and an error term:

$$r_{i,t} = \mu_i + \epsilon_{i,t} ,$$

where μ_i is the constant mean return for asset i , and $\epsilon_{i,t}$ is the shock at time t . This error term further decomposed into a time-varying volatility component and a standardized white noise process:

$$\epsilon_{i,t} = \sigma_{i,t} z_{i,t} ,$$

Here, $z_{i,t}$ is an independently and identically distributed process with a mean of zero and a variance of one, commonly assumed to follow a standard normal distribution, $z_{i,t} \sim N(0,1)$.

The term $\sigma_{i,t}$ represents the conditional standard deviation at time t .

The core of the model is the conditional variance equation which specifies the evolution of $\sigma_{i,t}^2$ as a function of past information:

$$\sigma_{i,t}^2 = \omega_i + \alpha_i \epsilon_{i,t-1}^2 + \beta_i \sigma_{i,t-1}^2 .$$

The parameters of this equation have distinct economic interpretations where ω_i is a constant term, representing the long run average variance intercept. α_i is the ARCH parameter, which measures the sensitivity of current volatility to the magnitude of the previous period's shock ($\epsilon_{i,t-1}^2$). A larger α_i indicates a more pronounced and immediate reaction to market news. β_i is the GARCH parameter, which captures the persistence of volatility by measuring the influence of the previous period's conditional variance ($\sigma_{i,t-1}^2$) on the current period's variance. A larger β_i signifies that volatility shocks have a long lasting impact. For the process to be covariance stationary, the condition $\alpha_i + \beta_i < 1$ must hold. The sum of these two parameters indicates the degree of volatility persistence. The GARCH modelling stage serves as dual function. Primarily, it provides a robust model of the time-varying volatility of each asset and more importantly it ensures that the inputs to the Vector Autoregressive Model satisfy the assumption of constant error variance.

3.8 Rolling-Window Estimation

Financial market connectedness is not static; it evolves over time and often intensifies during periods of stress. So far, the methodology discussed relates to the static approach, however, to capture these dynamics Diebold and Yilmaz (2009) extended the static full sample analysis by implementing a rolling-window estimation procedure. This dynamic approach allows for the visualisation of time-varying spillovers and their correlation with significant economic events providing valuable insights into the evolution of market interdependence. For this study, a horizon of $H = 10$ days is used and a window width of $w=200$ days. A shorter window makes the index more responsive to recent events but can lead to noisy parameter estimates whereas a longer window produces more stable estimates but may be slow to detect structural changes.

4. Data Set Analysis

4.1 Introduction

This chapter details the data, sample selection and preliminary analytical framework employed in this study. The subsequent section introduces the specific indices, outlines the data sources and sample periods, presents a preliminary analysis covering descriptive statistics, time-series properties and correlation statistics which is useful to form a-priori expectations.

4.2 Data Sample, Data Description and Data Sources

The empirical analysis is founded upon daily sector index price data from 09/10/2001 to 31/12/2024 (6060 observations) from two major developed markets: United States and Europe. The analysis is carried out within and across regions hence not only examining financial interconnectedness at a macro-regional level but also within specific market segments. All data was obtained from Bloomberg as it is widely recognized as the industry standard for financial market data and analytics. Utilizing this platform ensures access to reliable and extensive data which is essential for constructing the analytical framework for this study.

For the European market, the analysis utilizes a selection of STOXX Europe 600 sector indices. These indices are derived from the broader STOXX Europe 600 benchmark, which comprises 600 large, mid, and small-capitalization companies across 17 European nations. The sector indices are constructed according to the Industry Classification Benchmark (ICB),

which categorises companies based on their primary source of revenue, ensuring a consistent and economically meaningful grouping.

For the US market, the analysis employs S&P500 sector indices. These are derived from the Standard & Poor's 500 (S&P500) index, the most used benchmark for US large-cap equities. The S&P500 tracks the performance of 500 of the largest publicly traded companies in the US, representing approximately 80% of the total domestic market capitalization. The sector indices are based on the Global Industry Classification Standard (GICS), a joint creation of Standard & Poor's and MSCI. The full list of indices is shown hereunder.

<i>Ticker</i>	<i>Market</i>	<i>Index Name</i>
SX3P	EU	STOXX Europe 600 Food & Beverage
SX6P	EU	STOXX Europe 600 Utilities
SX86P	EU	STOXX Europe 600 Real Estate
SX8P	EU	STOXX Europe 600 Technology
SXDP	EU	STOXX Europe 600 Health Care
SXEP	EU	STOXX Europe 600 Oil & GAS
SXFP	EU	STOXX Europe 600 Financial Services
SXKP	EU	STOXX Europe 600 Telecommunications
SXNP	EU	STOXX Europe 600 Industrial Goods & Services
SXPP	EU	STOXX Europe 600 Basic Resources
SXQP	EU	STOXX Europe 600 Personal & Household Goods
S5COND	US	S&P 500 Consumer Discretionary
S5CONS	US	S&P 500 Consumer Staples
S5HLTH	US	S&P 500 Health Care
S5INDU	US	S&P 500 Industrials

S5INFT	US	S&P 500 Information Technology
S5MATR	US	S&P 500 Materials
S5RLST	US	S&P 500 Real Estate
S5TELS	US	S&P 500 Telecommunication Services
S5UTIL	US	S&P 500 Utilities
SPF	US	S&P 500 Financials
SPN	US	S&P 500 Energy

Table 4.1: EU and US Sector Indices

The reasoning behind this choice of sample is twofold. Firstly, the selected indices being the US and EU market are two pivotal regions with substantial economic and financial integration. Hence, it makes them ideal for this study since the scope of this paper is to capture the connectedness and the spillover effect emanating from the US and EU.

Secondly, is the timeframe of this sample which captures periods of economic distress and periods where markets are calm and free from any crises. To improve the way volatility connectedness, spillovers and correlation patterns are studied the full sample further divided into four sub-periods. These periods are not chosen at random but are split to match major structural breaks and macroeconomic phases that shaped global markets over the past two decades. The defined periods are as follows:

Period	Date	Description
1	October 9, 2001 – December 31, 2006	This period captures the recovery from the dot-com bubble collapse and the subsequent period of economic growth and relatively low volatility.
2	January 1, 2007 – December 31, 2012	This period is dominated by the Global Financial Crisis (GFC) of 2007 – 2009, and the subsequent European sovereign debt crisis. It is characterised by extreme market volatility, systemic risk and significant policy interventions.
3	January 1, 2013 – December 31, 2019	This period represents the post-crisis recovery phase, market by unconventional monetary policies, including quantitative easing and a prolonged environment of low interest rates, which fostered a sustained bull market with relatively low volatility.
4	January 1, 2020 – December 31, 2024	This timeline kicks off with the COVID-19 pandemic which triggered a sharp market crash followed by a fast, policy-driven rebound. It also includes the emergence of significant inflationary pressures, a cycle of monetary tightening, and heightened geopolitical tensions including the ongoing Russia-Ukraine and the Gaza wars.

Table 4.2: Description of Sub-Samples

Therefore, five samples are considered: the full sample covering all data points and the four sub-samples which cover the observed changes in volatility, correlation and other market dynamics providing a more detailed analysis.

4.3 Returns Data Description

To analyse the price movements of the selected indices, daily returns are calculated. The approach adopted, is the use of continuously compounded returns or logarithmic (log) returns.

The log return (r_t) at time t is calculated from the index price level (P_t) as:

$$r_t = \ln\left(\frac{P_t}{P_{t-1}}\right) \quad (4.1)$$

where P_{t-1} is the price level in the previous period and \ln denotes the natural logarithm.

4.3.1 Descriptive Statistics

To understand the characteristics of the indices, the descriptive statistics for each sample were computed. Tables A.1 to A.10 in Appendix 3 provide the descriptive statistics for the returns series of all the indices both US and EU under study. Over the full sample, US sector indices generally exhibited higher mean returns when compared to EU indices. For instance, S5INFT recorded a mean return of 0.046%, while SX8P had a mean return of 0.017%.

Similarly, S5RLST averaged 0.036% versus 0.0049% for SX86P. This suggests a stronger long-term performance trend in the US market, particularly in growth-oriented sectors. In terms of risk, as measured by the standard deviation of returns, the levels were similar between the two markets. However, certain US sectors such as Real Estate and Financials, displayed higher levels of volatility (1.83% and 1.80%, respectively) than most European sectors. The notable exception in Europe was SXPP, which was the most volatile index in the entire dataset with a standard deviation of 2.03%, reflecting its high sensitivity to global commodity price fluctuations.

The analysis of higher-order moments provides strong evidence against the assumption of normally distributed returns. Firstly, nearly all return series in both markets exhibit negative skewness. This is a commonly observed trait of stock returns, indicating that the return distributions are asymmetric with a longer left tail. For example, SXEP shows a skewness of -0.467 and S5COND has a skewness of -0.300. This implies that large negative returns occur

with greater frequency than large positive returns of the same magnitude. Secondly, all series show significant positive excess kurtosis. The kurtosis values are substantially higher than the value of 3.0 associated with a normal distribution. For instance, SX6P has a kurtosis of 17.6, and SPN has a kurtosis of 17.5. This “fat-tailed” property signifies that extreme events, both positive and negative, are far more probable than a normal distribution would predict. The combination of negative skewness and high kurtosis is confirmed by the Jarque-Bera test for normality. For every return series in the sample, the Jarque-Bera statistic is exceptionally large and the corresponding p-value is effectively zero, leading to a rejection of the null hypothesis of normality.

Daily returns are in line with a-priori expectations. In the post-dotcom recovery phase, most sectors in both regions posted positive mean returns with standard deviations at relatively moderate levels, reflecting a period of economic expansions. During the GFC, mean daily returns declined substantially with numerous sectors in both the EU and US registering negative average returns for the six-year period. The SX6P index declined by -0.037% versus the -0.051% for SPF. Simultaneously, standard deviation spiked, where SPF which was the focus of the crisis more than doubled from 1.15% in Period 1 to 2.82% in Period 2. This period was characterised by a sustained environment of high risk and poor performance. During the post-crisis recovery, fueled by monetary stimulus, market characteristics shifted again.

Mean returns became strongly positive for most sectors, and standard deviation fell significantly, indicating a much calmer and more favourable market environment. For instance, the mean return for the EU Financial sector swung from -0.040% in Period 2 to 0.045% in Period 3. The COVID-19 pandemic period similarly to the financial crisis saw a sharp increase in standard deviation across most indices. For most of the indices, skewness

grew more negatively, reflecting the sudden crash decline in early 2020. Kurtosis also increased substantially, pointing to a period dominated by extreme tail events.

A deeper comparison of the two crisis periods (GFC and COVID-19 shock) reveal an asymmetric market response. While both periods induced high volatility, the nature of that risk was different. The GFC was characterized by a prolonged period of increased standard deviation reflecting high uncertainty while the COVID-19 shock was characterized by a more dramatic spike in kurtosis. For instance, the kurtosis for SX6P rose from 15.3 in Period 2 to 25.5 in Period 4, while for S5CONS, increased from 13.8 to 19.9. This suggests that the GFC was a crisis of sustained high volatility, whereas COVID-19 was a crisis of extreme, sharp, tail-event risk.

4.3.2 Test Statistics

Before extracting the conditional variance, it is essential to establish the time-series properties of data which is achieved by testing for stationarity and heteroskedasticity in the series. For the former, this study employs two widely recognized unit root tests to provide a more robust assessment of stationarity: the Augmented Dickey-Fuller (ADF) test and the Kwiatkowski-Phillips-Schmidt-Shin (KPSS) test. To address heteroskedasticity, the Autoregressive Conditional Heteroskedasticity (ARCH) Engle test is conducted.

The ADF test assesses the null hypothesis (H_0) that a unit root exists in the time series, implying that the series is non stationary and denoted as $I(1)$. The alternative hypothesis (H_1) implies that process is stationary meaning it does not have a unit root, $I(0)$. On the other hand, the KPSS test adopts a null hypothesis (H_0) of stationarity while the alternative hypothesis (H_1) implies that the series is non-stationary. The KPSS test's underlying methodology is

based on a linear regression that decomposes a time series into three components: a deterministic trend, a random walk, and a stationary term.

For all the 22 return series the ADF test statistic is highly negative and statistically significant at all levels leading to a strong rejection of the null hypothesis of a unit root. This provides evidence that the return series do not contain a stockastic trend and are not I(1) processes. The KPSS test results, while sometimes rejecting the null of stationarity at level, consistently fail to reject the null for the first-differenced series. Hence, given the results from both tests all indices are stationary for all samples (see Tables A.11 to A.20 in Appendix 4).

The ARCH-LM test, which tests for volatility clustering into the series, shows that the null hypothesis of no ARCH effects is rejected for all indices, indicating the presence of volatility clustering.

4.3.3 Correlation Analysis

Understanding the interrelationships between sectors is a key part of this section as correlation plays an important role in the economy since it reflects the relationship between variables. Both intra-market and cross-market correlations are computed to measure the long-term connectedness within the European and US markets.

The correlation structure reveals economic clusters, where within the US market cyclical sectors whose performance is closely tied to the overall business cycle exhibit high correlation. The strongest correlations are observed between Industrial and Materials at 0.867, and between Industrials and Consumer Discretionary at 0.837. Similarly, in the EU, the Financial Services and Industrial Goods & Services sectors are very highly correlated at 0.894. Conversely more defensive sectors, which provide essential goods and services, tend

to be less correlated with the broader market. For instance the US Utilities shows some of the weakest correlations with other sectors, such as Information Technology at 0.506.

Correlations are not static over time, they fluctuate with market conditions often following the pattern of higher correlation in crises and lower in calm periods. A key finding is the powerful contagion effect during periods of market crisis. In Period 2 (GFC) and Period 4 (COVID), the average cross-sectional correlations increased substantially compared to the calmer periods. For example, the US Real Estate index and the Energy index was at 0.18 during Period 1 while during the GFC, this correlation more than trippled to 0.62.

Post financial crisis, in a calmer policy-supported environment return correlations generally subsided. In the European landscape, correlation between SXPP and SX3P sectors fell to just 0.399, as investors rotated into growth-oriented assets. Similarly, in the US, the Utilities sector's return correlation with the Financial sector delined to 0.211, highlighting defensive sectors as potential safe havens during periods of economic expansion.

However, the COVID pandemic triggered another sharp increase, with return correlations rising across the board as systemic risk factors once again dominated sector-specific dynamics. For instance, SPF and S5INDU increased to 0.904, indicating that the market-wide shock of the pandemic synchronized directional movements across many economic segments.

Beyond intra-market dynamics, the correlation between EU and US indices is a critical feature of the global financial system. Over the long term, these markets have been increasingly integrated, a trend driven by globalization, cross-border capital flows and the internationalization of major corporations.

4.4 Volatility Data Description

Financial market volatility is not constant over time but exhibits periods of high and low turbulence often known as volatility clustering. To capture this time-varying nature of risk, the conditional volatility for each return series is extracted providing a daily measure of expected volatility.

4.4.1 Descriptive Statistics

Tables A.36 to A.45 report descriptive statistics for the volatility series of each index under study covering all samples. Over the full sample, all of the volatility series exhibit distinct characteristics. Both markets show comparable levels of volatility, however defensive sectors like Utilities and Consumer Staples tend to be on the lower end of the volatility range. Conversely, more cyclical or technology oriented sectors are near the higher end (S5INFT averaged 2.25% versus 2.71% for SX8P). A notable sector was SXPP having a mean volatility of 4.04% implying the effect of global events like pandemics or geopolitical events. Similarly to the return series, the mean volatility levels are highest during the crisis periods of Period 2 and Period 4 and are significantly lower in Period 1 and Period 3 providing clear evidence of volatility clustering.

All volatility series exhibit strong positive skewness. For example the European Utilities shows a volatility skewness of 9.24 while the US Consumer Staples has a skewness of 10.35 over the full sample. This indicates that the distribution of volatility is highly asymmetric with a long right tail. This translates to a market that typically experiences long periods of low volatility that are hit by sudden and sharp spikes in risk, after which volatility tends to decay more slowly. Furthermore, the kurtosis of all volatility series is extremely high, far exceeding that of the return series (e.g. SX6P: 116.5; S5CONS: 141.3). This extreme leptokurtosis implies that massive spikes in volatility are an integral feature of the market's risk dynamics. All sector

indices do not follow a normal distribution as this is confirmed by the Jarque-Bera test, where the null hypothesis is rejected at all significance levels.

4.4.2 Test Statistics

Tables A.46 to A.55 show the results for the stationarity test of the volatility series. The ADF test frequently rejects the null hypothesis of unit root mostly at all levels of significance. The KPSS often rejects the null hypothesis of stationarity at level however rejecting the null hypothesis at the first difference.

4.4.3 Correlation Analysis

The correlations for volatility are significantly higher than for returns, indicating that the level of market risk is far more synchronized. In the US market, nearly all pairwise volatility correlations are above 0.80, with the weakest being between S5RLST and S5CONS at a moderate of 0.608. The evolution of volatility correlations shows the contagion of risk during crises is far more evident than the contagion of returns.

During Period 2, the Real Estate sector which was the center of the global problem, saw a substantial increase in its correlations. In the US, during Period 4, nearly all pairwise correlations were above 0.90 (the highest being between S5MATR and S5HLTH at 0.987). The EU experienced similar results where in crisis periods, volatility correlations intensified dramatically demonstrating that, during market stress, diversification benefits are diminished as risk become highly synchronized.

Conversely, Period 3 demonstrates the opposite, with correlations diminished significantly. For example, the correlation between defensive US Utilities and several cyclical sectors

dropped. Its correlation with the European cyclical sector, such as Financials fell to 0.16 and Industrials fell to 0.23.

4.5 Conclusion

From initial observations, US and EU markets are deeply interconnected, however this relationship is not static. The analysis consistently shows that sector returns in both markets do not follow a normal distribution and exhibit negative skewness and significant excess kurtosis. The GFC and COVID-19 periods were characterized by a substantial increase in volatility and correlations both within and across markets. This contagion effect diminishes the benefits of diversification in such periods. Lastly, the analysis differentiates between the GFC which was a crisis of prolonged high volatility and the COVID-19 shock which was characterized by an extreme spike in tail-risk suggesting that the nature of a crisis dictates the specific type of risk.

5. Results and Analysis

5.1 Introduction

This chapter presents the empirical results of the volatility connectedness for the US and EU indices. The methodology of Diebold and Yilmaz (2012) is used, using a GFEVD derived from a VAR. The primary objective is to quantify and interpret the network of volatility transmission, both within each region and between them. Hence, the primary sources and recipients of financial shocks are identified and understand how these roles evolve in response to changing macroeconomic conditions.

The analysis begins with a static full sample analysis, which establishes a long-term baseline measure of average connectedness for the US market, EU market and the combined markets. The analysis then proceeds to a comparative static analysis across four distinct sub-periods. This will lead to a detailed analysis of how the structure of systemic risk responds to major economic crises. Finally, since the dynamics of volatility spillovers change across time a rolling window analysis of all periods is conducted to trace the evolution of connectedness over time.

5.2 Static Full Sample Sectoral Connectedness

This section considers the volatility connectedness from a sectoral perspective within the US and the EU. Table 5.1 outlines the results from the full sample for the US. The diagonal elements indicate own variance shares, while off-diagonals indicate spillovers *from* other indices. The last column (“From Others”) indicates, for each index, the total percentage of volatility driven by shocks from all other indices. The “Contribution to others” shows the total volatility each index transmits to the rest of the system and the difference between what an

index contributes to others and what it receives “Net Contribution” indicates whether that index is a net transmitter or net receiver of volatility.

Over the full sample, the 11 sectoral indices exhibit a high degree of internal connectedness (81.0%), indicating that most volatility shocks are transmitted and absorbed within the domestic market. Looking at the diagonal elements, SPF has the highest value (25.2%) suggesting a significant portion of volatility is self-generated, though it remains a highly connected part of the system. Similarly, sectors including S5RLST (22.4%), S5TELS (22.3%) and S5CONS (21.0%) although influenced by the other indices, a substantial amount of volatility is also self-generated.

S5CONS while often considered defensive has the highest net contribution of 19.7% making the index the largest net transmitter of shocks in the system over the full period. Moreover, S5MATR being a core component of the economic supply chain has the highest contribution to others at 100.4% implying that shocks in the materials industry will naturally propagate to nearly all other sectors. Cyclical sectors including S5COND and S5INDU, where their performance is closely tied to the business cycle are also significant net transmitters.

On the other hand, S5UTIL is the largest net receiver of shocks with a net contribution of -40.8%. While receiving the most amount of spillover from others, it contributes the least to the system. This is a characteristic of defensive, interest-rate sensitive sectors that react to, rather than drive, broad market movements. Similarly, S5RLST has the second highest negative net contribution of -32.1%, where similarly to Utilities, it is highly sensitive to macroeconomic conditions that are often driven by shocks in other sectors.

FULL PERIOD

	S5COND	S5CONS	S5HLTH	S5INDU	S5INFT	S5MATR	S5RLST	SPF	SPN	S5TELS	S5UTIL	From Others
S5COND	15.2	9.0	9.3	10.9	10.4	10.8	5.5	8.2	7.0	9.6	4.1	84.8
S5CONS	9.9	21.0	11.7	9.0	8.6	9.0	2.7	5.6	7.8	8.5	6.2	79.0
S5HLTH	9.4	13.2	17.7	9.2	9.4	9.8	2.8	6.1	7.3	9.1	6.0	82.3
S5INDU	10.9	9.8	8.5	15.8	9.3	11.9	5.2	8.8	8.8	7.0	4.0	84.2
S5INFT	11.4	9.7	9.4	10.5	18.0	9.4	3.3	6.8	6.0	11.4	4.0	82.0
S5MATR	10.1	9.5	10.2	10.9	8.3	15.8	4.7	7.6	9.3	8.0	5.6	84.2
S5RLST	10.9	5.4	5.1	10.2	5.8	9.7	22.4	17.4	4.7	6.3	2.2	77.6
SPF	10.3	5.1	5.4	11.5	6.9	9.5	13.0	25.2	5.7	5.5	2.0	74.8
SPN	8.2	10.1	10.7	9.8	7.0	11.9	2.9	7.0	20.7	6.7	5.0	79.3
S5TELS	10.2	10.5	10.4	7.2	10.2	9.2	3.1	5.6	6.3	22.3	5.1	77.7
S5UTIL	8.2	16.4	12.1	8.0	8.2	9.2	2.3	4.5	7.0	8.9	15.1	84.9
Contribution to others	99.5	98.7	92.7	97.4	84.1	100.4	45.5	77.7	69.9	81.0	44.1	891.0
Net Contribution	14.7	19.7	10.4	13.2	2.1	16.2	-32.1	2.9	-9.4	3.3	-40.8	81.00%

Table 5.1: US Full Sample Connectedness

The IT sector plays as a balanced role in the system with a small positive net contribution of 2.1%. Despite its large market capitalization, it does not act as a dominant net transmitter in this framework. Key pairwise spillovers include the financials and real estate sector (reflecting financing and rate-sensitivity channels) and the industrials and materials.

Table 5.2 details the connectedness analysis for the 11 European STOXX 600 sectors. Similar to the US, the total connectedness for the European market is 80.50%, however the sectoral roles differ from those in the US reflecting the distinct structure of the European economy.

The primary net transmitters of volatility are sectors heavily linked with Utilities (22.3%) Financial Services (17.8%) and Personal and Household Goods (15.6%). The former is the leading net transmitter of shocks which is particularly an interesting finding as Utilities are often considered defensive. However, they are a primary source of systemic risk, which could arise due to their sensitivity to energy prices, regulation and interest rate policies which have wide-ranging economic effects.

The Real Estate sector has the highest self-driven volatility with a value of 25.8% likely due to its high sensitivity to property market cycles, interest rates and regulatory changes that can be distinct from broader equity market movements. It also has a negative net contribution of -14.6% implying that it is a net receiver which aligns with its sensitivity to the financial health of banks, industrial demand for commercial property and overall economic sentiment. Technology is the largest net receiver (-29.0%). Its own share is 22.6% while only transmits a value of 48.4% to other sectors which is the lowest “contribution to others” implying that technology is heavily driven by outside influences.

FULL PERIOD

	SX3P	SX6P	SX86P	SX8P	SXDP	SXEP	SXFP	SXKP	SXNP	SXPP	SXQP	From Others
SX3P	19.8	11.7	5.4	3.8	11.7	6.8	8.7	8.1	7.5	4.7	11.7	80.2
SX6P	10.7	18.9	5.2	3.5	10.8	7.4	9.9	9.1	8.4	6.1	9.9	81.1
SX86P	7.5	9.4	25.8	3.9	4.5	5.9	12.4	6.7	9.5	5.7	8.6	74.2
SX8P	6.3	7.1	5.1	22.6	6.8	5.6	10.1	9.5	10.4	6.0	10.6	77.4
SXDP	12.1	10.9	3.7	4.3	24.7	5.9	8.5	9.2	6.3	4.2	10.3	75.3
SXEP	9.2	10.9	5.3	4.3	8.1	18.6	9.3	7.7	9.6	8.1	8.8	81.4
SXFP	7.5	10.3	9.3	5.6	6.2	7.3	15.8	8.9	11.4	7.7	10.1	84.2
SXKP	8.5	12.7	5.3	5.9	10.0	6.7	9.8	20.1	6.8	4.2	10.0	79.9
SXNP	8.3	10.8	7.7	6.1	6.2	8.3	11.7	7.6	14.0	9.0	10.3	86.0
SXPP	7.5	9.5	6.3	4.9	5.8	8.6	11.6	5.9	11.9	18.7	9.3	81.3
SXQP	11.2	10.2	6.3	6.0	9.3	6.6	10.1	8.3	9.6	6.5	15.9	84.1
Contribution to others	88.9	103.4	59.6	48.4	79.4	69.2	102.0	80.9	91.5	62.1	99.7	885.1
Net Contribution	8.7	22.3	-14.6	-29.0	4.1	-12.2	17.8	1.0	5.5	-19.2	15.6	80.50%

Table 5.2: EU Full Sample Connectedness

Analysing pairwise relationships, Financial Services (10.1%), Industrial (10.4%) and Personal Goods (10.6%) contribute the most to Technology reflecting the sensitive nature of technology firms (exposure to global demand, supply chains and market sentiment). Furthermore, looking at the strongest pairwise linkages are from Utilities to Telecommunications (12.7%) and Financial Services to Real Estate (12.4%).

5.2.1 Static Full Sample Regional Connectedness

This section outlines the interdependence between the US and the EU. The initial finding is the total connectedness for the combined markets stands at 86.70%. However, when decomposing the sectoral connectedness, the connectedness between the US and EU stands at 33.03%. The main findings over the full sample are that Europe is the net transmitter (60.0%) of shocks while US sectors are the main absorbers of volatility (-60.0%). The most significant cross-regional spillovers occur between corresponding sectors in the US and EU, highlighting the deeply globalized nature of specific industries.

The most notable relationship exists between the US and EU Energy sector. The largest spillover from the US to EU is from SPN to SXEP with a value of 8.1%. Similarly, the largest spillover from the EU to the US is the direct reciprocal from SXEP to SPN at 7.7%. This shows that US and EU energy markets do not act independently but as two core components of a single global energy system. Shocks to oil and gas prices, or demand in one region are immediately transmitted to the other.

FULL PERIOD

	S5COND	S5CONS	S5HLTH	S5INDU	S5INFT	S5MATR	S5RLST	SPF	SPN	S5TELS	S5UTIL	SX3P	SX6P	SX86P	SX8P	SXDP	SXEP	SXFP	SXKP	SXNP	SXPP	SXQP	From Others
S5COND	10.3	6.2	5.9	7.9	6.8	7.1	3.2	5.3	5.1	5.8	2.6	2.9	3.9	3.0	2.3	2.9	3.4	4.0	1.6	3.6	2.8	3.5	89.7
S5CONS	5.6	12.7	6.3	5.9	4.8	5.3	1.3	3.3	5.3	4.2	3.6	4.6	7.0	2.5	1.5	4.8	4.8	3.9	3.4	3.1	2.3	3.7	87.3
S5HLTH	5.5	8.3	10.6	6.2	5.3	5.8	1.3	3.6	5.1	4.5	3.5	4.0	6.1	2.3	1.6	5.4	3.8	4.5	2.9	3.4	2.6	3.7	89.4
S5INDU	7.0	6.6	5.1	11.3	5.7	7.8	3.0	5.7	6.4	3.8	2.4	2.6	3.8	3.3	2.1	2.8	4.8	3.9	2.1	3.9	2.9	3.0	88.7
S5INFT	7.1	6.3	5.4	7.4	11.1	5.8	1.8	4.4	4.5	6.0	2.3	3.1	4.5	2.5	3.5	3.7	4.0	4.4	3.1	3.5	2.3	3.6	88.9
S5MATR	6.0	6.1	6.0	7.4	4.9	9.9	2.2	4.4	6.5	4.1	3.5	3.3	5.2	2.9	2.1	3.4	3.9	4.5	2.2	4.3	3.9	3.5	90.1
S5RLST	8.6	4.7	3.6	9.0	4.4	7.2	17.7	14.2	3.7	4.2	1.6	1.4	1.8	2.5	1.2	1.4	2.2	2.2	0.5	2.5	3.4	2.0	82.3
SPF	7.5	4.0	3.7	9.2	5.1	6.9	9.5	19.9	4.4	3.5	1.2	1.3	1.6	3.3	1.6	1.4	3.0	3.3	0.9	2.9	3.4	2.4	80.1
SPN	4.4	5.9	6.0	6.2	3.8	6.8	1.1	3.8	13.9	3.2	2.9	4.0	5.9	2.2	1.6	3.9	7.7	4.0	2.2	3.8	3.5	3.2	86.1
S5TELS	6.1	7.2	5.9	4.9	5.5	5.4	1.4	3.3	4.8	13.8	3.1	4.0	5.9	2.0	2.3	4.9	3.6	3.9	2.9	3.1	2.4	3.7	86.2
S5UTIL	4.9	10.6	7.0	5.5	4.4	5.8	1.1	2.6	5.3	4.4	10.2	3.9	7.0	2.6	1.3	4.9	4.0	3.7	3.6	2.5	1.7	3.0	89.8
SX3P	2.8	4.9	4.1	2.7	2.1	3.1	0.5	2.4	3.5	2.1	1.6	13.8	8.1	3.2	3.0	8.3	5.1	6.2	5.2	5.4	3.6	8.4	86.2
SX6P	2.4	4.6	4.2	2.8	1.9	3.4	0.4	2.1	4.0	2.0	1.9	7.3	13.0	3.2	2.8	7.7	6.0	7.0	6.0	6.0	4.5	6.8	87.0
SX86P	3.5	3.4	1.9	4.5	2.6	3.4	1.3	3.3	2.8	1.5	1.2	5.0	6.0	17.3	3.2	3.4	5.2	8.6	4.4	7.0	4.5	6.0	82.7
SX8P	3.5	2.0	1.8	3.6	4.7	3.4	0.7	2.3	1.7	2.4	1.3	4.3	5.1	3.4	17.0	4.9	4.3	7.3	6.9	7.4	4.3	7.8	83.0
SXDP	2.8	4.9	5.6	2.6	2.4	2.7	0.4	2.0	2.7	2.4	1.5	7.9	7.5	2.3	3.3	17.9	4.2	6.1	5.9	4.4	3.0	7.3	82.1
SXEP	2.7	4.4	3.5	4.3	2.5	4.2	0.7	2.4	8.1	1.7	1.7	5.4	6.9	3.0	3.2	5.2	12.2	6.1	4.4	6.0	5.6	5.8	87.8
SXFP	3.1	3.4	2.9	3.6	2.7	3.8	0.7	2.7	3.0	2.0	1.7	5.1	7.0	6.2	4.2	4.4	5.7	11.1	6.1	8.1	5.5	7.1	88.9
SXKP	2.1	4.0	3.1	2.6	2.9	2.6	0.3	1.8	2.6	2.0	1.4	6.0	9.1	3.5	5.0	7.4	5.6	7.5	14.7	5.1	3.3	7.4	85.3
SXNP	3.5	3.9	3.1	4.4	2.7	4.8	1.0	2.8	3.8	2.0	1.8	5.3	7.1	4.9	4.3	4.2	5.7	7.9	4.7	9.3	6.0	6.9	90.7
SXPP	3.2	3.3	3.3	3.9	2.3	5.5	1.2	3.5	4.1	1.8	1.5	4.6	6.0	3.9	3.4	3.8	6.2	7.8	3.6	7.9	13.3	6.1	86.7
SXQP	3.3	3.5	3.1	3.3	2.5	3.5	0.9	2.4	2.8	1.9	1.4	7.7	7.0	4.2	4.6	6.7	5.1	7.3	5.7	6.9	4.8	11.5	88.5
Contribution to others	95.6	108.1	91.5	108.0	80.0	104.3	34.0	78.1	90.2	65.3	43.7	93.7	122.5	66.7	58.0	95.6	98.4	114.0	78.2	100.6	76.1	104.9	1907.5
Net Contribution	5.9	20.8	2.1	19.3	-8.9	14.2	-48.3	-2.0	4.1	-20.9	-46.1	7.5	35.5	-16.0	-25.0	13.5	10.6	25.1	-7.1	9.9	-10.6	16.4	86.70%

Table 5.3: US and EU Full Sample Connectedness

	US	EU	From Others
US	707.1	393.5	393.5
EU	333.5	767.0	333.5
Contribution to others	333.5	393.5	727.0
Net Contribution	-60.0	60.0	33.03%

Table 5.4: Full Sample US and EU Pairwise Connectedness

This pattern of strong intra-industry linkage extends to other globalized sectors. Significant spillovers are transmitted from the S5HLTH to its EU counterpart SXDP with a value of 5.6% and from S5MATR to SXPP at 5.5%. This reflects the global nature of these industries, where regulatory news, R&D breakthroughs and commodity demand trends are not restricted by regional borders. Importantly to note is that the EU Utilities sector is a main transmitter to the defensive sectors in the US; spillover to S5CONS, S5UTIL and S5HLTH are 7.0%, 7.0% and 6.1% respectively, showing that shocks to this sector driven by regional energy concerns are transmitted to the US defensive sectors.

5.3 Static Period 1 Sectoral Connectedness

This period, characterized by relative macroeconomic stability and low inflation serves as a crucial pre-crisis baseline. The US equity market experienced relatively stable growth and low volatility after recovering from the early 2000s dotcom bust. Table 5.5 outlines the US sectoral connectedness within this period. The resulting total connectedness of 59.60% is within the a priori expectations indicating that during the pre-crisis period while there is moderate level of connectedness, the market was significantly less integrated.

Furthermore, the diagonal elements increased significantly when compared to the full period. This is expected, implying that the sector-specific factors played a much stronger role in driving volatility. The Real Estate sector is the most extreme case with a value of 58.8% reflecting the US housing bubble, where the sector's performance was dictated by its own dynamics rather than influences from the broader market. In contrast, the more cyclically oriented sectors had the lowest own variance shocks such as Industrials (22.7%) and Financials (25.4%). This indicates that these sectors were highly sensitive to the overall business cycle.

PERIOD 1

	S5COND	S5CONS	S5HLTH	S5INDU	S5INFT	S5MATR	S5RLST	SPF	S5TELS	SPN	S5UTIL	From Others
S5COND	28.4	9.6	7.8	13.3	7.2	9.5	2.4	11.4	2.3	3.1	5.1	71.6
S5CONS	8.8	41.6	16.3	7.1	1.6	5.9	0.8	4.3	0.7	3.9	9.0	58.4
S5HLTH	6.2	13.2	48.6	7.2	2.4	3.5	0.3	5.0	1.2	3.8	8.6	51.4
S5INDU	12.6	7.4	7.7	22.7	7.5	12.8	3.0	13.3	3.8	2.2	7.0	77.3
S5INFT	9.5	1.6	4.0	13.5	41.9	5.9	1.4	8.5	6.6	0.7	6.3	58.1
S5MATR	11.4	11.4	5.2	12.4	3.4	28.8	2.8	9.4	1.9	3.7	9.7	71.2
S5RLST	5.9	4.8	2.2	5.7	0.8	5.1	58.8	6.4	0.2	0.2	10.0	41.2
SPF	10.7	6.9	6.9	14.7	4.6	10.7	3.8	25.4	4.1	2.1	10.1	74.6
S5TELS	3.6	10.7	5.2	12.5	5.1	4.3	0.5	6.5	48.1	2.4	1.2	51.9
SPN	3.5	18.4	9.7	4.0	0.4	4.1	0.2	1.9	1.1	45.1	11.6	54.9
S5UTIL	2.2	10.8	6.2	3.5	0.6	4.1	6.6	8.1	0.2	3.1	54.7	45.3
Contribution to others	74.4	94.9	71.2	93.7	33.6	65.9	21.7	74.7	22.1	25.1	78.7	656.0
Net Contribution	2.8	36.5	19.8	16.4	-24.5	-5.3	-19.5	0.1	-29.8	-29.8	33.4	59.60%

Table 5.5: US Period 1 Connectedness (9/10/2001 - 31/12/2006)

Interestingly to note is that for Period 1, the role of defensive sectors acted as major net transmitters. Consumer Staples was the largest net transmitter by a significant margin (36.5%), followed by Utilities (33.4%) and Health Care (19.8%). This suggests that during this stable growth period, subtle shifts in these non-cyclical sectors may have served as leading transmitters for the rest of the market.

On the other hand, the largest net receivers of shocks were Telecommunication Services (-29.8%), Energy (-29.8%) and Information Technology at -24.5%. This implies these sectors were largely reactive. Energy's performance was influenced by economic demand generated by other sectors whereas for Technology and Telecoms, this may reflect their position in the capital investment cycle of this period, where their prospects were heavily dependent on the financial health and spending patterns of the wider economy.

Examining key pairwise relationships, the largest spillovers in the system occurred between defensive sectors, not cyclical ones. The largest spillover is from Consumer Staples to Telecommunication Services valued at 18.4%. This could reflect how the financial health and investment sentiment surrounding the staples sector spilled over into other sectors perceived as defensive.

Similarly, Health Care to Consumer Staples had the second largest spillover at 16.3% implying that volatility in one defensive sector directly influenced volatility in another. As expected in an economic expansion, the link between the industrial and financial sectors was dominant. The spillover from the Industrials sector to Financials was at 14.7% showing the dependence of the financial system on the health of the real economy. The reciprocal spillover from Financials to Industrials was at 13.3% demonstrating the critical role of credit and financial conditions in engaging industrial activity.

Table 5.6 outlines the EU sectoral connectedness during Period 1. This period was characterised by the Euro launch where the Euro became the new currency for millions of Europeans in 12 member states and in 2004 there was a significant event where 10 new countries joined the EU promoting growth. This could be shown in the total connectedness value of 72.60% indicating a highly integrated system. Notably this level of connectedness is significantly higher than the 59.60% observed in the US market during the same era.

Examining the diagonal elements, the Real Estate sector displayed the highest independence with a value of 40.4%. It is also a clear net absorber of shocks as it does not influence much volatility back to the system. Importantly to note is the role of the Financial Services as it is the central hub of all indices. Having the second lowest diagonal value (20.7%), it acts as the main transmitter of volatility highlighting the proactive role of Financial Institutions and European banks in driving the market. Looking at its spillover to other indices they are quite large showing the importance and dependence on the financial sector during this period. It recorded the largest spillover of 15.0% where financial sector sentiment and lending conditions were the primary driver of the industrial sector.

PERIOD 1

	SX3P	SX6P	SX86P	SX8P	SXDP	SXEP	SXFP	SXKP	SXNP	SXPP	SXQP	From Others
SX3P	28.9	10.5	2.5	1.8	12.0	9.3	10.6	5.4	5.2	1.7	12.1	71.1
SX6P	5.0	25.7	5.1	3.1	11.7	9.1	10.9	7.0	6.2	3.6	12.8	74.3
SX86P	0.7	5.7	40.4	1.5	2.4	3.8	13.0	3.3	11.1	12.0	6.3	59.6
SX8P	1.3	4.8	1.1	29.3	4.2	3.1	11.6	13.1	14.4	5.5	11.8	70.7
SXDP	6.5	11.8	2.7	3.2	30.1	6.6	11.1	7.5	6.2	1.7	12.6	69.9
SXEP	4.4	9.9	3.4	3.5	9.5	25.6	12.1	6.5	7.3	5.3	12.5	74.4
SXFP	3.1	8.0	7.7	5.7	8.1	6.7	20.7	8.6	12.8	6.7	12.0	79.3
SXKP	1.6	8.1	2.5	10.6	7.3	5.4	11.7	31.9	7.4	2.7	10.9	68.1
SXNP	2.5	6.4	5.8	8.3	4.9	5.5	15.0	5.9	22.8	11.1	11.9	77.2
SXPP	2.4	6.2	9.0	4.7	3.6	6.4	12.8	3.8	14.1	26.6	10.3	73.4
SXQP	5.7	10.4	4.3	6.1	9.0	7.4	13.0	8.4	10.6	5.6	19.6	80.4
Contribution to others	33.2	82.0	44.1	48.3	72.5	63.3	121.8	69.4	95.2	55.7	113.1	798.6
Net Contribution	-37.9	7.7	-15.5	-22.4	2.6	-11.1	42.5	1.3	18.0	-17.7	32.7	72.60%

Table 5.6: EU Period 1 Connectedness (9/10/2001 - 31/12/2006)

Another strong transmitter of volatility is the SXQP with a value of 113.1% (net contribution of 32.7%) highlighting the importance of consumer sentiment and spending as a key driver of the European economy. It absorbs broadly from SX6P, SXFP and SXNP and sends similarly large shocks to SX3P (12.1%), SX6P (12.8%), SXDP (12.6%) and SXEP (12.5%).

Throughout this period the largest net receiver of shocks was the defensive SX3P with a value of -37.9% where it is the most affected by SXQP (12.1%) and SXDP (12.0%).

5.3.1 Static Period 1 Regional Connectedness

Similar to the full period, the EU is the main transmitter of volatility and the US being the main absorber of shocks with the difference that the EU influenced the US substantially. As expected, both regions exhibited strong internal spillovers where spillovers from EU sectors to other EU sectors was at 959.8% while the US-to-US internal spillover was 761.9%. The total magnitude of shocks transmitted from the US to the EU was 140.4% while the reciprocal flow was substantially stronger as spillover from EU to US was 338.0%.

The EU Technology sector was the primary sector for the strongest US shocks. It received the most from the US Information Technology with a value of 7.0% reflecting the way the post-dotcom US tech cycle pulled EU tech. Moreover, it was affected by US Financials (4.9%) and US Consumer Discretionary (4.5%) indicating that the performance of the EU mainly influenced by the US tech scene.

PERIOD 1

	S5COND	S5CONS	S5HLTH	S5INDU	S5INFT	S5MATR	S5RLST	SPF	SPN	S5TELS	S5UTIL	SX3P	SX6P	SX86P	SX8P	SXDP	SXEP	SXFP	SXKP	SXNP	SXPP	SXQP	From Others
S5COND	18.4	3.9	2.7	8.2	5.2	6.0	1.5	7.2	1.9	1.3	2.2	1.5	6.1	0.9	3.0	3.8	3.5	5.4	4.3	4.4	1.7	6.9	81.6
S5CONS	4.6	25.0	7.2	3.7	0.5	3.0	0.3	2.2	2.7	0.4	3.5	0.6	6.7	1.3	3.1	7.2	2.6	6.8	5.7	4.8	1.7	6.4	75.0
S5HLTH	4.5	6.6	36.5	5.0	1.9	2.2	0.2	3.9	2.9	1.0	3.6	0.7	2.0	1.6	1.8	4.7	1.0	6.2	4.6	3.3	1.2	4.4	63.5
S5INDU	9.4	3.6	2.8	17.5	6.7	10.5	2.3	10.1	1.3	2.7	3.6	0.4	3.4	0.4	2.6	3.3	1.9	3.9	5.1	3.0	1.2	4.3	82.5
S5INFT	7.3	0.5	1.6	9.2	29.7	4.2	0.7	6.4	0.3	5.8	2.3	1.3	0.9	0.1	6.7	0.5	0.8	3.6	9.1	4.6	0.7	3.9	70.3
S5MATR	7.7	5.4	2.0	8.4	2.2	21.0	2.0	7.0	2.4	1.1	5.7	0.2	4.7	1.3	2.8	3.0	2.2	4.4	3.3	5.5	2.5	5.1	79.0
S5RLST	5.0	2.5	1.3	4.5	0.5	4.9	58.7	4.5	0.0	0.2	6.4	0.2	1.6	0.2	0.9	1.6	1.2	1.3	1.2	1.5	0.5	1.3	41.3
SPF	7.3	2.7	2.1	10.2	3.5	9.1	2.8	20.7	1.2	2.7	6.0	0.5	4.1	0.3	2.3	5.6	3.2	4.1	4.3	2.6	1.2	3.5	79.3
SPN	2.3	9.7	4.5	2.0	0.2	1.9	0.1	1.2	36.2	0.8	6.6	0.1	3.3	1.3	1.2	2.8	7.1	4.1	3.3	3.7	3.1	4.4	63.8
S5TELS	2.1	6.2	1.6	9.1	4.3	2.6	0.5	4.5	1.7	42.9	0.6	0.7	2.8	0.2	2.3	3.2	1.8	2.2	5.3	1.6	0.9	2.9	57.1
S5UTIL	1.3	5.1	1.9	2.0	0.1	4.0	5.1	7.3	3.3	0.5	49.6	0.0	1.6	0.2	1.0	3.1	2.8	3.3	3.6	2.8	0.1	1.4	50.4
SX3P	3.2	3.4	2.1	0.6	0.9	0.8	0.0	0.7	0.3	0.8	1.2	23.9	9.8	3.0	2.5	6.1	7.4	8.7	5.4	5.9	2.6	11.1	76.1
SX6P	2.6	1.3	0.7	1.0	0.9	1.1	0.1	1.3	0.8	0.4	0.1	3.4	24.0	5.0	3.1	8.1	8.4	9.7	6.3	6.1	4.2	11.2	76.0
SX86P	0.1	0.0	0.1	0.1	0.3	0.2	0.8	0.0	0.3	0.1	0.1	0.5	5.9	36.8	1.6	2.0	4.2	12.7	3.6	10.8	13.7	6.3	63.2
SX8P	4.5	0.1	0.1	4.0	7.0	2.7	1.8	4.9	0.1	1.4	0.4	1.4	3.6	0.9	21.2	2.8	3.2	8.2	9.6	9.2	4.0	9.0	78.8
SXDP	2.5	2.2	2.8	1.0	1.1	0.7	0.2	1.8	0.6	0.4	0.4	3.7	11.5	3.2	3.6	20.8	6.2	10.1	6.3	7.1	3.0	10.7	79.2
SXEP	1.9	0.7	0.6	0.8	0.5	0.3	0.2	0.8	2.9	0.4	0.4	2.9	10.5	3.7	3.4	7.1	22.6	10.3	6.0	6.6	6.4	10.8	77.4
SXFP	2.5	0.5	0.7	1.3	1.8	1.0	0.5	2.0	0.3	0.4	0.9	1.7	7.5	8.1	4.7	4.9	5.8	18.3	7.6	11.4	7.5	10.4	81.7
SXKP	2.1	0.1	0.3	2.5	5.0	0.9	0.1	1.6	0.1	1.4	0.1	1.4	7.8	2.7	8.8	4.6	5.2	10.6	25.6	6.7	2.9	9.4	74.4
SXNP	3.3	0.3	0.2	1.7	2.1	2.0	1.1	2.4	0.3	0.7	1.1	2.2	5.8	5.6	5.8	3.6	5.4	12.3	5.1	18.2	11.1	9.8	81.8
SXPP	1.7	0.4	0.3	0.9	0.8	1.5	0.5	1.1	0.5	0.4	0.8	1.6	5.6	8.8	3.6	2.6	6.0	10.7	3.2	12.4	27.1	9.5	72.9
SXQP	3.9	0.8	0.7	1.6	2.1	1.4	0.6	1.7	0.3	0.3	0.2	4.6	9.9	4.2	5.2	6.0	6.4	10.9	7.7	8.7	6.4	16.6	83.4
Contribution to others	79.7	56.1	36.3	77.7	47.4	61.2	21.3	72.6	24.1	23.2	46.3	29.8	115.1	53.1	70.0	86.9	86.2	149.6	110.5	122.6	76.3	142.7	1588.8
Net Contribution	-1.9	-18.9	-27.2	-4.8	-22.9	-17.8	-20.0	-6.7	-39.7	-33.9	-4.1	-46.3	39.1	-10.1	-8.8	7.7	8.8	67.9	36.1	40.8	3.4	59.3	72.20%

Table 5.7: US and EU Period 1 Connectedness (9/10/2001 - 31/12/2006)

	US	EU	From Others
US	761.9	338.0	338.0
EU	140.4	959.8	140.4
Contributions to others	140.4	338.0	478.4
Net Contribution	-197.6	197.6	21.74%

Table 5.8: Period 1 US and EU Pairwise Connectedness (9/10/2001 - 31/12/2006)

Regarding the influence of the EU and US, the largest spillover was from EU Telecoms to US Technology (9.1%) highlighting the deep integration of the global technology and communications sectors. European defensive sectors (Health Care and Utilities) affected the Consumer Staples sector in the US as the EU's policies, especially the shift towards promoting a more integrated approach to health and development, influenced discussions in the US about the role of public health.

