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Article

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Tail-risk spillovers and interconnectedness in international logistics markets: a QVAR approach

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ABSTRACT

This research explores the interdependence within the international logistics sector among 17 nations, utilizing a quantile-based technique to assess the transmission of returns. By analyzing daily data from DataStream spanning from 1 June 2016, to 12 August 2024, we apply the Quantile