5.4 Static Period 2 Sectoral Connectedness

This section analyses the connectedness of the US and EU markets during its turbulent period in recent history. Spanning from the early signs of distress in the subprime mortgage market through the collapse of Lehman Brothers in 2008, the Great Recession, and the subsequent sovereign debt crisis in Europe, this period represents a shift from the relative calm period of the preceding years.

The total connectedness in the US rises to 84.80% up from 59.60% in the pre-crisis period indicating that most fluctuations are caused by other indices rather than own volatility. As expected in the a priori expectation the diagonal values decreased from the previous period implying that sector-specific shocks do not influence much on any index.

The financial sector retained the highest level of idiosyncratic risk at 25.60% which makes sense due to the nature of the crisis as it originated from the sector itself. The collapse of subprime mortgage-backed securities, counterparty risk failures and substantial leverage all contribute to the diagonal value. However, a surprising result is that it is a net receiver of shocks given the importance of this sector in this period.

PERIOD 2

	S5COND	S5CONS	S5HLTH	S5INDU	S5INFT	S5MATR	S5RLST	SPF	SPN	S5TELS	S5UTIL	From Others
S5COND	12.0	9.1	9.6	9.9	10.0	10.1	5.2	7.3	9.7	9.5	7.7	88.0
S5CONS	9.5	13.0	12.6	7.2	9.2	9.2	2.8	4.8	11.1	10.2	10.4	87.0
S5HLTH	8.6	11.3	16.0	7.3	9.5	9.4	2.3	5.0	10.9	10.1	9.6	84.0
S5INDU	11.3	7.7	8.9	14.0	10.3	11.1	5.3	7.9	9.0	8.1	6.3	86.0
S5INFT	10.2	8.5	10.3	8.9	13.2	10.2	3.8	7.2	9.9	9.7	8.0	86.8
S5MATR	9.4	8.8	10.7	9.1	9.9	13.2	3.8	5.6	12.1	9.1	8.5	86.8
S5RLST	11.5	5.6	5.1	11.2	7.4	8.2	18.7	15.0	6.1	7.3	3.8	81.3
SPF	10.8	3.7	5.2	10.7	9.5	7.7	11.9	25.6	5.7	5.9	3.2	74.4
SPN	8.6	10.4	13.2	6.7	8.9	10.5	2.8	5.3	14.3	9.5	9.8	85.7
S5TELS	9.3	10.7	11.2	6.4	9.3	9.2	3.2	4.9	11.1	13.8	10.8	86.2
S5UTIL	7.9	12.0	13.6	6.0	8.0	9.3	2.1	3.8	12.9	10.6	13.8	86.2
Contribution to others	97.0	88.0	100.4	83.4	92.1	95.1	43.3	66.7	98.5	89.9	78.1	932.5
Net Contribution	9.0	1.0	16.4	-2.6	5.3	8.3	-38.0	-7.7	12.8	3.7	-8.1	84.80%

Table 5.9: US Period 2 Connectedness (1/01/2007 - 31/12/2012)

Since this period also captures the aftermath of the financial crisis, where there was massive government and central bank interventions directed at the Financial sector such contributions “To others” and “From others” could have affected this value. It has the highest pairwise spillover to the Real Estate sector (15.0%) with a reciprocal value of 11.9%. This represents the core narrative of the GFC where the implosion of the financial system is directly transmitting a shock to the housing market.

Real Estate is the largest net receiver despite having the second largest own share variance (18.7%). The sector was also the centre of the crisis’s origin but was ultimately a recipient of the financial system’s collapse. As credit markets froze and mortgages defaulted, the financial shockwave was absorbed by the real estate market, leading to its price collapse. The main transmitter was the health care sector (16.4%) which could arise from the reallocation of capital into defensive equity sectors. This could have made the sector sensitive to new information which could trigger large movements in case of any kind of news.

Moreover, the Affordable Care Act (ACA) in 2010 was signed and since health care is a massive component of the US economy, any uncertainty would have naturally spilled over into the rest of the economy. In this period, Utilities acted as an absorber of shocks (-8.1%) rather than a net transmitter as seen in the previous period.

Turning to European sectoral connectedness, the analysis begins with the American subprime crisis and transitions directly to the European sovereign debt crisis from 2010-2012. The latter was characterised by the near collapse of several Eurozone economies (notably Greece, Ireland, Portugal, Spain and Italy) and intense pressure on the European banking system. Similar to the US, the total connectedness increased to 82.4% (versus 72.6% in Period 1).

PERIOD 2

	SX3P	SX6P	SX86P	SX8P	SXDP	SXEP	SXFP	SXKP	SXNP	SXPP	SXQP	From Others
SX3P	20.5	10.4	4.0	5.1	14.0	7.2	9.3	8.6	5.9	5.0	10.1	79.5
SX6P	13.4	16.3	2.2	4.0	16.4	8.5	8.8	10.4	6.2	5.0	8.9	83.7
SX86P	7.1	3.1	31.3	8.0	2.7	5.2	12.8	5.9	9.2	7.6	7.2	68.7
SX8P	8.5	6.4	6.3	16.2	6.4	9.7	10.8	6.8	10.7	8.5	9.6	83.8
SXDP	14.1	10.7	2.4	4.0	24.0	7.2	9.1	9.0	5.6	5.0	9.0	76.0
SXEP	10.2	9.6	3.1	6.4	9.6	14.0	10.0	9.0	9.2	9.3	9.6	86.0
SXFP	8.3	7.3	8.3	7.5	5.4	10.1	15.4	9.9	10.5	8.4	8.8	84.6
SXKP	12.7	10.5	4.3	5.5	11.9	9.0	9.3	16.0	6.5	4.7	9.7	84.0
SXNP	9.4	8.0	6.4	7.9	7.4	10.5	11.2	8.3	12.3	8.9	9.8	87.7
SXPP	7.8	6.7	5.9	7.6	6.8	11.9	11.8	7.2	10.9	14.4	8.9	85.6
SXQP	12.5	8.0	5.0	7.1	10.9	9.1	9.5	8.4	8.7	7.1	13.7	86.3
Contribution to others	104.0	80.7	48.1	63.0	91.5	88.5	102.5	83.5	83.4	69.4	91.3	905.9
Net Contribution	24.5	-3.0	-20.6	-20.8	15.5	2.5	17.9	-0.5	-4.3	-16.2	5.0	82.40%

Table 5.10: EU Period 2 Connectedness (1/01/2007 - 31/12/2012)

As shown in Table 5.10, Real Estate has the highest own variance with 31.3% since the financial crisis originated in the real estate market. Such value could be explained by a significant degree of independence, reflecting country-specific housing busts (such as Spain and Ireland). The financial services sector saw its own variance value decrease to 15.4%, which unlike its US counterpart, the European financial sector did not retain a high degree of self-generated risk. However, it had the highest contribution of volatility (102.5% with a net contribution of 17.9%) due to the collapsing value of the sovereign bonds it held on to its balance sheets.

As the value of government bonds collapsed, the banks holding them became unstable, transmitting solvency risk to the rest of the economy. Moreover, when analysing its pairwise relationships its highest transmitter was to Real Estate (12.8%) reflecting how the banking crises froze credit and affected the property markets across Europe. Furthermore, it had an impact on the real economy as it registered a value of 11.2% to Industrial Goods & Services.

The largest net receivers during the period were sectors tied to investment and growth. Technology at -20.8% and Real Estate at -20.6% were the primary absorbers of shocks from the collapsing financial system. The largest spillover occurred entirely within the defensive sector revealing a market driven by pure sentiment. The single largest spillover was from Health Care to Utilities at 16.4%, followed by a spillover of 14.1% from Food & Beverage to Health Care and their reciprocal of 14.0%.

5.4.1 Static Period 2 Regional Connectedness

As shown in Table 5.12, during the crisis and post-crisis period, the US is the net transmitter of shocks (80.2%). Furthermore, when comparing to period one the connectedness between the two markets increased to 36.72% confirming that during crisis, markets are more integrated.

In Table 5.11 volatility is not driven by a single sector but rather multiple, moderate flows from several sectors in the US into multiple European sectors. As seen in Section 5.4, SPF and S5RLST, while at the core of the crisis, they were not the main transmitters, however SPF had a small effect on the EU Real estate sector of 4.4% and 3.2% to the EU financials.

S5INFT was a major source of shocks alongside S5HLTH. On the receiving end, the EU financial sector was among the large recipients of US originated volatility. This confirms that the collapse of US mortgage related assets on the balance sheets of European banks was a primary source of contagion. As the crisis evolved the spillover table above captures the second phase of the crisis of the sovereign debt crisis showing the effects from EU sectors to US sectors.

US sectors, particularly Health Care, Consumer Staples and Utilities were significant recipients of EU originated shocks, absorbing a substantial share of European volatility. This is a crucial finding as since the initial GFC shock was largely financial to financial transmission, the European crisis had a wider impact. The threat of a European banking collapse and a deep prolonged recession affected global growth prospects, affecting US consumer and business confidence and thus transmitting volatility to more defensive sectors of the US economy.

PERIOD 2

	S5COND	S5CONS	S5HLTH	S5INDU	S5INFT	S5MATR	S5RLST	SPF	SPN	S5TELS	S5UTIL	SX3P	SX6P	SX86P	SX8P	SXDP	SXEP	SXFP	SXKP	SXNP	SXPP	SXQP	From Others
S5COND	8.8	6.4	6.4	7.7	7.1	6.8	4.0	5.4	6.2	6.1	4.5	2.9	2.3	2.8	2.2	2.6	2.9	3.8	1.9	3.0	3.1	3.3	91.2
S5CONS	6.4	9.4	8.5	5.0	6.1	5.9	1.9	3.1	6.7	6.4	6.3	4.3	4.3	1.7	1.5	4.0	3.3	4.0	2.7	2.6	2.6	3.3	90.6
S5HLTH	5.2	7.5	11.1	4.9	6.0	5.7	1.4	3.3	6.3	5.9	5.4	4.1	5.1	1.5	1.6	5.2	3.6	4.5	3.0	2.8	2.8	3.4	88.9
S5INDU	8.3	5.3	6.3	11.2	7.6	8.0	4.2	6.1	6.2	5.1	3.7	1.9	1.8	3.6	2.0	1.6	2.4	3.9	1.4	3.7	3.3	2.6	88.8
S5INFT	6.9	5.7	6.8	6.5	9.6	6.6	2.5	5.0	6.0	6.0	4.6	2.6	3.0	2.4	2.4	3.1	3.1	4.8	2.4	3.3	3.2	3.4	90.4
S5MATR	5.8	5.7	6.9	6.4	6.4	8.9	2.3	3.6	7.6	5.1	4.7	3.4	3.6	2.5	2.4	3.4	3.7	4.7	2.2	3.7	3.8	3.1	91.1
S5RLST	9.8	4.4	3.5	9.6	5.8	6.0	16.1	12.9	4.0	5.2	2.2	1.4	0.9	2.6	1.4	1.6	2.5	1.7	0.5	2.2	3.4	2.2	83.9
SPF	8.1	2.2	3.4	8.4	7.1	5.3	9.4	21.3	3.6	3.7	1.5	0.9	0.6	5.1	2.1	1.1	2.6	3.6	0.6	3.0	3.8	2.6	78.7
SPN	5.1	6.7	8.3	4.4	5.4	6.4	1.4	3.2	8.7	5.2	5.2	4.7	5.0	1.6	2.0	5.2	4.1	4.6	3.0	2.9	3.6	3.4	91.3
S5TELS	5.8	7.4	7.1	4.1	6.0	5.5	2.0	3.1	6.3	9.3	6.5	4.5	4.2	1.6	2.3	4.6	4.0	3.9	2.8	2.6	2.9	3.6	90.7
S5UTIL	4.5	8.2	8.7	3.8	4.7	5.5	1.0	1.9	7.4	6.2	8.7	5.7	5.6	1.5	1.8	5.5	3.9	4.0	3.6	2.1	2.6	3.1	91.3
SX3P	3.5	5.2	6.0	2.7	4.4	3.2	0.9	2.5	3.5	3.9	3.8	11.7	6.2	2.0	3.4	7.6	5.3	5.8	4.7	3.7	3.5	6.6	88.3
SX6P	3.4	6.5	6.8	2.8	4.0	3.5	1.1	2.3	4.1	3.9	4.1	7.0	9.6	1.1	2.9	8.1	5.9	5.2	5.2	3.8	3.5	5.4	90.4
SX86P	3.0	1.4	1.6	4.1	3.2	3.1	1.6	4.4	1.7	1.6	1.7	4.4	2.5	22.0	5.3	2.3	4.6	9.2	4.6	6.8	5.4	5.4	78.0
SX8P	3.4	2.7	3.0	3.8	4.7	3.9	1.0	2.8	2.8	3.0	2.8	5.3	4.7	4.0	11.4	4.3	6.4	7.2	4.1	6.8	5.3	6.6	88.6
SXDP	4.1	6.3	7.3	3.0	4.8	3.7	1.0	2.8	4.2	4.1	3.3	7.5	6.0	1.4	2.5	12.9	4.2	5.6	4.0	3.1	3.2	5.3	87.1
SXEP	4.2	5.7	5.9	3.7	4.7	4.9	1.6	2.7	5.3	4.2	4.3	5.4	5.7	1.8	3.5	4.4	7.4	5.6	3.7	4.6	5.2	5.3	92.6
SXFP	3.5	4.0	3.8	3.9	4.5	4.3	1.2	3.2	3.8	3.6	3.4	5.0	4.7	5.4	4.7	3.0	6.2	9.7	5.1	6.3	5.0	5.7	90.3
SXKP	3.5	5.7	5.3	2.9	3.9	3.3	1.0	2.4	4.1	3.5	4.3	7.5	6.6	2.7	3.9	6.2	5.5	5.8	9.1	3.7	3.1	6.0	90.9
SXNP	4.2	4.4	4.4	4.6	4.6	4.9	1.6	2.8	4.3	3.6	3.4	5.3	4.9	4.0	4.6	3.7	5.8	6.6	3.9	7.1	5.1	5.8	92.9
SXPP	4.9	4.7	4.6	5.1	5.1	5.7	2.0	3.5	4.8	4.3	3.5	4.1	3.9	3.2	3.7	3.3	6.3	6.3	3.1	5.4	8.0	4.9	92.0
SXQP	4.2	4.3	4.4	3.6	4.3	3.8	1.5	2.8	3.6	3.3	3.1	7.5	5.0	3.1	4.7	5.8	5.8	6.1	4.4	5.3	4.6	8.8	91.2
Contribution to others	107.9	110.3	119.1	100.8	110.1	106.0	44.5	79.8	102.5	93.9	82.3	95.4	86.3	55.6	60.9	86.7	92.1	107.0	66.9	81.3	78.8	91.0	1959.1
Net Contribution	16.7	19.7	30.2	12.0	19.7	14.9	-39.4	1.1	11.2	3.2	-9.0	7.1	-4.1	-22.4	-27.7	-0.4	-0.5	16.7	-24.0	-11.6	-13.2	-0.2	89.10%

Table 5.11: US and EU Period 2 Connectedness (1/01/2007 - 31/12/2012)

	US	EU	From Others
US	736.6	364.0	364.0
EU	444.2	656.1	444.2
Contribution to others	444.2	364.0	808.2
Net Contribution	80.2	-80.2	36.72%

Table 5.12: Period 2 US and EU Pairwise Connectedness (1/01/2007 - 31/12/2012)

5.5 Static Period 3 Sectoral Connectedness

This period analyses the immediate aftermath of the Global Financial Crisis and preceding the COVID-19 pandemic. During this era, the US was defined by persistently low interest rates, large-scale quantitative easing by the federal reserve, moderate economic growth and the rise of the technology sector.

As seen in Table 5.13 the total connectedness for this period stood at 75.00%. This finding is critically important as although it is lower than the peak crisis level of 84.80%, it is substantially higher than the 59.60% of the pre-crisis era. This demonstrates that the market did not revert to its previous state of lower integration. Instead, a “new normal” of increased connectedness was established however it reflects a market that remained highly sensitive to macroeconomic news.

The Utilities had the highest own volatility value of 41.1% while also being the largest net receiver. Two key pairwise relationships dominate: large inflows from Real Estate (18.1%) and Consumer Staples (12.8%) where in a low but rising rate world, utilities absorb shocks linked to REITs and defensives while sending little back to the market with the exception to Real Estate (10.1%).

Both Real Estate at 31.3% and Energy at 29.8% were also relatively independent driven by the separate narratives of low mortgage rates and volatile global oil prices respectively. For the first time, the primary sources of systemic risk were the Consumer Discretionary sector at 26.0% and the Information Technology sector at 23.2%. This marks a structural shift away from the pre-crisis dominance of the defensive sectors. The post-crisis bull market was clearly driven by a new growth pattern centred on technological innovation. Health Care also remained a strong net transmitter at 20.2%.

PERIOD 3

	S5COND	S5CONS	S5HLTH	S5INDU	S5INFT	S5MATR	S5RLST	SPF	SPN	S5TELS	S5UTIL	From Others
S5COND	20.0	7.1	11.3	12.0	16.2	9.3	3.7	9.6	5.0	5.3	0.6	80.0
S5CONS	9.5	24.6	11.2	8.7	8.7	5.9	8.7	9.3	4.2	4.9	4.3	75.4
S5HLTH	12.2	9.5	21.9	10.7	11.1	9.0	5.0	10.5	5.3	3.3	1.6	78.1
S5INDU	13.0	8.0	10.8	17.1	13.4	11.5	3.3	11.9	5.5	4.7	0.9	82.9
S5INFT	15.3	6.9	10.7	12.5	21.3	9.1	2.6	10.5	4.8	5.8	0.6	78.7
S5MATR	11.6	7.6	10.1	12.3	10.9	18.8	3.4	11.7	9.3	3.4	0.9	81.2
S5RLST	8.9	12.5	8.4	5.2	5.7	4.2	31.3	6.9	3.6	3.2	10.1	68.7
SPF	11.1	8.2	10.8	13.2	11.4	10.8	4.0	20.7	5.3	3.3	1.2	79.3
SPN	9.7	8.0	9.5	7.4	9.5	10.4	3.4	8.1	29.8	2.8	1.3	70.2
S5TELS	11.0	10.1	8.3	8.8	12.1	5.3	4.4	6.2	4.0	28.0	1.7	72.0
S5UTIL	3.8	12.8	7.2	3.0	2.8	2.1	18.1	4.3	2.7	2.2	41.1	58.9
Contribution to others	106.0	90.8	98.3	93.7	101.9	77.7	56.6	88.8	49.7	38.7	23.2	825.3
Net Contribution	26.0	15.4	20.2	10.8	23.2	-3.5	-12.1	9.5	-20.5	-33.3	-35.7	75.00%

Table 5.13: US Period 3 Connectedness (1/01/2013 - 31/12/2019)

The largest shock absorbers were sectors which were largely reactive to the policies and growth trends set elsewhere. Utilities at -35.7%, Energy at -33.3% and Telecommunication Services at -20.5% were the primary absorbers of volatility shocks. The spillover from Information Technology to Consumer Discretionary was quite impactful at 16.2% where technological platforms and innovations influenced consumer spending habits. The reciprocal spillover from Consumer Discretionary to Information Technology, was also high at 15.3% showing that strong consumer demand and engagement, increased growth of tech companies. The highest single spillover was from Real Estate to Utilities at 18.1% highlighting how REIT repricing coincides with utility valuations when rates move.

With respect to the European Indices, this period was influenced by the European Central Bank, which deployed numerous unconventional monetary policies, including long-term refinancing operations and eventually quantitative easing. Similar to the US, the total connectedness for this period is 78.40% which, although it is less than the crisis period of 82.40%, it is still higher than the 72.60% pre-crisis.

The Basic Resources sector displayed the highest degree of independence at 29.8% whose performance is largely dictated by volatile global commodity prices. It is also the largest net receiver (-41.1%) driven primarily by Energy (12.3%) and Industrials (9.9%) and transmits little back to the economy. The sectors most integrated into the network were the interest rate sensitive ones: Utilities at 15.2% and Financial Services (19.4%). Financials transmit heavily across the network (108.4% to others, with a net contribution of 27.8%). It spills mostly to Industrials (15.9%), Real Estate (14.6%), Telecom (13.5%) and Utilities (13.2%) implying that credit conditions propagate into property and network industries.

PERIOD 3

	SX3P	SX6P	SX86P	SX8P	SXDP	SXEP	SXFP	SXKP	SXNP	SXPP	SXQP	From Others
SX3P	23.4	6.4	5.2	5.9	13.1	6.3	7.0	6.5	8.8	2.2	15.2	76.6
SX6P	6.5	15.2	12.8	4.0	5.4	6.3	13.2	12.3	11.2	2.2	10.9	84.8
SX86	5.1	12.2	17.9	3.5	4.3	4.9	14.6	12.8	12.0	2.0	10.7	82.1
SX8P	6.9	5.9	6.9	19.9	7.2	5.1	11.5	7.9	14.7	2.4	11.6	80.1
SXDP	13.9	4.6	4.2	8.0	25.2	6.5	6.8	6.7	9.3	3.0	11.8	74.8
SXEP	8.9	7.0	6.0	5.5	8.5	20.8	8.3	8.0	10.5	7.3	9.3	79.2
SXFP	3.9	10.0	14.0	5.0	3.4	4.7	19.4	12.3	15.2	2.2	10.0	80.6
SXKP	5.9	10.7	12.1	4.5	5.6	6.3	13.5	16.3	11.9	2.4	10.8	83.7
SXNP	5.4	8.0	10.7	7.7	4.8	6.0	15.9	10.4	17.6	3.1	10.5	82.4
SXPP	6.1	4.1	4.3	5.1	8.7	12.3	7.3	5.4	9.9	29.8	7.0	70.2
SXQP	11.7	8.1	8.3	6.2	8.8	5.4	10.4	9.0	11.1	2.3	18.7	81.3
Contribution to others	74.2	77.0	84.6	55.4	69.6	63.8	108.4	91.4	114.6	29.1	107.7	875.9
Net Contribution	-2.4	-7.8	2.5	-24.7	-5.2	-15.4	27.8	7.7	32.2	-41.1	26.4	79.60%

Table 5.14: EU Period 3 Connectedness (1/01/2013 - 31/12/2019)

The Industrial Goods & Services emerges as the largest net transmitter of shocks with a contribution of 32.2%. This suggests that the activity of the real economy's industrial core became the primary driver of the market during the recovery. This is expected since the industrial sector is a critical component of most economic supply chains, with products and services used across numerous sectors. The Technology sector, contrary to its counterpart in the US is a major net absorber of shocks at -24.7% and mostly affected by Industrials (14.7%) and Finance (11.5%).

5.5.1 Static Period 3 Regional Connectedness

As the US and Eurozone got into different economic and policy trajectories, the US economy entered a phase of sustained growth while Europe's recovery was more fragile. In response, the ECB moved in the opposite direction of the FED, launching a series of increasingly aggressive monetary easing measures, starting the quantitative easing program that began in 2015. The UK's 2016 referendum to leave the EU (Brexit) initiated a prolonged period of complex negotiations creating significant uncertainty in the EU. The spillover data shown in Table 5.16 saw a decrease of spillovers: from US to EU at 251.2% and EU to US at 226.0%. As expected, connectedness between the markets decreased to 21.69%.

The nature of the spillovers also transformed. While core US sectors like Information technology and Financials remained notable transmitters (24.8% and 35.9% respectively), their impact on the EU was moderate. For instance, S5INFT to SX8P (5.2%) and from SPF to SXFP (5.0%). This suggests that spillovers were no longer driven by fears of systemic collapse but rather by the transmission of macroeconomic fundamentals and policy signals from a recovering US economy to a more fragile European one.

PERIOD 3

	S5COND	S5CONS	S5HLTH	S5INDU	S5INFT	S5MATR	S5RLST	SPF	SPN	S5TELS	S5UTIL	SX3P	SX6P	SX86P	SX8P	SXDP	SXEP	SXFP	SXKP	SXNP	SXPP	SXQP	From Others
S5COND	16.5	5.8	9.3	9.9	13.4	7.9	3.1	8.1	4.5	4.3	0.7	1.4	0.7	1.1	2.7	0.6	0.9	1.9	1.2	2.9	0.6	2.4	83.5
S5CONS	7.4	20.1	8.5	7.0	6.8	4.7	7.0	7.6	3.7	4.0	4.0	3.0	1.4	1.0	1.8	1.9	1.1	1.3	1.3	2.1	0.6	3.9	79.9
S5HLTH	9.3	7.2	16.7	8.5	8.8	6.9	3.8	8.4	4.0	2.7	1.4	2.9	1.1	1.1	2.4	2.8	1.3	2.0	1.5	3.1	0.8	3.3	83.3
S5INDU	10.0	6.3	8.6	13.5	10.4	9.2	2.7	9.6	4.9	3.6	0.9	1.4	1.2	1.7	2.7	0.8	1.0	2.7	1.8	3.6	0.9	2.5	86.5
S5INFT	12.2	5.4	8.8	10.0	17.3	7.7	2.2	8.8	4.7	4.4	0.6	1.3	0.8	1.2	3.7	0.7	0.6	2.0	1.3	3.2	0.5	2.5	82.7
S5MATR	8.0	5.2	6.6	8.8	7.9	13.2	2.3	8.2	6.4	2.5	0.7	2.4	1.9	2.5	2.6	1.6	2.6	3.5	2.9	4.6	1.9	3.7	86.8
S5RLST	7.0	9.9	6.3	4.2	4.6	3.3	25.3	5.2	3.0	2.8	8.8	3.2	1.3	1.5	1.3	2.5	1.3	1.4	1.3	1.8	0.7	3.4	74.7
SPF	7.7	5.7	7.5	9.3	8.1	7.5	2.5	14.5	3.9	2.4	0.9	1.9	2.4	3.1	2.3	1.7	1.9	4.3	3.3	4.7	1.3	3.3	85.5
SPN	7.2	6.1	6.3	5.7	7.6	7.3	2.6	6.1	21.3	2.4	1.0	2.7	1.1	1.1	2.1	1.6	5.8	1.9	1.9	3.1	1.9	3.3	78.7
S5TELS	9.6	9.2	7.7	7.7	10.5	5.1	4.5	6.0	4.4	25.6	1.9	0.8	0.2	0.2	2.4	0.4	0.4	0.3	0.3	1.2	0.3	1.3	74.4
S5UTIL	3.1	11.0	5.7	2.5	2.4	1.6	15.9	3.7	1.9	1.8	35.0	2.5	1.4	0.9	0.7	2.4	1.9	0.6	0.9	1.1	0.5	2.5	65.0
SX3P	2.4	3.5	2.5	2.2	2.0	2.7	1.9	4.3	2.3	0.4	0.9	17.7	5.0	4.3	3.9	9.2	4.6	5.4	5.1	6.4	1.7	11.6	82.3
SX6P	2.0	1.8	1.8	2.2	2.0	2.6	0.9	4.9	1.2	0.2	0.4	5.0	12.4	10.8	2.8	4.0	5.0	10.7	10.1	8.8	1.7	8.8	87.6
SX86P	1.7	0.9	1.1	1.6	1.8	2.2	1.0	4.0	0.8	0.1	0.2	4.2	10.5	15.2	2.9	3.4	4.0	12.5	10.9	10.2	1.5	9.1	84.8
SX8P	4.1	1.8	2.9	3.7	5.2	4.5	0.8	5.0	2.1	0.7	0.2	4.5	4.3	5.5	13.2	4.3	3.4	8.2	5.7	10.0	1.8	8.1	86.8
SXDP	2.7	2.7	4.0	2.3	2.4	3.3	1.8	4.5	2.6	0.3	0.8	9.9	3.5	3.5	5.0	18.2	4.6	5.1	5.1	6.5	2.3	8.7	81.8
SXEP	2.3	2.4	1.7	2.0	2.0	3.5	0.9	4.3	5.0	0.2	0.4	6.6	5.5	5.0	3.6	5.9	15.7	6.5	6.2	7.7	5.5	7.1	84.3
SXFP	2.2	0.8	1.4	2.7	2.4	3.4	0.3	5.0	1.0	0.2	0.1	3.1	8.3	11.8	3.7	2.5	3.7	15.5	10.1	12.0	1.7	8.1	84.5
SXKP	2.2	1.3	1.5	1.9	1.8	2.7	0.6	4.1	1.4	0.3	0.2	4.7	9.0	10.5	3.3	4.3	5.1	11.2	13.5	9.6	1.9	8.9	86.5
SXNP	3.1	1.0	1.7	3.6	3.5	4.2	0.4	5.1	1.8	0.4	0.1	3.8	6.3	8.9	5.1	3.2	4.3	12.2	8.1	13.0	2.3	7.9	87.0
SXPP	2.2	1.0	1.8	2.2	1.8	4.8	0.8	4.4	3.6	0.2	0.3	4.6	3.2	3.4	3.6	6.3	9.5	5.6	4.1	7.4	23.6	5.4	76.4
SXQP	2.4	2.4	2.0	2.2	2.1	3.0	1.2	4.1	1.8	0.4	0.5	8.9	6.5	6.9	4.4	6.5	4.1	8.2	7.2	8.4	1.9	14.7	85.3
Contribution to others	108.8	91.4	97.8	100.1	107.5	98.1	57.5	121.4	65.0	34.2	24.8	78.7	75.5	85.9	63.1	66.6	67.3	107.5	90.4	118.3	32.3	116.0	1808.2
Net Contribution	25.3	11.5	14.5	13.6	24.8	11.3	-17.2	35.9	-13.7	-40.2	-40.2	-3.6	-12.1	1.1	-23.7	-15.2	-17.0	23.0	3.9	31.3	-44.1	30.7	82.20%

Table 5.15: US and EU Period 3 Connectedness (1/01/2013 - 31/12/2019)

	US	EU	From Others
US	874.4	226.0	226.0
EU	251.2	848.1	251.2
Contribution to others	251.2	226.0	477.2
Net Contribution	25.2	-25.2	21.69%

Table 5.16: Period 3 US and EU Pairwise Connectedness (1/01/2013 - 31/12/2019)

Announcements and actions by the Federal Reserve related to tapering asset purchases and raising interest rate created volatility in US markets which then propagated to Europe. Research from this period indicates that US unconventional monetary policies generally had stronger and more persistent cross-border impacts than those of the ECB, a finding consistent with the US remaining the net transmitter of volatility to the EU¹.

The diminished role of European financial index as shock transmitter, is particularly noteworthy as the spillover contribution to the US fell substantially. Similarly, the spillover from SXDP and S5HLTH dropped from 5.2% in the previous period to just 2.8%. Interestingly, despite the political and economic uncertainty generated by the Brexit referendum in 2016, the aggregate spillover data does not show a significant increase in risk transmission from the EU to the US suggesting that from the perspective of the US financial system, the direct contagion effect of Brexit was limited during this period.

5.6 Static Period 4 Sectoral Connectedness

The pandemic and the subsequent inflation/war shocks retightened the US network with a total connectedness of 85.6% surpassing even the peak of the 2008 financial crisis, indicating that the market became more connected and systematically driven than before. This period was defined by the COVID collapse and rebound, 2021-2022 supply chain and inflation surge, the Russia-Ukraine war and energy repricing and an aggressive Federal Reserve tightening cycle.

The Consumer Staples sector had a high own variance value of 23.6% which is expected due to its position at the centre of this period's shocks. It had the highest contribution of

¹ See the Global Impact of US and euro area unconventional monetary policies: a comparison <https://www.bis.org/publ/work610.pdf>. Last Accessed on 20/09/2025.

volatility to others at 152.2% with a net contribution of 75.8%. The largest spillovers were almost all transmitted from Consumer Staples with the defensive sectors being the most affected followed by all the other sectors, implying that when the Consumer Staples move, it pushes the rest of the market more than any other sector.

Notably, the Financials, when compared to previous periods, acted as net transmitter of volatility (105.6% contribution to others with a net contribution of 19.8%) transmitting the impact of the FED decisions of monetary and fiscal policy across the economy. The Energy sector's role (Net contribution of 19.4%) was tied directly to the war in Ukraine and post-pandemic supply/demand imbalances, which triggered an energy price shock that propagated outwards directly impacting all other sectors. The Materials sector (net contribution of 17.4%) was also a key transmitter, propagating the effects of the global supply chain disruption and input cost inflation.

On the other hand, the main net absorbers of shocks were the Real Estate sector being the largest net receiver of -70.5% followed by other rate sensitive sectors: Utilities (-50.0%) and Consumer Discretionary (-23.6%). Real Estate mostly absorbed economy wide shocks: COVID shifts, fast rise in interest rates, inflation and cost pressures from materials and energy. Higher rates and tighter financing show up clearly in the strong links from Staples, Financials and Industrials into REITs. Unlike the GFC era, the link from REITs to banks is little (3.0%) so property prices reflect macro stress more than they create it.

PERIOD 4

	S5COND	S5CONS	S5HLTH	S5INDU	S5INFT	S5MATR	S5RLST	SPF	SPN	S5TELS	S5UTIL	From Others
S5COND	13.4	13.1	7.4	11.4	10.7	10.0	3.0	8.7	7.4	11.5	3.6	86.6
S5CONS	6.4	23.6	6.7	12.4	7.2	9.5	1.2	10.3	10.5	7.6	4.6	76.4
S5HLTH	5.9	17.7	10.6	12.4	8.1	10.6	2.4	10.1	9.1	7.7	5.4	89.4
S5INDU	5.8	15.4	7.2	15.1	6.8	11.7	2.4	12.1	12.6	6.2	4.8	84.9
S5INFT	8.3	15.8	7.6	12.0	11.6	10.3	2.4	9.4	8.3	10.4	3.9	88.4
S5MATR	6.1	14.7	8.5	13.0	7.9	12.6	2.7	11.5	10.7	7.5	4.7	87.4
S5RLST	6.7	14.5	8.3	11.8	8.6	11.0	5.5	11.3	9.0	8.4	4.8	94.5
SPF	5.0	16.8	6.9	13.2	6.8	11.1	3.0	14.2	12.9	6.6	3.5	85.8
SPN	3.8	12.8	7.1	13.2	5.1	11.5	1.3	13.9	23.6	5.0	2.7	76.4
S5TELS	9.1	14.4	6.9	11.0	9.4	9.0	2.1	7.7	7.0	19.5	3.7	80.5
S5UTIL	5.8	16.8	8.7	11.5	8.1	10.2	3.6	10.6	8.4	7.9	8.3	91.7
Contribution to others	63.0	152.2	75.4	121.8	78.8	104.8	24.0	105.6	95.8	79.0	41.7	942.0
Net Contribution	-23.6	75.8	-14.0	36.9	-9.6	17.4	-70.5	19.8	19.4	-1.5	-50.0	85.60%

Table 5.17: US Period 4 Connectedness (1/01/2020 - 31/12/2024)

In Europe, the period commenced with the global COVID-19 pandemic and was immediately followed by a severe energy crisis caused by the war in Ukraine. These events triggered the 2021-2022 energy shock and leading to a surge in inflation and an aggressive tightening cycle by the ECB. The total connectedness for the European market surged to a new high of 86.40% which even surpassed the peak of the sovereign debt crisis. The low own variance values across nearly all sectors shows that the market was driven by economic news thus increasing the integration of the whole system.

Utilities and Health Care are the two strongest net transmitters. Utilities sends 107.9% to the rest of the system (net of 21.8%), being closely related to other rate-sensitive and infrastructure sectors. It transmits to Telecommunications (12.8%) and Real Estate, (12.3%) and Health (11.84%) and Industrials (10.5%). This is expected as it became the primary channel through which the geopolitical shock was transmitted to the rest of the economy through supply uncertainty. Health care transmits as much (105.2% and net of 21.4%) affecting mostly Utilities (11.8%), Food & Beverage (11.2%) and Telecommunications (11.5%) reflecting the way the pandemic demand and health system policy spilled into defensives and networks.

Real Estate is the largest net absorber (-32.0%), mainly driven by Utilities (12.3%), Health Care (10.9%) and Telecommunications (9.0%). Higher rates, changing energy costs and tighter financing are all absorbed by the property sector, however it transmits very little to the market (54.3%), which is consistent with stronger bank balance sheets than in the sovereign debt era. Technology is the second largest absorber (-26.6%) mainly affected by Industrials (10.7%) and Personal & Household Goods (10.5%).

PERIOD 4

	SX3P	SX6P	SX86P	SX8P	SXDP	SXEP	SXFP	SXKP	SXNP	SXPP	SXQP	From Others
SX3P	14.2	10.2	4.8	5.9	11.2	9.4	7.2	10.2	9.1	6.3	11.4	85.8
SX6P	10.1	13.9	5.6	5.3	11.8	9.9	7.8	10.0	8.8	7.9	9.0	86.1
SX86P	9.4	12.3	13.7	5.9	10.9	7.4	8.3	9.0	8.4	6.2	8.5	86.3
SX8P	8.7	9.0	6.2	14.8	8.8	7.5	8.8	7.8	10.7	7.3	10.5	85.2
SXDP	10.8	11.4	4.9	6.0	16.2	8.0	7.3	10.8	8.7	6.9	9.0	83.8
SXEP	9.7	10.1	4.5	5.1	10.6	15.4	7.7	10.2	9.0	9.7	8.2	84.6
SXFP	9.4	10.7	6.8	6.7	10.2	8.8	10.3	8.8	10.4	8.5	9.4	89.7
SXKP	9.8	12.8	5.5	4.7	11.5	10.2	7.8	13.1	8.2	7.6	8.8	86.9
SXNP	9.5	10.5	5.9	6.8	10.1	9.5	8.9	9.8	10.9	8.3	9.7	89.1
SXPP	9.2	10.8	4.8	5.4	10.4	10.8	8.0	9.9	9.5	12.7	8.6	87.3
SXQP	11.5	10.0	5.5	6.8	9.7	8.5	7.9	8.6	9.8	7.0	14.6	85.4
Contribution to others	98.0	107.9	54.3	58.6	105.2	90.1	79.6	95.2	92.5	75.9	93.1	950.4
Net Contribution	12.2	21.8	-32.0	-26.6	21.4	5.5	-10.1	8.3	3.4	-11.4	7.7	86.40%

Table 5.18: EU Period 4 Connectedness (1/01/2020 - 31/12/2024)

Notable is the Financial sector, which became a net receiver of shocks with a net contribution of -10.1%. For the first time throughout all periods, one of the main transmitters of volatility moved into a reactive position. This can be attributed to the nature of the crisis as they were financial in origin. The financial sector was absorbing the real economy (10.4%) including the impact of the energy crisis and the direct effects of the ECB's rapid interest rate hikes on its balance sheet. The largest spillovers throughout this period were between the sectors that were at the centre of the crisis.

5.6.1 Static Period 4 Regional Connectedness

Following fiscal and monetary stimulus by both the ECB and FED to combat the pandemic, a surge of inflation that began in 2021 continued to accelerate in 2022. The FED began raising interest rates in March 2022, followed by the ECB in July 2022 initiating one of the most coordinated global rate-hiking cycles in decades.

The spillover data during this period illustrate financial connectedness intensified and the direction of volatility spillovers changed once again. Total volatility spillovers from the US to EU surged to 376.4% while from EU to US spillovers peaked at 645.5% with a connectedness 46.45% between the combined markets.

The nature of the spillovers from the EU during this period was fundamentally different from the sovereign debt crisis era. European sectors such as SXEP and SX6P became significant transmitters of volatility to the US. For instance, SXEP transmitted the largest spillover of 9.7% to SPN while SX6P transmitted a spillover of 8.3% to S5CONS indicating that the European energy crisis was creating uncertainty that impacted even defensive US sectors.

PERIOD 4

	S5COND	S5CONS	S5HLTH	S5INDU	S5INFT	S5MATR	S5RLST	SPF	SPN	S5TELS	S5UTIL	SX3P	SX6P	SX86P	SX8P	SXDP	SXEP	SXFP	SXKP	SXNP	SXPP	SXQP	From Others
S5COND	6.3	6.3	3.3	5.2	4.7	4.6	1.2	3.5	3.3	5.1	2.0	4.6	6.5	3.2	4.2	6.3	5.8	4.4	4.9	5.1	5.0	4.4	93.7
S5CONS	2.8	8.6	2.7	5.0	2.5	4.1	0.4	3.3	4.1	2.7	2.4	6.0	8.3	2.9	3.1	7.6	7.2	4.4	6.7	5.0	5.4	4.8	91.4
S5HLTH	2.6	7.5	4.4	5.2	3.0	4.6	0.9	3.5	3.7	3.0	3.0	5.8	7.5	3.0	3.1	7.5	6.3	4.4	6.1	5.2	5.2	4.5	95.6
S5INDU	2.5	6.0	3.1	6.3	2.5	5.1	0.9	4.6	5.1	2.4	2.4	5.3	7.1	2.9	3.0	7.1	7.5	4.5	6.1	5.5	5.6	4.3	93.7
S5INFT	3.6	6.3	3.1	5.0	4.5	4.4	0.8	3.2	3.4	4.1	2.2	5.3	7.4	3.1	4.3	7.1	6.2	4.6	5.9	5.4	5.3	4.7	95.5
S5MATR	2.7	6.3	3.7	5.7	3.1	5.7	1.1	4.4	4.6	3.0	2.6	5.4	7.2	3.1	3.0	6.8	6.6	4.3	5.9	5.2	5.2	4.4	94.3
S5RLST	2.9	6.4	3.4	5.2	3.1	4.9	2.2	4.1	3.9	3.2	2.7	5.3	7.9	3.9	2.9	6.9	6.4	4.3	6.1	5.0	5.4	4.1	97.8
SPF	2.1	5.9	2.7	5.3	2.1	4.6	0.9	4.7	5.1	2.2	1.9	6.0	8.3	2.9	3.0	7.7	7.7	4.5	6.7	5.5	5.6	4.7	95.3
SPN	1.7	4.7	3.2	5.5	1.8	5.1	0.5	5.5	9.9	2.0	1.5	5.9	6.5	2.1	2.7	7.1	9.7	3.9	6.0	5.2	5.2	4.2	90.1
S5TELS	4.0	6.1	2.9	4.8	3.8	4.1	0.7	2.9	3.0	8.1	2.0	4.9	6.7	3.6	4.4	6.8	5.8	4.8	5.5	5.4	5.2	4.4	91.9
S5UTIL	2.4	7.4	3.5	4.8	2.9	4.3	1.4	3.6	3.5	2.9	4.4	5.7	8.1	3.9	2.8	7.1	6.1	4.4	6.5	4.9	5.2	4.3	95.6
SX3P	2.5	5.8	2.5	4.5	2.2	3.9	0.3	3.7	4.8	2.3	1.8	9.5	6.5	2.6	3.9	7.4	7.0	4.4	6.4	6.1	4.2	7.5	90.5
SX6P	2.0	5.5	2.0	4.6	1.8	3.7	0.3	3.1	4.1	1.9	2.3	6.3	9.6	3.6	3.7	7.9	7.4	5.3	7.5	6.1	5.8	5.8	90.4
SX86P	3.3	5.8	2.6	4.3	2.7	4.0	1.1	3.3	3.1	3.8	2.6	5.5	7.6	8.6	3.8	6.8	5.5	4.9	6.2	5.4	4.4	4.9	91.4
SX8P	3.8	4.1	2.4	4.5	3.9	4.1	0.5	3.1	2.8	3.6	2.2	5.0	5.6	3.8	10.6	5.5	5.0	5.8	5.1	7.2	4.8	6.7	89.4
SXDP	2.5	5.5	2.9	4.6	2.2	3.8	0.2	3.0	3.5	2.8	2.0	6.8	7.3	3.0	4.3	11.5	6.0	4.8	6.5	6.1	4.9	5.7	88.5
SXEP	1.6	4.4	2.6	5.1	1.6	4.4	0.3	4.6	7.6	1.7	1.7	5.9	6.5	2.6	3.3	7.0	10.4	4.9	6.3	6.0	6.3	5.0	89.6
SXFP	2.9	5.0	2.6	5.1	2.7	4.4	0.7	3.7	3.5	2.6	2.6	5.5	6.7	4.0	4.5	6.5	6.2	6.7	5.9	6.9	5.8	5.8	93.3
SXKP	1.9	5.5	2.4	5.0	2.1	4.2	0.5	3.9	4.9	2.3	1.9	6.2	8.4	3.2	3.4	7.7	7.6	4.8	7.6	5.7	5.5	5.3	92.4
SXNP	2.7	4.9	2.7	5.2	2.5	4.4	0.7	3.9	3.9	2.5	2.5	5.6	6.6	3.6	4.6	6.4	6.5	5.7	6.0	7.4	5.6	6.0	92.6
SXPP	1.9	5.4	2.3	4.9	1.8	4.1	0.2	3.5	4.3	1.9	2.5	5.5	7.3	3.0	3.6	7.0	7.5	5.5	6.6	6.5	9.0	5.6	91.0
SXQP	2.4	4.8	2.4	4.3	2.2	3.9	0.4	3.3	3.5	2.2	2.1	7.5	6.6	3.4	4.8	6.5	6.3	5.3	6.1	6.8	5.0	10.3	89.7
Contribution to others	54.8	119.7	59.0	103.9	55.3	90.9	13.8	77.6	85.7	58.1	46.7	119.8	150.7	67.4	76.5	146.4	140.2	99.8	129.2	120.2	110.6	107.1	2033.5
Net Contribution	-38.9	28.3	-36.6	10.2	-40.2	-3.4	-84.0	-17.7	-4.4	-33.8	-48.9	29.3	60.3	-24.0	-12.9	57.9	50.6	6.5	36.8	27.6	19.6	17.4	92.40%

Table 5.19: US and EU Period 4 Connectedness (1/01/2020 - 31/12/2024)

	US	EU	From Others
US	454.3	645.5	645.5
EU	376.4	723.9	376.4
Contribution to others	376.4	645.5	1021.9
Net Contribution	-269.1	269.1	46.45%

Table 5.20: Period 4 US and EU Pairwise Connectedness (1/01/2020 - 31/12/2024)

This period demonstrates that in the modern global economy, geopolitical events that create severe disruptions can become dominant drivers of international financial spillovers capable of minimizing the impact of domestic policy actions. With respect to the US spillovers, the largest impact was SPN to SXEP (7.6%) being the two energy sectors.

5.7 Dynamic Connectedness

In the previous section, the connectedness outlined was static which although it provides a valuable measure of market integration it does not reveal the evolution of risk transmission over time. Financial markets are dynamic systems where the intensity of volatility spillovers can change instantly in response to new information, shifts in investor sentiment and emerging macroeconomic or geopolitical crises.

To capture this time-varying nature of systemic risk, this study employs a 200-day rolling window analysis of the total connectedness for all markets with a 10-day forecast horizon. Figures 5.1 – 5.3 illustrate the dynamic connectedness for the full period for the combined markets and individually. The rest of the rolling window analysis for the combined countries and for each country for every period is presented in Appendix 9.

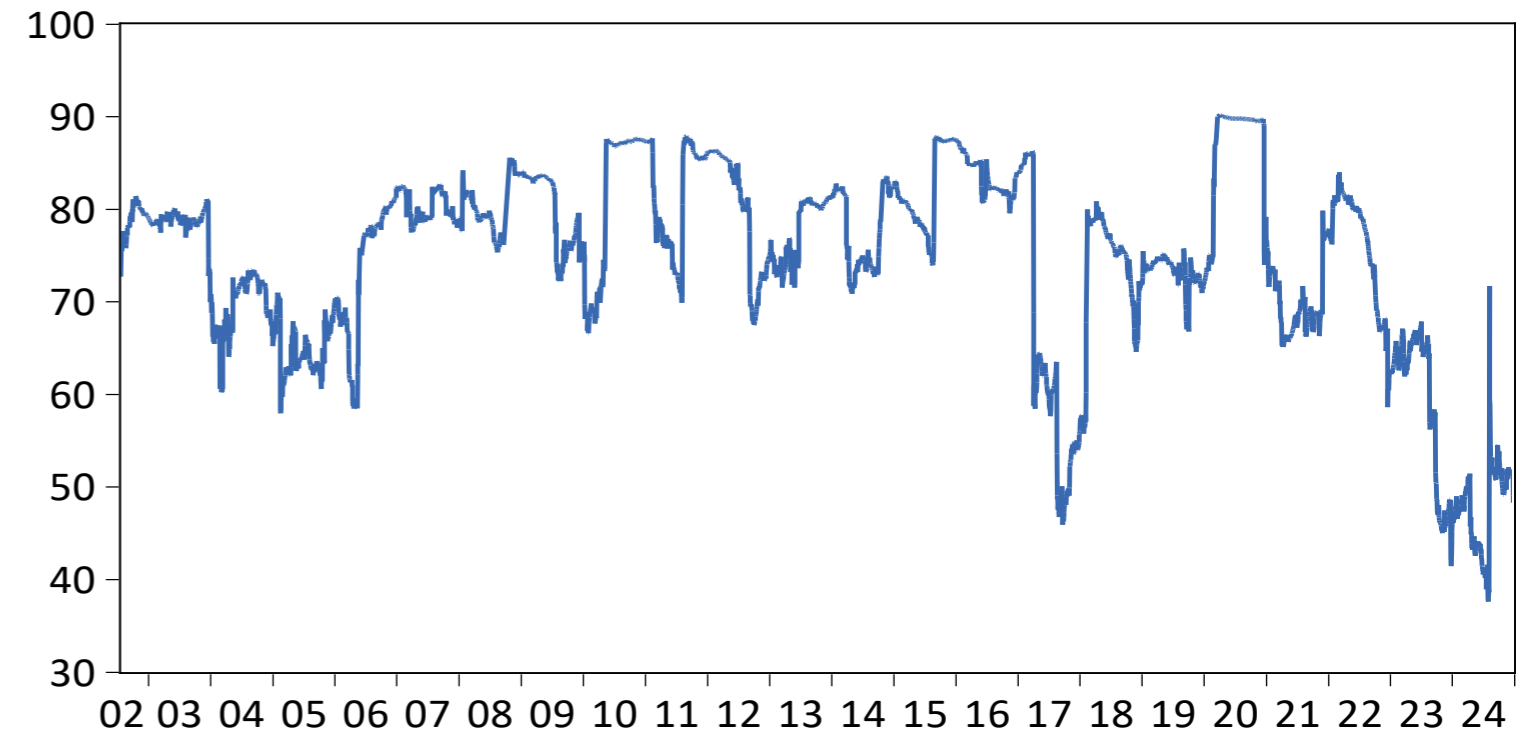
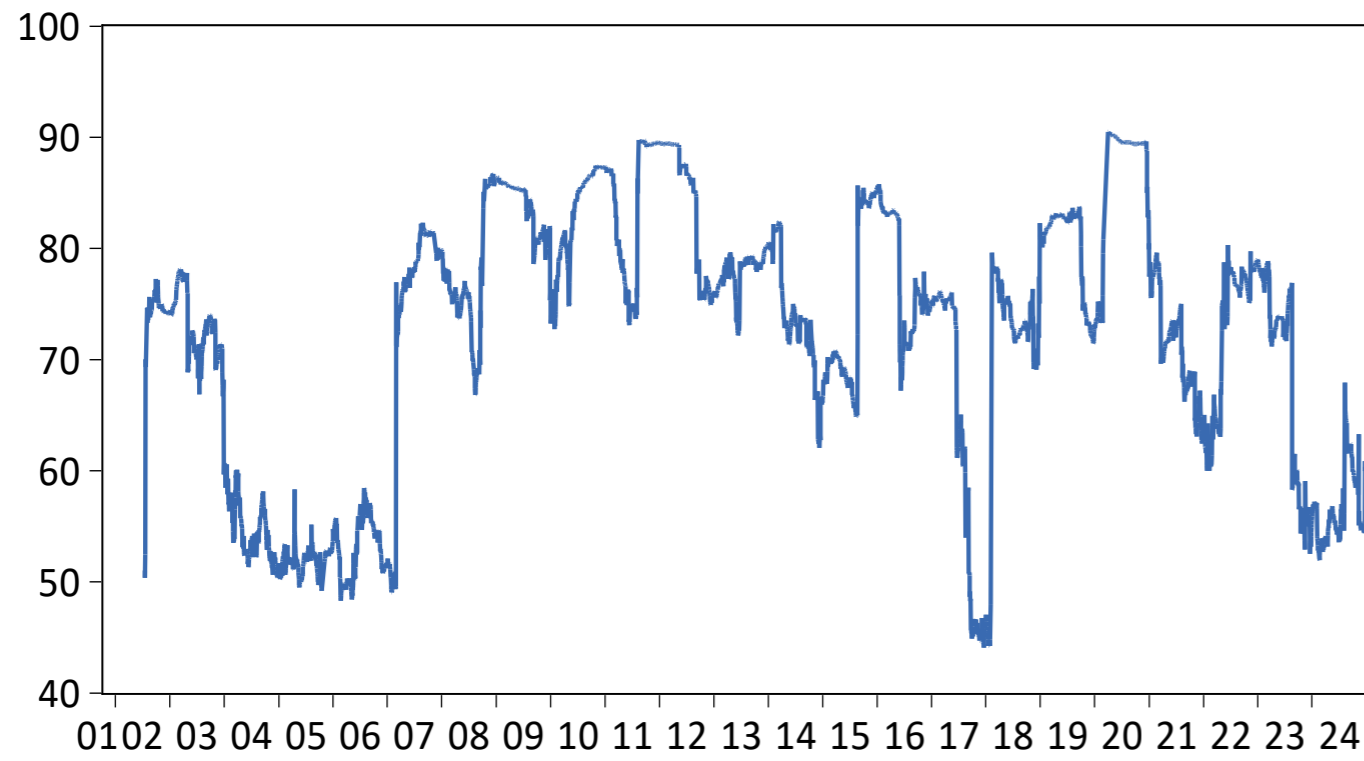


Figure 5.1: US (Left) and EU (Right) Full Sample Rolling Window Analysis

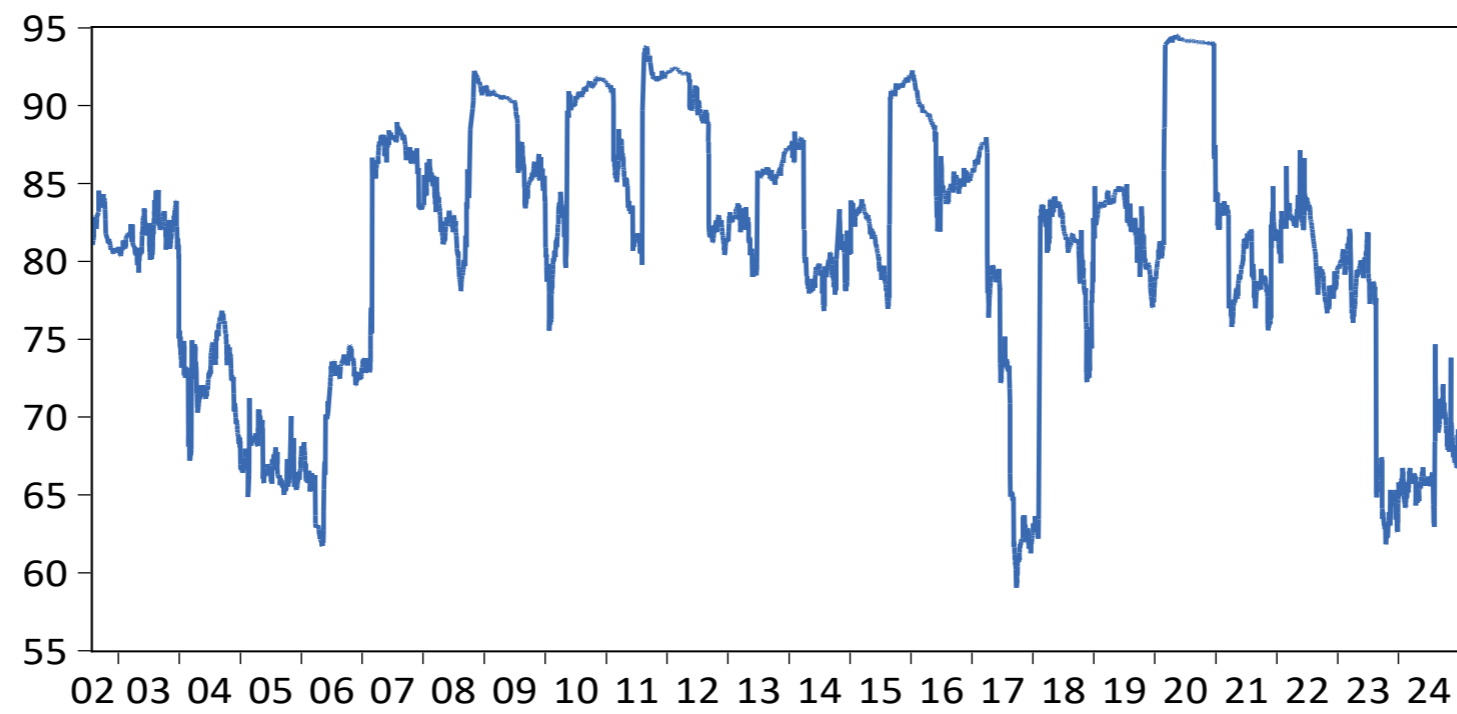


Figure 5.2: US and EU Combined Full Sample Analysis

Initially, the analysis begins with a high level of connectedness following the dotcom bubble crash. Following the rebound and recovery, the EU and US indices stayed relatively low and stable (falling from around 85% to the mid-50s to mid-60s on the chart). This was a period characterised with steady global expansion, stable economic growth, low inflation and normal financial market volatility. Indices in both regions generally moved on their own fundamentals, hence systemic risk was perceived to be minimal, and the benefits of cross-regional diversification were robust.

As the subprime crisis unfolded and credit markets took over in 2008, the connectedness index surged to its highest levels. Figure 5.2 shows the spike from 2006-2009 whereby in late 2008 the index climbed into the 90s, indicating very strong co-movement of EU and US volatility and clear example of financial contagion. This spike corresponds with the Lehman collapse, global market crashes and massive policy interventions. This confirms the contagion effect where crisis periods are defined by sharply higher cross-market correlations.

Following the initial peak of the GFC, the total connectedness does not revert to pre-crisis levels. Instead, it remains in a state of extreme elevation as eurozone fiscal strains became systemic. The index, which had fallen after 2009, increased again in late 2010 and into 2011. This rise corresponds to the unfolding sovereign debt turmoil in Greece, Ireland, and other EU countries. These events spilled over into stock markets where European banks and sovereign bonds sold off and global risk aversion picked up. However, the impact was less extreme than in 2008 as the subsequent ECB policies (Long Term Repo Operations and the European Stability Mechanism²) fiscal adjustments contained the panic by 2012 and the connectedness index saw a downward movement. Throughout this phase, EU financial

² See the European Stability Mechanism of the European Union https://economy-finance.ec.europa.eu/eu-financial-assistance/euro-area-countries/european-stability-mechanism-esm_en. Last Accessed on 20/09/2025.

industries were key shock propagators within Europe, but the US economy only saw a moderate shift. Overall, connectedness was elevated by the debt crisis but through policies, it remained below GFC levels.

From 2013 through 2019, the connectedness index settled into the mid 60s to low 70s and at the end of the period, it shows a gradual upward trend. This reflects the extended recovery and synchronized growth under monetary policy where both Europe and the US expanded but no new major crisis erupted. The slow rise in the index over these years likely reflects the increased cross-border linkages (e.g. globalization of supply chains and finance) even as volatility remained stable.

Notable short period spikes did occur around specific events, for instance the mid 2015 oil price crash and China slowdown caused a brief uptick in connectedness. Furthermore, the late 2018 saw a bump during the US-China trade tensions and global growth worries.

The pandemic era produced the largest jump in connectedness since the GFC. In March 2020, as COVID-19 outbreaks led to global lockdowns and an equity crash, the connectedness index shot up sharply toward the 90%. All sectors in both regions experienced contagion at once which is in line with recent research (Costa et al., 2021). Over the rest of 2020, intensive policy support through both fiscal stimulus and monetary easing helped moderate volatility, and the index eased from its March peak. A smaller secondary rise occurred in late 2020/early 2021 as new virus waves and policy shift kept markets on edge. By mid-2021 connectedness was returning toward pre-pandemic norms.

Following the pandemic, in 2022-2024, the connectedness index moved higher again in response to war and inflation but then returned to its normal level. The first half of 2022 saw a sudden spike driven by Russia's invasion of Ukraine, surging oil/gas prices and accelerating global inflation. These shocks had broad cross-border effects on sectors (for instance energy and materials). However as central banks aggressively raised rates and markets incorporated the news, systemic volatility gradually eased. Through 2023 the index drifted downward and by early 2024 it was back in the low 70s. This decline reflects a combination of factors including inflation peaking and retreating, no new global crash events and relative stabilization of commodity markets.

5.8 Conclusion

This chapter measured how volatility moves within and across the US and EU indices with the objective to identify the main transmitters and absorbers of volatility and how these roles change across major macro and geopolitical events. Full sample sectoral results show that both markets are highly interconnected internally. In the US, S5CONS and S5MATR are key transmitters, while S5UTIL and S5RLST are the largest absorbers. In Europe, the sector mix differs as Utilities and Financial Services emerge as strong transmitters, while Technology and Real Estate tend to absorb shocks reflecting different economic structures.

Across regions, Europe is a transmitter and the US is a receiver over the full sample but over periods this dynamic changes. The largest bilateral links are most notably between Energy sectors followed by Financials, Industrials and Defensives. Period 1 illustrated moderate integration for the US and slightly higher for the EU, while cross border flows are EU led as being the main transmitter. Period 2 highlights the GFC and Eurozone sovereign debt crisis, and the US becomes the main net transmitter across regions. In Period 3, integration eases but stays above pre-crisis with the US still being the net transmitter however spillovers are

concentrated in tech and energy rather than financials. Period 4 highlights the pandemic and geopolitical events, which saw a surge in integration and the direction of volatility flips and EU becomes the main transmitter. The dominant channels are EU energy and EU financials pushing into the US energy and defensives.

The rolling window analysis confirms these static findings, clearly illustrating how connectedness spikes during periods of crisis; notably the GFC, COVID-19 and the 2022 inflation/war shock, and decreases during periods of stability. It validates the narrative that market become highly correlated and integrated when faced with systemic threats.

6. Conclusion

The purpose of this paper is to investigate the connectedness of US and European sector indices over the past two decades applying the Diebold and Yilmaz framework. The analysis yields clear evidence that financial markets in these two major economies are deeply interconnected, though the strength and direction of linkages vary significantly over time and across sectors. By combining a static full sample with sub-period analysis and a dynamic rolling-window approach, the research captures both the long-run structure of volatility spillovers and their evolution through major crises and calm periods.

Overall, both the US and European markets exhibit high internal volatility connectedness indicating that within each region, volatility shocks propagate extensively among sectors. However, the roles of specific sectors differ by region. In the US, Consumer Staples and Materials emerged as persistent net transmitters of volatility shocks in the full sample, while Utilities and Real Estate were the largest net absorbers. This aligns with the notion that sectors tied to broad economic demand or global supply drive systemic risk, whereas defensive or interest-sensitive sectors, tend to absorb shocks from others.

In Europe, a different pattern was observed: Utilities and Financial Services were key net transmitters, whereas Technology and Real Estate were major receivers of volatility spillovers. The European Utilities is noteworthy since it is likely reflecting the region's sensitivity to energy prices and policy, which can ripple into financing conditions and consumer costs. The European financial sector, while pivotal, exhibited a dynamic role. It was a dominant volatility sender in normal times and post the 2008 recovery but notably became a net receiver during the pandemic and energy-crisis period, indicating that in non-financial crisis it was absorbing real-economic shocks rather than originating them.

Cross-region, the US and EU markets are moderately linked but with changing roles. Over the entire sample, Europe appears as a net transmitter of volatility to the US, however during the Global Financial Crisis and its aftermath, the US was the primary source of volatility transmitted to Europe which is in line with the a priori expectations. This aligns with Diebold and Yilmaz (2015) and others who find that volatility shocks in the US, tend to ripple strongly in Europe, confirming the US's typical role as a net transmitter. During Period 2, as shown in Table 5.11, European markets (particularly European financials) during the Eurozone sovereign debt crisis transmitted volatility back to the US, mainly impacting US defensive sectors.

Notably, the energy price shock and geopolitical conflict of 2022 saw Europe again becoming the net transmitter of volatility to US markets. The results highlight that the European energy sector's turmoil and related policy uncertainty propagated strongly into US volatility. The most significant illustration of global connectedness came with the COVID-19 pandemic. A substantial spike in volatility rallied which exceeded GFC levels. This result aligns with the observations of Zhang et al., (2020) that international stock markets' volatilities became highly correlated during the COVID outbreak. Costa et al., (2021) report an extraordinary increase in total connectedness among US sector indices during the early global spread of COVID-19 which aligns with the results of this study. Not only did cross-regional spillovers surge, but the traditionally "safer" sectors moved together with all the other sectors which diminishes the benefits of diversification.

The magnitude of cross-regional connectedness fluctuated across time with the highest being during COVID-19 and the subsequent Russia-Ukraine war (around 46.45%). Within-region shocks were generally more dominant than cross-region, supporting the view that markets are usually more affected by domestic factors than by distant markets. This is consistent with the findings of Yarovaya et al., (2016). In practical terms, during stable

periods, European sectors' volatility was driven mostly by European news and similarly for the US.

Crucially, every major crisis in the sample used, led to a sharp spike in connectedness both within and between the US and Europe. This is confirmed by the rolling analysis, as it vividly captures the classic contagion phenomenon. After the GFC volatility connectedness never returned to its pre-crisis lows, suggesting a structural shift toward greater financial integration. Even in the calmer period (2013-2019), the spillover index was still relatively high.

These outcomes carry several implications. First, the high and variable connectedness implies that systemic risk is dynamic. For investors, this means stress-testing portfolios for such correlation spikes is crucial. For policymakers and regulators, the results highlight the need for cross-border coordination and robust crisis management frameworks. Moreover, identifying which sectors are “transmitters” and “receivers” of volatility can help in detecting or predicting financial crises.

6.1 Limitations and Recommendations for Further Studies

The findings and limitations of this paper naturally open avenues for future work. First, the connectedness estimates are derived from a specific modelling approach using a GARCH (1,1). This approach may not capture all aspects of volatility dynamics, such as asymmetries. For example, this study did not differentiate between downside risk spillovers and upside risk spillovers. Future studies could extend the methodology by employing asymmetric GARCH models or realized volatility measures to see if the connectedness network changes when accounting for these variations.

The rolling-window analysis required a technical interpolation for a few data points due to software constraints. While this ensured continuity in the time-varying spillover index, it introduces a minor approximation. The interpolation was carefully handled, but it nonetheless means that some high fluctuations in the dynamic index should be interpreted with caution. Researchers with more advanced estimation tools might avoid this step. Lastly, the study focuses solely on equity sector indices in two developed regions. This choice, by design, leaves out other asset classes (bonds, commodities, etc.) and other important markets (e.g. emerging economies). Including such classes could change the network structure.

7. References

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Appendices

Appendix 1 – Graphical Representation – US Prices and Returns

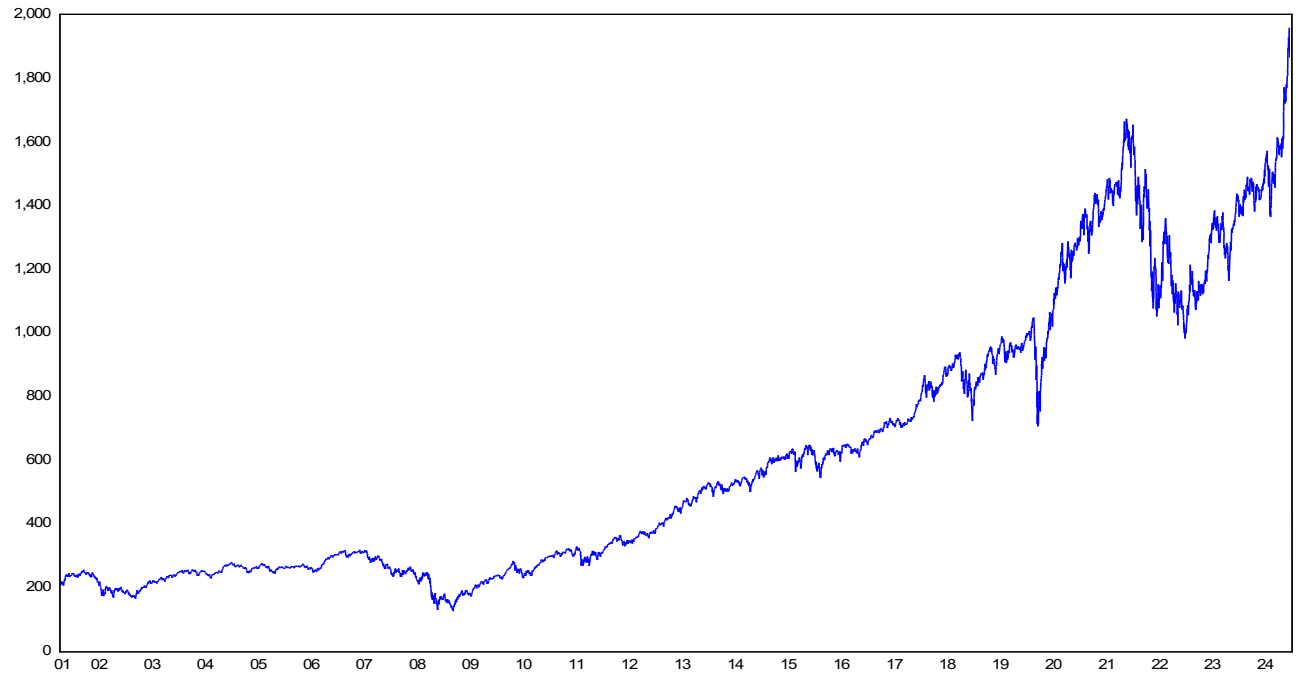


Figure A. 1: S5COND Prices

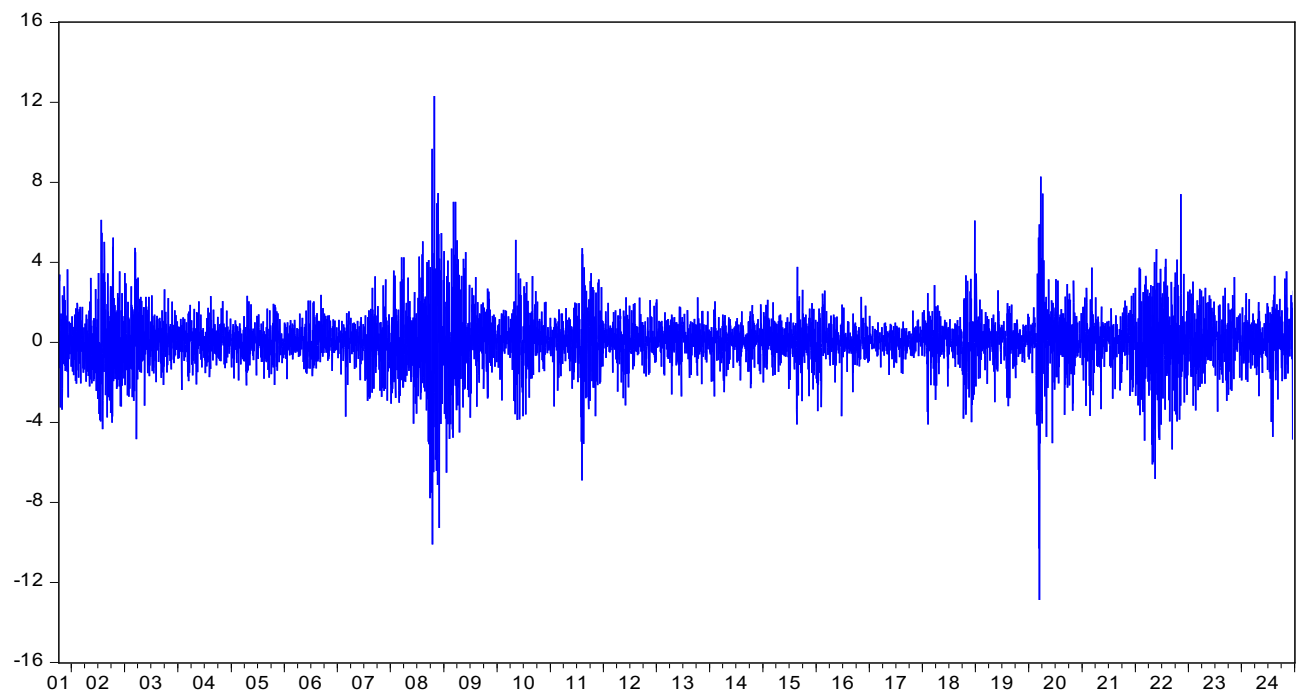


Figure A. 2: S5COND Returns

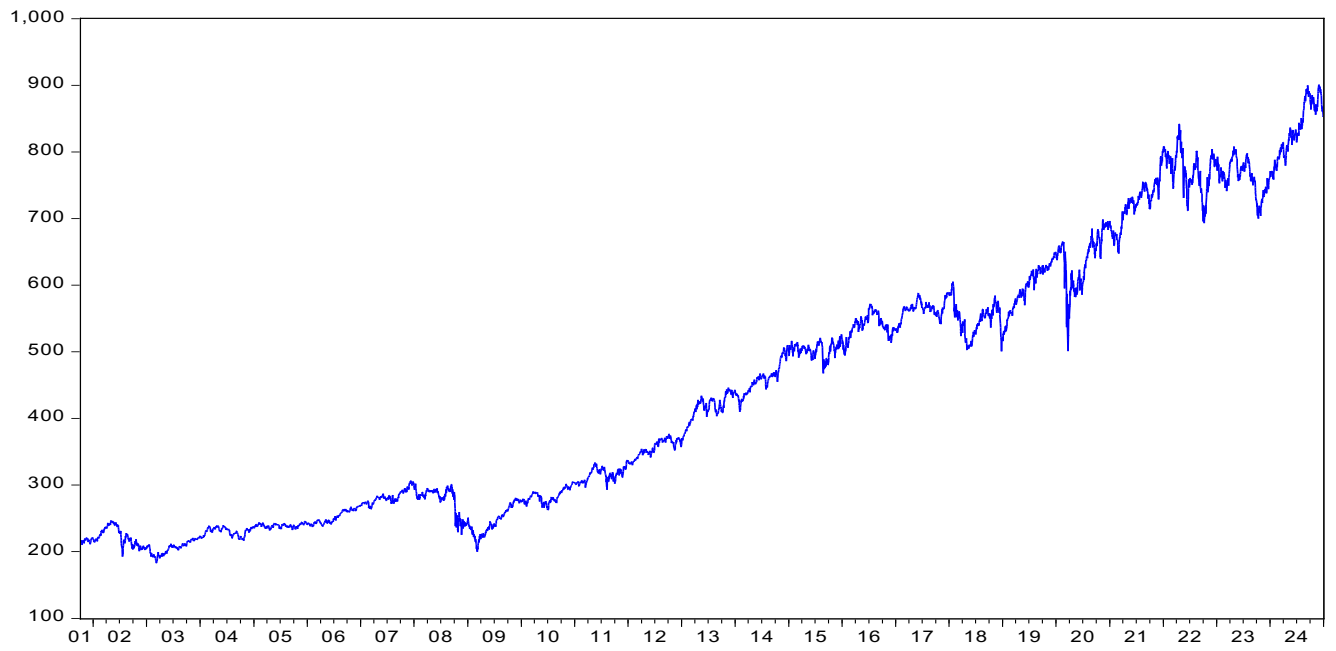


Figure A. 3: S5CONS Prices

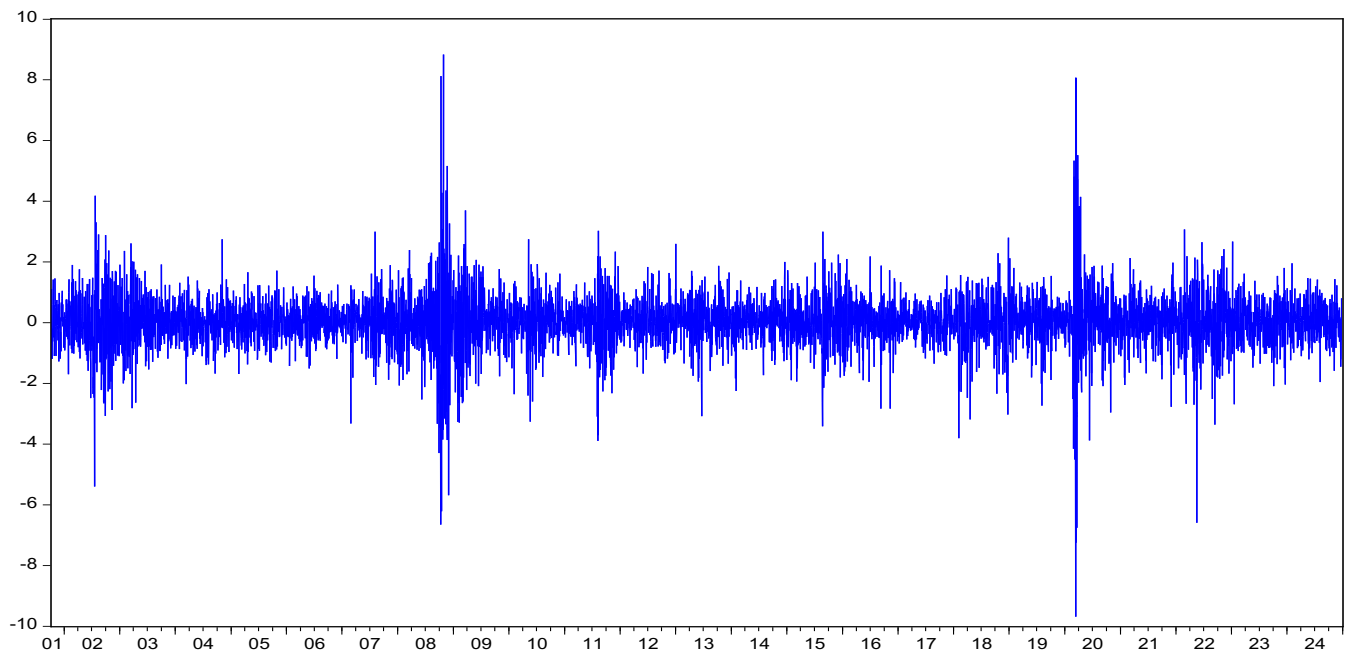


Figure A. 4: S5CONS Returns

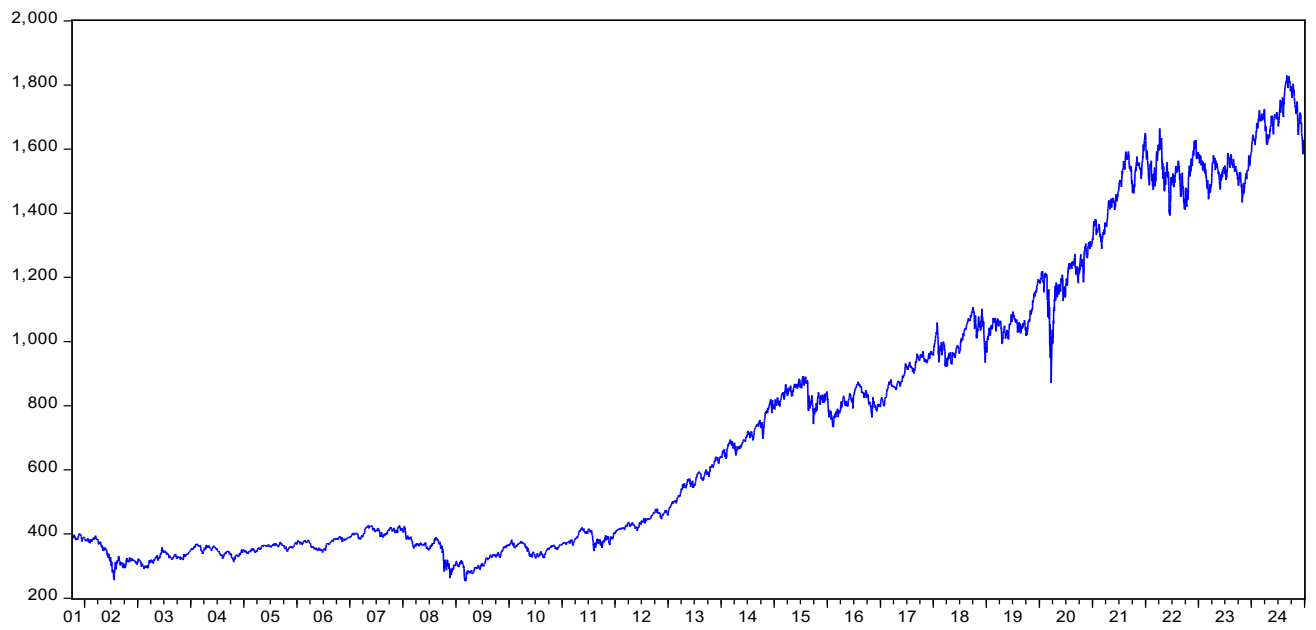


Figure A. 5: S5HLTH Prices

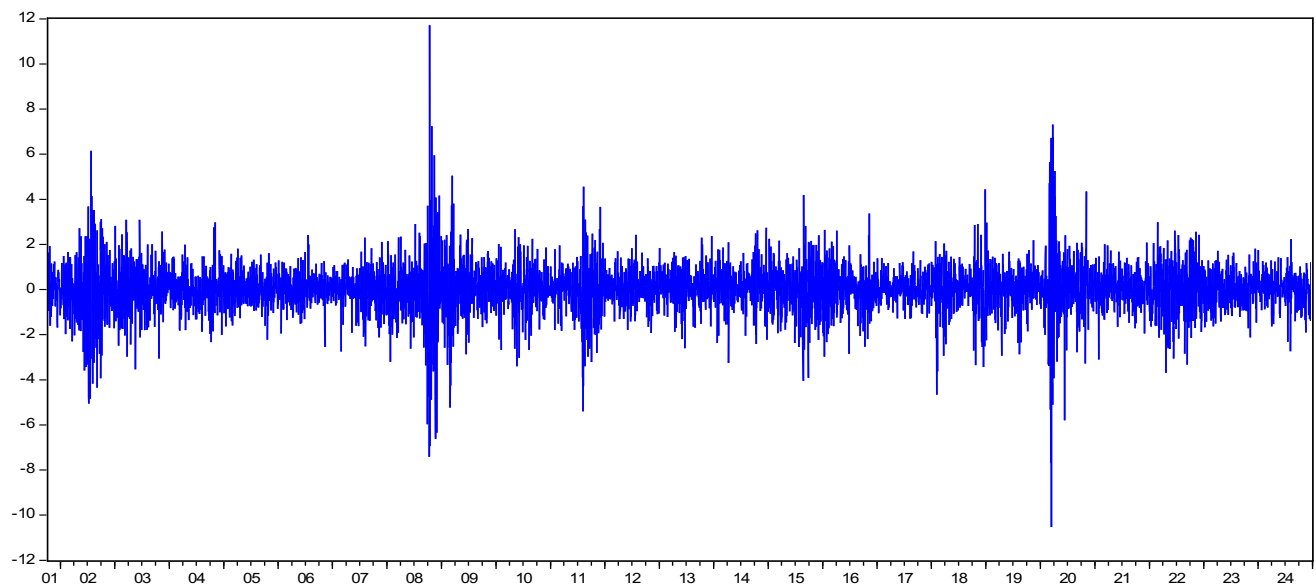


Figure A. 6: S5HLTH Returns

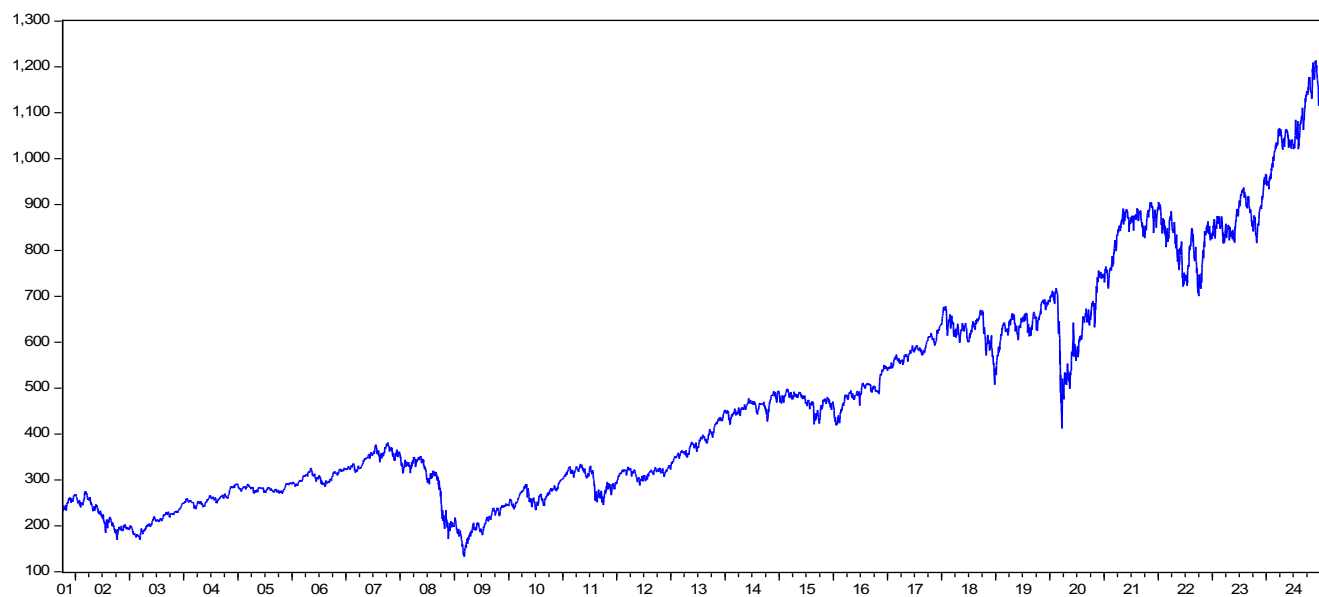


Figure A. 7: S5INDU Prices

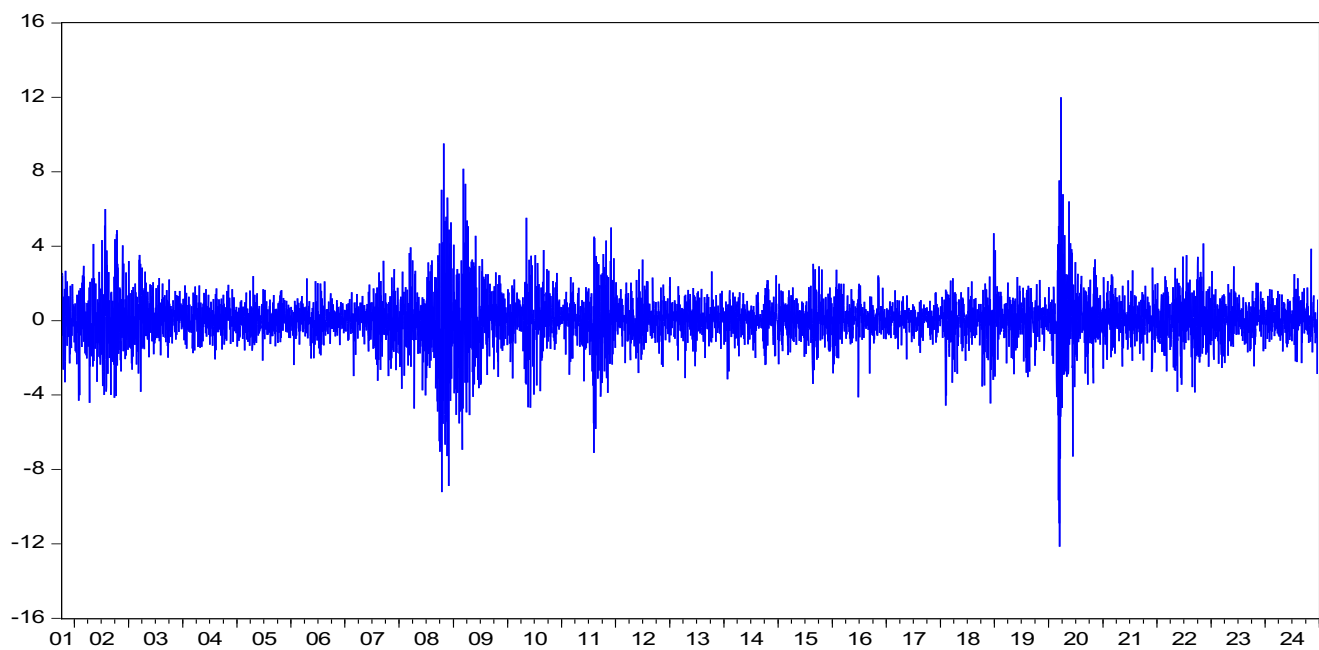


Figure A. 8: S5INDU Returns

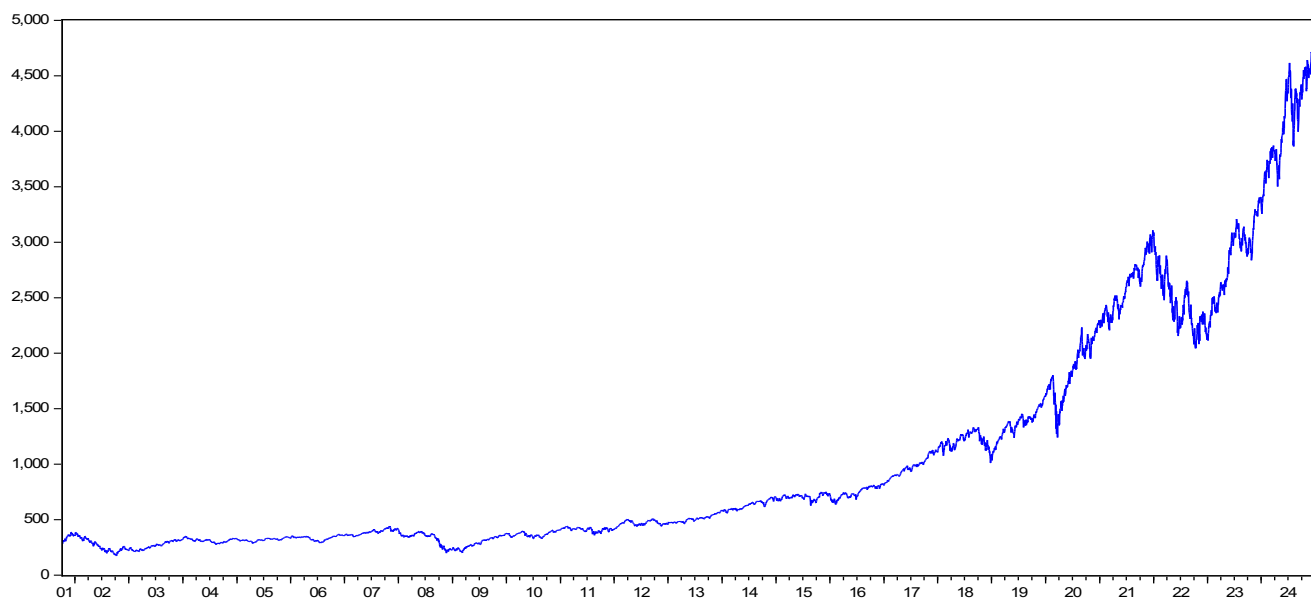


Figure A. 9: S5INFT Prices

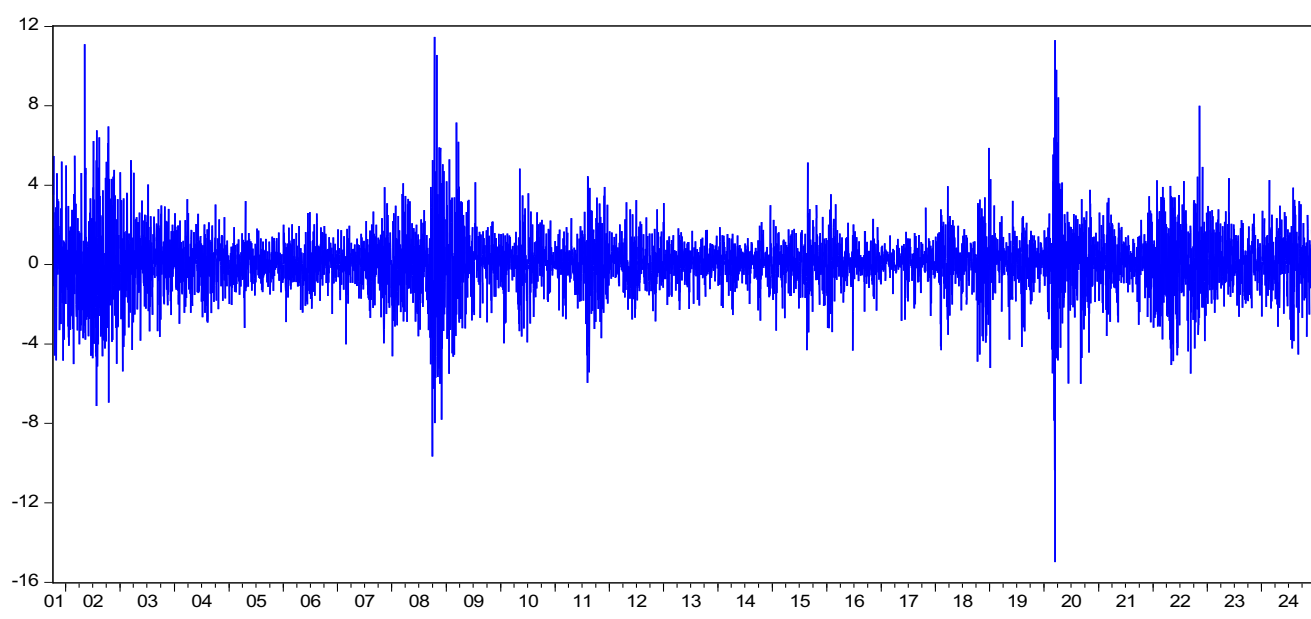


Figure A. 10: S5INFT Returns

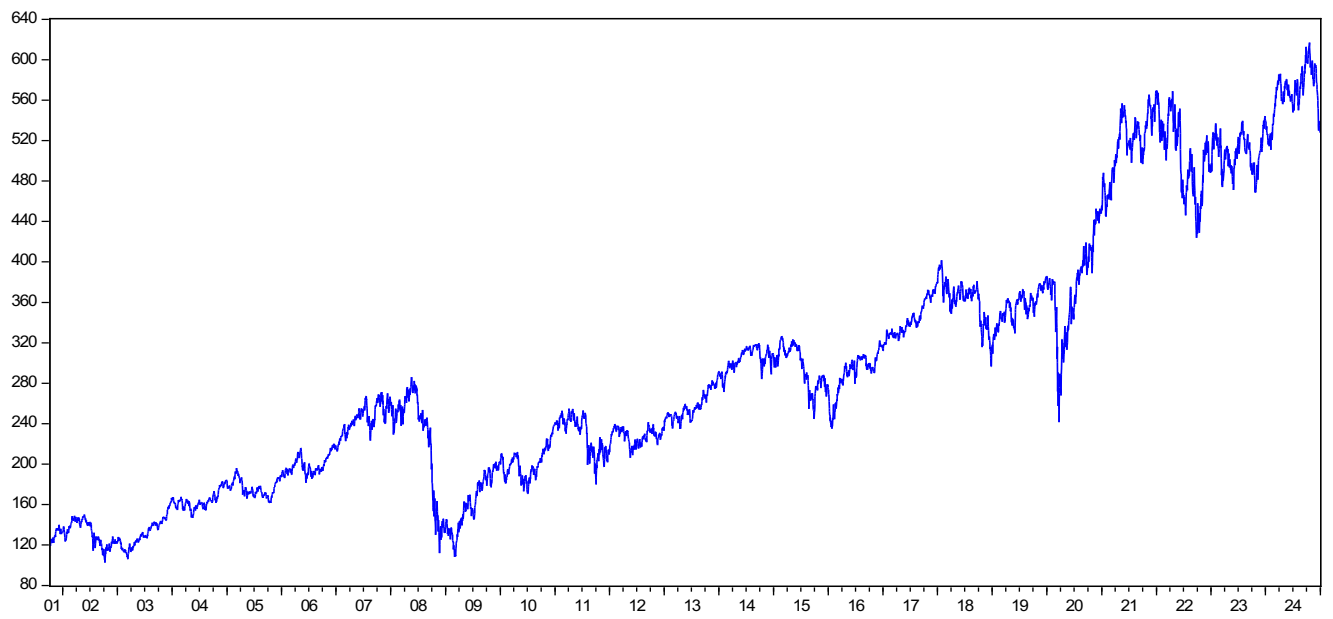


Figure A. 11: S5MATR Prices

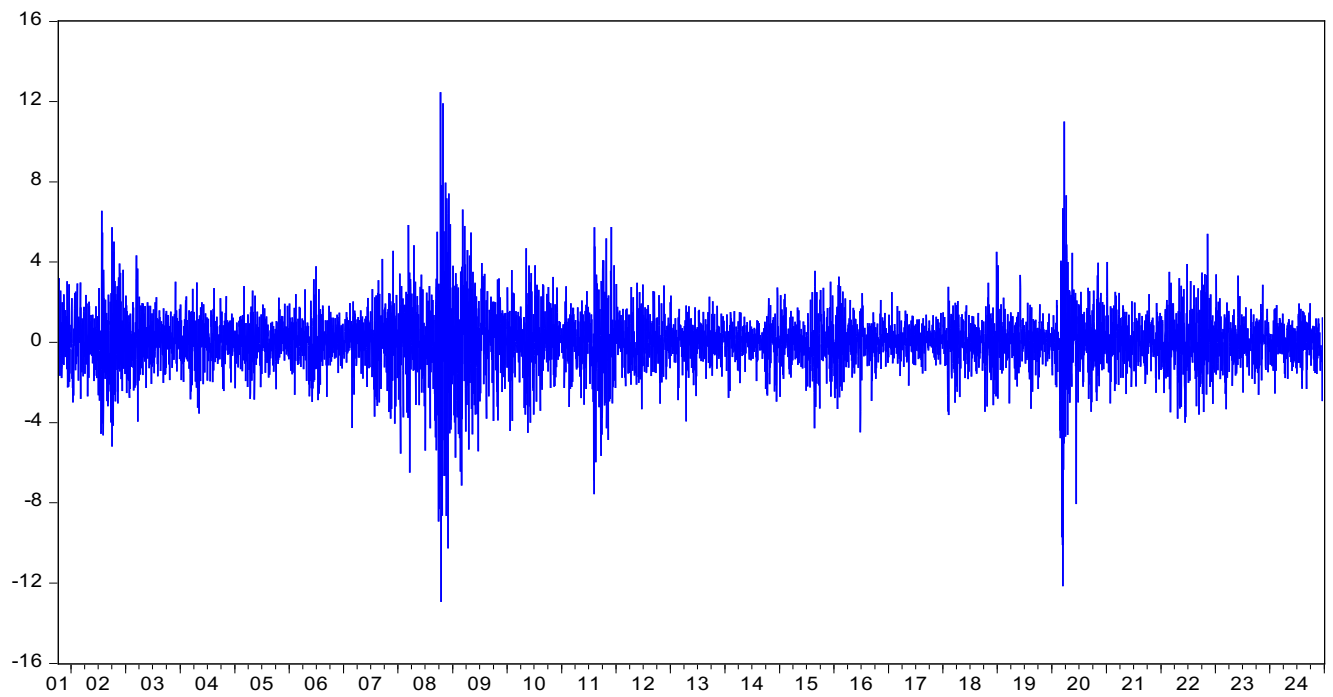


Figure A. 12: S5MATR Returns



Figure A. 13: S5RLST Prices

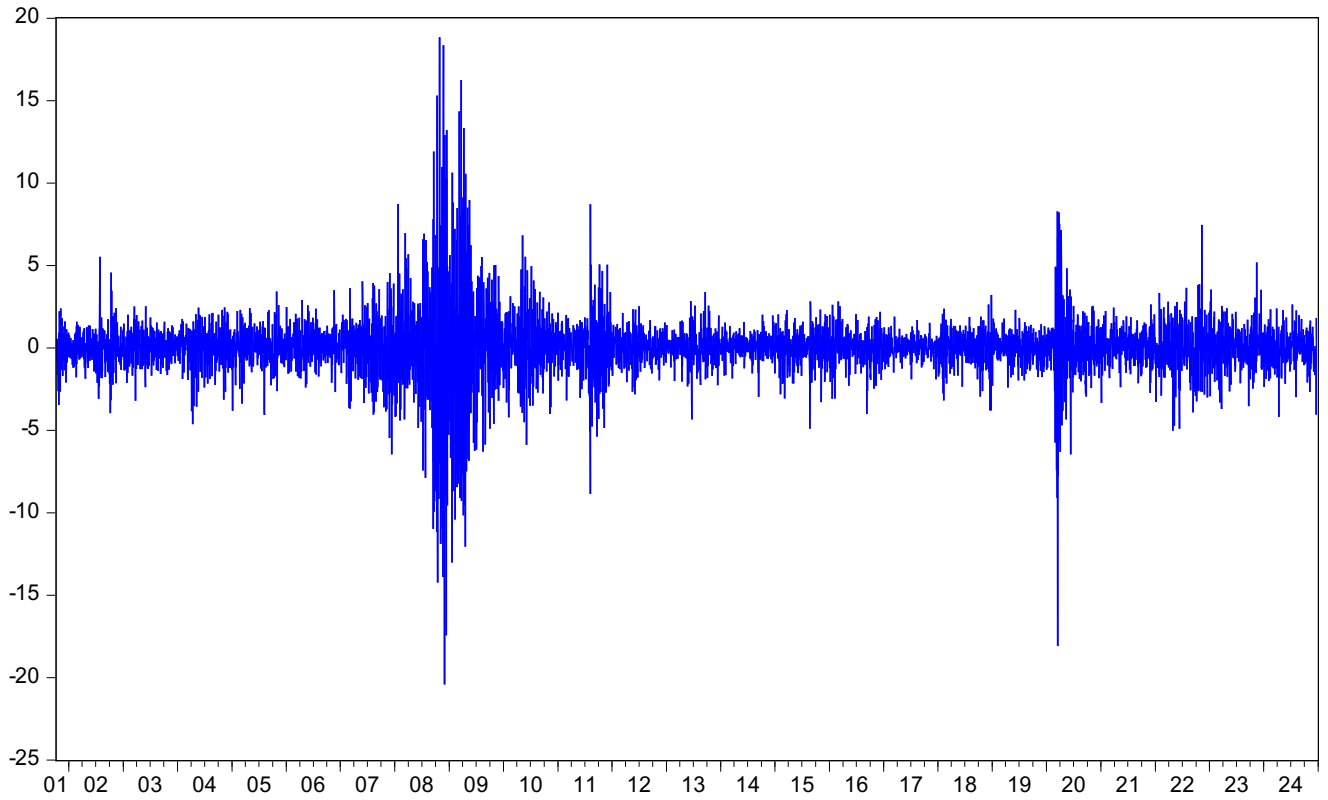


Figure A. 14: S5RLST Returns

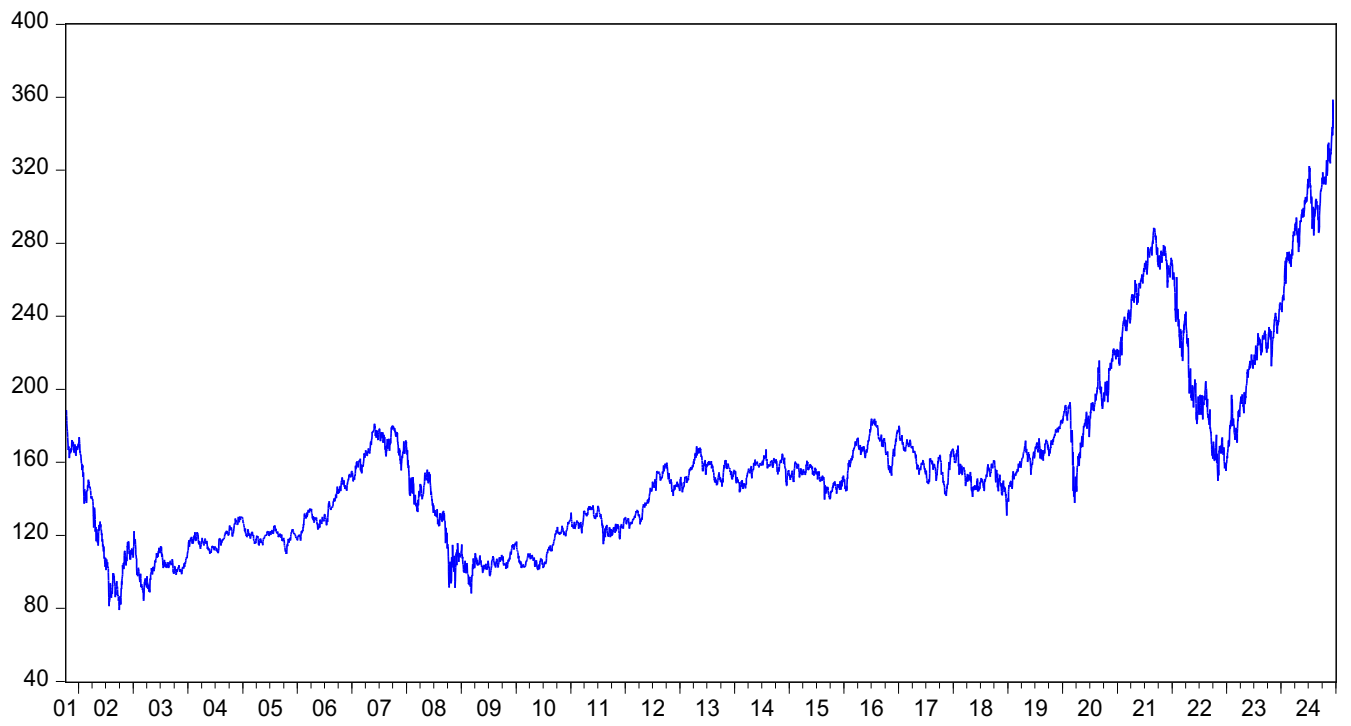


Figure A. 15: S5TELS Prices

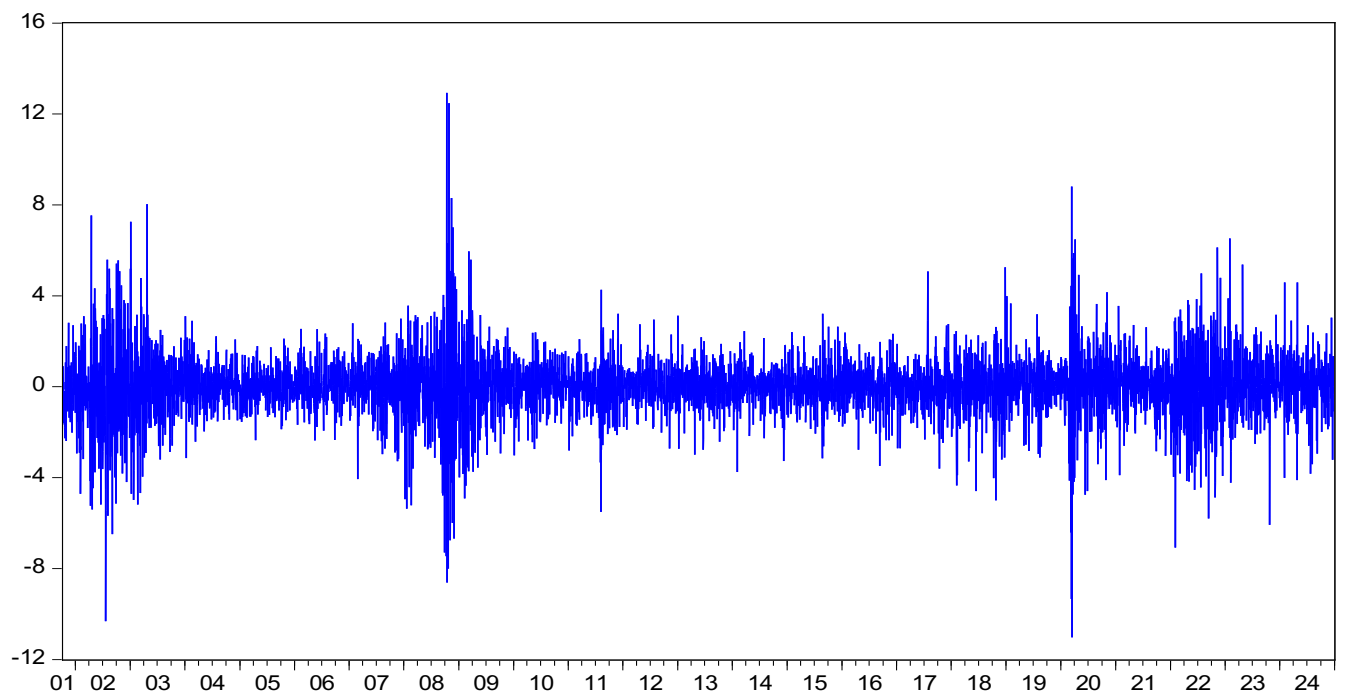


Figure A. 16: S5TELS Returns

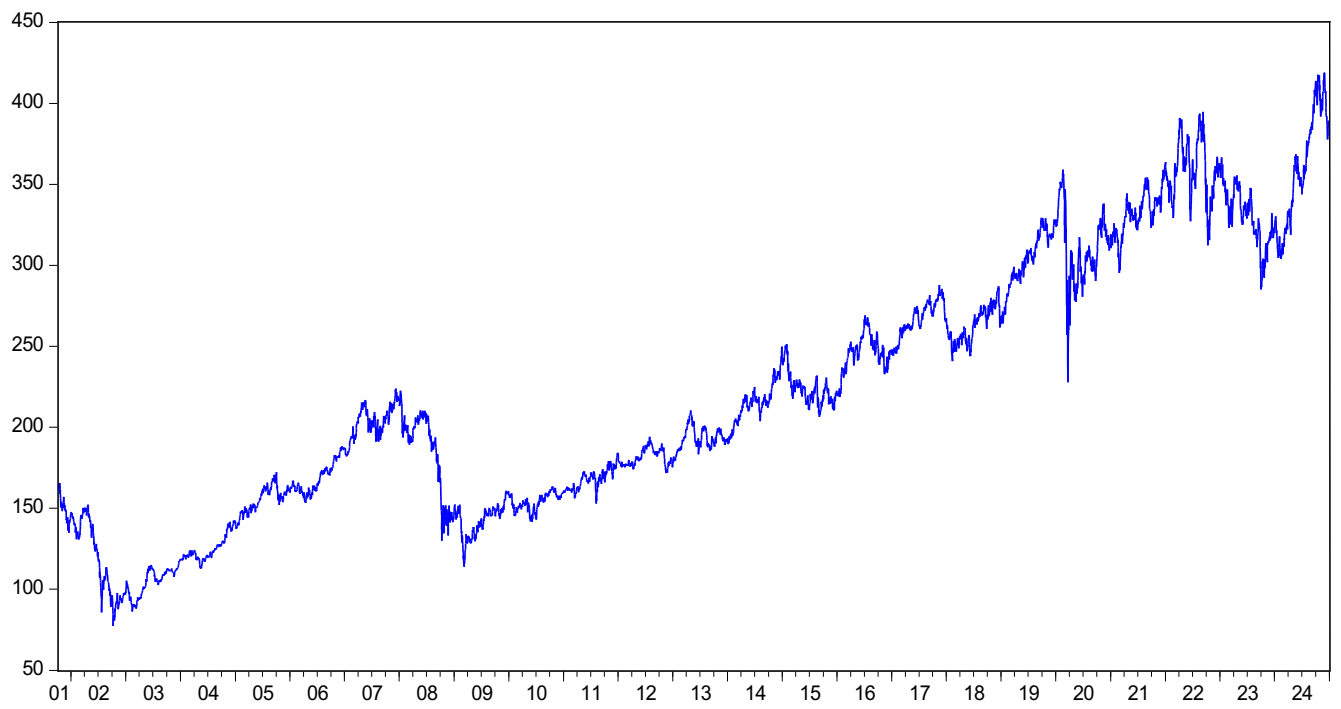


Figure A. 17: S5UTIL Prices

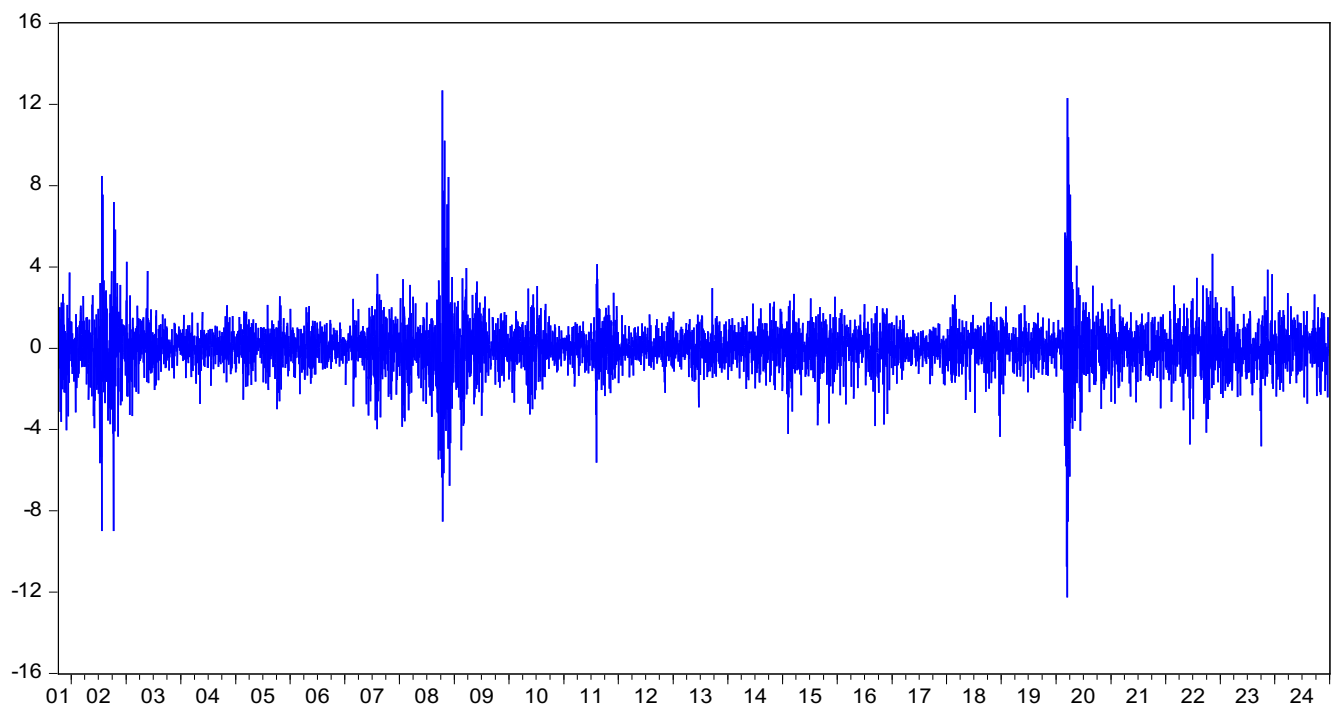


Figure A. 18: S5UTIL Returns

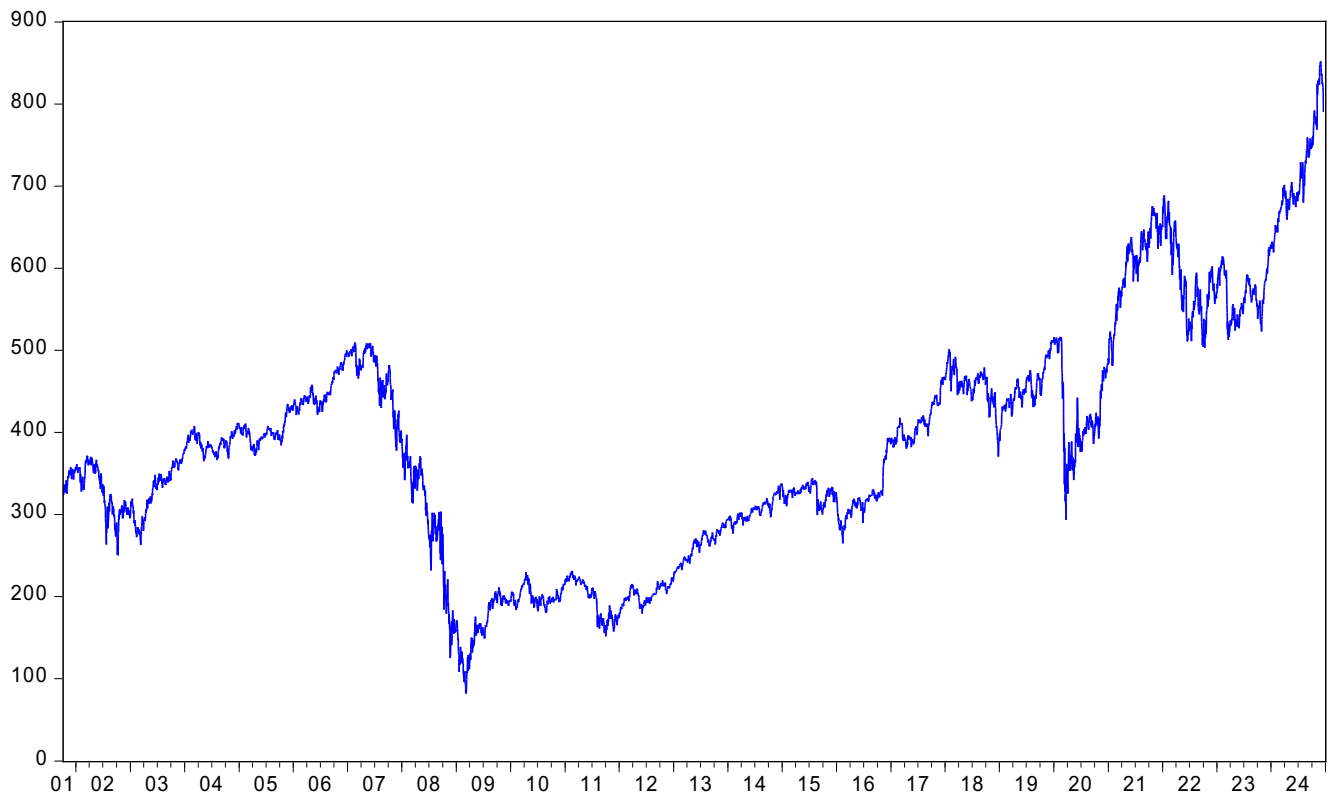


Figure A. 19: SPF Prices

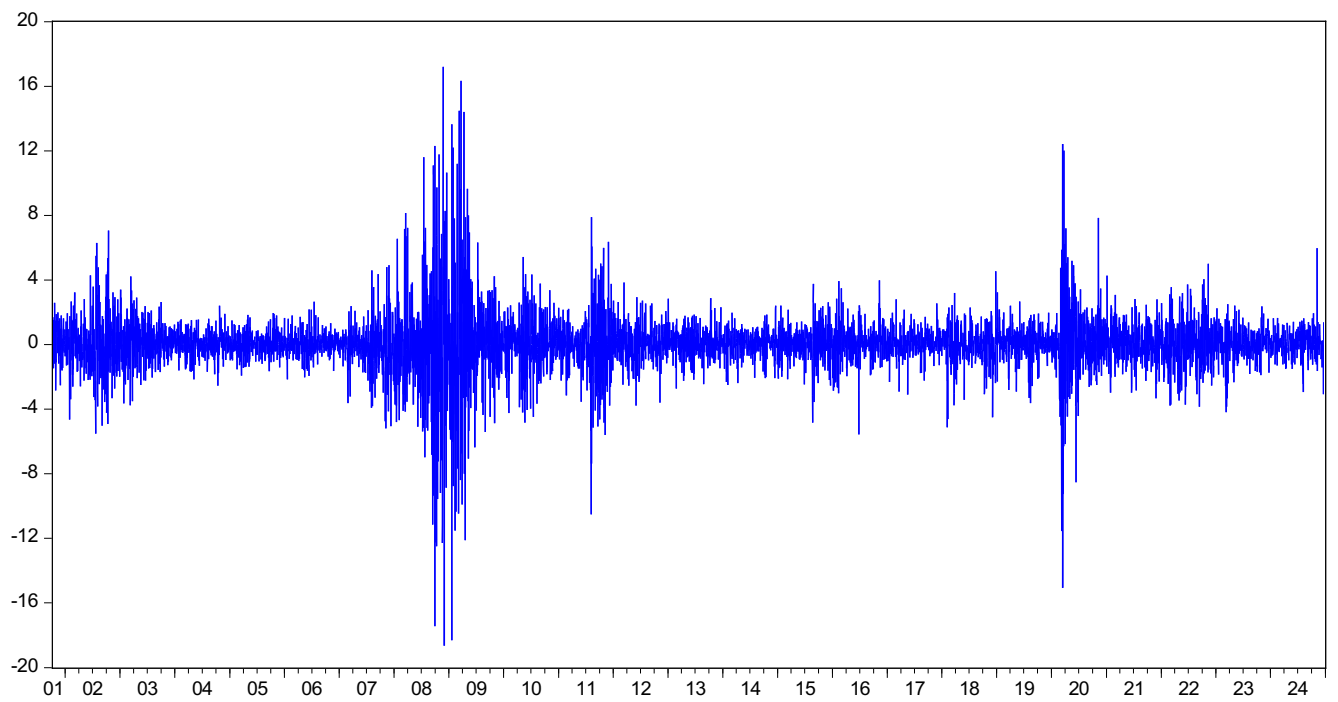


Figure A. 20: SPF Returns

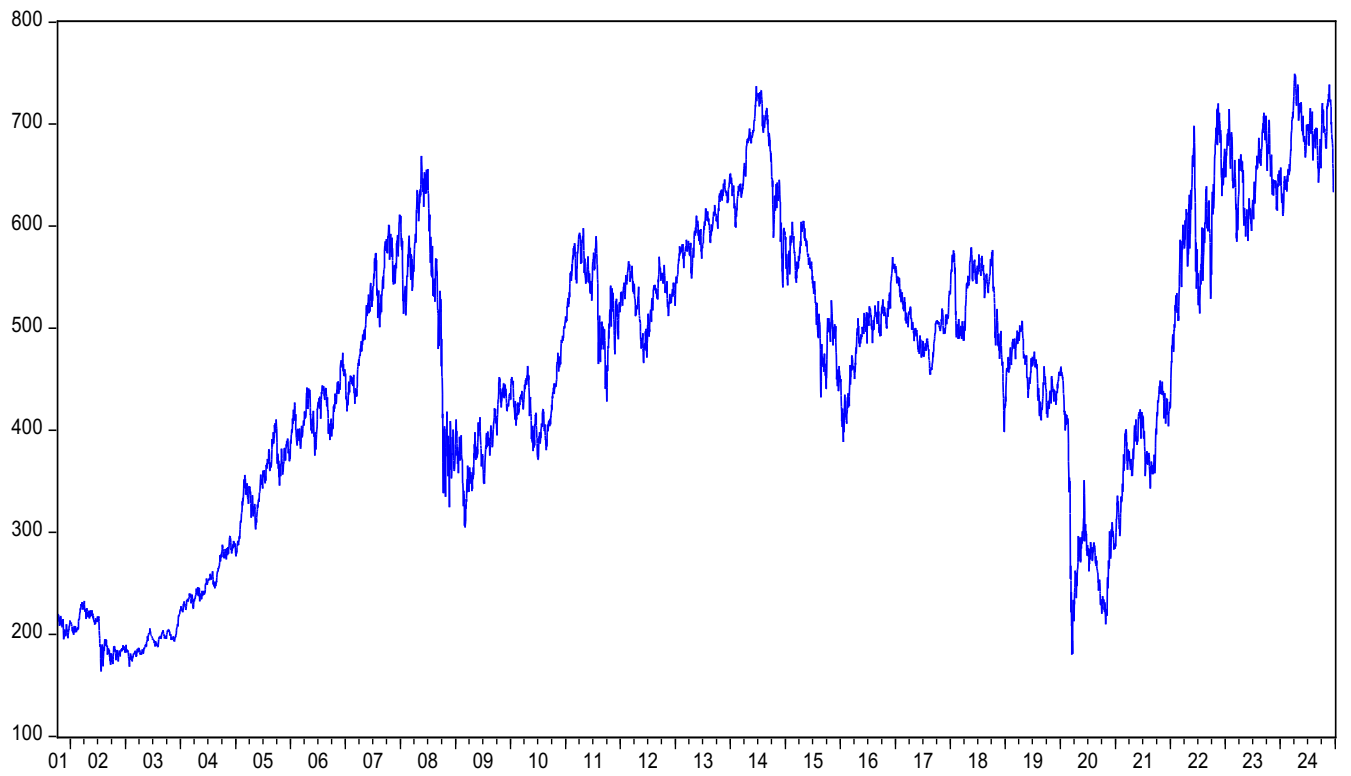


Figure A. 21: SPN Prices

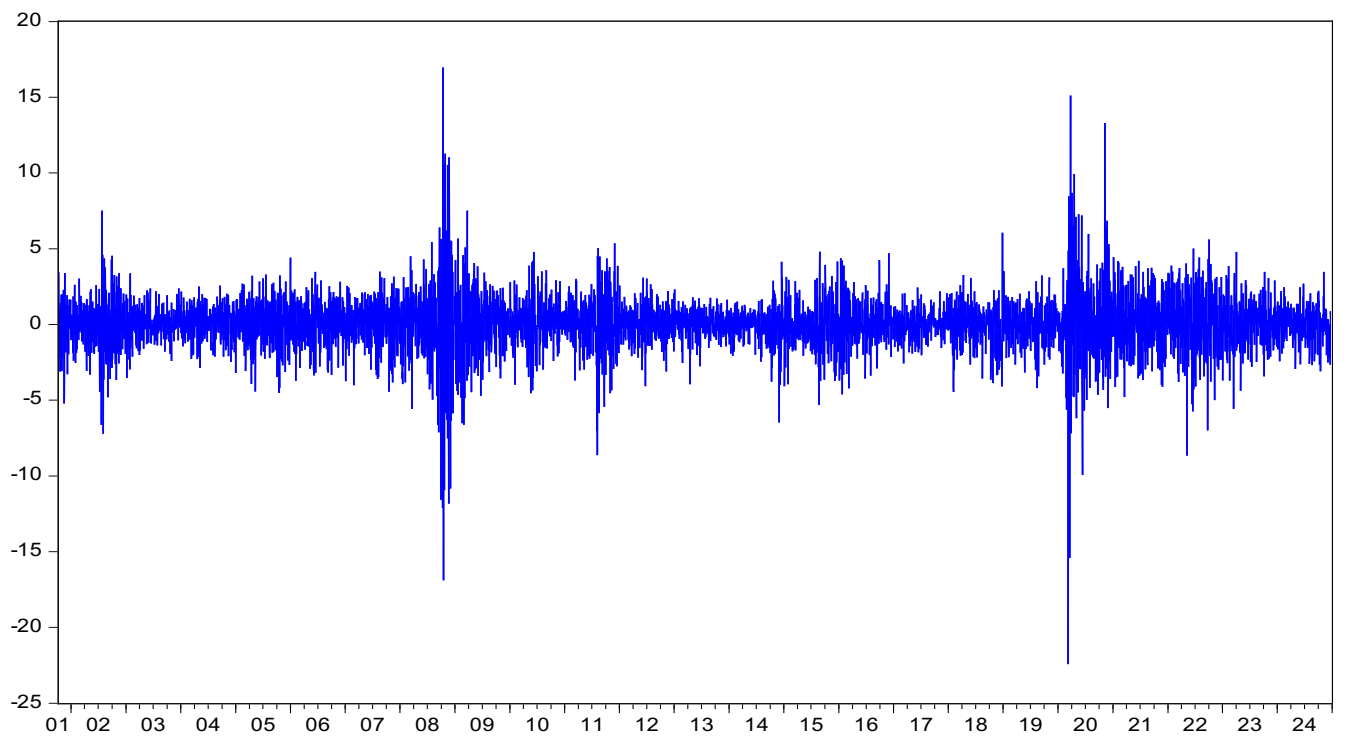


Figure A. 22: SPN Returns

Appendix 2 - Graphical Representation – EU Prices and Returns

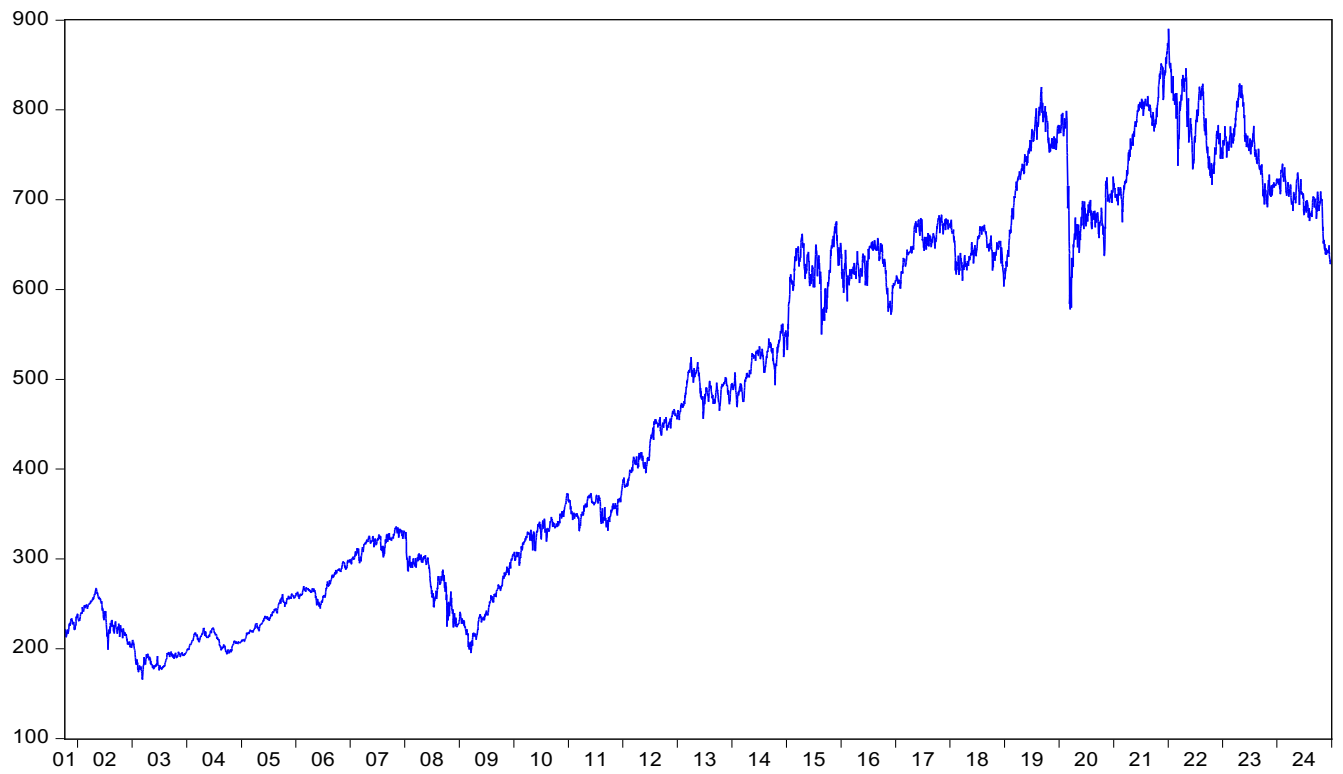


Figure A. 23: SX3P Prices

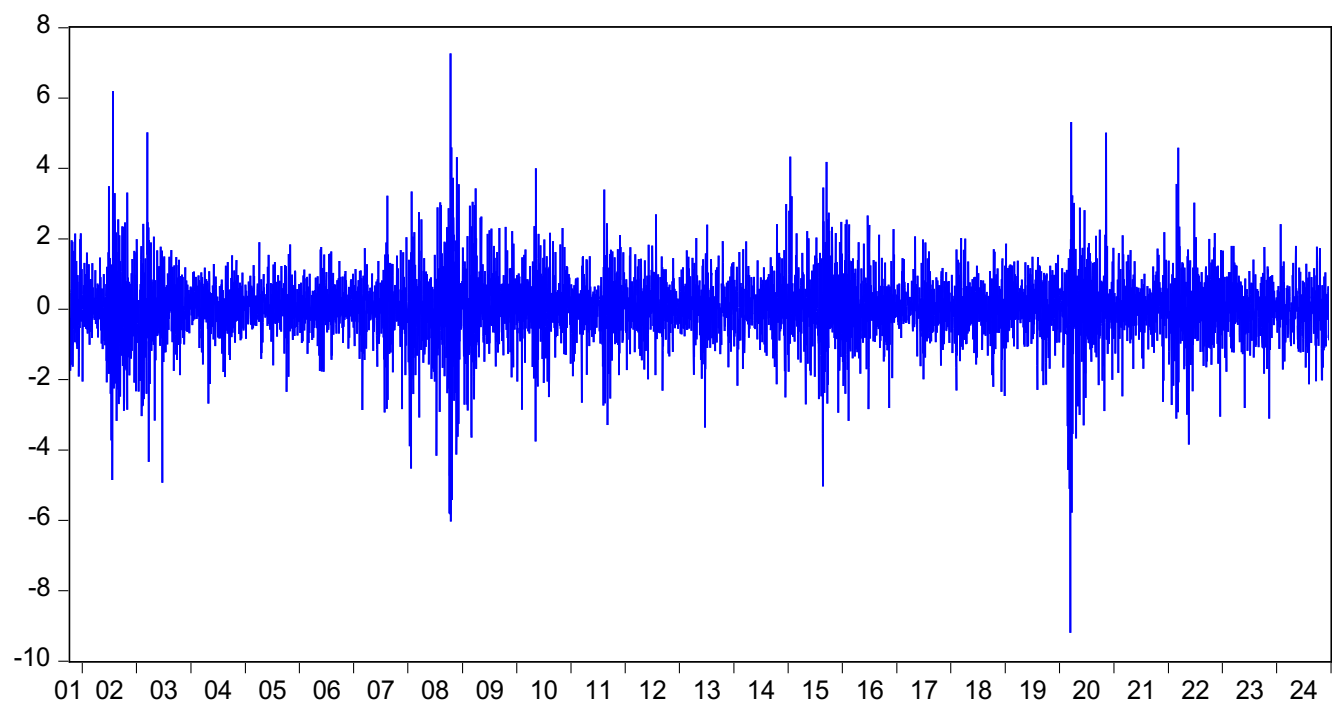


Figure A. 24: SX3P Returns



Figure A. 25: SX6P Prices

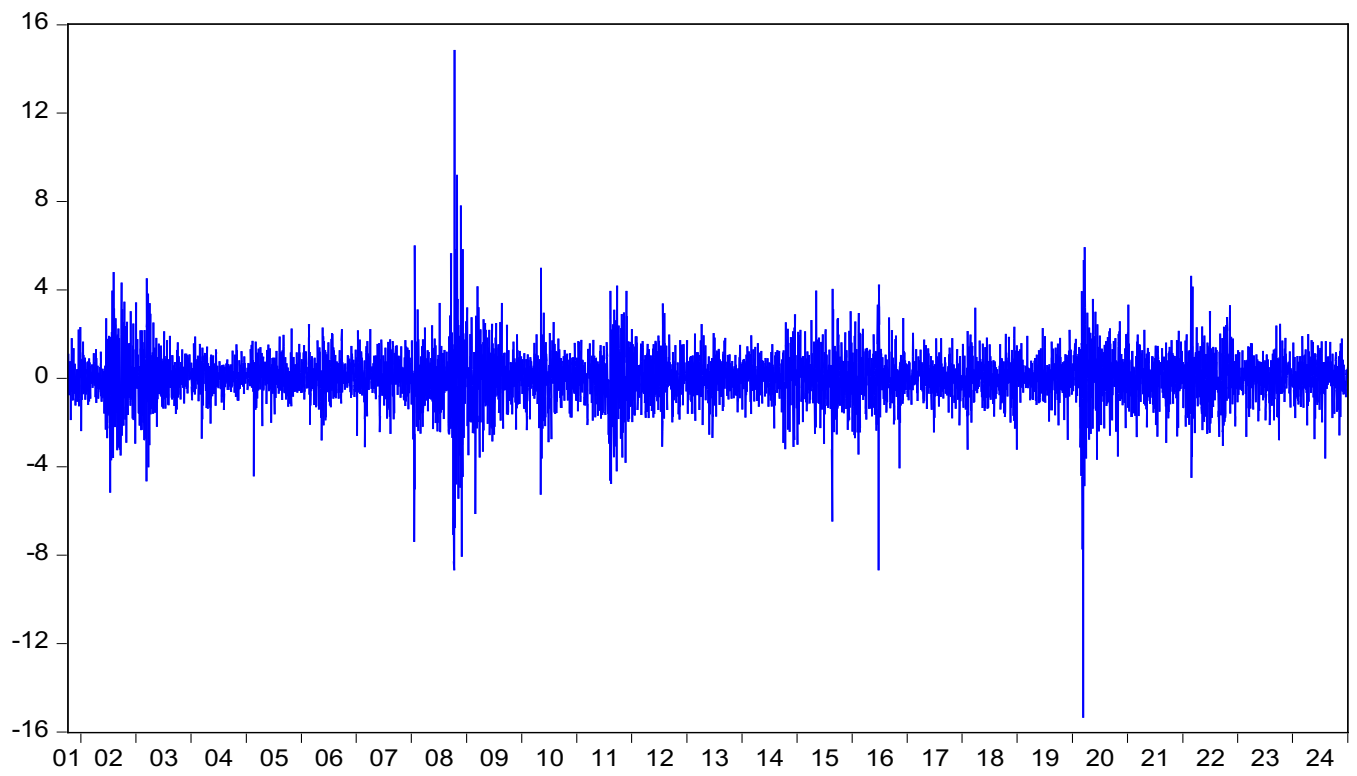


Figure A. 26: SX6P Returns



Figure A. 27: SX86P Prices

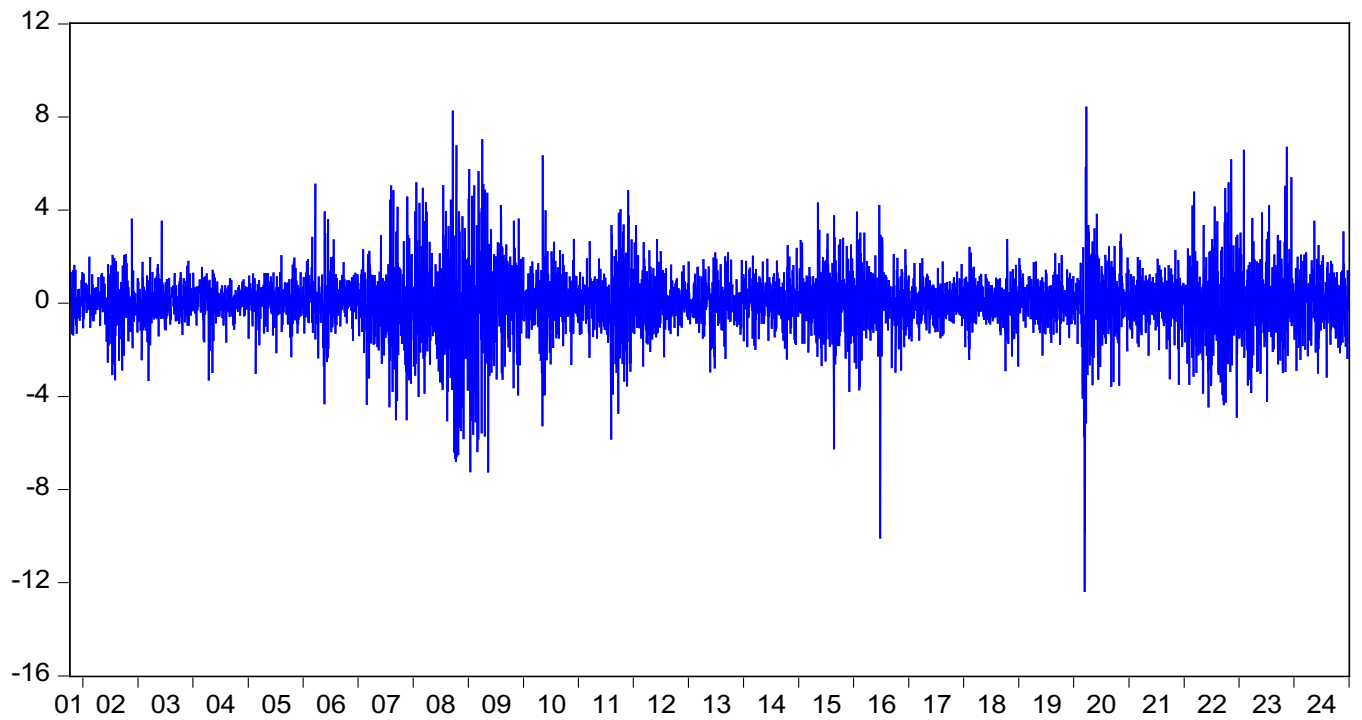


Figure A. 28: SX86P Returns



Figure A. 29: SX8P Prices

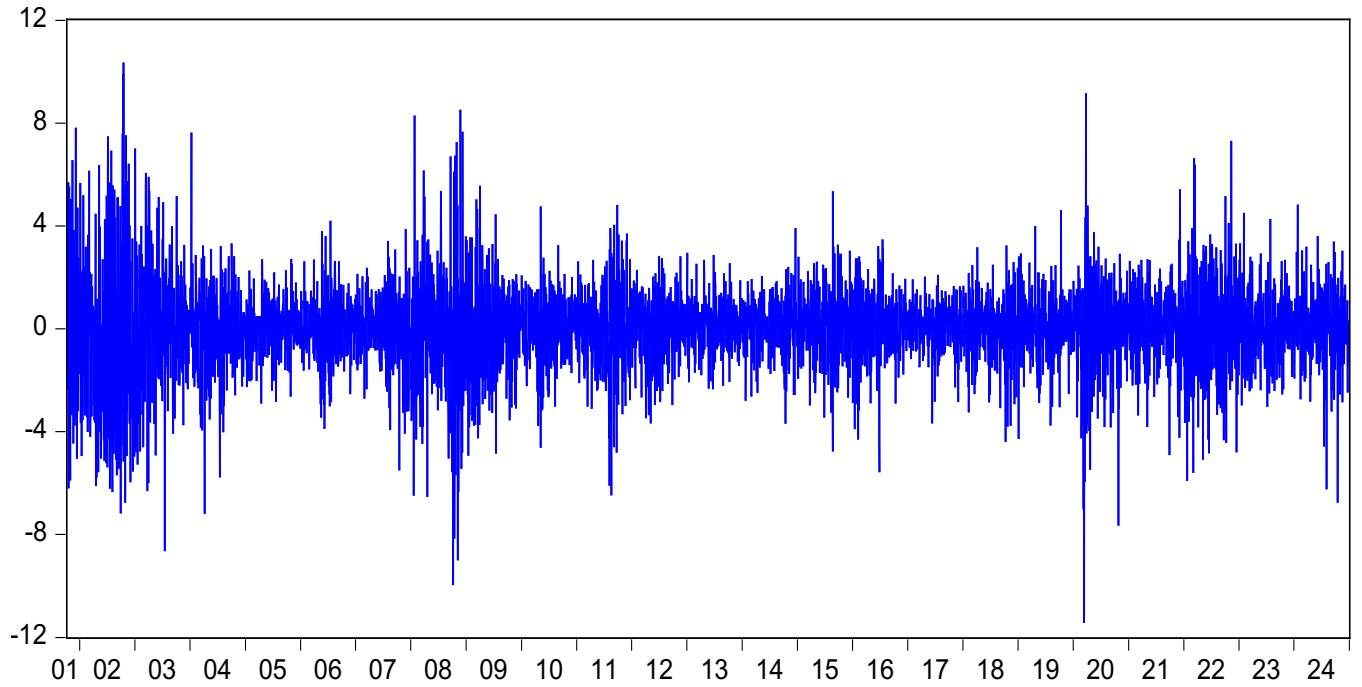


Figure A. 30: SX8P Returns



Figure A. 31: SXP Prices

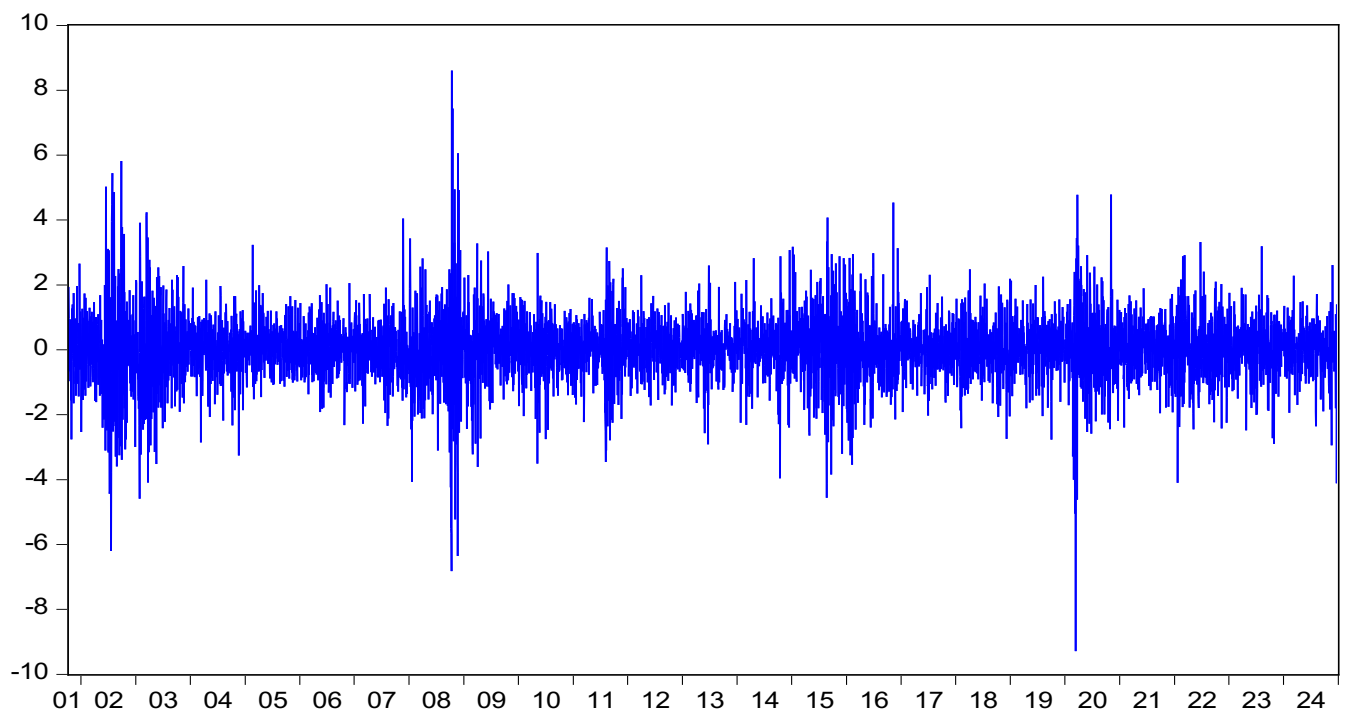


Figure A. 32: SXP Returns

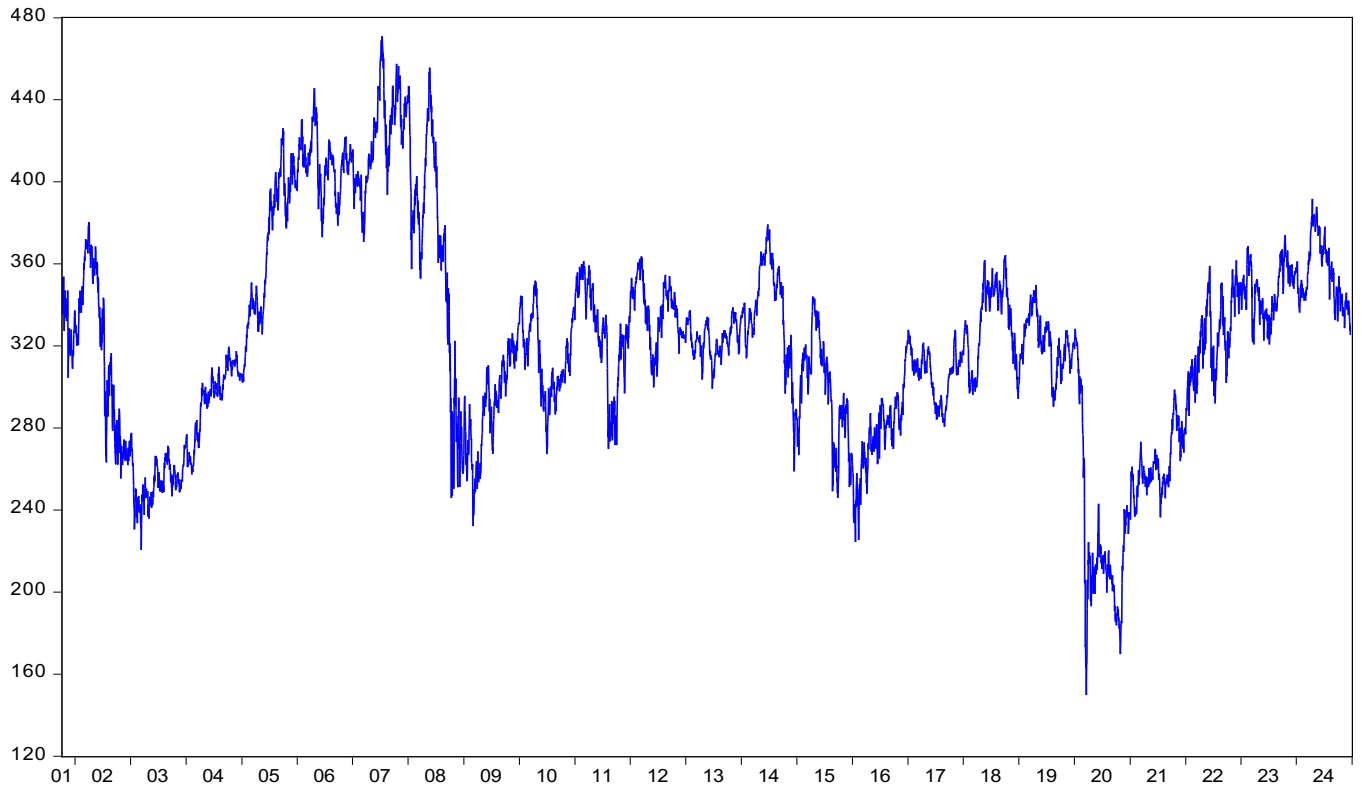


Figure A. 33: SXEP Prices

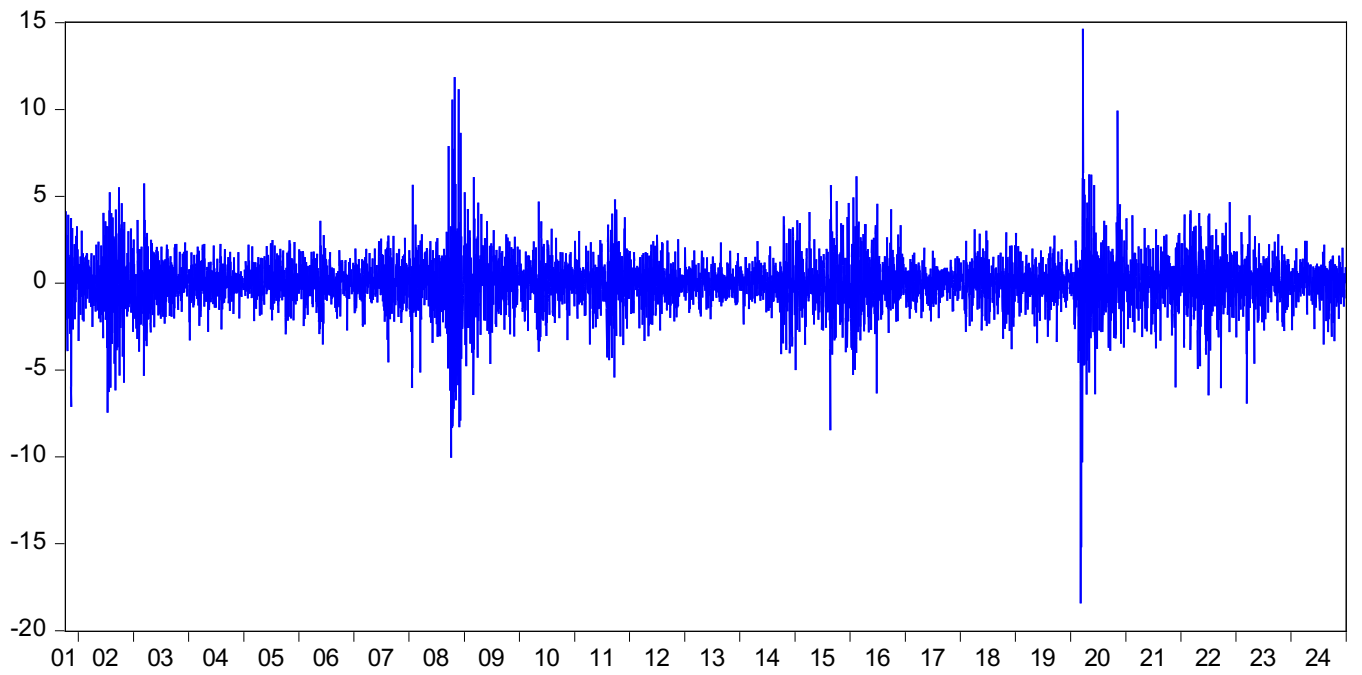


Figure A. 34: SXEP Returns



Figure A. 35: SXFP Prices

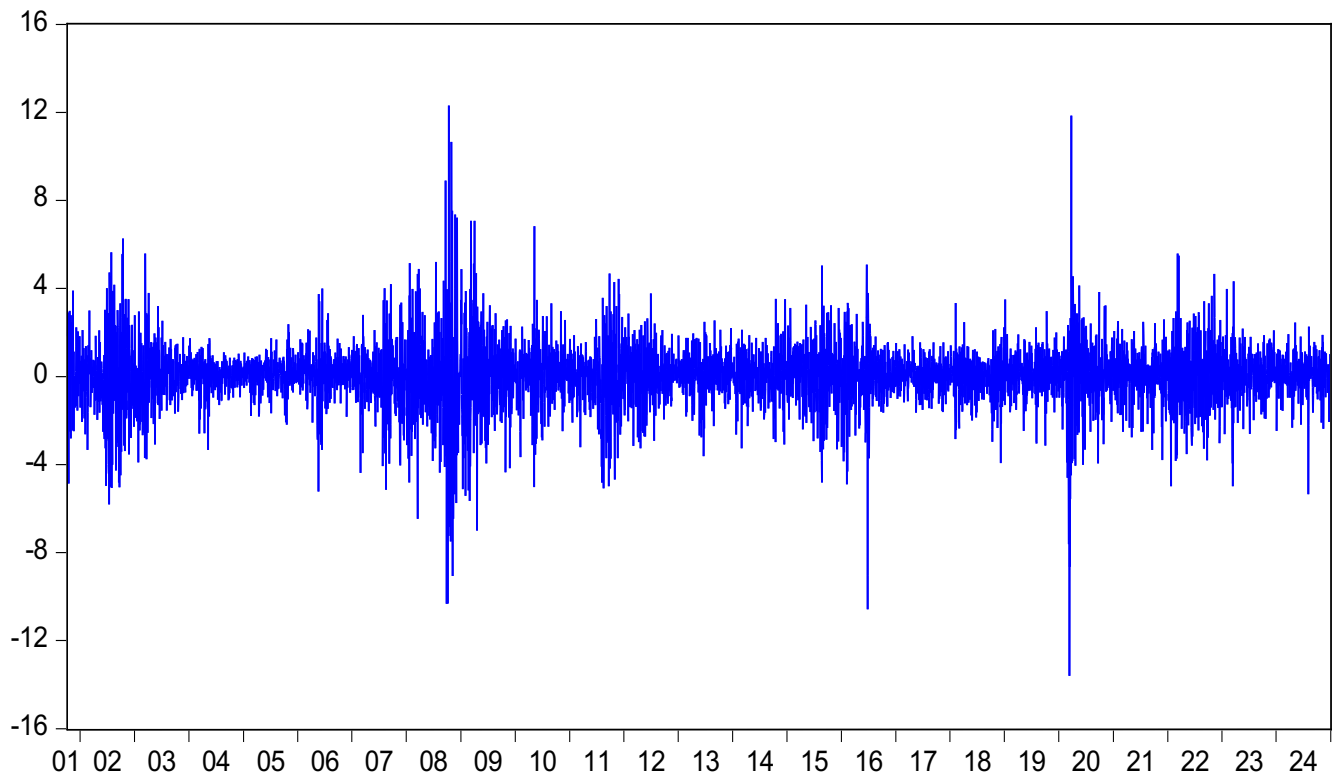


Figure A. 36: SXFP Returns



Figure A. 37: SXKP Prices

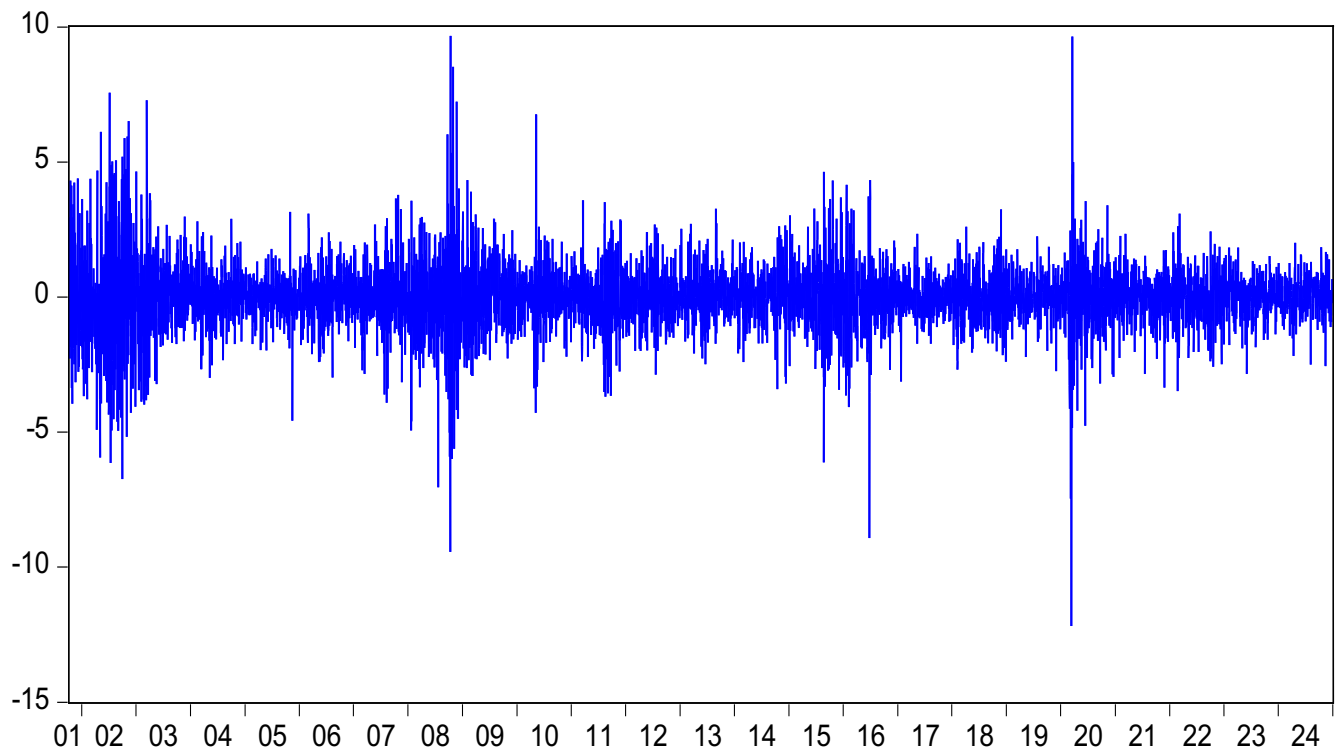


Figure A. 38: SXKP Returns



Figure A. 39: SXNP Prices

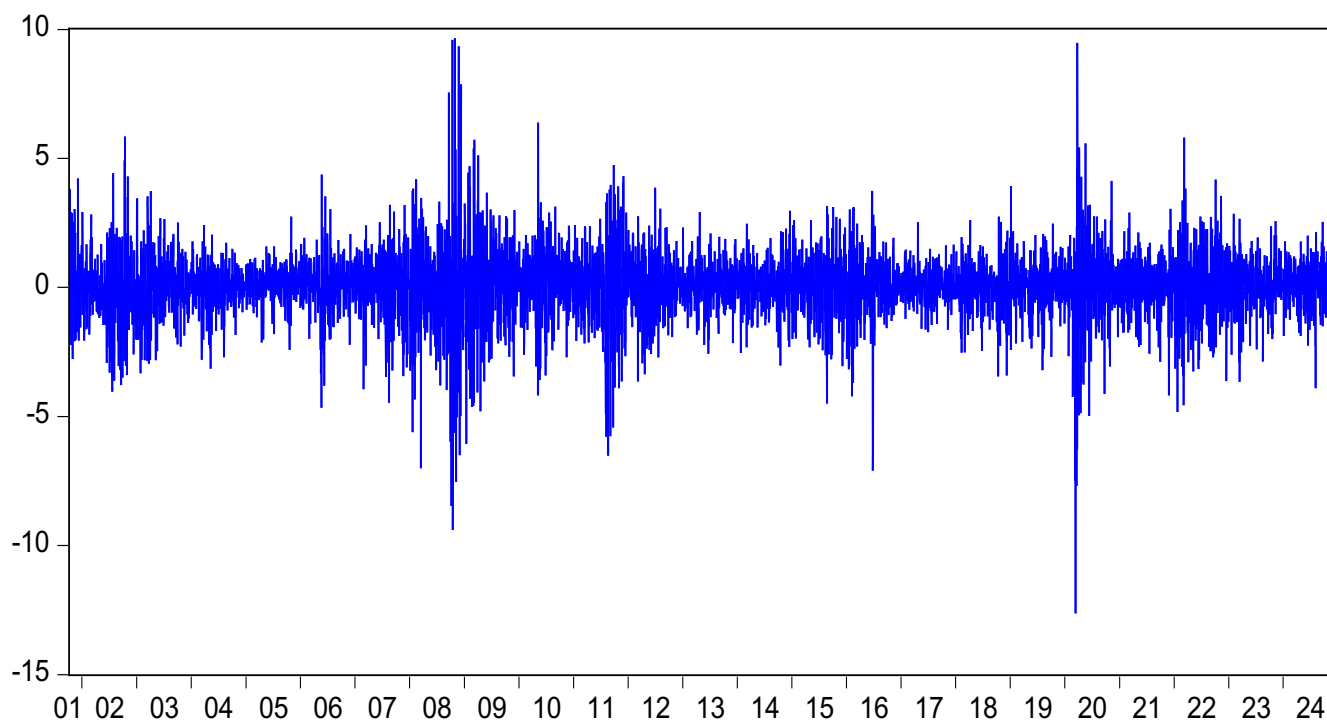


Figure A. 40: SXNP Returns



Figure A. 41: SXPP Prices

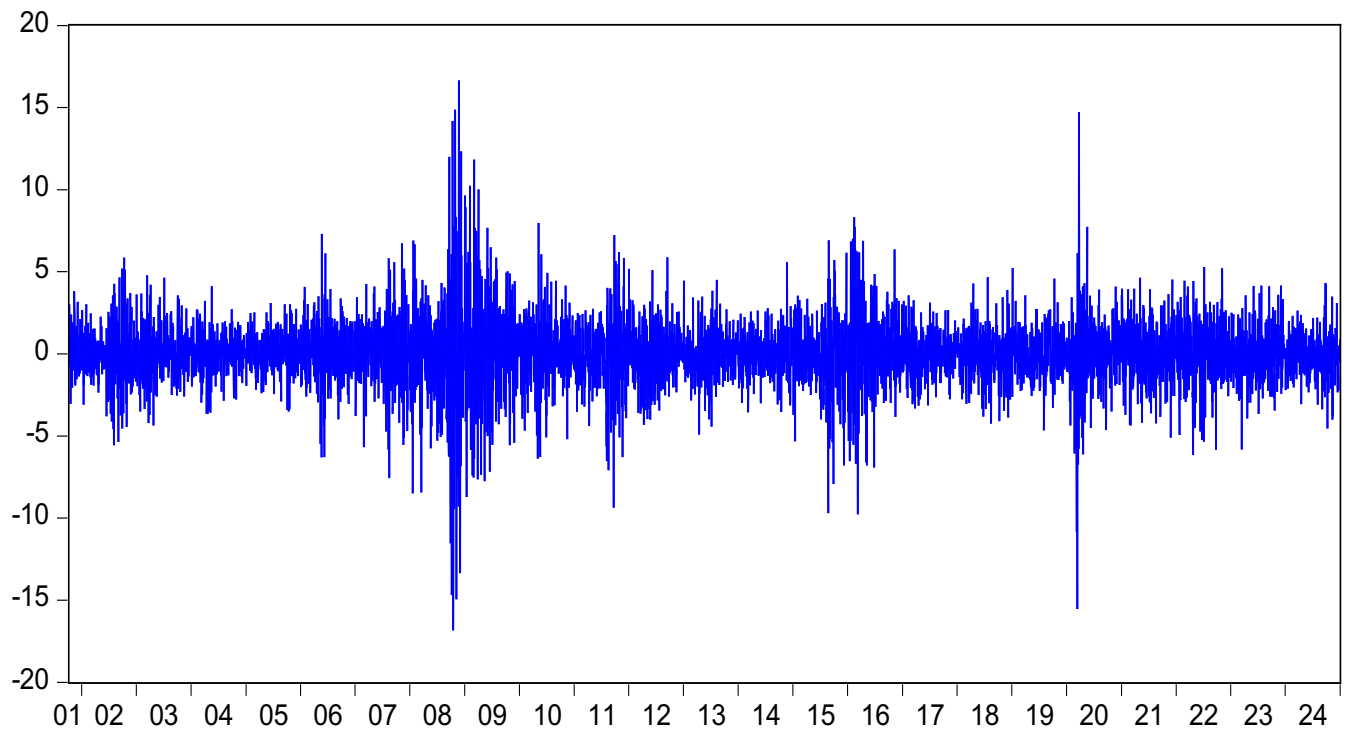


Figure A. 42: SXPP Returns



Figure A. 43: SXQP Prices

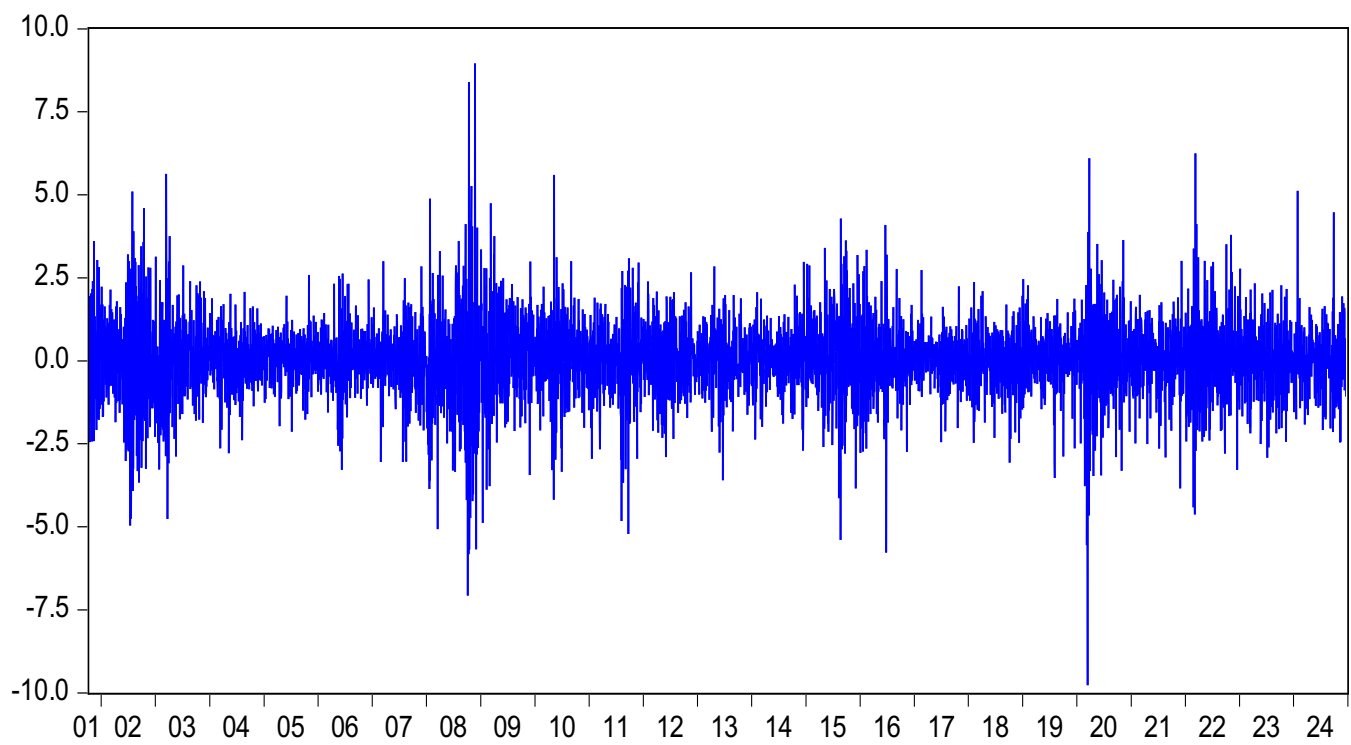


Figure A. 44: SXQP Returns

Appendix 3 – Descriptive Statistics – Returns Data

	Mean	Median	Max.	Min.	Std. Dev.	Skewness	Kurtosis	Jarque-Bera	Prob.	Obs.
S5COND	0.0361	0.0492	12.3132	-12.8761	1.3645	-0.3002	10.5270	14396.7000** *	0.0000	6060
S5CONS	0.0228	0.0188	8.8353	-9.6900	0.8867	-0.2362	15.8929	42028.8500** *	0.0000	6060
S5HLTH	0.0236	0.0217	11.7131	-10.5284	1.0620	-0.2109	12.6517	23566.5600** *	0.0000	6060
S5INDU	0.0259	0.0319	12.0008	-12.1550	1.3037	-0.4161	11.7583	19543.6700** *	0.0000	6060
S5INFT	0.0461	0.0610	11.4610	-14.9833	1.5090	-0.1027	9.7700	11583.5400** *	0.0000	6060
S5MATR	0.0246	0.0300	12.4730	-12.9339	1.4627	-0.3934	11.2216	17223.7600** *	0.0000	6060
S5RLST	0.0155	0.0309	18.8511	-20.4227	1.8315	-0.1970	23.3499	104621.7000** *	0.0000	6060
S5TELS	0.0100	0.0060	12.9261	-11.0301	1.3697	-0.0684	10.9446	15941.7400** *	0.0000	6060
S5UTIL	0.0144	0.0375	12.6840	-12.2653	1.2130	-0.0729	16.8415	48381.1100** *	0.0000	6060
SPF	0.0150	0.0070	17.2013	-18.6390	1.8010	-0.2187	21.7020	88363.7600** *	0.0000	6060
SPN	0.0186	0.0023	16.9604	-22.4172	1.7622	-0.6360	17.5231	53665.9100** *	0.0000	6060

Notes: *, **, *** signify rejection of the null hypothesis at the 10, 5 and 1% significance level, respectively

Table A. 1: US Returns Full Sample Descriptive Statistics

	Mean	Median	Max.	Min.	Std. Dev.	Skewness	Kurtosis	Jarque-Bera	Prob.	Obs.
SX3P	0.0173	0.0199	7.2695	-9.1960	0.9543	-0.3861	8.9274	9021.7650***	0.0000	6060
SX6P	0.0053	0.0079	14.8584	-15.3592	1.1695	-0.4397	17.6462	54359.4800** *	0.0000	6060
SX86P	0.0049	0.0294	8.4388	-12.3891	1.3054	-0.3955	9.4294	10595.7600** *	0.0000	6060
SX8P	0.0166	0.0569	10.3518	-11.4406	1.6461	-0.0986	7.0326	4115.9600***	0.0000	6060
SXDP	0.0146	0.0203	8.6038	-9.2895	1.0210	-0.1805	8.9115	8856.8240***	0.0000	6060
SXEP	0.0000	0.0133	14.6505	-18.4310	1.5304	-0.4671	14.4018	33045.6100** *	0.0000	6060
SXFP	0.0193	0.0629	12.3124	-13.5911	1.4112	-0.3794	11.6417	19001.7800** *	0.0000	6060
SXKP	0.0046	0.0000	9.6639	-12.1785	1.2459	-0.0866	10.2982	13456.5500** *	0.0000	6060
SXNP	0.0245	0.0560	9.6588	-12.6260	1.3208	-0.3745	9.8651	12041.9600** *	0.0000	6060
SXPP	0.0153	0.0107	16.6603	-16.8428	2.0307	-0.1881	10.3912	13829.9300** *	0.0000	6060
SXQP	0.0264	0.0525	8.9561	-9.7667	1.1340	-0.1887	7.8270	5919.1700***	0.0000	6060

Notes: *, **, *** signify rejection of the null hypothesis at the 10, 5 and 1% significance level, respectively

Table A. 2: EU Returns Full Sample Descriptive Statistics

	Mean	Median	Max.	Min.	Std. Dev.	Skewness	Kurtosis	Jarque-Bera	Prob.	Obs.
S5COND	0.0284	0.0102	6.1300	-4.8352	1.1603	0.2323	5.7043	427.5936***	0.0000	1363
S5CONS	0.0164	0.0212	4.1838	-5.3947	0.7648	-0.2001	6.6900	782.3604***	0.0000	1363
S5HLTH	0.0008	0.0000	6.1435	-5.0598	1.0069	-0.1380	6.8094	828.4399***	0.0000	1363
S5INDU	0.0243	0.0000	5.9888	-4.4142	1.1108	0.1192	5.9377	493.3532***	0.0000	1363
S5INFT	0.0171	0.0165	11.1015	-7.1284	1.6630	0.3147	6.3066	643.4293***	0.0000	1363
S5MATR	0.0439	0.0154	6.5567	-5.1870	1.2558	0.0844	4.9866	225.7489***	0.0000	1363
S5RLST	0.0424	0.0408	5.5208	-4.6353	1.0530	-0.2190	4.8378	202.8617***	0.0000	1364
S5TELS	-0.0136	0.0000	8.0276	-10.3203	1.4452	-0.0353	8.5884	1773.8670***	0.0000	1363
S5UTIL	0.0108	0.0429	8.4832	-8.9962	1.2069	-0.3908	12.4373	5092.6640***	0.0000	1363
SPF	0.0312	0.0000	7.0669	-5.5123	1.1499	0.2659	7.5434	1188.3520***	0.0000	1363
SPN	0.0560	0.0412	7.5115	-7.2121	1.3857	-0.3513	5.1460	289.5852***	0.0000	1363

Notes: *, **, *** signify rejection of the null hypothesis at the 10, 5 and 1% significance level, respectively

Table A. 3: US Returns Period 1 Descriptive Statistics

	Mean	Median	Max.	Min.	Std. Dev.	Skewness	Kurtosis	Jarque-Bera	Prob.	Obs.
SX3P	0.0214	0.0128	6.1934	-4.9327	0.9003	-0.1404	7.9224	1380.5370***	0.0000	1363
SX6P	0.0378	0.0139	4.8115	-5.1761	1.0042	-0.1056	6.1354	560.8559***	0.0000	1363
SX86P	0.0764	0.0875	5.1382	-4.3379	0.8131	-0.1697	6.9754	904.0702***	0.0000	1363
SX8P	0.0028	0.0514	10.3518	-8.6485	2.0941	0.1930	5.4362	345.5390***	0.0000	1363
SXDP	-0.0012	0.0000	5.8210	-6.1962	1.1104	0.0090	6.8197	828.6084***	0.0000	1363
SXEP	0.0151	0.0000	5.7362	-7.4460	1.3828	-0.4118	6.1820	613.5409***	0.0000	1363
SXFP	0.0449	0.0943	6.2737	-5.8085	1.2358	-0.2439	7.0275	934.7239***	0.0000	1363
SXKP	0.0047	0.0085	7.5695	-6.7391	1.5114	0.2185	6.1750	583.3520***	0.0000	1363
SXNP	0.0328	0.0512	5.8418	-4.6558	1.1185	-0.0319	5.3792	321.7153***	0.0000	1363
SXPP	0.0718	0.0779	7.3012	-6.2979	1.5167	-0.0341	4.6817	160.8684***	0.0000	1363
SXQP	0.0453	0.0521	5.6301	-4.9559	1.0981	-0.0149	5.4954	353.7014***	0.0000	1363

Notes: *, **, *** signify rejection of the null hypothesis at the 10, 5 and 1% significance level, respectively

Table A. 4: EU Returns Period 1 Descriptive Statistics

	Mean	Median	Max.	Min.	Std. Dev.	Skewness	Kurtosis	Jarque-Bera	Prob.	Obs.
S5COND	0.0138	0.0142	12.3132	-10.0992	1.6928	-0.0393	9.0346	2376.5960***	0.0000	1566
S5CONS	0.0189	0.0288	8.8353	-6.6485	1.0083	0.0830	13.7677	7567.1000***	0.0000	1566
S5HLTH	0.0112	0.0354	11.7131	-7.4152	1.2068	-0.0118	14.0835	8015.6680***	0.0000	1566
S5INDU	0.0012	0.0263	9.5164	-9.2150	1.6777	-0.3574	7.3538	1270.2210***	0.0000	1566
S5INFT	0.0168	0.0593	11.4610	-9.6701	1.6057	-0.0247	8.7564	2162.3260***	0.0000	1566
S5MATR	0.0059	0.0295	12.4730	-12.9339	1.9794	-0.3721	8.3546	1906.9430***	0.0000	1566
S5RLST	-0.0105	0.0000	18.8511	-20.4227	3.0060	0.0151	11.0523	4230.8190***	0.0000	1566
S5TELS	-0.0039	0.0000	12.9261	-8.6124	1.5070	0.3336	13.3803	7059.8150***	0.0000	1566
S5UTIL	-0.0031	0.0088	12.6840	-8.5299	1.3422	0.4311	15.0623	9542.2440***	0.0000	1566
SPF	-0.0515	0.0000	17.2013	-18.6390	2.8240	-0.0621	11.8278	5085.9720***	0.0000	1566
SPN	0.0100	0.0235	16.9604	-16.8836	2.0781	-0.3797	13.6018	7371.6110***	0.0000	1566

Notes: *, **, *** signify rejection of the null hypothesis at the 10, 5 and 1% significance level, respectively

Table A. 5: US Returns Period 2 Descriptive Statistics

	Mean	Median	Max.	Min.	Std. Dev.	Skewness	Kurtosis	Jarque-Bera	Prob.	Obs.
SX3P	0.0274	0.0649	7.2695	-6.0348	1.0959	-0.3422	7.6747	1456.4810***	0.0000	1566
SX6P	-0.0374	0.0000	14.8584	-8.6815	1.4555	0.2788	15.3279	9936.7080***	0.0000	1566
SX86P	-0.0459	0.0000	8.2778	-7.2702	1.7154	-0.1892	5.6336	461.9028***	0.0000	1566
SX8P	-0.0188	0.0150	8.5161	-9.9712	1.7008	-0.1976	6.7304	918.2113***	0.0000	1566
SXDP	0.0061	0.0250	8.6038	-6.8172	1.0688	0.0366	11.5655	4787.5740***	0.0000	1566
SXEP	-0.0155	0.0000	11.8585	-10.0372	1.7171	-0.0051	10.3581	3532.7420***	0.0000	1566
SXFP	-0.0395	0.0064	12.3124	-10.3231	1.8096	-0.0342	8.6167	2058.7540***	0.0000	1566
SXKP	-0.0229	0.0000	9.6639	-9.4359	1.3473	0.0756	9.5627	2811.7110***	0.0000	1566
SXNP	0.0052	0.0803	9.6588	-9.3918	1.7099	-0.1800	7.3816	1261.1350***	0.0000	1566
SXPP	-0.0107	0.0000	16.6603	-16.8428	2.7642	-0.1345	8.3915	1901.4250***	0.0000	1566
SXQP	0.0178	0.0673	8.9561	-7.0679	1.3097	-0.0710	7.8247	1520.1620***	0.0000	1566

Notes: *, **, *** signify rejection of the null hypothesis at the 10, 5 and 1% significance level, respectively

Table A. 6: EU Returns Period 2 Descriptive Statistics

	Mean	Median	Max.	Min.	Std. Dev.	Skewness	Kurtosis	Jarque-Bera	Prob.	Obs.
S5COND	0.0528	0.0893	6.0896	-4.0988	0.9026	-0.4213	6.4425	955.6360***	0.0000	1826
S5CONS	0.0320	0.0193	2.9974	-3.8022	0.7162	-0.4544	5.2988	464.8756***	0.0000	1826
S5HLTH	0.0516	0.0553	4.4428	-4.6609	0.8972	-0.3842	5.3754	474.2280***	0.0000	1826
S5INDU	0.0404	0.0510	4.6902	-4.5625	0.9067	-0.4898	5.5689	575.0944***	0.0000	1826
S5INFT	0.0682	0.0821	5.8737	-5.2007	1.0379	-0.4566	6.4497	968.8686***	0.0000	1826
S5MATR	0.0265	0.0433	4.5158	-4.4805	0.9913	-0.3258	4.7345	261.1915***	0.0000	1826
S5RLST	0.0254	0.0573	3.3772	-4.9069	0.8910	-0.5248	5.2156	457.3090***	0.0000	1826
S5TELS	0.0119	0.0259	5.2546	-5.0007	0.9747	-0.2583	5.7276	586.3510***	0.0000	1826
S5UTIL	0.0336	0.0668	2.9554	-4.3591	0.8584	-0.5845	4.9463	392.1670***	0.0000	1826
SPF	0.0459	0.0526	4.5431	-5.5589	0.9994	-0.4222	5.8487	671.6676***	0.0000	1826
SPN	-0.0085	0.0000	6.0555	-6.4696	1.2222	-0.2113	5.1930	379.4829***	0.0000	1826

Notes: *, **, *** signify rejection of the null hypothesis at the 10, 5 and 1% significance level, respectively

Table A. 7: US Returns Period 3 Descriptive Statistics

	Mean	Median	Max.	Min.	Std. Dev.	Skewness	Kurtosis	Jarque-Bera	Prob.	Obs.
SX3P	0.0289	0.0010	4.3381	-5.0343	0.8363	-0.0459	5.5134	481.2912***	0.0000	1826
SX6P	0.0174	0.0302	4.2412	-8.6840	0.9641	-0.5909	8.7797	2647.8430***	0.0000	1826
SX86P	0.0219	0.0222	4.3356	-10.1013	0.9797	-0.7367	11.2226	5309.2070***	0.0000	1826
SX8P	0.0459	0.0655	5.3480	-5.5782	1.1339	-0.2745	4.7067	244.5641***	0.0000	1826
SXDP	0.0341	0.0285	4.5379	-4.5571	0.9168	-0.1136	5.3329	417.9869***	0.0000	1826
SXEP	-0.0007	0.0266	6.1548	-8.4630	1.2396	-0.2196	6.4292	909.3647***	0.0000	1826
SXFP	0.0454	0.0676	5.0757	-10.5752	1.1084	-0.9361	11.4281	5671.1130***	0.0000	1826
SXKP	0.0046	0.0000	4.6379	-8.9187	1.0371	-0.2758	8.0154	1936.9930***	0.0000	1826
SXNP	0.0316	0.0400	3.9276	-7.0914	0.9901	-0.4927	6.3392	922.2255***	0.0000	1826
SXPP	-0.0001	0.0000	8.3343	-9.7637	1.7195	-0.1087	6.3108	837.5915***	0.0000	1826
SXQP	0.0310	0.0372	4.2876	-5.7729	0.9495	-0.2654	5.8679	647.2170***	0.0000	1826

Notes: *, **, *** signify rejection of the null hypothesis at the 10, 5 and 1% significance level, respectively

Table A. 8: EU Returns Period 3 Descriptive Statistics

	Mean	Median	Max.	Min.	Std. Dev.	Skewness	Kurtosis	Jarque-Bera	Prob.	Obs.
S5COND	0.0474	0.0976	8.2869	-12.8761	1.6322	-0.7235	9.0128	2079.6910***	0.000 0	1305
S5CONS	0.0212	0.0073	8.0747	-9.6900	1.0507	-0.4560	19.8986	15572.7000***	0.000 0	1305
S5HLTH	0.0230	0.0000	7.3138	-10.5284	1.1424	-0.3814	15.7286	8841.2840***	0.000 0	1305
S5INDU	0.0371	0.0473	12.0008	-12.1550	1.4419	-0.5944	16.9313	10629.9400***	0.000 0	1305
S5INFT	0.0805	0.0719	11.3002	-14.9833	1.7566	-0.4078	11.0551	3564.2510***	0.000 0	1305
S5MATR	0.0243	0.0275	11.0034	-12.1470	1.4887	-0.5534	13.2881	5821.9550***	0.000 0	1305
S5RLST	0.0048	0.0133	8.2802	-18.0910	1.5726	-1.1654	20.8819	17682.4800***	0.000 0	1305
S5TELS	0.0484	0.0723	8.8021	-11.0301	1.5741	-0.4532	8.1753	1501.0460***	0.000 0	1305
S5UTIL	0.0122	0.0114	12.3204	-12.2653	1.4563	-0.1737	17.7001	11756.5900***	0.000 0	1305
SPF	0.0347	0.0321	12.4251	-15.0707	1.6476	-0.5674	18.4961	13126.9900***	0.000 0	1305
SPN	0.0277	0.0219	15.1108	-22.4172	2.2689	-0.9104	16.8105	10551.1700***	0.000 0	1305

Notes: *, **, *** signify rejection of the null hypothesis at the 10, 5 and 1% significance level, respectively

Table A. 9: US Returns Period 4 Descriptive Statistics

	Mean	Median	Max.	Min.	Std. Dev.	Skewness	Kurtosis	Jarque-Bera	Prob.	Obs.
SX3P	-0.0153	0.0014	5.3182	-9.1960	0.9815	-0.9182	12.7470	5349.2140***	0.000 0	1305
SX6P	0.0055	0.0000	5.9303	-15.3592	1.2060	-1.8657	25.4963	28275.3400***	0.000 0	1305
SX86P	0.0327	0.0000	8.4388	-12.3891	1.5302	-0.3605	9.2364	2143.0660***	0.000 0	1305
SX8P	0.0326	0.0754	9.1593	-11.4406	1.6538	-0.4195	7.0092	912.3067***	0.000 0	1305
SXDP	0.0140	0.0239	4.7833	-9.2895	1.0035	-0.7994	10.6487	3320.0320***	0.000 0	1305
SXEP	0.0038	0.0297	14.6505	-18.4310	1.7879	-1.0475	20.9958	17847.8800***	0.000 0	1305
SXFP	0.0265	0.0690	11.8635	-13.5911	1.4153	-0.7248	15.6117	8762.7960***	0.000 0	1305
SXKP	0.0053	0.0438	9.6388	-12.1785	1.0685	-1.1020	23.6944	23550.5900***	0.000 0	1305
SXNP	0.0292	0.0882	9.4784	-12.6260	1.3846	-0.7911	12.6457	5195.1910***	0.000 0	1305
SXPP	0.0091	0.0285	14.7300	-15.5461	1.8560	-0.3834	10.9374	3457.7030***	0.000 0	1305
SXQP	0.0107	0.0625	6.2465	-9.7667	1.1808	-0.4362	8.9827	1987.6070***	0.000 0	1305

Notes: *, **, *** signify rejection of the null hypothesis at the 10, 5 and 1% significance level, respectively

Table A. 10: EU Returns Period 4 Descriptive Statistics

Appendix 4 – Stationary Test Statistics – Returns Data

	<i>ADF in Level</i>	<i>KPSS in Level</i>
S5COND	-81.33111***	0.110068***
S5CONS	-86.08361***	0.042387***
S5HLTH	-83.12082***	0.193976***
S5INDU	-81.7593***	0.0769***
S5INFT	-85.11561***	0.266204***
S5MATR	-81.65218***	0.02216***
S5RLST	-92.81102***	0.034002***
S5TELS	-82.34457***	0.287324***
S5UTIL	-84.09511***	0.077521***
SPF	-36.48719***	0.186385***
SPN	-82.88773***	0.072634***

Notes: For ADF *, **, *** signify rejection of the Null hypothesis at the 10, 5 and 1% significance levels
For KPSS *, **, *** signify failure to reject the Null hypothesis at the 10, 5 and 1% significance levels

Table A. 11: US Returns Full Sample Stationarity Tests

	<i>ADF in Level</i>	<i>KPSS in Level</i>
SX3P	-57.86559***	0.118119***
SX6P	-78.49797***	0.05694***
SX86P	-74.64491***	0.124476***
SX8P	-77.51964***	0.149463***
SXDP	-76.18005***	0.17945***
SXEP	-77.15954***	0.022306***
SXFP	-75.65843***	0.095411***
SXKP	-49.07336***	0.028330***
SXNP	-75.56126***	0.042682***
SXPP	-77.80632***	0.069443***
SXQP	-48.55172***	0.052227***

Notes: For ADF *, **, *** signify rejection of the Null hypothesis at the 10, 5 and 1% significance levels
For KPSS *, **, *** signify failure to reject the Null hypothesis at the 10, 5 and 1% significance levels

Table A. 12: EU Returns Full Sample Stationarity Tests

	<i>ADF in Level</i>	<i>KPSS in Level</i>
S5COND	-38.00437***	0.067445***
S5CONS	-39.30461***	0.083573***
S5HLTH	-36.55811***	0.147541***
S5INDU	-37.86816***	0.131008***
S5INFT	-38.02045***	0.067681***
S5MATR	-38.09874***	0.047698***
S5RLST	-35.68745***	0.369108**
S5TELS	-37.01967***	0.536123*
S5UTIL	-37.05277***	0.507671*
SPF	-38.13966***	0.082138***
SPN	-37.18627***	0.216067***

Notes: For ADF *, **, *** signify rejection of the Null hypothesis at the 10, 5 and 1% significance levels
 For KPSS *, **, *** signify failure to reject the Null hypothesis at the 10, 5 and 1% significance levels

Table A. 13: US Returns Period 1 Stationarity Tests

	<i>ADF in Level</i>	<i>KPSS in Level</i>
SX3P	-38.41277***	0.299548***
SX6P	-40.33219***	1.0197
SX86P	-36.76014***	0.656617*
SX8P	-35.82529***	0.116734***
SXDP	-35.55315***	0.532781*
SXEP	-38.89289***	0.238672***
SXFP	-36.50366***	0.664626*
SXKP	-24.44391***	0.218365***
SXNP	-24.38109***	0.398945**
SXPP	-36.58600***	0.219344***
SXQP	-38.66179***	0.195695***

Notes: For ADF *, **, *** signify rejection of the Null hypothesis at the 10, 5 and 1% significance levels
 For KPSS *, **, *** signify failure to reject the Null hypothesis at the 10, 5 and 1% significance levels

Table A. 14: EU Returns Period 1 Stationarity Tests

	<i>ADF in Level</i>	<i>KPSS in Level</i>
S5COND	-41.21943***	0.285041***
S5CONS	-33.25231***	0.140326***
S5HLTH	-23.22687***	0.187455***
S5INDU	-42.14967***	0.160777***
S5INFT	-43.54256***	0.119164***
S5MATR	-41.81714***	0.088783***
S5RLST	-50.28133***	0.274175***
S5TELS	-32.3876***	0.245416***
S5UTIL	-32.37211***	0.126855***
SPF	-45.98097***	0.270581***
SPN	-33.10722***	0.071557***

Notes: For ADF *, **, ***, signify rejection of the Null hypothesis at the 10, 5 and 1% significance levels
For KPSS *, **, ***, signify failure to reject the Null hypothesis at the 10, 5 and 1% significance levels

Table A. 15: US Returns Period 2 Stationarity Tests

	<i>ADF in Level</i>	<i>KPSS in Level</i>
SX3P	-32.05506***	0.278217***
SX6P	-31.11514***	0.061467***
SX86P	-37.76435***	0.550472*
SX8P	-40.08216***	0.206973***
SXDP	-18.77755***	0.387464**
SXEP	-40.22062***	0.058027***
SXFP	-38.35858***	0.289576***
SXKP	-20.04264***	0.086509***
SXNP	-38.05478***	0.180692***
SXPP	-39.40928***	0.08214***
SXQP	-26.52025***	0.34105***

Notes: For ADF *, **, ***, signify rejection of the Null hypothesis at the 10, 5 and 1% significance levels
For KPSS *, **, ***, signify failure to reject the Null hypothesis at the 10, 5 and 1% significance levels

Table A. 16: EU Returns Period 2 Stationarity Tests

	<i>ADF in Level</i>	<i>KPSS in Level</i>
S5COND	-42.37089***	0.064505***
S5CONS	-43.00349***	0.110578***
S5HLTH	-42.36886***	0.176434***
S5INDU	-41.82249***	0.07685***
S5INFT	-32.83477***	0.046091***
S5MATR	-41.70032***	0.043422***
S5RLST	-41.58518***	0.026806***
S5TELS	-42.42487***	0.042559***
S5UTIL	-32.47463***	0.029802***
SPF	-43.37021***	0.061981***
SPN	-42.60558***	0.068086***

Notes: For ADF *, **, ***, signify rejection of the Null hypothesis at the 10, 5 and 1% significance levels
For KPSS *, **, *** signify failure to reject the Null hypothesis at the 10, 5 and 1% significance levels

Table A. 17: US Returns Period 3 Stationarity Tests

	<i>ADF in Level</i>	<i>KPSS in Level</i>
SX3P	-41.86595***	0.037739***
SX6P	-42.43943***	0.080929***
SX86P	-40.48429***	0.068814***
SX8P	-42.92359***	0.027262***
SXDP	-42.08718***	0.12416***
SXEP	-40.17008***	0.029333***
SXFP	-22.00512***	0.085543***
SXKP	-41.57053***	0.3137***
SXNP	-40.91803***	0.033455***
SXPP	-42.55483***	0.120642***
SXQP	-42.30716***	0.074739***

Notes: For ADF *, **, ***, signify rejection of the Null hypothesis at the 10, 5 and 1% significance levels
For KPSS *, **, *** signify failure to reject the Null hypothesis at the 10, 5 and 1% significance levels

Table A. 18: EU Returns Period 3 Stationarity Tests

	<i>ADF in Level</i>	<i>KPSS in Level</i>
S5COND	-24.29854***	0.08998***
S5CONS	-10.51199***	0.026133***
S5HLTH	-11.44372***	0.061044***
S5INDU	-10.49575***	0.049358***
S5INFT	-11.15458***	0.071898***
S5MATR	-11.23986***	0.066604***
S5RLST	-24.1764***	0.042414***
S5TELS	-41.12912***	0.177784***
S5UTIL	-11.02346***	0.034228***
SPF	-10.53448***	0.096576***
SPN	-12.04835***	0.108689***

Notes: For ADF *, **, *** signify rejection of the Null hypothesis at the 10, 5 and 1% significance levels
For KPSS *, **, *** signify failure to reject the Null hypothesis at the 10, 5 and 1% significance levels

Table A. 19: US Returns Period 4 Stationarity Tests

	<i>ADF in Level</i>	<i>KPSS in Level</i>
SX3P	-36.31353***	0.093094***
SX6P	-35.6185***	0.016803***
SX86P	-34.79756***	0.071956***
SX8P	-36.46554***	0.04302***
SXDP	-35.13266***	0.027298***
SXEP	-34.651***	0.09468***
SXFP	-23.46248***	0.061821***
SXKP	-22.67075***	0.091656***
SXNP	-36.37916***	0.057791***
SXPP	-36.72916***	0.079688***
SXQP	-37.69371***	0.033159***

Notes: For ADF *, **, *** signify rejection of the Null hypothesis at the 10, 5 and 1% significance levels
For KPSS *, **, *** signify failure to reject the Null hypothesis at the 10, 5 and 1% significance levels

Table A. 20: EU Returns Period 4 Stationarity Tests

Appendix 5 – Correlation Statistics – Returns Data

Correlation Probability	S5COND	S5CONS	S5HLTH	S5INDU	S5INFT	S5MATR	S5RLST	SPN	SPF	S5UTIL	S5TELS
S5COND	1.0000										
S5CONS	0.6948	1.0000									
S5HLTH	0.7146	0.7531	1.0000								
S5INDU	0.8372	0.7208	0.7483	1.0000							
S5INFT	0.8326	0.6205	0.6905	0.7816	1.0000						
S5MATR	0.7675	0.6638	0.6888	0.8671	0.7223	1.0000					
S5RLST	0.6782	0.6016	0.5707	0.6920	0.5742	0.6505	1.0000				
SPN	0.5599	0.5146	0.5523	0.6851	0.5304	0.7091	0.4780	1.0000			
SPF	0.7435	0.6099	0.6463	0.8068	0.6592	0.7314	0.7631	0.6279	1.0000		
S5UTIL	0.5380	0.6787	0.6070	0.6048	0.5063	0.5797	0.5716	0.4907	0.5071	1.0000	
S5TELS	0.7120	0.6057	0.6151	0.6584	0.7031	0.6070	0.5227	0.4840	0.5912	0.5210	1.0000

Table A. 21: US Indices Returns Correlation - Full Sample

Correlation Probability	SX3P	SX6P	SX86P	SX8P	SXDP	SXEP	SXFP	SXKP	SXNP	SXPP	SXQP
SX3P	1.0000										
SX6P	0.6846	1.0000									
SX86P	0.5763	0.6161	1.0000								
SX8P	0.5691	0.5940	0.5653	1.0000							
SXDP	0.6983	0.6282	0.4912	0.5890	1.0000						
SXEP	0.5707	0.6601	0.5171	0.5645	0.5267	1.0000					
SXFP	0.6650	0.7097	0.7648	0.7666	0.6337	0.6889	1.0000				
SXKP	0.6385	0.7127	0.5557	0.6693	0.6345	0.6063	0.7092	1.0000			
SXNP	0.6697	0.7028	0.7135	0.7981	0.6163	0.7069	0.8943	0.6882	1.0000		
SXPP	0.4982	0.5761	0.5552	0.5969	0.4373	0.7275	0.7227	0.5383	0.7696	1.0000	
SXQP	0.7909	0.7141	0.6608	0.7503	0.6976	0.6360	0.8054	0.7184	0.8247	0.6338	1.0000

Table A. 22: EU Indices Returns Correlation - Full Sample

Correlation Probability	S5COND	S5CONS	S5HLTH	S5INDU	S5INFT	S5MATR	S5RLST	S5TELS	S5UTIL	SPF	SPN
S5COND	1.0000										
S5CONS	0.6539	1.0000									
S5HLTH	0.6575	0.6488	1.0000								
S5INDU	0.8524	0.6616	0.7017	1.0000							
S5INFT	0.7652	0.4650	0.5645	0.7594	1.0000						
S5MATR	0.7437	0.5667	0.5736	0.8047	0.6235	1.0000					
S5RLST	0.4892	0.3957	0.4111	0.4942	0.3874	0.4852	1.0000				
S5TELS	0.6004	0.4569	0.5298	0.6268	0.6102	0.5225	0.3778	1.0000			
S5UTIL	0.4960	0.4377	0.4699	0.5381	0.4343	0.4713	0.4444	0.4303	1.0000		
SPF	0.6508	0.4602	0.5407	0.6872	0.5951	0.5711	0.3398	0.5332	0.4501	1.0000	
SPN	0.3692	0.2992	0.3701	0.3927	0.3285	0.3647	0.1835	0.3515	0.3307	0.5000	1.0000

Table A. 23: US Indices Returns Correlation - Period 1

Correlation Probability	SX3P	SX6P	SX86P	SX8P	SXDP	SXEP	SXFP	SXKP	SXNP	SXPP	SXQP
SX3P	1.0000										
SX6P	0.7008	1.0000									
SX86P	0.4816	0.5735	1.0000								
SX8P	0.5195	0.6177	0.4616	1.0000							
SXDP	0.6666	0.6706	0.4624	0.6008	1.0000						
SXEP	0.6197	0.6900	0.4919	0.5435	0.6279	1.0000					
SXFP	0.6531	0.7464	0.7334	0.7634	0.6780	0.6806	1.0000				
SXKP	0.5765	0.6717	0.4741	0.7739	0.6229	0.5758	0.7543	1.0000			
SXNP	0.6170	0.6961	0.6311	0.8017	0.6365	0.6367	0.8477	0.7299	1.0000		
SXPP	0.5117	0.5915	0.5643	0.6190	0.5086	0.6248	0.7051	0.5649	0.7817	1.0000	
SXQP	0.7270	0.7771	0.6065	0.8049	0.7188	0.6883	0.8518	0.7670	0.8553	0.7034	1.0000

Table A. 24: EU Indices Returns Correlation - Period 1

Correlation Probability	S5COND	S5CONS	S5HLTH	S5INDU	S5INFT	S5MATR	S5RLST	S5TELS	S5UTIL	SPF	SPN
S5COND	1.0000										
S5CONS	0.8422	1.0000									
S5HLTH	0.8131	0.8696	1.0000								
S5INDU	0.9158	0.8118	0.8056	1.0000							
S5INFT	0.8877	0.7845	0.7869	0.8771	1.0000						
S5MATR	0.8339	0.7490	0.7528	0.8834	0.8411	1.0000					
S5RLST	0.8144	0.6698	0.6434	0.7891	0.7407	0.7145	1.0000				
S5TELS	0.7685	0.7723	0.7404	0.7430	0.7482	0.6965	0.6444	1.0000			
S5UTIL	0.7198	0.7983	0.7769	0.7285	0.7014	0.7175	0.5836	0.7286	1.0000		
SPF	0.8330	0.6958	0.7042	0.8244	0.7691	0.7368	0.8648	0.6910	0.6020	1.0000	
SPN	0.7495	0.7367	0.7467	0.8038	0.7783	0.8770	0.6151	0.6843	0.7657	0.6642	1.0000

Table A. 25: US Indices Returns Correlation - Period 2

Correlation Probability	SX3P	SX6P	SX86P	SX8P	SXDP	SXEP	SXFP	SXKP	SXNP	SXPP	SXQP
SX3P	1.0000										
SX6P	0.6933	1.0000									
SX86P	0.5951	0.6041	1.0000								
SX8P	0.6262	0.6883	0.6777	1.0000							
SXDP	0.7017	0.6482	0.4994	0.5642	1.0000						
SXEP	0.6712	0.7971	0.6327	0.7245	0.5919	1.0000					
SXFP	0.6676	0.7442	0.8372	0.8069	0.5959	0.7932	1.0000				
SXKP	0.6724	0.7707	0.6170	0.7003	0.6610	0.7059	0.7297	1.0000			
SXNP	0.6848	0.7593	0.7755	0.8338	0.5860	0.8179	0.9124	0.7233	1.0000		
SXPP	0.5788	0.6791	0.6634	0.7190	0.4679	0.8204	0.8154	0.6181	0.8562	1.0000	
SXQP	0.8050	0.7486	0.7191	0.7712	0.7036	0.7657	0.8192	0.7532	0.8507	0.7206	1.0000

Table A. 26: EU Indices Returns Correlation - Period 2

Correlation Probability	S5COND	S5CONS	S5HLTH	S5INDU	S5INFT	S5MATR	S5RLST	S5TELS	S5UTIL	SPF	SPN
S5COND	1.0000										
S5CONS	0.6331	1.0000									
S5HLTH	0.7295	0.6255	1.0000								
S5INDU	0.8120	0.6174	0.7100	1.0000							
S5INFT	0.8300	0.5675	0.7065	0.7753	1.0000						
S5MATR	0.7292	0.5555	0.6477	0.8396	0.7007	1.0000					
S5RLST	0.5273	0.6420	0.5112	0.4847	0.4611	0.4513	1.0000				
S5TELS	0.5667	0.5548	0.4881	0.5431	0.5171	0.4852	0.4355	1.0000			
S5UTIL	0.2878	0.5832	0.3381	0.2990	0.2632	0.2748	0.6445	0.3576	1.0000		
SPF	0.7630	0.5562	0.6900	0.8265	0.7088	0.7516	0.4392	0.4997	0.2114	1.0000	
SPN	0.5840	0.4221	0.5125	0.6711	0.5511	0.7131	0.3405	0.4244	0.2301	0.6235	1.0000

Table A. 27: US Indices Returns Correlation - Period 3

Correlation Probability	SX3P	SX6P	SX86P	SX8P	SXDP	SXEP	SXFP	SXKP	SXNP	SXPP	SXQP
SX3P	1.0000										
SX6P	0.6884	1.0000									
SX86P	0.6757	0.6906	1.0000								
SX8P	0.6374	0.5911	0.6054	1.0000							
SXDP	0.7570	0.6322	0.6288	0.6789	1.0000						
SXEP	0.5308	0.6117	0.4762	0.5607	0.5295	1.0000					
SXFP	0.6780	0.6783	0.7168	0.7814	0.7165	0.6500	1.0000				
SXKP	0.6720	0.7473	0.6838	0.6412	0.6792	0.6040	0.7439	1.0000			
SXNP	0.6916	0.6730	0.6819	0.8320	0.7237	0.7033	0.8891	0.7240	1.0000		
SXPP	0.3992	0.4574	0.4077	0.5217	0.4164	0.7149	0.5938	0.4781	0.6642	1.0000	
SXQP	0.8369	0.7062	0.7212	0.7292	0.7513	0.5715	0.7763	0.7166	0.7933	0.4860	1.0000

Table A. 28: EU Indices Returns Correlation - Period 3

Correlation Probability	S5COND	S5CONS	S5HLTH	S5INDU	S5INFT	S5MATR	S5RLST	S5TELS	S5UTIL	SPF	SPN
S5COND	1.0000										
S5CONS	0.5838	1.0000									
S5HLTH	0.6368	0.7831	1.0000								
S5INDU	0.7308	0.7096	0.7452	1.0000							
S5INFT	0.8502	0.6092	0.6982	0.7190	1.0000						
S5MATR	0.7073	0.6940	0.7350	0.9007	0.6998	1.0000					
S5RLST	0.6560	0.7243	0.7403	0.7719	0.6438	0.7546	1.0000				
S5TELS	0.8093	0.5682	0.6326	0.6540	0.8366	0.6449	0.5900	1.0000			
S5UTIL	0.4780	0.7651	0.6977	0.6643	0.4895	0.6539	0.7836	0.4581	1.0000		
SPF	0.6835	0.6745	0.7132	0.9038	0.6624	0.8581	0.7356	0.6318	0.6254	1.0000	
SPN	0.4238	0.4345	0.4750	0.6963	0.4187	0.6782	0.4927	0.3958	0.4226	0.7178	1.0000

Table A. 29: US Indices Returns Correlation - Period 4

Correlation Probability	SX3P	SX6P	SX86P	SX8P	SXDP	SXEP	SXFP	SXKP	SXNP	SXPP	SXQP
SX3P	1.0000										
SX6P	0.6626	1.0000									
SX86P	0.5652	0.6244	1.0000								
SX8P	0.5449	0.5038	0.5957	1.0000							
SXDP	0.6762	0.5880	0.4664	0.5545	1.0000						
SXEP	0.4451	0.4978	0.4294	0.4470	0.3742	1.0000					
SXFP	0.6724	0.6467	0.7213	0.7914	0.6109	0.5887	1.0000				
SXKP	0.6678	0.6976	0.5533	0.4736	0.5701	0.5588	0.6533	1.0000			
SXNP	0.6858	0.6341	0.6886	0.8221	0.5981	0.6141	0.9007	0.6299	1.0000		
SXPP	0.4659	0.4793	0.4821	0.5659	0.3981	0.7018	0.6704	0.5138	0.6867	1.0000	
SXQP	0.7842	0.6223	0.6080	0.7240	0.6247	0.4872	0.7819	0.6366	0.8019	0.5999	1.0000

Table A. 30: EU Indices Returns Correlation - Period 4

		US											EU											
US	Correlation Probability	S5COND	S5CONS	S5HLTH	S5INDU	S5INFT	S5MATR	S5RLST	SPF	SPN	S5TELS	S5UTIL	SX3P	SX6P	SX86P	SX8P	SXDP	SXEP	SXFP	SXKP	SXNP	SXPP	SXQP	
		S5COND	1.0000																					
	S5CONS	0.6948	1.0000																					
	S5HLTH	0.7146	0.7531	1.0000																				
	S5INDU	0.8372	0.7208	0.7483	1.0000																			
	S5INFT	0.8326	0.6205	0.6905	0.7816	1.0000																		
	S5MATR	0.7675	0.6638	0.6888	0.8671	0.7223	1.0000																	
	S5RLST	0.6782	0.6016	0.5707	0.6920	0.5742	0.6505	1.0000																
	SPF	0.7435	0.6099	0.6463	0.8068	0.6592	0.7314	0.7631	1.0000															
	SPN	0.5599	0.5146	0.5523	0.6851	0.5304	0.7091	0.4780	0.6279	1.0000														
	S5TELS	0.7120	0.6057	0.6151	0.6584	0.7031	0.6070	0.5227	0.5912	0.4840	1.0000													
	S5UTIL	0.5380	0.6787	0.6070	0.6048	0.5063	0.5797	0.5716	0.5071	0.4907	0.5210	1.0000												
EU	SX3P	0.3718	0.4167	0.3895	0.3996	0.3265	0.3845	0.2758	0.3357	0.3146	0.3390	0.3145	1.0000											
	SX6P	0.4131	0.4234	0.4348	0.4557	0.3877	0.4573	0.3179	0.3870	0.3843	0.3708	0.4101	0.6846	1.0000										
	SX86P	0.4189	0.3225	0.3433	0.4424	0.3627	0.4288	0.3556	0.3976	0.3348	0.3314	0.3068	0.5763	0.6161	1.0000									
	SX8P	0.4953	0.2995	0.3879	0.4909	0.5457	0.4820	0.3000	0.4071	0.3313	0.4134	0.2585	0.5691	0.5940	0.5653	1.0000								
	SXDP	0.3504	0.3504	0.4548	0.3626	0.3351	0.3390	0.2424	0.3150	0.2637	0.3136	0.2640	0.6983	0.6282	0.4912	0.5890	1.0000							
	SXEP	0.3752	0.3148	0.3616	0.4743	0.3535	0.4952	0.2622	0.3979	0.5884	0.3214	0.3076	0.5707	0.6601	0.5171	0.5645	0.5267	1.0000						
	SXFP	0.5071	0.3683	0.4331	0.5495	0.4723	0.5443	0.3529	0.4924	0.4323	0.4096	0.3254	0.6650	0.7097	0.7648	0.7666	0.6337	0.6889	1.0000					
	SXKP	0.4104	0.3673	0.3984	0.4383	0.4080	0.4300	0.2801	0.3851	0.3512	0.3995	0.3204	0.6385	0.7127	0.5557	0.6693	0.6345	0.6063	0.7092	1.0000				
	SXNP	0.5238	0.3764	0.4376	0.5866	0.4926	0.5795	0.3758	0.4979	0.4471	0.4090	0.3205	0.6697	0.7028	0.7135	0.7981	0.6163	0.7069	0.8943	0.6882	1.0000			
	SXPP	0.4148	0.3004	0.3424	0.5004	0.3953	0.5701	0.3039	0.4083	0.4824	0.3203	0.2773	0.4982	0.5761	0.5552	0.5969	0.4373	0.7275	0.7227	0.5383	0.7696	1.0000		
		SXQP	0.4925	0.4234	0.4317	0.5033	0.4601	0.4908	0.3475	0.4321	0.3608	0.4038	0.3296	0.7909	0.7141	0.6608	0.7503	0.6976	0.6360	0.8054	0.7184	0.8247	0.6338	1.0000

Table A. 31: US and EU Indices Returns Correlation - Full Sample

		US											EU											
	Correlation Probability	S5COND	S5CONS	S5HLTH	S5INDU	S5INFT	S5MATR	S5RLST	SPF	SPN	S5TELS	S5UTIL	SX3P	SX6P	SX86P	SX8P	SXDP	SXEP	SXFP	SXKP	SXNP	SXPP	SXQP	
	US		1.0000																					
	S5COND	1.0000																						
	S5CONS	0.6539	1.0000																					
	S5HLTH	0.6575	0.6488	1.0000																				
	S5INDU	0.8524	0.6616	0.7017	1.0000																			
	S5INFT	0.7652	0.4650	0.5645	0.7594	1.0000																		
	S5MATR	0.7437	0.5667	0.5736	0.8047	0.6235	1.0000																	
	S5RLST	0.4892	0.3957	0.4111	0.4942	0.3874	0.4852	1.0000																
	SPF	0.6508	0.4602	0.5407	0.6872	0.5951	0.5711	0.3398	1.0000															
	SPN	0.3692	0.2992	0.3701	0.3927	0.3285	0.3647	0.1835	0.5000	1.0000														
	S5TELS	0.6004	0.4569	0.5298	0.6268	0.6102	0.5225	0.3778	0.5332	0.3515	1.0000													
	S5UTIL	0.4960	0.4377	0.4699	0.5381	0.4343	0.4713	0.4444	0.4501	0.3307	0.4303	1.0000												
EU													1.0000											
	SX3P	0.3557	0.3211	0.2917	0.3451	0.2322	0.3376	0.2258	0.2754	0.2083	0.3283	0.2276	1.0000											
	SX6P	0.4287	0.3350	0.3390	0.4183	0.3408	0.4019	0.2872	0.3548	0.2478	0.3530	0.2579	0.7008	1.0000										
	SX86P	0.2915	0.1939	0.2192	0.2935	0.2448	0.3012	0.2067	0.1894	0.1385	0.2408	0.1728	0.4816	0.5735	1.0000									
	SX8P	0.5003	0.2105	0.3110	0.4859	0.5515	0.4529	0.2703	0.4203	0.2048	0.4236	0.2345	0.5195	0.6177	0.4616	1.0000								
	SXDP	0.3757	0.2992	0.3984	0.3752	0.2841	0.3432	0.2325	0.3326	0.2459	0.3130	0.1944	0.6666	0.6706	0.4624	0.6008	1.0000							
	SXEP	0.3417	0.2498	0.2850	0.3657	0.2758	0.3986	0.2276	0.3080	0.3373	0.2933	0.2672	0.6197	0.6900	0.4919	0.5435	0.6279	1.0000						
	SXFP	0.4538	0.2525	0.3047	0.4614	0.3994	0.4510	0.2862	0.4014	0.2431	0.4086	0.2709	0.6531	0.7464	0.7334	0.7634	0.6780	0.6806	1.0000					
	SXKP	0.4381	0.2274	0.3023	0.4281	0.4312	0.4039	0.2488	0.3756	0.2092	0.4377	0.2040	0.5765	0.6717	0.4741	0.7739	0.6229	0.5758	0.7543	1.0000				
	SXNP	0.4487	0.2368	0.2811	0.4538	0.4121	0.4717	0.2856	0.3524	0.1861	0.3543	0.2377	0.6170	0.6961	0.6311	0.8017	0.6365	0.6367	0.8477	0.7299	1.0000			
	SXPP	0.3613	0.1704	0.2034	0.3858	0.3274	0.4663	0.2304	0.2610	0.1785	0.2838	0.1878	0.5117	0.5915	0.5643	0.6190	0.5086	0.6248	0.7051	0.5649	0.7817	1.0000		
	SXQP	0.4913	0.3016	0.3285	0.4767	0.4311	0.4694	0.3049	0.3938	0.2396	0.3823	0.2514	0.7270	0.7771	0.6065	0.8049	0.7188	0.6883	0.8518	0.7670	0.8553	0.7034	1.0000	

Table A. 32: US and EU Indices Returns Correlation - Period 1

		US											EU											
	Correlation Probability	S5COND	S5CONS	S5HLTH	S5INDU	S5INFT	S5MATR	S5RLST	SPF	SPN	S5TELS	S5UTIL	SX3P	SX6P	SX86P	SX8P	SXDP	SXEP	SXFP	SXKP	SXNP	SXPP	SXQP	
	US		1.0000																					
	S5COND	1.0000																						
	S5CONS	0.8422	1.0000																					
	S5HLTH	0.8131	0.8696	1.0000																				
	S5INDU	0.9158	0.8118	0.8056	1.0000																			
	S5INFT	0.8877	0.7845	0.7869	0.8771	1.0000																		
	S5MATR	0.8339	0.7490	0.7528	0.8834	0.8411	1.0000																	
	S5RLST	0.8144	0.6698	0.6434	0.7891	0.7407	0.7145	1.0000																
	SPF	0.8330	0.6958	0.7042	0.8244	0.7691	0.7368	0.8648	1.0000															
	SPN	0.7495	0.7367	0.7467	0.8038	0.7783	0.8770	0.6151	0.6642	1.0000														
	S5TELS	0.7685	0.7723	0.7404	0.7430	0.7482	0.6965	0.6444	0.6910	0.6843	1.0000													
	S5UTIL	0.7198	0.7983	0.7769	0.7285	0.7014	0.7175	0.5836	0.6020	0.7657	0.7286	1.0000												
EU													1.0000											
	SX3P	0.4324	0.4615	0.4487	0.4298	0.3960	0.4074	0.2668	0.3386	0.4035	0.4137	0.3830	1.0000											
	SX6P	0.4830	0.4875	0.5360	0.5117	0.4844	0.5166	0.2952	0.3942	0.5285	0.4642	0.4842	0.6933	1.0000										
	SX86P	0.4900	0.3980	0.4116	0.5196	0.4592	0.4854	0.3382	0.4369	0.4346	0.4109	0.3802	0.5951	0.6041	1.0000									
	SX8P	0.5148	0.4192	0.4611	0.5482	0.5358	0.5421	0.3643	0.4523	0.4910	0.4248	0.3908	0.6262	0.6883	0.6777	1.0000								
	SXDP	0.3924	0.4211	0.4874	0.3890	0.3822	0.3529	0.2588	0.3390	0.3507	0.3897	0.3599	0.7017	0.6482	0.4994	0.5642	1.0000							
	SXEP	0.4699	0.4241	0.4673	0.5161	0.4767	0.5491	0.2961	0.3875	0.5801	0.4370	0.4456	0.6712	0.7971	0.6327	0.7245	0.5919	1.0000						
	SXFP	0.5483	0.4563	0.4941	0.5824	0.5348	0.5781	0.3693	0.4849	0.5346	0.4613	0.4393	0.6676	0.7442	0.8372	0.8069	0.5959	0.7932	1.0000					
	SXKP	0.4767	0.4647	0.4946	0.4828	0.4765	0.4684	0.2986	0.3925	0.4638	0.4776	0.4421	0.6724	0.7707	0.6170	0.7003	0.6610	0.7059	0.7297	1.0000				
	SXNP	0.5751	0.4772	0.5146	0.6203	0.5574	0.6115	0.4068	0.4972	0.5506	0.4735	0.4485	0.6848	0.7593	0.7755	0.8338	0.5860	0.8179	0.9124	0.7233	1.0000			
	SXPP	0.4932	0.4040	0.4308	0.5498	0.5064	0.6129	0.3403	0.4066	0.5664	0.4051	0.4306	0.5788	0.6791	0.6634	0.7190	0.4679	0.8204	0.8154	0.6181	0.8562	1.0000		
	SXQP	0.5599	0.5075	0.5159	0.5583	0.5310	0.5282	0.3869	0.4658	0.4791	0.4888	0.4461	0.8050	0.7486	0.7191	0.7712	0.7036	0.7657	0.8192	0.7532	0.8507	0.7206	1.0000	

Table A. 33: US and EU Indices Returns Correlation - Period 2

		US											EU											
	Correlation Probability	S5COND	S5CONS	S5HLTH	S5INDU	S5INFT	S5MATR	S5RLST	SPF	SPN	S5TELS	S5UTIL	SX3P	SX6P	SX86P	SX8P	SXDP	SXEP	SXFP	SXKP	SXNP	SXPP	SXQP	
	US	S5COND	1.0000																					
S5CONS		0.6331	1.0000																					
S5HLTH		0.7295	0.6255	1.0000																				
S5INDU		0.8120	0.6174	0.7100	1.0000																			
S5INFT		0.8300	0.5675	0.7065	0.7753	1.0000																		
S5MATR		0.7292	0.5555	0.6477	0.8396	0.7007	1.0000																	
S5RLST		0.5273	0.6420	0.5112	0.4847	0.4611	0.4513	1.0000																
SPF		0.7630	0.5562	0.6900	0.8265	0.7088	0.7516	0.4392	1.0000															
SPN		0.5840	0.4221	0.5125	0.6711	0.5511	0.7131	0.3405	0.6235	1.0000														
S5TELS		0.5667	0.5548	0.4881	0.5431	0.5171	0.4852	0.4355	0.4997	0.4244	1.0000													
S5UTIL		0.2878	0.5832	0.3381	0.2990	0.2632	0.2748	0.6445	0.2114	0.2301	0.3576	1.0000												
EU	SX3P	0.3399	0.3991	0.3317	0.3467	0.3491	0.3122	0.3161	0.3214	0.2388	0.2577	0.2338	1.0000											
	SX6P	0.3375	0.3551	0.3219	0.3581	0.3337	0.3387	0.3336	0.3505	0.2913	0.2651	0.2795	0.6884	1.0000										
	SX86P	0.3722	0.3450	0.3301	0.3699	0.3607	0.3338	0.3724	0.3629	0.2492	0.2367	0.2227	0.6757	0.6906	1.0000									
	SX8P	0.4632	0.2766	0.3978	0.4676	0.5054	0.4328	0.2399	0.4586	0.3173	0.2625	0.0805	0.6374	0.5911	0.6054	1.0000								
	SXDP	0.3403	0.3046	0.4242	0.3469	0.3463	0.3134	0.2571	0.3660	0.2338	0.2284	0.1430	0.7570	0.6322	0.6288	0.6789	1.0000							
	SXEP	0.3797	0.2571	0.3236	0.4574	0.3670	0.4800	0.2215	0.4624	0.6012	0.2768	0.1177	0.5308	0.6117	0.4762	0.5607	0.5295	1.0000						
	SXFP	0.4509	0.2998	0.3965	0.4813	0.4345	0.4552	0.2447	0.5185	0.3514	0.2596	0.0810	0.6780	0.6783	0.7168	0.7814	0.7165	0.6500	1.0000					
	SXKP	0.3806	0.3298	0.3434	0.3841	0.3471	0.3710	0.2832	0.4310	0.3007	0.2882	0.1660	0.6720	0.7473	0.6838	0.6412	0.6792	0.6040	0.7439	1.0000				
	SXNP	0.4899	0.3127	0.4125	0.5504	0.4922	0.5201	0.2604	0.5368	0.4072	0.2949	0.0833	0.6916	0.6730	0.6819	0.8320	0.7237	0.7033	0.8891	0.7240	1.0000			
	SXPP	0.3669	0.1979	0.2893	0.4683	0.3608	0.5227	0.1942	0.4409	0.4820	0.2407	0.0309	0.3992	0.4574	0.4077	0.5217	0.4164	0.7149	0.5938	0.4781	0.6642	1.0000		
	SXQP	0.4299	0.4034	0.3755	0.4256	0.4260	0.3850	0.3126	0.4062	0.2910	0.2850	0.1858	0.8369	0.7062	0.7212	0.7292	0.7513	0.5715	0.7763	0.7166	0.7933	0.4860	1.0000	

Table A. 34: US and EU Indices Returns Correlation - Period 3

		US											EU												
	Correlation Probability	S5COND	S5CONS	S5HLTH	S5INDU	S5INFT	S5MATR	S5RLST	SPF	SPN	S5TELS	S5UTIL	SX3P	SX6P	SX86P	SX8P	SXDP	SXEP	SXFP	SXKP	SXNP	SXPP	SXQP		
	US	S5COND	1.0000																						
S5CONS		0.5838	1.0000																						
S5HLTH		0.6368	0.7831	1.0000																					
S5INDU		0.7308	0.7096	0.7452	1.0000																				
S5INFT		0.8502	0.6092	0.6982	0.7190	1.0000																			
S5MATR		0.7073	0.6940	0.7350	0.9007	0.6998	1.0000																		
S5RLST		0.6560	0.7243	0.7403	0.7719	0.6438	0.7546	1.0000																	
SPF		0.6835	0.6745	0.7132	0.9038	0.6624	0.8581	0.7356	1.0000																
SPN		0.4238	0.4345	0.4750	0.6963	0.4187	0.6782	0.4927	0.7178	1.0000															
S5TELS		0.8093	0.5682	0.6326	0.6540	0.8366	0.6449	0.5900	0.6318	0.3958	1.0000														
S5UTIL		0.4780	0.7651	0.6977	0.6643	0.4895	0.6539	0.7836	0.6254	0.4226	0.4581	1.0000													
EU	SX3P	0.3370	0.4467	0.4434	0.4478	0.3261	0.4599	0.4092	0.4638	0.3338	0.3236	0.3651	1.0000												
	SX6P	0.3559	0.4493	0.4582	0.4612	0.3575	0.4817	0.4708	0.4716	0.3362	0.3444	0.5217	0.6626	1.0000											
	SX86P	0.4046	0.2757	0.3407	0.4376	0.3510	0.4601	0.5044	0.4424	0.3275	0.3605	0.3436	0.5652	0.6244	1.0000										
	SX8P	0.5391	0.2884	0.4030	0.4876	0.5851	0.5186	0.3863	0.4447	0.3058	0.4905	0.2480	0.5449	0.5038	0.5957	1.0000									
	SXDP	0.3148	0.3636	0.5076	0.3580	0.3410	0.3736	0.3358	0.3318	0.2236	0.2999	0.3211	0.6762	0.5880	0.4664	0.5545	1.0000								
	SXEP	0.2857	0.2707	0.3185	0.5067	0.2840	0.5118	0.3173	0.5179	0.7244	0.2462	0.2993	0.4451	0.4978	0.4294	0.4470	0.3742	1.0000							
	SXFP	0.5229	0.3759	0.4772	0.6051	0.5023	0.6184	0.4930	0.6155	0.4613	0.4549	0.3764	0.6724	0.6467	0.7213	0.7914	0.6109	0.5887	1.0000						
	SXKP	0.3643	0.4542	0.4557	0.4809	0.3576	0.5073	0.4391	0.5193	0.4262	0.3554	0.4462	0.6678	0.6976	0.5533	0.4736	0.5701	0.5588	0.6533	1.0000					
	SXNP	0.5162	0.3704	0.4639	0.6393	0.4999	0.6359	0.4781	0.6149	0.4763	0.4483	0.3551	0.6858	0.6341	0.6886	0.8221	0.5981	0.6141	0.9007	0.6299	1.0000				
	SXPP	0.3665	0.3154	0.3577	0.5213	0.3584	0.6036	0.3613	0.5202	0.5473	0.3083	0.3086	0.4659	0.4793	0.4821	0.5659	0.3981	0.7018	0.6704	0.5138	0.6867	1.0000			
	SXQP	0.4576	0.4235	0.4522	0.5081	0.4382	0.5434	0.4237	0.4999	0.3477	0.4060	0.3518	0.7842	0.6223	0.6080	0.7240	0.6247	0.4872	0.7819	0.6366	0.8019	0.5999	1.0000		

Table A. 35: US and EU Indices Returns Correlation - Period 4

Appendix 6 – Descriptive Statistics – Volatility Data

	Mean	Median	Max.	Min.	Std. Dev.	Skewness	Kurtosis	Jarque-Bera	Prob.	Obs.
S5COND	1.8467	1.0221	36.5049	0.2771	2.7570	5.6820	45.8542	496320.5000** *	0.000 0	6060
S5CONS	0.7517	0.4715	26.9438	0.1917	1.3566	10.3508	141.2911	4937127.0000 ***	0.000 0	6060
S5HLTH	1.0859	0.6901	24.2662	0.2616	1.6709	7.4324	73.6082	1314637.0000 ***	0.000 0	6060
S5INDU	1.6446	0.9350	39.4387	0.3024	2.6159	6.9515	69.7921	1175255.0000 ***	0.000 0	6060
S5INFT	2.2539	1.3595	48.5734	0.3592	3.0237	5.9067	56.8841	768369.9000** *	0.000 0	6060
S5MATR	2.1005	1.2492	39.5221	0.3791	3.2735	6.4915	54.3257	707729.2000** *	0.000 0	6060
S5RLST	3.2388	1.1138	104.6708	0.2806	8.7459	6.3782	50.4552	609717.8000** *	0.000 0	6060
S5TELS	1.8442	1.1016	30.7532	0.3814	2.4809	5.5314	43.1251	437433.9000** *	0.000 0	6060
S5UTIL	1.4335	0.8542	44.0354	0.2846	2.8102	8.3640	89.5676	1962880.0000 ***	0.000 0	6060
SPF	3.1329	1.1688	78.7293	0.3147	7.3922	5.4711	36.4754	313184.0000** *	0.000 0	6060
SPN	3.1047	1.8056	74.8907	0.4471	5.6410	7.4030	68.6791	1144574.0000 ***	0.000 0	6060

*Notes: *, **, *** signify rejection of the null hypothesis at the 10, 5 and 1% significance level, respectively*

Table A. 36: US Volatility Full Sample Descriptive Statistics

	Mean	Median	Max.	Min.	Std. Dev.	Skewness	Kurtosis	Jarque-Bera	Prob.	Obs.
SX3P	0.9082	0.6251	15.9256	0.2066	1.0774	6.4375	61.7366	912978.1000 ***	0.0000	6060
SX6P	1.3427	0.8425	41.0103	0.3110	2.1671	9.2401	116.4782	3337752.0000 0***	0.0000	6060
SX86P	1.7392	0.9891	27.3073	0.2364	2.1920	4.1523	28.7378	184678.6000 ***	0.0000	6060
SX8P	2.7100	1.7461	22.9700	0.5623	2.7404	2.9769	13.4280	36408.6300* **	0.0000	6060
SXDP	1.0147	0.7097	16.2266	0.3223	1.1006	5.6817	47.8361	540198.9000 ***	0.0000	6060
SXEP	2.3513	1.4488	49.2324	0.4076	3.5717	6.6871	59.8923	862439.2000 ***	0.0000	6060
SXFP	2.0132	1.1256	39.0814	0.2921	3.0005	5.8601	49.1632	572770.6000 ***	0.0000	6060
SXKP	1.5262	0.9146	24.8957	0.3534	1.9443	4.9318	36.8184	313346.0000 ***	0.0000	6060
SXNP	1.7520	1.0866	30.3528	0.2779	2.3886	5.9840	50.8009	613111.2000 ***	0.0000	6060
SXPP	4.0399	2.6085	66.6760	0.9195	5.3480	6.1567	51.7296	637862.9000 ***	0.0000	6060
SXQP	1.2816	0.9228	15.5505	0.3148	1.2864	4.8977	37.4163	323308.6000 ***	0.0000	6060

*Notes: *, **, *** signify rejection of the null hypothesis at the 10, 5 and 1% significance level, respectively*

Table A. 37: EU Volatility Full Sample Descriptive Statistics

	Mean	Median	Max.	Min.	Std. Dev.	Skewness	Kurtosis	Jarque-Bera	Prob.	Obs.
S5COND	1.3398	0.8215	7.7276	0.2999	1.3343	2.3787	8.7894	3188.8510***	0.000 0	1363
S5CONS	0.5682	0.4060	4.0060	0.2026	0.4925	3.4594	18.0217	15533.6900***	0.000 0	1363
S5HLTH	0.9904	0.6561	8.3672	0.2751	1.1081	3.9109	20.4182	20704.7000***	0.000 0	1363
S5INDU	1.2203	0.7294	6.2746	0.3283	1.1076	2.1212	7.6246	2236.7740***	0.000 0	1363
S5INFT	2.8060	1.4522	12.3104	0.4667	2.7438	1.3820	3.8137	471.4587***	0.000 0	1363
S5MATR	1.5460	1.1628	7.9665	0.5989	1.1154	3.0576	13.9646	8951.4250***	0.000 0	1363
S5RLST	1.1132	0.9383	6.3590	0.4964	0.6127	3.3588	19.6207	18251.4100***	0.000 0	1363
S5TELS	2.0814	0.9054	10.5825	0.3604	2.2866	1.6921	4.8869	852.6236***	0.000 0	1363
S5UTIL	1.4311	0.7538	20.0332	0.2498	2.1718	4.7085	29.7821	45771.8200***	0.000 0	1363
SPF	1.2937	0.7481	11.1191	0.2962	1.4725	3.0876	14.1617	9240.9080***	0.000 0	1363
SPN	1.9126	1.5782	10.9441	0.7138	1.2850	3.1955	17.0916	13596.9300***	0.000 0	1363

Notes: *, **, *** signify rejection of the null hypothesis at the 10, 5 and 1% significance level, respectively

Table A. 38: US Volatility Period 1 Descriptive Statistics

	Mean	Median	Max.	Min.	Std. Dev.	Skewness	Kurtosis	Jarque-Bera	Prob.	Obs.
SX3P	0.8032	0.4845	7.2514	0.1963	0.8638	3.1973	16.1056	12076.6300***	0.000 0	1363
SX6P	0.9817	0.5997	5.8953	0.2311	0.9953	2.5874	9.5637	3967.4340***	0.000 0	1363
SX86P	0.6668	0.5235	3.0144	0.2627	0.4040	2.3974	10.2014	4250.9310***	0.000 0	1363
SX8P	4.4062	2.7598	18.8870	0.6398	4.1315	1.3908	4.1258	511.4027***	0.000 0	1363
SXDP	1.1760	0.7280	9.1202	0.3312	1.2405	2.8911	12.1772	6681.7880***	0.000 0	1363
SXEP	1.8719	1.2025	10.6841	0.4094	1.7773	2.3682	8.3320	2888.5930***	0.000 0	1363
SXFP	1.5196	0.7162	11.9202	0.2038	1.9183	2.5091	9.6817	3965.6080***	0.000 0	1363
SXKP	2.2129	1.0363	10.5408	0.3929	2.3117	1.6492	4.7979	801.4033***	0.000 0	1363
SXNP	1.2627	0.8022	7.5500	0.2300	1.1454	2.1201	7.6610	2254.8330***	0.000 0	1363
SXPP	2.2742	1.7956	10.1346	0.8484	1.3622	2.2852	9.1405	3327.7430***	0.000 0	1363
SXQP	1.1761	0.7472	6.4445	0.3020	1.0678	2.1648	7.8484	2399.5490***	0.000 0	1363

Notes: *, **, *** signify rejection of the null hypothesis at the 10, 5 and 1% significance level, respectively

Table A. 39: EU Volatility Period 1 Descriptive Statistics

	Mean	Median	Max.	Min.	Std. Dev.	Skewness	Kurtosis	Jarque-Bera	Prob.	Obs.
S5COND	2.7927	1.5244	29.4826	0.1260	3.8719	3.7098	18.5585	19387.0400***	0.000 0	1566
S5CONS	0.9651	0.5342	16.3562	0.1078	1.6056	5.6142	40.3372	99189.2700***	0.000 0	1566
S5HLTH	1.3803	0.7832	23.3667	0.1634	2.1971	5.2273	36.7214	81329.8400***	0.000 0	1566
S5INDU	2.7954	1.5854	21.6303	0.1320	3.4024	2.9772	12.7998	8579.8260***	0.000 0	1566
S5INFT	2.5248	1.5393	25.2591	0.4005	3.1941	3.8115	19.5259	21611.8800***	0.000 0	1566
S5MATR	3.8609	2.2783	40.3771	0.2519	5.0317	4.1830	22.9652	30576.2500***	0.000 0	1566
S5RLST	9.0498	3.2997	112.721 2	0.3434	16.5815	3.3338	15.0175	12324.2300***	0.000 0	1566
S5TELS	2.1588	1.1446	31.6826	0.3181	3.5414	4.7878	28.2901	47716.1500***	0.000 0	1566
S5UTIL	1.8001	0.9492	32.2857	0.2368	3.4210	5.6903	40.2090	98790.1700***	0.000 0	1566
SPF	7.9630	2.8294	81.4006	0.1131	13.0761	2.7453	10.2807	5425.9390***	0.000 0	1566
SPN	4.1721	2.1974	68.2903	0.7533	7.2355	5.3380	35.3032	75525.1800***	0.000 0	1566

Notes: *, **, *** signify rejection of the null hypothesis at the 10, 5 and 1% significance level, respectively

Table A. 40: US Volatility Period 2 Descriptive Statistics

	Mean	Median	Max.	Min.	Std. Dev.	Skewness	Kurtosis	Jarque-Bera	Prob.	Obs.
SX3P	1.1871	0.7762	18.3880	0.2536	1.5417	6.1440	52.6468	170680.8000***	0.000 0	1566
SX6P	2.0798	1.1465	46.5859	0.4271	3.5966	6.7395	60.3400	226388.4000***	0.000 0	1566
SX86P	3.0750	1.8266	23.5180	0.3443	3.1094	2.0340	8.0058	2714.8370***	0.000 0	1566
SX8P	2.9261	2.0347	19.2942	0.6167	2.7746	2.9552	13.7008	9750.9390***	0.000 0	1566
SXDP	1.1097	0.6842	21.4060	0.2792	1.6538	6.4962	55.8002	192922.1000***	0.000 0	1566
SXEP	2.8851	1.6929	38.0509	0.4847	4.4413	4.9314	30.0835	54208.9300***	0.000 0	1566
SXFP	3.3289	1.9630	38.8686	0.4604	4.2649	4.2324	25.2701	37036.5200***	0.000 0	1566
SXKP	1.8047	1.2169	24.1988	0.4334	2.2347	5.5645	41.7618	106118.3000***	0.000 0	1566
SXNP	2.9589	1.9004	27.7449	0.4545	3.3944	3.8666	21.2867	25721.9800***	0.000 0	1566
SXPP	7.7011	4.4801	81.8809	1.1211	10.0373	4.0088	21.4098	26309.0500***	0.000 0	1566
SXQP	1.7163	1.1868	16.8560	0.3940	1.8290	4.3412	27.0481	42653.5200***	0.000 0	1566

Notes: *, **, *** signify rejection of the null hypothesis at the 10, 5 and 1% significance level, respectively

Table A. 41: EU Volatility Period 2 Descriptive Statistics

	Mean	Median	Max.	Min.	Std. Dev.	Skewness	Kurtosis	Jarque-Bera	Prob.	Obs.
S5COND	0.8140	0.5860	7.5915	0.2807	0.6792	3.3076	18.7171	22124.0700***	0.000 0	1826
S5CONS	0.5260	0.4094	3.6595	0.1994	0.3649	3.3339	19.4545	23982.3200***	0.000 0	1826
S5HLTH	0.8129	0.6205	5.0338	0.2689	0.5601	2.6758	13.0864	9919.3810***	0.000 0	1826
S5INDU	0.8295	0.6491	4.7641	0.3512	0.5102	2.6582	12.8591	9545.8820***	0.000 0	1826
S5INFT	1.0768	0.7733	7.7802	0.3750	0.8897	3.0998	15.2702	14379.1200***	0.000 0	1826
S5MATR	0.9887	0.7660	5.1091	0.3813	0.6137	2.2901	9.7064	5018.0180***	0.000 0	1826
S5RLST	0.8081	0.6661	4.3982	0.3125	0.4822	2.7873	14.5037	12432.8800***	0.000 0	1826
S5TELS	0.9506	0.8273	3.7327	0.5469	0.3824	2.5713	12.1701	8409.9530***	0.000 0	1826
S5UTIL	0.7492	0.6986	1.7994	0.3156	0.2766	1.1975	4.4017	585.8775***	0.000 0	1826
SPF	1.0116	0.7915	6.5116	0.4532	0.6857	3.6233	21.4324	29845.1300***	0.000 0	1826
SPN	1.5111	1.1661	6.8170	0.4315	0.9987	1.9862	7.8673	3003.0210***	0.000 0	1826

Notes: *, **, *** signify rejection of the null hypothesis at the 10, 5 and 1% significance level, respectively

Table A. 42: US Volatility Period 3 Descriptive Statistics

	Mean	Median	Max.	Min.	Std. Dev.	Skewness	Kurtosis	Jarque-Bera	Prob.	Obs.
SX3P	0.7013	0.5736	4.5543	0.2242	0.4557	3.3442	19.3908	23844.0400***	0.000 0	1826
SX6P	0.9387	0.7578	7.6816	0.3700	0.6632	5.0069	38.9401	105905.5000**	0.000 0	1826
SX86P	0.9722	0.7135	12.7773	0.3375	0.9441	6.2815	60.3535	262278.5000**	0.000 0	1826
SX8P	1.2812	1.0930	6.0307	0.5720	0.6132	2.5158	13.3144	10020.5300***	0.000 0	1826
SXDP	0.8358	0.6611	5.0091	0.3277	0.5389	2.9389	15.0437	13664.5200***	0.000 0	1826
SXEP	1.5469	1.0283	9.0691	0.3936	1.3454	2.3624	9.2043	4627.1130***	0.000 0	1826
SXFP	1.2383	0.8570	28.3084	0.3496	1.5835	8.9161	116.8151	1009768.0000***	0.000 0	1826
SXKP	1.0794	0.8012	10.5703	0.3509	0.9554	4.5253	32.4989	72439.0500***	0.000 0	1826
SXNP	0.9850	0.7624	11.5272	0.3294	0.7902	5.4422	51.9991	191683.3000**	0.000 0	1826
SXPP	2.9372	2.2091	16.6423	1.0256	2.2508	2.7756	11.4526	7780.4510***	0.000 0	1826
SXQP	0.9116	0.7167	6.6128	0.2972	0.6580	3.4695	20.8835	27996.2700***	0.000 0	1826

Notes: *, **, *** signify rejection of the null hypothesis at the 10, 5 and 1% significance level, respectively

Table A. 43: EU Volatility Period 3 Descriptive Statistics

	Mean	Median	Max.	Min.	Std. Dev.	Skewness	Kurtosis	Jarque-Bera	Prob.	Obs.
S5COND	2.6561	1.8289	37.9166	0.4981	3.1895	5.7037	46.2352	108717.8000***	0.000 0	1305
S5CONS	1.0080	0.5506	27.2195	0.2669	2.1944	8.0431	75.4237	299277.5000***	0.000 0	1305
S5HLTH	1.2216	0.6931	25.4821	0.2272	2.3689	6.9372	56.2037	164382.8000***	0.000 0	1305
S5INDU	1.9171	1.0701	47.5909	0.4996	3.9436	7.6160	67.9802	242210.4000***	0.000 0	1305
S5INFT	2.9583	2.0423	51.3108	0.8529	3.9493	7.0670	64.2746	215017.9000***	0.000 0	1305
S5MATR	2.1453	1.2912	38.9299	0.5945	3.7017	6.7361	54.4694	153913.8000***	0.000 0	1305
S5RLST	2.3261	1.3898	52.0826	0.6719	4.3782	7.3560	64.9386	220372.6000***	0.000 0	1305
S5TELS	2.4462	1.7295	34.5038	0.6024	2.5444	6.1727	56.1684	161998.5000***	0.000 0	1305
S5UTIL	1.8494	1.1614	41.9120	0.5441	3.6253	7.6289	66.8575	234387.6000***	0.000 0	1305
SPF	2.6767	1.2757	103.0261	0.4581	6.7571	8.9826	99.3704	522543.6000***	0.000 0	1305
SPN	5.3429	3.2783	85.9920	0.4819	9.1352	5.7604	40.8852	85260.7200***	0.000 0	1305

Notes: *, **, *** signify rejection of the null hypothesis at the 10, 5 and 1% significance level, respectively

Table A. 44: US Volatility Period 4 Descriptive Statistics

	Mean	Median	Max.	Min.	Std. Dev.	Skewness	Kurtosis	Jarque-Bera	Prob.	Obs.
SX3P	0.9476	0.6699	12.9681	0.1648	1.1516	6.0257	46.7715	112076.7000***	0.000 0	1305
SX6P	1.3813	0.9692	38.3060	0.2773	2.2444	10.1075	128.037 2	872335.4000***	0.000 0	1305
SX86P	2.3925	1.7044	25.5809	0.2334	2.4897	5.1685	37.7297	71394.7800***	0.000 0	1305
SX8P	2.7700	2.2752	19.4668	1.1254	1.8630	4.1647	27.8181	37264.1800***	0.000 0	1305
SXDP	0.9921	0.7824	12.9007	0.1427	0.9129	6.8438	63.2270	207421.3000***	0.000 0	1305
SXEP	3.2312	1.9837	52.7628	0.5801	5.2541	6.2280	46.6703	112134.9000***	0.000 0	1305
SXFP	1.9355	1.2817	33.1027	0.5945	2.7629	7.4588	69.2257	250580.3000***	0.000 0	1305
SXKP	1.0847	0.7171	24.7703	0.2436	1.8273	8.4464	84.3796	375622.8000***	0.000 0	1305
SXNP	1.9016	1.2003	32.5209	0.4242	2.8564	6.7484	57.1199	169167.5000***	0.000 0	1305
SXPP	3.3406	2.7556	33.4030	0.7120	2.8439	6.2063	49.0392	123631.4000***	0.000 0	1305
SXQP	1.3465	1.0944	13.7786	0.2275	1.1019	5.8256	46.6918	111181.9000***	0.000 0	1305

Notes: *, **, *** signify rejection of the null hypothesis at the 10, 5 and 1% significance level, respectively

Table A. 45: EU Volatility Period 4 Descriptive Statistics

Appendix 7 – Stationarity Test Statistics – Volatility Data

	<i>ADF in Level</i>	<i>ADF in 1st Difference</i>	<i>KPSS in Level</i>	<i>KPSS in 1st Difference</i>
S5COND	-7.761101***	-21.4115***	0.175795***	0.009351***
S5CONS	-9.988038***	-21.31071***	0.072999***	0.002484***
S5HLTH	-11.40794***	-19.9317***	0.094792***	0.003568***
S5INDU	-8.328653***	-21.47061***	0.176804***	0.005993***
S5INFT	-8.970783***	-42.84882***	0.383797**	0.014646***
S5MATR	-7.125574***	-21.80333***	0.330452***	0.005479***
S5RLST	-5.572826***	-15.62924***	0.469002*	0.008466***
S5TELS	-8.305259***	-20.15553***	0.299959***	0.004894***
S5UTIL	-9.796226***	-18.03913***	0.116695***	0.003731***
SPF	-3.957614***	-20.78561***	0.440285**	0.006756***
SPN	-7.273164***	-22.79072***	0.15001***	0.004907***

*Notes: For ADF *, **, ***, signify rejection of the Null hypothesis at the 10, 5 and 1% significance levels*

*For KPSS *, **, *** signify failure to reject the Null hypothesis at the 10, 5 and 1% significance levels*

Table A. 46: US Volatility Full Sample Stationarity Tests

	<i>ADF in Level</i>	<i>ADF in 1st Difference</i>	<i>KPSS in Level</i>	<i>KPSS in 1st Difference</i>
SX3P	-10.94036***	-22.71893***	0.179644***	0.003271***
SX6P	-12.12593***	-23.56543***	0.139859***	0.003723***
SX86P	-8.832897***	-28.41565***	0.315543***	0.00485***
SX8P	-5.919961***	-85.08369***	1.6133	0.070695***
SXDP	-10.157***	-31.14597***	0.36215**	0.003655***
SXEP	-7.216909***	-20.11368***	0.080396***	0.006657***
SXFP	-8.728916***	-16.90468***	0.292374***	0.0045***
SXKP	-9.673824***	-36.06271***	1.1551	0.006852***
SXNP	-7.979809***	-16.43052***	0.239975***	0.006279***
SXPP	-6.657573***	-13.9149***	0.369741**	0.007574***
SXQP	-9.128194***	-31.01355***	0.230522***	0.004212***

*Notes: For ADF *, **, ***, signify rejection of the Null hypothesis at the 10, 5 and 1% significance levels*

*For KPSS *, **, *** signify failure to reject the Null hypothesis at the 10, 5 and 1% significance levels*

Table A. 47: EU Volatility Full Sample Stationarity Tests

	<i>ADF in Level</i>	<i>ADF in 1st Difference</i>	<i>KPSS in Level</i>	<i>KPSS in 1st Difference</i>
S5COND	-3.84336***	-11.34386***	2.0226	0.089369***
S5CONS	-3.699999***	-16.7561	1.4597	0.017663***
S5HLTH	-3.393265**	-9.132367***	1.2082	0.027347***
S5INDU	-2.826531*	-13.62593***	2.4372	0.049396***
S5INFT	-3.101363**	-14.95278***	3.2615	0.272632***
S5MATR	-4.786788***	-10.08006***	1.2803	0.016516***
S5RLST	-7.900773***	-28.38783***	0.09331***	0.010086***
S5TELS	-1.8572	-36.63645***	2.2908	0.068669***
S5UTIL	-4.877925***	-12.92609***	1.2864	0.012536***
SPF	-3.595973***	-11.48142***	1.7687	0.022635***
SPN	-5.1624	-10.56602***	0.434346**	0.032872***

*Notes: For ADF *, **, ***, signify rejection of the Null hypothesis at the 10, 5 and 1% significance levels
For KPSS *, **, ***, signify failure to reject the Null hypothesis at the 10, 5 and 1% significance levels*

Table A. 48: US Volatility Period 1 Stationarity Tests

	<i>ADF in Level</i>	<i>ADF in 1st Difference</i>	<i>KPSS in Level</i>	<i>KPSS in 1st Difference</i>
SX3P	-3.512796***	-39.44624***	1.3521	0.016936***
SX6P	-3.19759**	-39.6479***	0.9518	0.031854***
SX86P	-4.265542***	-35.44698***	0.226093***	0.013921***
SX8P	-2.71323*	-40.07003***	3.1378	0.220857***
SXDP	-3.085752**	-11.88669***	1.4156	0.025777***
SXEP	-3.627402***	-36.3607***	1.7015	0.060801***
SXFP	-3.360808**	-19.42554***	1.3720	0.04699***
SXKP	-1.9467	-38.54872***	2.5850	0.068194***
SXNP	-5.154964***	-25.23052***	1.3399	0.066099***
SXPP	-3.961661***	-37.8839***	0.32425***	0.030331***
SXQP	-2.840663*	-39.78306***	1.7367	0.024613***

*Notes: For ADF *, **, ***, signify rejection of the Null hypothesis at the 10, 5 and 1% significance levels
For KPSS *, **, ***, signify failure to reject the Null hypothesis at the 10, 5 and 1% significance levels*

Table A. 49: EU Volatility Period 1 Stationarity Tests

	<i>ADF in Level</i>	<i>ADF in 1st Difference</i>	<i>KPSS in Level</i>	<i>KPSS in 1st Difference</i>
S5COND	-3.670759***	-8.722116***	0.529203*	0.040964***
S5CONS	-3.486205***	-9.728963***	0.359818**	0.017224***
S5HLTH	-4.026491***	-11.33973***	0.296986***	0.014762***
S5INDU	-3.657964***	-9.188644***	0.428446**	0.042941***
S5INFT	-4.197759***	-8.377192***	0.434126**	0.036454***
S5MATR	-3.254944**	-10.93365***	0.433856**	0.032289***
S5RLST	-3.145744**	-9.539741***	0.733103*	0.042378***
S5TELS	-4.456515***	-8.474652***	0.568821*	0.028292***
S5UTIL	-4.279441***	-9.13094***	0.490013*	0.017535***
SPF	-3.579964***	-13.43974***	0.7446	0.030689***
SPN	-3.204043**	-12.72486***	0.383947**	0.01948***

*Notes: For ADF *, **, *** signify rejection of the Null hypothesis at the 10, 5 and 1% significance levels
For KPSS *, **, *** signify failure to reject the Null hypothesis at the 10, 5 and 1% significance levels*

Table A. 50: US Volatility Period 2 Stationarity Tests

	<i>ADF in Level</i>	<i>ADF in 1st Difference</i>	<i>KPSS in Level</i>	<i>KPSS in 1st Difference</i>
SX3P	-6.203586***	-14.66247***	0.508025*	0.01251***
SX6P	-4.652926***	-11.69975***	0.258907***	0.013017***
SX86P	-4.543608***	-25.79503***	1.1218	0.02793***
SX8P	-3.071669**	-42.37419***	0.600669*	0.04768***
SXDP	-6.194905***	-16.3694***	0.410357**	0.01049***
SXEP	-3.742374***	-9.069487***	0.368592**	0.022429***
SXFP	-4.840981***	-9.428508***	0.553712*	0.027356***
SXKP	-4.95173***	-37.09381***	0.486244*	0.013568***
SXNP	-4.258941***	-8.065426***	0.396384**	0.034275***
SXPP	-3.648075***	-7.904781***	0.595476*	0.033113***
SXQP	-4.582728***	-15.51548***	0.437923**	0.021913***

*Notes: For ADF *, **, *** signify rejection of the Null hypothesis at the 10, 5 and 1% significance levels
For KPSS *, **, *** signify failure to reject the Null hypothesis at the 10, 5 and 1% significance levels*

Table A. 51: EU Volatility Period 2 Stationarity Tests

	<i>ADF in Level</i>	<i>ADF in 1st Difference</i>	<i>KPSS in Level</i>	<i>KPSS in 1st Difference</i>
S5COND	-8.604758***	-46.07135***	0.26502***	0.010548***
S5CONS	-11.28199***	-18.65306***	0.122916***	0.037326***
S5HLTH	-7.23854***	-42.94525***	0.155208***	0.007427***
S5INDU	-9.571081***	-45.95247***	0.3382***	0.017938***
S5INFT	-9.136377***	-33.48709***	0.628776*	0.015849***
S5MATR	-8.747833***	-22.70405***	0.177847***	0.01284***
S5RLST	-8.557172***	-42.99809***	0.140822***	0.01215***
S5TELS	-9.644366***	-32.5542***	0.9049	0.05612***
S5UTIL	-4.167178***	-41.01692***	0.380563**	0.018353***
SPF	-12.36197***	-22.15196***	0.238027***	0.019628***
SPN	-4.306104***	-42.77742***	0.369496**	0.015415***

*Notes: For ADF *, **, *** signify rejection of the Null hypothesis at the 10, 5 and 1% significance levels
For KPSS *, **, *** signify failure to reject the Null hypothesis at the 10, 5 and 1% significance levels*

Table A. 52: US Volatility Period 3 Stationarity Tests

	<i>ADF in Level</i>	<i>ADF in 1st Difference</i>	<i>KPSS in Level</i>	<i>KPSS in 1st Difference</i>
SX3P	-5.823159***	-39.21632***	0.539227*	0.014856***
SX6P	-7.839711***	-41.77746***	0.52094*	0.007118***
SX86P	-7.800357***	-40.27686***	0.545128*	0.008196***
SX8P	-7.573587***	-40.45295***	0.246771***	0.011937***
SXDP	-4.835965***	-40.87091***	0.597332*	0.015254***
SXEP	-4.387635***	-21.27629***	0.563607*	0.021688***
SXFP	-8.945873***	-30.71709***	0.339586***	0.009679***
SXKP	-6.737899***	-40.04288***	0.556301*	0.008764***
SXNP	-8.805219***	-30.35097***	0.256398***	0.007969***
SXPP	-3.174997**	-22.1352***	0.511496*	0.029343***
SXQP	-6.543393***	-39.91835***	0.445532**	0.01272***

*Notes: For ADF *, **, *** signify rejection of the Null hypothesis at the 10, 5 and 1% significance levels
For KPSS *, **, *** signify failure to reject the Null hypothesis at the 10, 5 and 1% significance levels*

Table A. 53: : EU Volatility Period 3 Stationarity Tests

	<i>ADF in Level</i>	<i>ADF in 1st Difference</i>	<i>KPSS in Level</i>	<i>KPSS in 1st Difference</i>
S5COND	-5.638858***	-12.77751***	0.372674**	0.013487***
S5CONS	-6.183059***	-12.48495***	0.501018*	0.009796***
S5HLTH	-6.604772***	-8.910303***	0.618142*	0.013224***
S5INDU	-6.649489***	-10.66992***	0.676936*	0.010701***
S5INFT	-5.729573***	-19.60249***	0.450079**	0.0129***
S5MATR	-6.087096***	-10.33688***	0.703126*	0.013264***
S5RLST	-5.280556***	-9.619194***	0.502497*	0.011823***
S5TELS	-6.400482***	-20.14436***	0.33759***	0.011715***
S5UTIL	-5.558067***	-11.33741***	0.451482**	0.011409***
SPF	-6.465484***	-12.90187***	0.695246*	0.009155***
SPN	-5.397753***	-10.92808***	1.0634	0.017701***

*Notes: For ADF *, **, ***, signify rejection of the Null hypothesis at the 10, 5 and 1% significance levels
For KPSS *, **, *** signify failure to reject the Null hypothesis at the 10, 5 and 1% significance levels*

Table A. 54: US Volatility Period 4 Stationarity Tests

	<i>ADF in Level</i>	<i>ADF in 1st Difference</i>	<i>KPSS in Level</i>	<i>KPSS in 1st Difference</i>
SX3P	-6.826719***	-10.1217***	0.714783*	0.014142***
SX6P	-7.473786***	-17.26347***	0.571597*	0.011786***
SX86P	-5.837982***	-11.60334***	0.217199***	0.016716***
SX8P	-5.909991***	-30.16719***	0.456625**	0.025746***
SXDP	-5.318652***	-32.80849***	0.689615*	0.01364***
SXEP	-4.96164***	-10.26644***	0.8635	0.015608***
SXFP	-6.810805***	-11.53102***	0.56962*	0.01933***
SXKP	-6.664571***	-10.96358***	0.7602	0.009409***
SXNP	-6.036021***	-11.0752***	0.65804*	0.011895***
SXPP	-4.671115***	-10.32996***	0.704377*	0.018839***
SXQP	-6.812432***	-19.58042***	0.475845*	0.016532***

*Notes: For ADF *, **, ***, signify rejection of the Null hypothesis at the 10, 5 and 1% significance levels
For KPSS *, **, *** signify failure to reject the Null hypothesis at the 10, 5 and 1% significance levels*

Table A. 55: EU Volatility Period 4 Stationarity Tests

Appendix 8 – Correlation Statistics – Volatility Data

Correlation Probability	S5COND	S5CONS	S5HLTH	S5INDU	S5INFT	S5MATR	S5RLST	SPF	SPN	S5TELS	S5UTIL
S5COND	1.0000										
S5CONS	0.8689	1.0000									
S5HLTH	0.8887	0.9346	1.0000								
S5INDU	0.9208	0.8974	0.9187	1.0000							
S5INFT	0.9002	0.8695	0.8946	0.9018	1.0000						
S5MATR	0.9404	0.8602	0.8998	0.9341	0.8536	1.0000					
S5RLST	0.8053	0.6083	0.6522	0.7695	0.6233	0.8215	1.0000				
SPF	0.8217	0.6724	0.7129	0.8252	0.6927	0.8241	0.9189	1.0000			
SPN	0.8875	0.8946	0.9051	0.9165	0.8381	0.9280	0.7008	0.7263	1.0000		
S5TELS	0.9118	0.8228	0.8637	0.8393	0.8944	0.8825	0.7022	0.7049	0.8361	1.0000	
S5UTIL	0.8424	0.9072	0.9224	0.8979	0.8841	0.8710	0.5984	0.6411	0.9014	0.8540	1.0000

Table A. 56: US Indices Volatility Correlation - Full Sample

Correlation Probability	SX3P	SX6P	SX86P	SX8P	SXDP	SXEP	SXFP	SXKP	SXNP	SXPP	SXQP
SX3P	1.0000										
SX6P	0.9103	1.0000									
SX86P	0.7215	0.7304	1.0000								
SX8P	0.6321	0.5587	0.4513	1.0000							
SXDP	0.9014	0.8528	0.5951	0.6941	1.0000						
SXEP	0.8767	0.8682	0.7463	0.6557	0.8190	1.0000					
SXFP	0.8817	0.8899	0.8444	0.6665	0.8249	0.8755	1.0000				
SXKP	0.8356	0.8090	0.6026	0.8137	0.8650	0.8045	0.8480	1.0000			
SXNP	0.8802	0.8983	0.8426	0.6620	0.7970	0.9185	0.9533	0.7974	1.0000		
SXPP	0.7672	0.8111	0.7701	0.5334	0.7212	0.8178	0.8420	0.6468	0.8713	1.0000	
SXQP	0.9394	0.8946	0.7533	0.7292	0.8918	0.8809	0.9185	0.8651	0.9191	0.8076	1.0000

Table A. 57: EU Indices Volatility Correlation - Full Sample

Correlation Probability	S5COND	S5CONS	S5HLTH	S5INDU	S5INFT	S5MATR	S5RLST	SPF	SPN	S5TELS	S5UTIL
S5COND	1.0000										
S5CONS	0.8810	1.0000									
S5HLTH	0.8036	0.9101	1.0000								
S5INDU	0.9469	0.8620	0.7813	1.0000							
S5INFT	0.8688	0.7212	0.6638	0.9293	1.0000						
S5MATR	0.8775	0.8623	0.7344	0.8949	0.7299	1.0000					
S5RLST	0.4481	0.4598	0.3956	0.3978	0.2406	0.5219	1.0000				
SPF	0.9056	0.8842	0.7896	0.9485	0.8016	0.9326	0.4750	1.0000			
SPN	0.7216	0.7445	0.7191	0.6799	0.5572	0.7321	0.4281	0.6657	1.0000		
S5TELS	0.8177	0.8377	0.7759	0.8893	0.8149	0.7644	0.2570	0.8789	0.5334	1.0000	
S5UTIL	0.8053	0.8671	0.8092	0.8189	0.6829	0.8512	0.6004	0.8668	0.7709	0.7242	1.0000

Table A. 58: US Indices Volatility Correlation - Period 1

Correlation Probability	SX3P	SX6P	SX86P	SX8P	SXDP	SXEP	SXFP	SXKP	SXNP	SXPP	SXQP
SX3P	1.0000										
SX6P	0.8900	1.0000									
SX86P	0.5057	0.5828	1.0000								
SX8P	0.6212	0.5792	0.2513	1.0000							
SXDP	0.9199	0.9153	0.4992	0.6263	1.0000						
SXEP	0.8294	0.7928	0.4907	0.7998	0.8268	1.0000					
SXFP	0.8472	0.8440	0.6748	0.7422	0.8788	0.9044	1.0000				
SXKP	0.7610	0.7574	0.3999	0.9118	0.8080	0.8637	0.8704	1.0000			
SXNP	0.7144	0.7109	0.6481	0.7519	0.7032	0.8344	0.9019	0.7560	1.0000		
SXPP	0.6138	0.6699	0.7954	0.4745	0.5758	0.6690	0.7609	0.5347	0.8332	1.0000	
SXQP	0.9135	0.9056	0.5845	0.7713	0.9127	0.9105	0.9341	0.8734	0.8530	0.7269	1.0000

Table A. 59: EU Indices Volatility Correlation - Period 1

Correlation Probability	S5COND	S5CONS	S5HLTH	S5INDU	S5INFT	S5MATR	S5RLST	SPF	SPN	S5TELS	S5UTIL
S5COND	1.0000										
S5CONS	0.9194	1.0000									
S5HLTH	0.9060	0.9667	1.0000								
S5INDU	0.9732	0.8710	0.8876	1.0000							
S5INFT	0.9738	0.9395	0.9358	0.9540	1.0000						
S5MATR	0.9707	0.9426	0.9330	0.9441	0.9714	1.0000					
S5RLST	0.9024	0.7344	0.7340	0.9044	0.8499	0.8377	1.0000				
SPF	0.8615	0.7173	0.7355	0.8850	0.8412	0.7908	0.9238	1.0000			
SPN	0.9366	0.9702	0.9533	0.8849	0.9496	0.9713	0.7701	0.7338	1.0000		
S5TELS	0.9499	0.9538	0.9192	0.8883	0.9525	0.9588	0.8127	0.7564	0.9635	1.0000	
S5UTIL	0.8954	0.9760	0.9480	0.8385	0.9157	0.9354	0.7129	0.6740	0.9720	0.9582	1.0000

Table A. 60: US Indices Volatility Correlation - Period 2

Correlation Probability	SX3P	SX6P	SX86P	SX8P	SXDP	SXEP	SXFP	SXKP	SXNP	SXPP	SXQP
SX3P	1.0000										
SX6P	0.9408	1.0000									
SX86P	0.7279	0.6776	1.0000								
SX8P	0.7927	0.8223	0.7975	1.0000							
SXDP	0.9300	0.9392	0.6744	0.8154	1.0000						
SXEP	0.8841	0.9303	0.7176	0.9094	0.8994	1.0000					
SXFP	0.8802	0.8846	0.8563	0.9063	0.8676	0.9276	1.0000				
SXKP	0.9317	0.9465	0.7516	0.8469	0.9083	0.9221	0.9256	1.0000			
SXNP	0.8620	0.8991	0.8106	0.9538	0.8711	0.9608	0.9567	0.9126	1.0000		
SXPP	0.8492	0.8729	0.8038	0.9248	0.8707	0.9641	0.9377	0.8740	0.9549	1.0000	
SXQP	0.9328	0.9331	0.7838	0.9118	0.9233	0.9508	0.9357	0.9459	0.9580	0.9299	1.0000

Table A. 61: EU Indices Volatility Correlation - Period 2

Correlation Probability	S5COND	S5CONS	S5HLTH	S5INDU	S5INFT	S5MATR	S5RLST	SPF	SPN	S5TELS	S5UTIL
S5COND	1.0000										
S5CONS	0.7217	1.0000									
S5HLTH	0.8248	0.7419	1.0000								
S5INDU	0.8939	0.7471	0.8371	1.0000							
S5INFT	0.9214	0.7048	0.7945	0.8945	1.0000						
S5MATR	0.8231	0.6843	0.8177	0.8809	0.8155	1.0000					
S5RLST	0.6209	0.7036	0.6606	0.5915	0.5492	0.5832	1.0000				
SPF	0.7494	0.7056	0.7383	0.8328	0.7766	0.8039	0.5537	1.0000			
SPN	0.6332	0.5340	0.7087	0.6482	0.6297	0.7738	0.5375	0.5575	1.0000		
S5TELS	0.6615	0.6233	0.5401	0.6364	0.6810	0.5368	0.4643	0.4849	0.4119	1.0000	
S5UTIL	0.3755	0.4534	0.5090	0.3732	0.3412	0.3763	0.6059	0.3007	0.5279	0.2941	1.0000

Table A. 62: US Indices Volatility Correlation - Period 3

Correlation Probability	SX3P	SX6P	SX86P	SX8P	SXDP	SXEP	SXFP	SXKP	SXNP	SXPP	SXQP
SX3P	1.0000										
SX6P	0.7561	1.0000									
SX86P	0.6589	0.9183	1.0000								
SX8P	0.7232	0.7495	0.7093	1.0000							
SXDP	0.8987	0.7260	0.6450	0.7432	1.0000						
SXEP	0.7969	0.7278	0.6307	0.6806	0.8425	1.0000					
SXFP	0.5904	0.8796	0.9249	0.7281	0.5744	0.5831	1.0000				
SXKP	0.7543	0.9225	0.9019	0.7697	0.7700	0.7845	0.8868	1.0000			
SXNP	0.6822	0.8632	0.8812	0.8424	0.6752	0.6766	0.9433	0.8894	1.0000		
SXPP	0.6061	0.5434	0.5097	0.4985	0.6937	0.8310	0.4647	0.6416	0.5316	1.0000	
SXQP	0.8899	0.8549	0.8175	0.8018	0.8343	0.7386	0.7828	0.8619	0.8320	0.5841	1.0000

Table A. 63: EU Indices Volatility Correlation - Period 3

Correlation Probability	S5COND	S5CONS	S5HLTH	S5INDU	S5INFT	S5MATR	S5RLST	SPF	SPN	S5TELS	S5UTIL
S5COND	1.0000										
S5CONS	0.9156	1.0000									
S5HLTH	0.9125	0.9539	1.0000								
S5INDU	0.8991	0.9616	0.9680	1.0000							
S5INFT	0.9610	0.9566	0.9616	0.9513	1.0000						
S5MATR	0.9195	0.9486	0.9870	0.9784	0.9614	1.0000					
S5RLST	0.9127	0.9405	0.9776	0.9572	0.9529	0.9807	1.0000				
SPF	0.8740	0.9483	0.9204	0.9687	0.9310	0.9364	0.9196	1.0000			
SPN	0.8574	0.8918	0.9450	0.9436	0.8956	0.9614	0.9293	0.8953	1.0000		
S5TELS	0.9340	0.8966	0.8837	0.8835	0.9362	0.8870	0.8776	0.8798	0.8150	1.0000	
S5UTIL	0.8866	0.9478	0.9778	0.9555	0.9385	0.9724	0.9795	0.9032	0.9221	0.8570	1.0000

Table A. 64: US Indices Volatility Correlation - Period 4

Correlation Probability	SX3P	SX6P	SX86P	SX8P	SXDP	SXEP	SXFP	SXKP	SXNP	SXPP	SXQP
SX3P	1.0000										
SX6P	0.8827	1.0000									
SX86P	0.8317	0.7686	1.0000								
SX8P	0.8623	0.7825	0.8113	1.0000							
SXDP	0.9236	0.9105	0.7960	0.8231	1.0000						
SXEP	0.9198	0.8520	0.8470	0.8200	0.8861	1.0000					
SXFP	0.9296	0.9095	0.8754	0.8852	0.9151	0.9243	1.0000				
SXKP	0.9186	0.9326	0.8441	0.8033	0.9168	0.9154	0.9326	1.0000			
SXNP	0.9481	0.8897	0.8758	0.8979	0.9219	0.9475	0.9780	0.9339	1.0000		
SXPP	0.8929	0.8309	0.8519	0.8311	0.8728	0.9566	0.9268	0.8906	0.9452	1.0000	
SXQP	0.9425	0.8825	0.7980	0.8748	0.8738	0.8541	0.9166	0.8776	0.9206	0.8442	1.0000

Table A. 65: EU Indices Volatility Correlation - Period 4

		US										EU											
Correlation Probability	S5COND	S5CONS	S5HLTH	S5INDU	S5INFT	S5MATR	S5RLST	SPF	SPN	S5TELS	S5UTIL	SX3P	SX6P	SX86P	SX8P	SXDP	SXEP	SXFP	SXKP	SXNP	SXPP	SXQP	
US	S5COND	1.0000																					
	S5CONS	0.8689	1.0000																				
	S5HLTH	0.8887	0.9346	1.0000																			
	S5INDU	0.9208	0.8974	0.9187	1.0000																		
	S5INFT	0.9002	0.8695	0.8946	0.9018	1.0000																	
	S5MATR	0.9404	0.8602	0.8998	0.9341	0.8536	1.0000																
	S5RLST	0.8053	0.6083	0.6522	0.7695	0.6233	0.8215	1.0000															
	SPF	0.8217	0.6724	0.7129	0.8252	0.6927	0.8241	0.9189	1.0000														
	SPN	0.8875	0.8946	0.9051	0.9165	0.8381	0.9280	0.7008	0.7263	1.0000													
	S5TELS	0.9118	0.8228	0.8637	0.8393	0.8944	0.8825	0.7022	0.7049	0.8361	1.0000												
	S5UTIL	0.8424	0.9072	0.9224	0.8979	0.8841	0.8710	0.5984	0.6411	0.9014	0.8540	1.0000											
EU	SX3P	0.8277	0.8490	0.8834	0.8040	0.7971	0.8343	0.6072	0.6688	0.8270	0.8141	0.8191	1.0000										
	SX6P	0.8307	0.8599	0.8694	0.7975	0.7630	0.8649	0.6521	0.6794	0.8433	0.8067	0.7924	0.9103	1.0000									
	SX86P	0.7990	0.7326	0.7240	0.8066	0.6874	0.7948	0.7218	0.7930	0.7558	0.6792	0.7028	0.7215	0.7304	1.0000								
	SX8P	0.6704	0.5229	0.6031	0.6193	0.7868	0.6308	0.4531	0.4932	0.5381	0.7370	0.6304	0.6321	0.5587	0.4513	1.0000							
	SXDP	0.7801	0.7673	0.8539	0.7354	0.7775	0.7826	0.5636	0.6040	0.7428	0.8136	0.7661	0.9014	0.8528	0.5951	0.6941	1.0000						
	SXEP	0.8747	0.8785	0.9015	0.9027	0.8602	0.9036	0.6707	0.6982	0.9511	0.8439	0.8968	0.8767	0.8682	0.7463	0.6557	0.8190	1.0000					
	SXFP	0.8628	0.8200	0.8528	0.8464	0.8143	0.8827	0.6902	0.7598	0.8220	0.8209	0.8084	0.8817	0.8899	0.8444	0.6665	0.8249	0.8755	1.0000				
	SXKP	0.7387	0.7575	0.8040	0.7385	0.8358	0.7449	0.4904	0.5668	0.7039	0.7994	0.7772	0.8356	0.8090	0.6026	0.8137	0.8650	0.8045	0.8480	1.0000			
	SXNP	0.8989	0.8497	0.8735	0.9017	0.8350	0.9337	0.7285	0.7699	0.8878	0.8304	0.8434	0.8802	0.8983	0.8426	0.6620	0.7970	0.9185	0.9533	0.7974	1.0000		
	SXPP	0.8386	0.6900	0.7490	0.7856	0.6733	0.9029	0.8600	0.8218	0.8040	0.7686	0.6880	0.7672	0.8111	0.7701	0.5334	0.7212	0.8178	0.8420	0.6468	0.8713	1.0000	
	SXQP	0.8628	0.8084	0.8551	0.8166	0.8210	0.8570	0.6487	0.7006	0.8079	0.8301	0.7929	0.9394	0.8946	0.7533	0.7292	0.8918	0.8809	0.9185	0.8651	0.9191	0.8076	1.0000

Table A. 66: US and EU Indices Volatility Correlation - Full Sample

		US											EU											
	Correlation Probability	S5COND	S5CONS	S5HLTH	S5INDU	S5INFT	S5MATR	S5RLST	SPF	SPN	S5TELS	S5UTIL	SX3P	SX6P	SX86P	SX8P	SXDP	SXEP	SXFP	SXKP	SXNP	SXPP	SXQP	
	US	S5COND	1.0000																					
S5CONS		0.8810	1.0000																					
S5HLTH		0.8036	0.9101	1.0000																				
S5INDU		0.9469	0.8620	0.7813	1.0000																			
S5INFT		0.8688	0.7212	0.6638	0.9293	1.0000																		
S5MATR		0.8775	0.8623	0.7344	0.8949	0.7299	1.0000																	
S5RLST		0.4481	0.4598	0.3956	0.3978	0.2406	0.5219	1.0000																
SPF		0.9056	0.8842	0.7896	0.9485	0.8016	0.9326	0.4750	1.0000															
SPN		0.7216	0.7445	0.7191	0.6799	0.5572	0.7321	0.4281	0.6657	1.0000														
S5TELS		0.8177	0.8377	0.7759	0.8893	0.8149	0.7644	0.2570	0.8789	0.5334	1.0000													
S5UTIL		0.8053	0.8671	0.8092	0.8189	0.6829	0.8512	0.6004	0.8668	0.7709	0.7242	1.0000												
EU	SX3P	0.8351	0.8938	0.8544	0.7565	0.6397	0.7563	0.4104	0.7832	0.6541	0.7491	0.7544	1.0000											
	SX6P	0.8119	0.8641	0.7946	0.7447	0.5860	0.7797	0.3875	0.7980	0.6058	0.7641	0.6931	0.8900	1.0000										
	SX86P	0.4088	0.4649	0.4454	0.3664	0.2425	0.5082	0.3344	0.4143	0.4912	0.3280	0.4190	0.5057	0.5828	1.0000									
	SX8P	0.8397	0.6873	0.5668	0.8935	0.9558	0.7333	0.2628	0.7887	0.4900	0.7644	0.6409	0.6212	0.5792	0.2513	1.0000								
	SXDP	0.8453	0.9232	0.9198	0.7934	0.6681	0.7682	0.4026	0.8240	0.6354	0.8002	0.7782	0.9199	0.9153	0.4992	0.6263	1.0000							
	SXEP	0.9026	0.8302	0.7672	0.8513	0.8022	0.7807	0.4090	0.7950	0.7669	0.7109	0.7619	0.8294	0.7928	0.4907	0.7998	0.8268	1.0000						
	SXFP	0.8897	0.8738	0.8274	0.8573	0.7632	0.8447	0.4724	0.8466	0.7290	0.7480	0.8133	0.8472	0.8440	0.6748	0.7422	0.8788	0.9044	1.0000					
	SXKP	0.9009	0.8396	0.7793	0.9487	0.9407	0.8040	0.3145	0.8749	0.6288	0.8837	0.7614	0.7610	0.7574	0.3999	0.9118	0.8080	0.8637	0.8704	1.0000				
	SXNP	0.8136	0.7086	0.5899	0.7707	0.7095	0.7905	0.4568	0.7468	0.5992	0.6004	0.6822	0.7144	0.7109	0.6481	0.7519	0.7032	0.8344	0.9019	0.7560	1.0000			
	SXPP	0.6190	0.5870	0.4920	0.5751	0.4323	0.6958	0.3615	0.6144	0.5997	0.4748	0.5215	0.6138	0.6699	0.7954	0.4745	0.5758	0.6690	0.7609	0.5347	0.8332	1.0000		
	SXQP	0.9088	0.8791	0.8203	0.8523	0.7677	0.8243	0.4039	0.8349	0.6618	0.7774	0.7423	0.9135	0.9056	0.5845	0.7713	0.9127	0.9105	0.9341	0.8734	0.8530	0.7269	1.0000	

Table A. 67: US and EU Indices Volatility Correlation - Period 1

		US										EU													
	Correlation Probability	S5COND	S5CONS	S5HLTH	S5INDU	S5INFT	S5MATR	S5RLST	SPF	SPN	S5TELS	S5UTIL	SX3P	SX6P	SX86P	SX8P	SXDP	SXEP	SXFP	SXKP	SXNP	SXPP	SXQP		
	US	S5COND	1.0000																						
S5CONS		0.9194	1.0000																						
S5HLTH		0.9060	0.9667	1.0000																					
S5INDU		0.9732	0.8710	0.8876	1.0000																				
S5INFT		0.9738	0.9395	0.9358	0.9540	1.0000																			
S5MATR		0.9707	0.9426	0.9330	0.9441	0.9714	1.0000																		
S5RLST		0.9024	0.7344	0.7340	0.9044	0.8499	0.8377	1.0000																	
SPF		0.8615	0.7173	0.7355	0.8850	0.8412	0.7908	0.9238	1.0000																
SPN		0.9366	0.9702	0.9533	0.8849	0.9496	0.9713	0.7701	0.7338	1.0000															
S5TELS		0.9499	0.9538	0.9192	0.8883	0.9525	0.9588	0.8127	0.7564	0.9635	1.0000														
S5UTIL		0.8954	0.9760	0.9480	0.8385	0.9157	0.9354	0.7129	0.6740	0.9720	0.9582	1.0000													
EU	SX3P	0.7918	0.9005	0.8978	0.7499	0.8350	0.8220	0.6234	0.6559	0.8775	0.8377	0.8933	1.0000												
	SX6P	0.8197	0.9302	0.9275	0.7738	0.8591	0.8646	0.6464	0.6301	0.9174	0.8746	0.9261	0.9408	1.0000											
	SX86P	0.7836	0.7275	0.7139	0.7969	0.7833	0.7535	0.7329	0.8222	0.7124	0.7282	0.7049	0.7279	0.6776	1.0000										
	SX8P	0.9296	0.8532	0.8454	0.9071	0.9262	0.9237	0.8173	0.7898	0.8814	0.9058	0.8495	0.7927	0.8223	0.7975	1.0000									
	SXDP	0.8365	0.9143	0.9211	0.7885	0.8681	0.8677	0.6727	0.6692	0.9088	0.8687	0.8982	0.9300	0.9392	0.6744	0.8154	1.0000								
	SXEP	0.9233	0.9475	0.9253	0.8729	0.9346	0.9516	0.7745	0.7230	0.9672	0.9543	0.9519	0.8841	0.9303	0.7176	0.9094	0.8994	1.0000							
	SXFP	0.8933	0.9145	0.8883	0.8657	0.9161	0.9093	0.7465	0.7721	0.9034	0.9107	0.9027	0.8802	0.8846	0.8563	0.9063	0.8676	0.9276	1.0000						
	SXKP	0.8326	0.9250	0.8969	0.7785	0.8655	0.8608	0.6358	0.6506	0.9087	0.8836	0.9255	0.9317	0.9465	0.7516	0.8469	0.9083	0.9221	0.9256	1.0000					
	SXNP	0.9390	0.9279	0.9100	0.9157	0.9443	0.9537	0.7862	0.7634	0.9352	0.9350	0.9145	0.8620	0.8991	0.8106	0.9538	0.8711	0.9608	0.9567	0.9126	1.0000				
	SXPP	0.9521	0.9188	0.9017	0.9223	0.9504	0.9596	0.8575	0.8243	0.9446	0.9434	0.9136	0.8492	0.8729	0.8038	0.9248	0.8707	0.9641	0.9377	0.8740	0.9549	1.0000			
	SXQP	0.9034	0.9286	0.9140	0.8612	0.9169	0.9138	0.7369	0.7382	0.9269	0.9086	0.9138	0.9328	0.9331	0.7838	0.9118	0.9233	0.9508	0.9357	0.9459	0.9580	0.9299	1.0000		

Table A. 68: US and EU Indices Volatility Correlation - Period 2

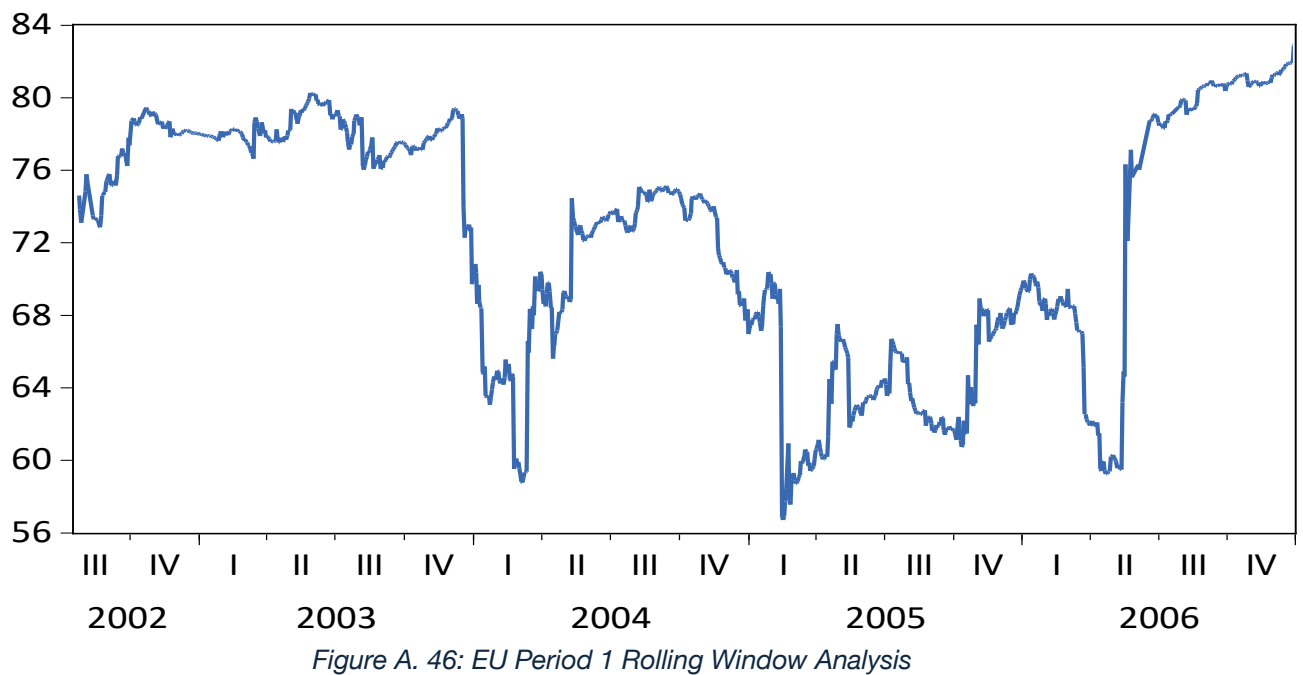
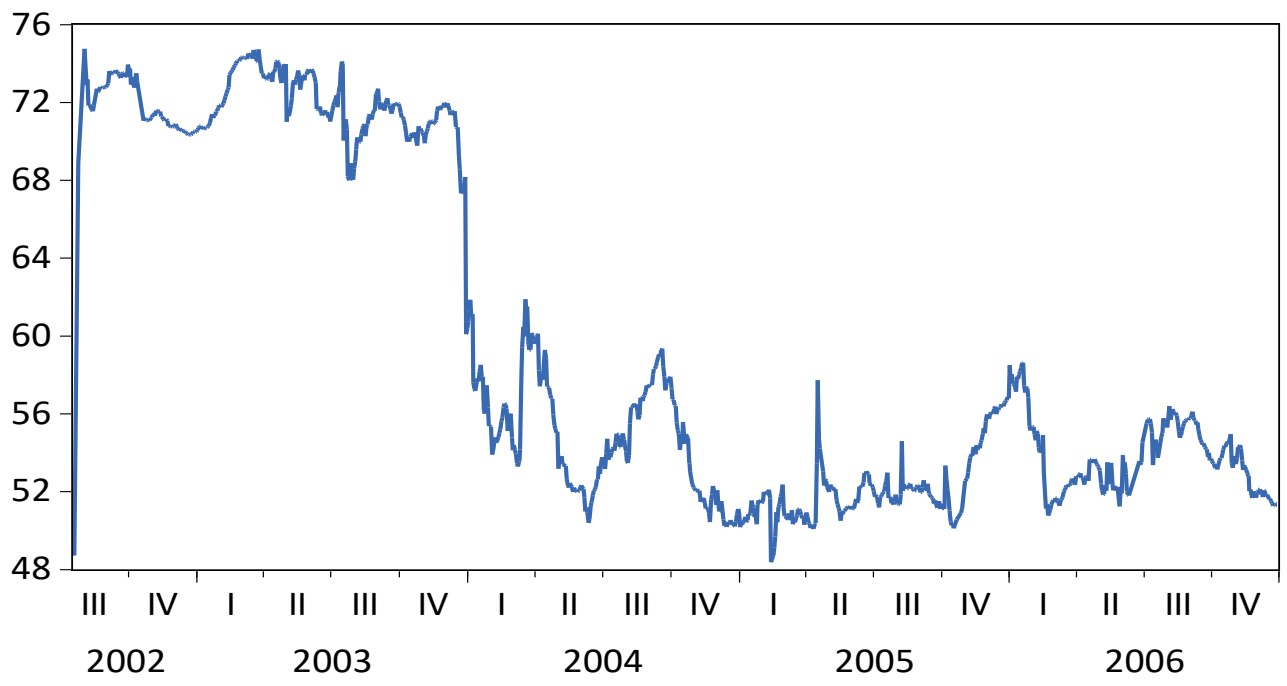
		US										EU												
	Correlation Probability	S5COND	S5CONS	S5HLTH	S5INDU	S5INFT	S5MATR	S5RLST	SPF	SPN	S5TELS	S5UTIL	SX3P	SX6P	SX86P	SX8P	SXDP	SXEP	SXFP	SXKP	SXNP	SXPP	SXQP	
US	S5COND	1.0000																						
	S5CONS	0.7217	1.0000																					
	S5HLTH	0.8248	0.7419	1.0000																				
	S5INDU	0.8939	0.7471	0.8371	1.0000																			
	S5INFT	0.9214	0.7048	0.7945	0.8945	1.0000																		
	S5MATR	0.8231	0.6843	0.8177	0.8809	0.8155	1.0000																	
	S5RLST	0.6209	0.7036	0.6606	0.5915	0.5492	0.5832	1.0000																
	SPF	0.7494	0.7056	0.7383	0.8328	0.7766	0.8039	0.5537	1.0000															
	SPN	0.6332	0.5340	0.7087	0.6482	0.6297	0.7738	0.5375	0.5575	1.0000														
	S5TELS	0.6615	0.6233	0.5401	0.6364	0.6810	0.5368	0.4643	0.4849	0.4119	1.0000													
	S5UTIL	0.3755	0.4534	0.5090	0.3732	0.3412	0.3763	0.6059	0.3007	0.5279	0.2941	1.0000												
EU	SX3P	0.5043	0.5294	0.6837	0.5246	0.4797	0.6598	0.5627	0.5368	0.7037	0.2408	0.4836	1.0000											
	SX6P	0.4331	0.4362	0.5475	0.4981	0.4283	0.6213	0.4299	0.5831	0.5560	0.1716	0.3494	0.7561	1.0000										
	SX86P	0.3845	0.3524	0.4504	0.4380	0.3796	0.5595	0.4188	0.5598	0.4517	0.1146	0.2878	0.6589	0.9183	1.0000									
	SX8P	0.6528	0.5150	0.6714	0.6792	0.6799	0.7456	0.4657	0.6284	0.6516	0.3961	0.3380	0.7232	0.7495	0.7093	1.0000								
	SXDP	0.4872	0.4875	0.7012	0.5131	0.4729	0.6676	0.5551	0.5382	0.7426	0.2240	0.4967	0.8987	0.7260	0.6450	0.7432	1.0000							
	SXEP	0.4172	0.3757	0.5726	0.4428	0.3951	0.6399	0.4326	0.4614	0.8445	0.1665	0.4942	0.7969	0.7278	0.6307	0.6806	0.8425	1.0000						
	SXFP	0.4112	0.3293	0.4387	0.4834	0.4102	0.5897	0.3142	0.6037	0.4198	0.1187	0.1607	0.5904	0.8796	0.9249	0.7281	0.5744	0.5831	1.0000					
	SXKP	0.4567	0.4093	0.5533	0.5041	0.4378	0.6624	0.4229	0.5898	0.6223	0.1778	0.3140	0.7543	0.9225	0.9019	0.7697	0.7700	0.7845	0.8868	1.0000				
	SXNP	0.5530	0.4235	0.5632	0.6137	0.5540	0.7140	0.3941	0.6646	0.5681	0.2427	0.2302	0.6822	0.8632	0.8812	0.8424	0.6752	0.6766	0.9433	0.8894	1.0000			
	SXPP	0.2656	0.2487	0.4142	0.2841	0.2455	0.4816	0.3489	0.3481	0.6425	0.0615	0.3599	0.6061	0.5434	0.5097	0.4985	0.6937	0.8310	0.4647	0.6416	0.5316	1.0000		
	SXQP	0.5281	0.5442	0.6500	0.5560	0.5116	0.6898	0.5326	0.6038	0.6303	0.2549	0.3992	0.8899	0.8549	0.8175	0.8018	0.8343	0.7386	0.7828	0.8619	0.8320	0.5841	1.0000	

Table A. 69: US and EU Indices Volatility Correlation - Period 3

		US										EU														
	Correlation Probability	S5COND	S5CONS	S5HLTH	S5INDU	S5INFT	S5MATR	S5RLST	SPF	SPN	S5TELS	S5UTIL	SX3P	SX6P	SX86P	SX8P	SXDP	SXEP	SXFP	SXKP	SXNP	SXPP	SXQP			
	US	S5COND	1.0000																							
S5CONS		0.9156	1.0000																							
S5HLTH		0.9125	0.9539	1.0000																						
S5INDU		0.8991	0.9616	0.9680	1.0000																					
S5INFT		0.9610	0.9566	0.9616	0.9513	1.0000																				
S5MATR		0.9195	0.9486	0.9870	0.9784	0.9614	1.0000																			
S5RLST		0.9127	0.9405	0.9776	0.9572	0.9529	0.9807	1.0000																		
SPF		0.8740	0.9483	0.9204	0.9687	0.9310	0.9364	0.9196	1.0000																	
SPN		0.8574	0.8918	0.9450	0.9436	0.8956	0.9614	0.9293	0.8953	1.0000																
S5TELS		0.9340	0.8966	0.8837	0.8835	0.9362	0.8870	0.8776	0.8798	0.8150	1.0000															
S5UTIL		0.8866	0.9478	0.9778	0.9555	0.9385	0.9724	0.9795	0.9032	0.9221	0.8570	1.0000														
EU	SX3P	0.8685	0.9161	0.9054	0.9161	0.8988	0.9094	0.8672	0.8852	0.8943	0.8353	0.8774	1.0000													
	SX6P	0.8130	0.9028	0.8259	0.8898	0.8594	0.8426	0.8000	0.9194	0.8006	0.8298	0.8117	0.8827	1.0000												
	SX86P	0.8740	0.8589	0.8848	0.8714	0.8755	0.9004	0.9034	0.8176	0.8438	0.8528	0.8992	0.8317	0.7686	1.0000											
	SX8P	0.8640	0.8045	0.8142	0.8150	0.8635	0.8292	0.7899	0.7741	0.7860	0.8219	0.7894	0.8623	0.7825	0.8113	1.0000										
	SXDP	0.8398	0.8981	0.8764	0.9064	0.8798	0.8789	0.8358	0.8881	0.8505	0.8448	0.8476	0.9236	0.9105	0.7960	0.8231	1.0000									
	SXEP	0.8552	0.8965	0.9333	0.9474	0.8950	0.9489	0.9055	0.9030	0.9759	0.8252	0.9087	0.9198	0.8520	0.8470	0.8200	0.8861	1.0000								
	SXFP	0.8941	0.9229	0.9153	0.9466	0.9247	0.9297	0.8948	0.9229	0.8830	0.8804	0.9024	0.9296	0.9095	0.8754	0.8852	0.9151	0.9243	1.0000							
	SXKP	0.8656	0.9617	0.9276	0.9593	0.9275	0.9377	0.9192	0.9562	0.9027	0.8675	0.9273	0.9186	0.9326	0.8441	0.8033	0.9168	0.9154	0.9326	1.0000						
	SXNP	0.8891	0.9191	0.9297	0.9522	0.9208	0.9441	0.9071	0.9100	0.9145	0.8632	0.9154	0.9481	0.8897	0.8758	0.8979	0.9219	0.9475	0.9780	0.9339	1.0000					
	SXPP	0.8704	0.8950	0.9333	0.9340	0.8988	0.9434	0.9083	0.8762	0.9345	0.8322	0.9168	0.8929	0.8309	0.8519	0.8311	0.8728	0.9566	0.9268	0.8906	0.9452	1.0000				
	SXQP	0.8335	0.8587	0.8322	0.8592	0.8526	0.8442	0.7983	0.8514	0.8041	0.8082	0.8047	0.9425	0.8825	0.7980	0.8748	0.8738	0.8541	0.9166	0.8776	0.9206	0.8442	1.0000			

Table A. 70: US and EU Indices Volatility Correlation - Period 4

Appendix 9 – Dynamic Connectedness – Rolling Window Analysis



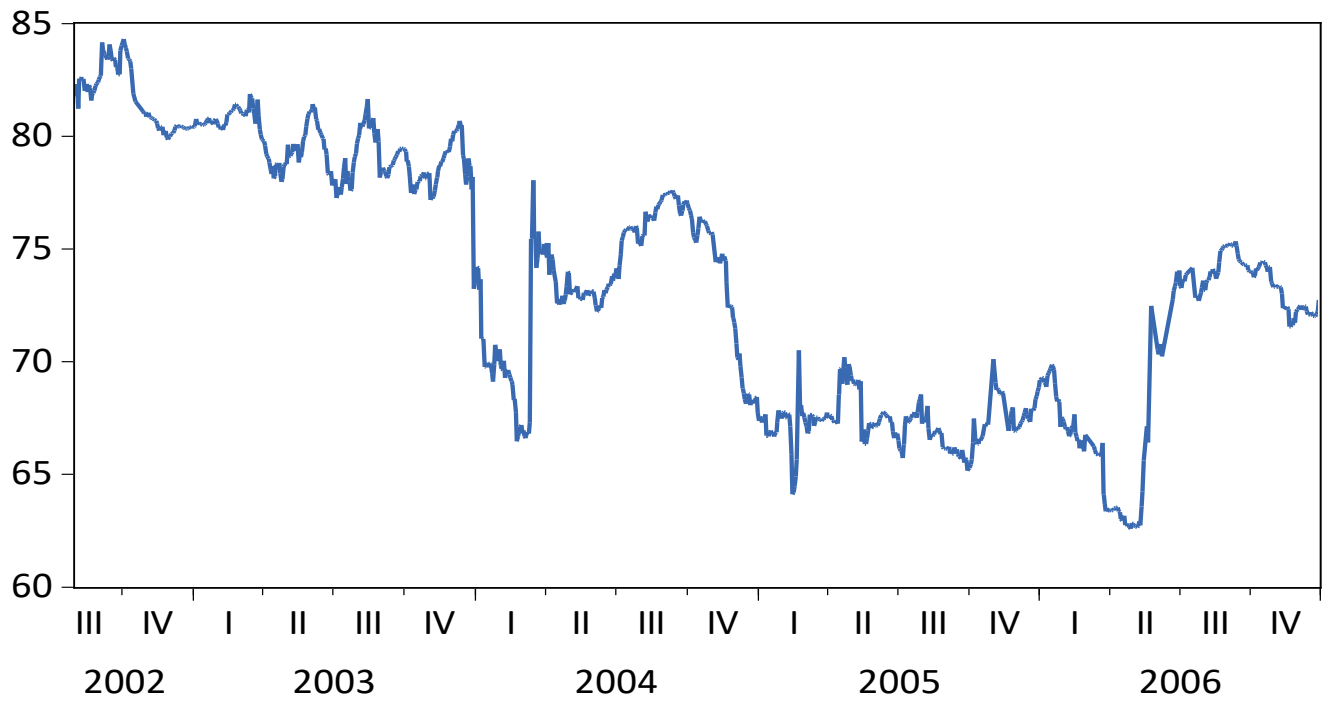


Figure A. 47: US and EU Period 1 Rolling Window Analysis

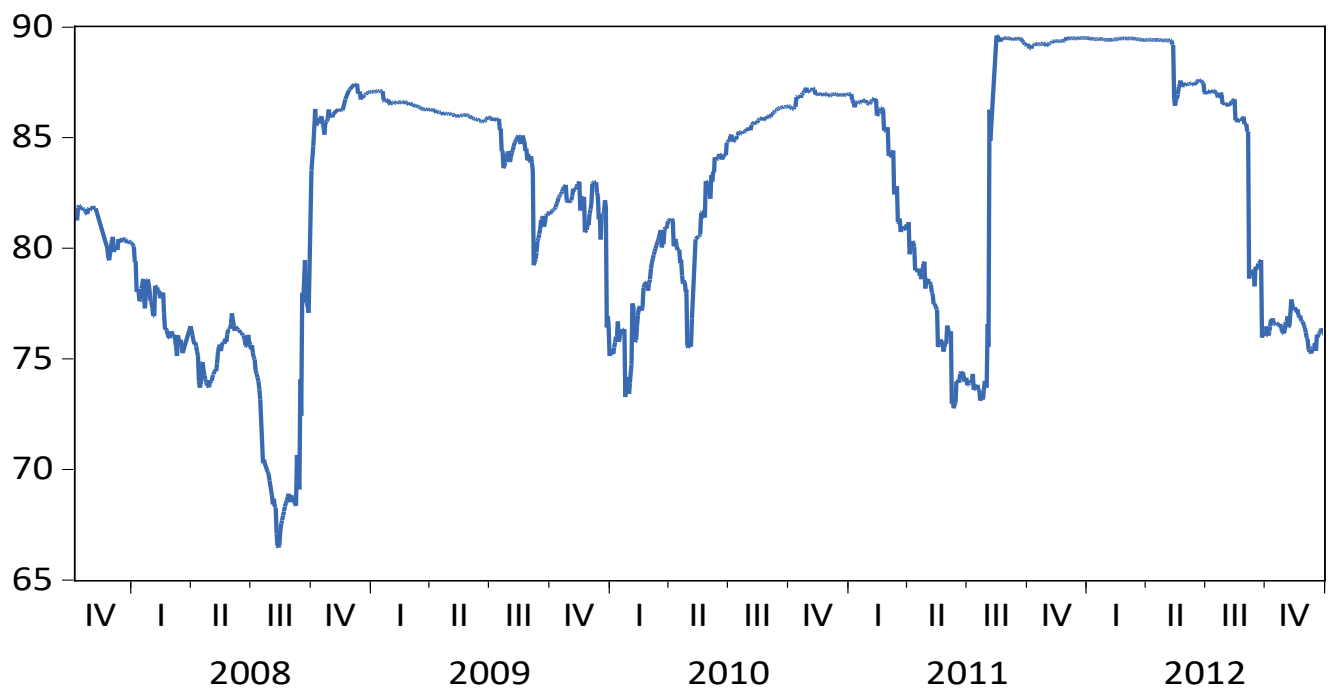


Figure A. 48: US Period 2 Rolling Window Analysis

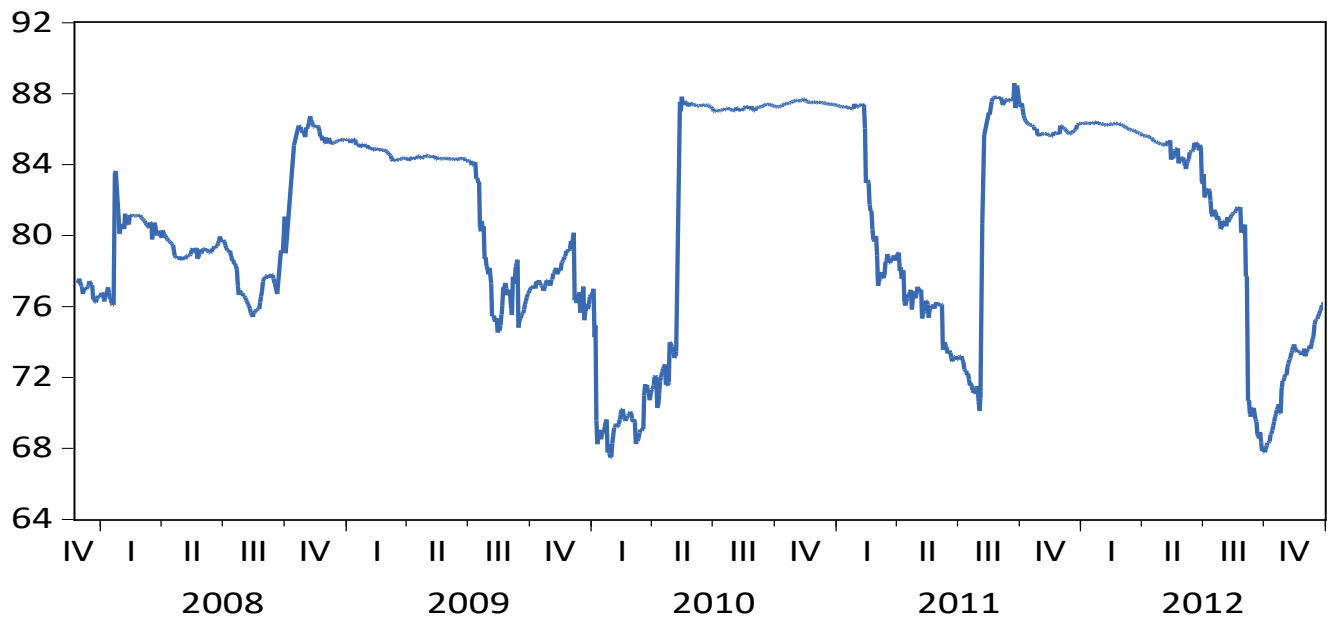


Figure A. 49: EU Period 2 Rolling Window Analysis

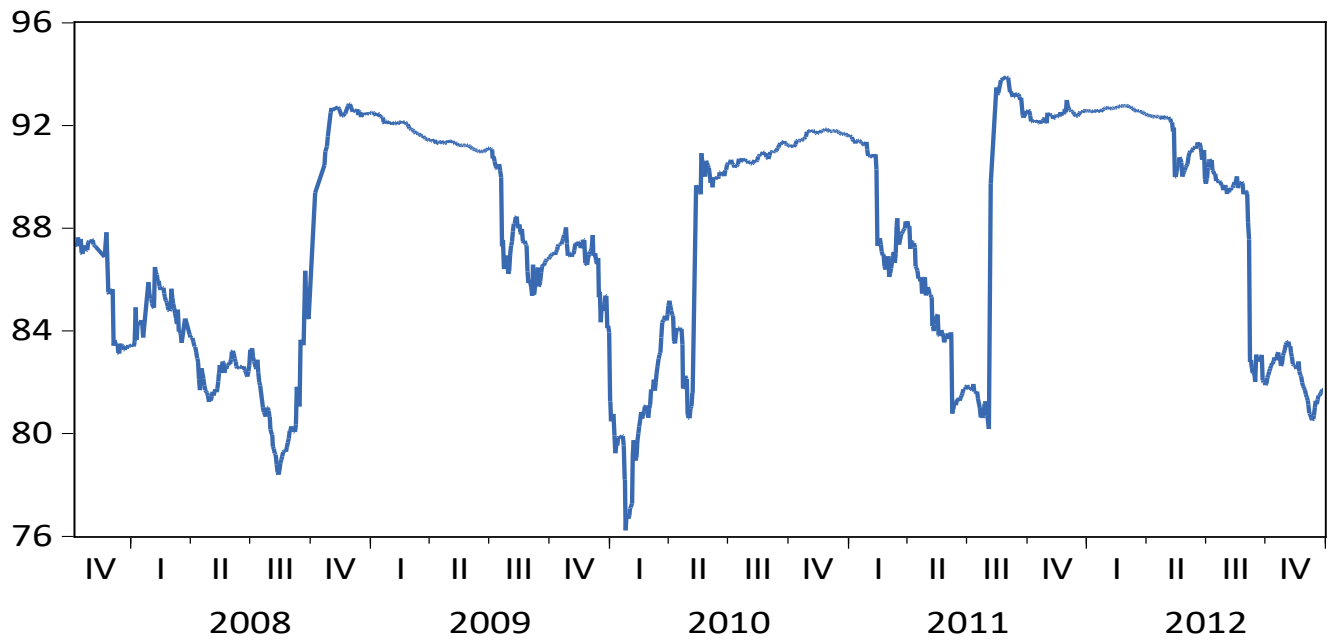


Figure A. 50: US and EU Period 2 Rolling Window Analysis

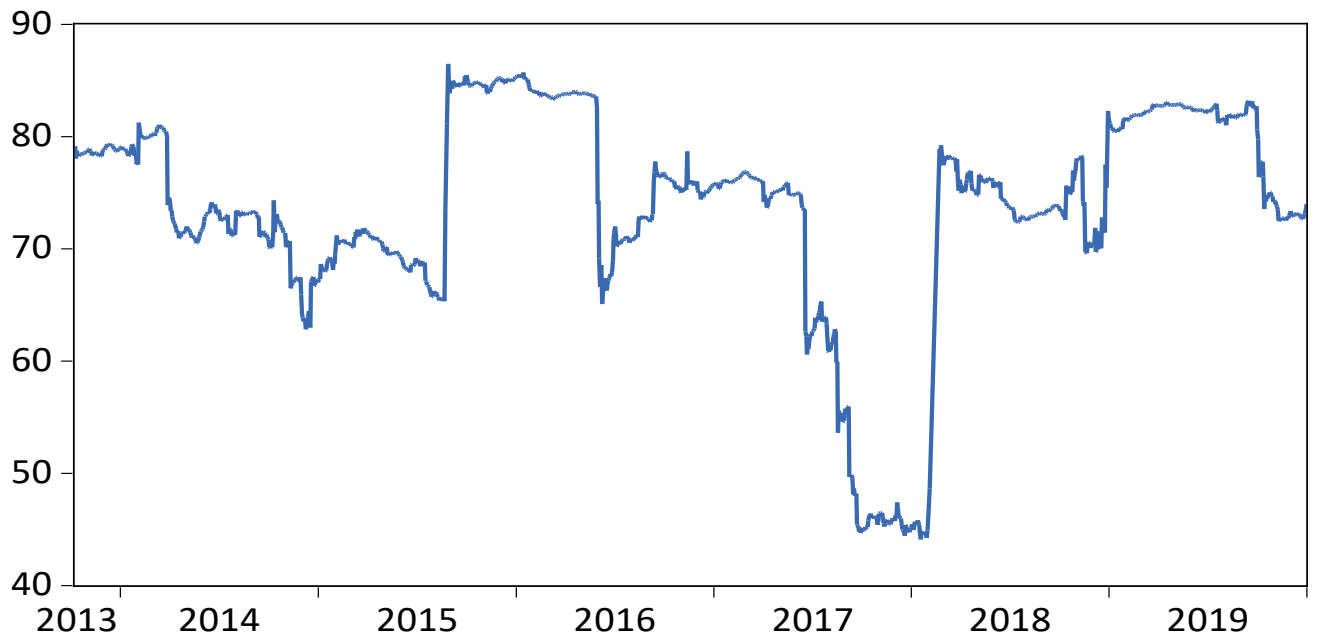


Figure A. 51: US Period 3 Rolling Window Analysis

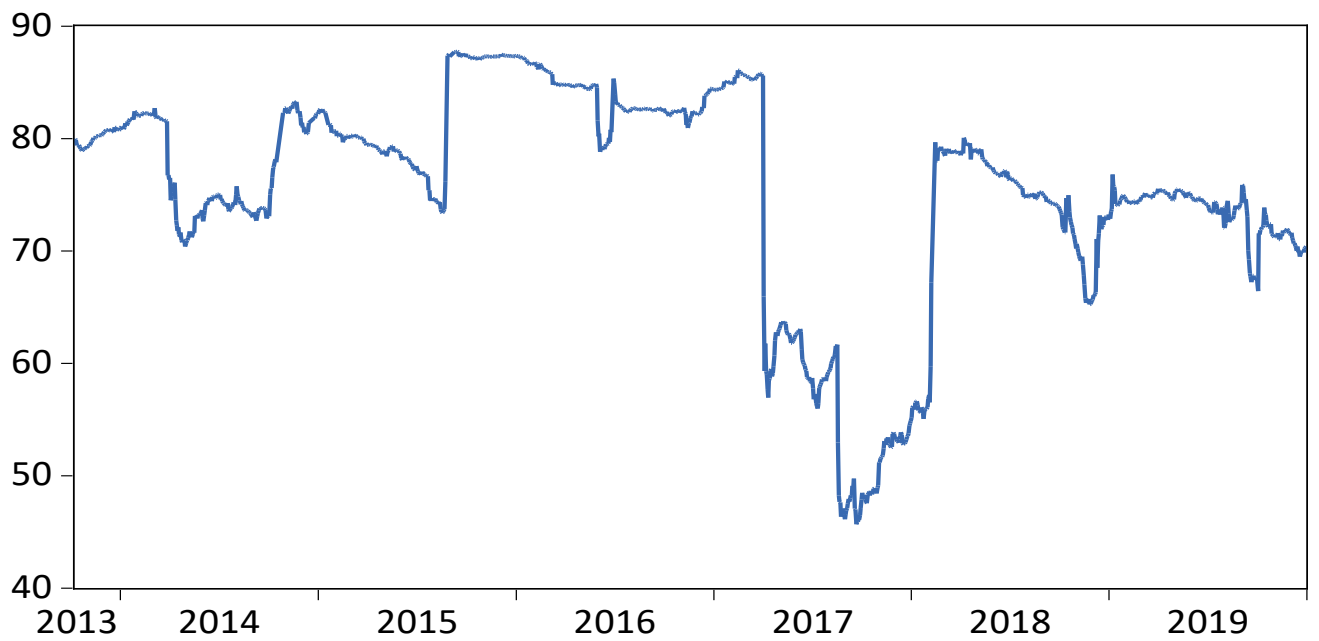


Figure A. 52: EU Period 3 Rolling Window Analysis

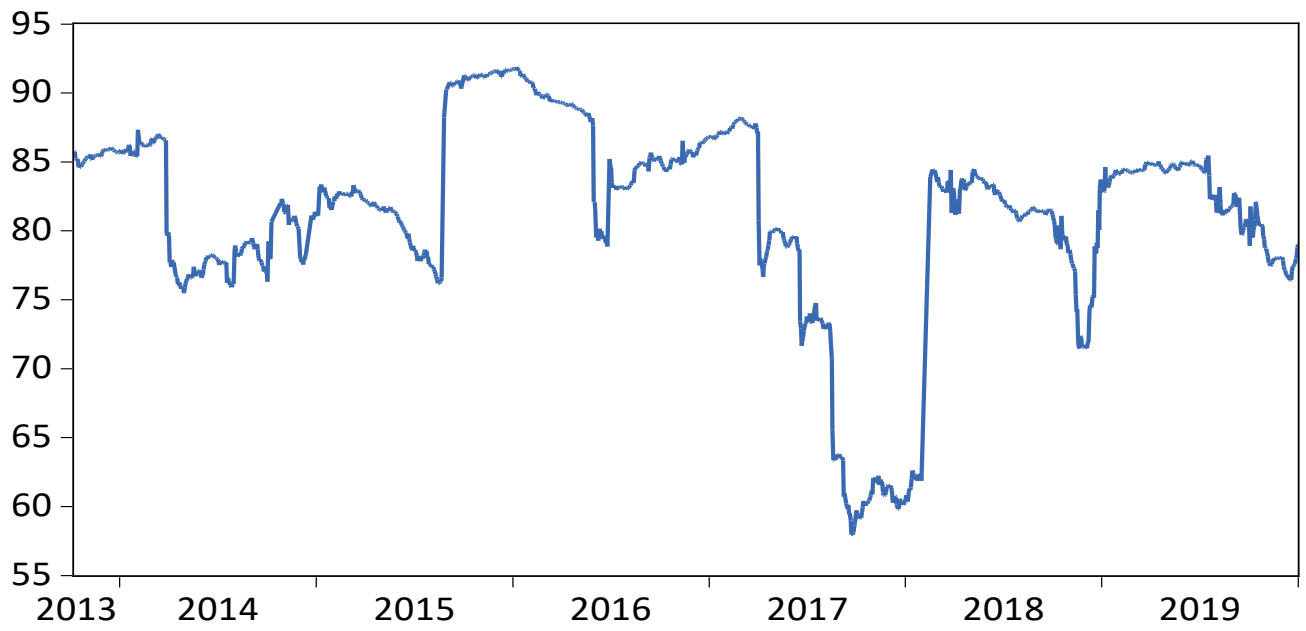


Figure A. 53: US and EU Period 3 Rolling Window Analysis

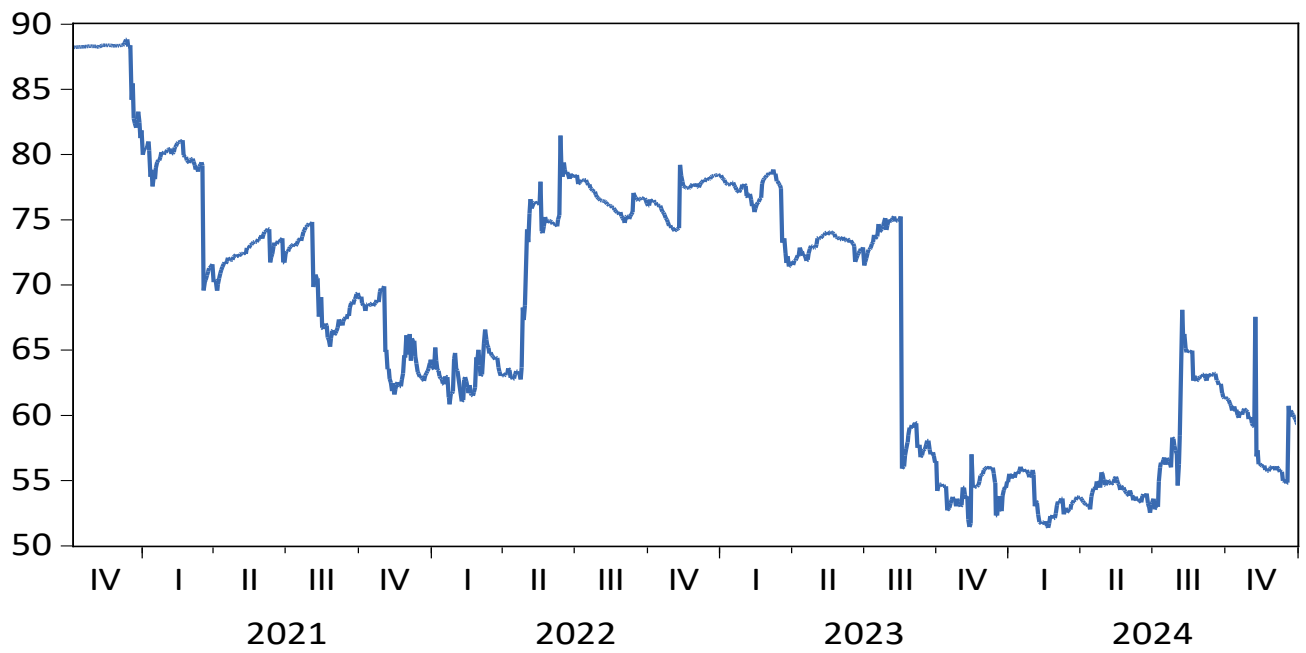


Figure A. 54: US Period 4 Rolling Window Analysis

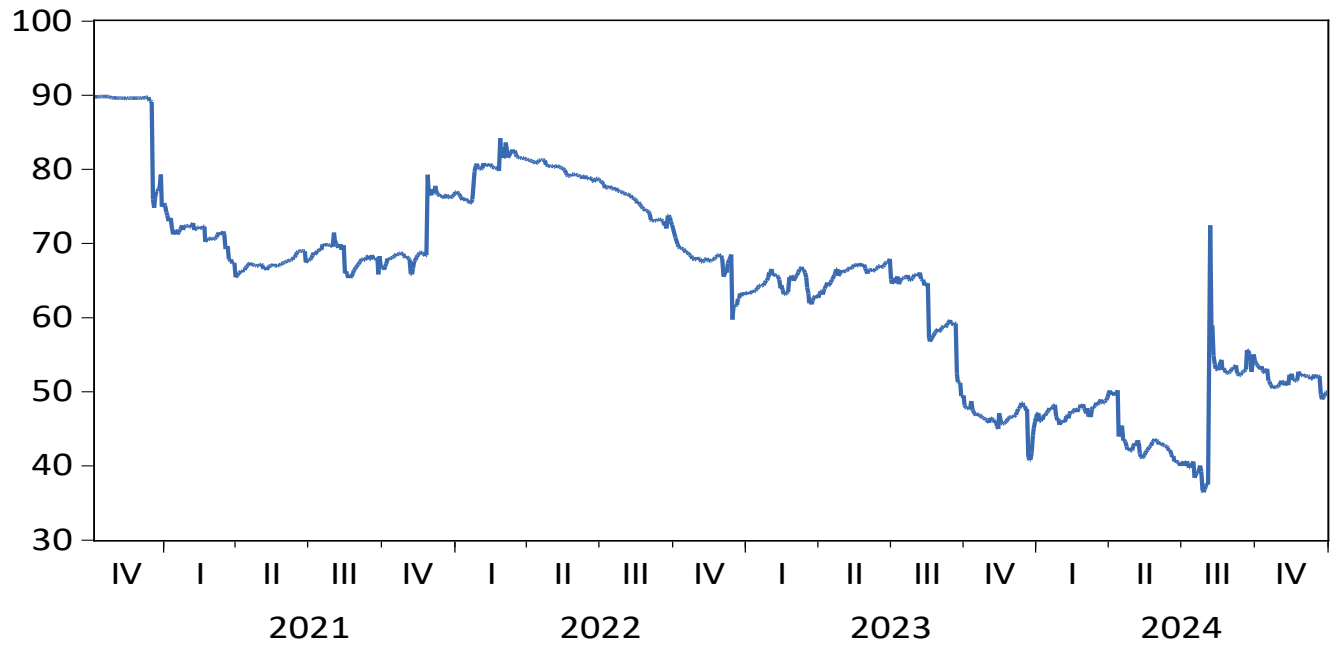


Figure A. 55: EU Period 4 Rolling Window Analysis

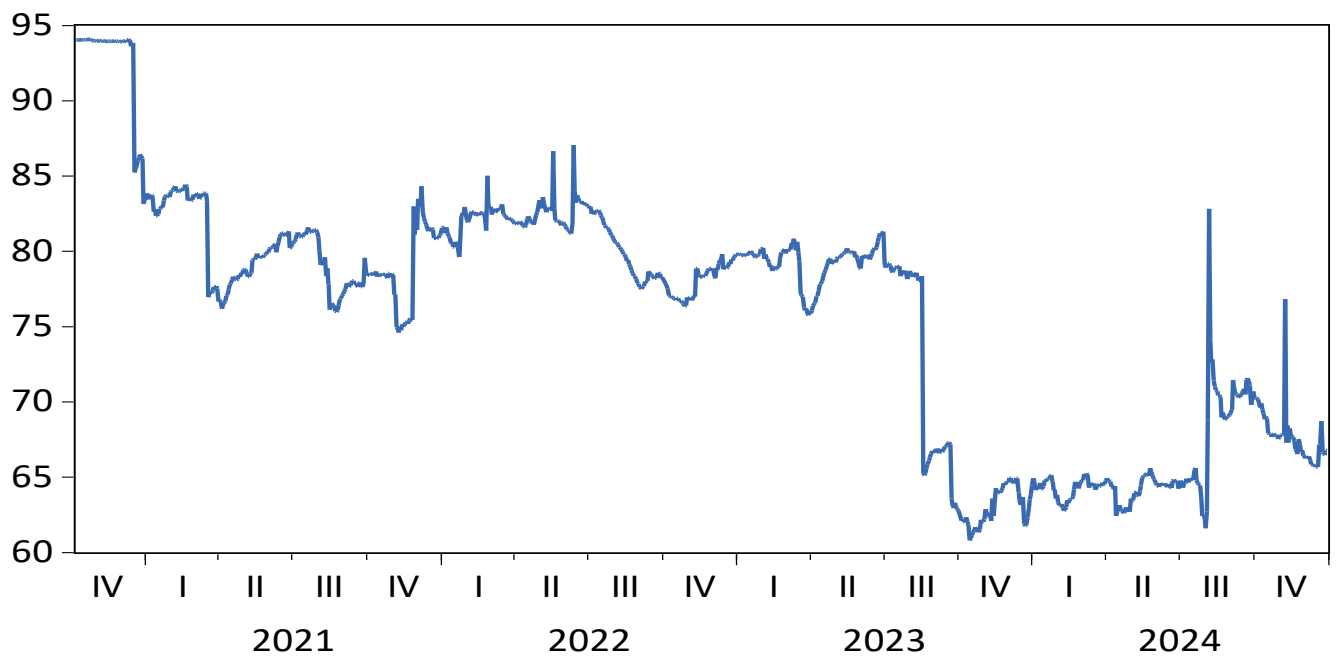


Figure A. 56: US and EU Period 4 Rolling Window Analysis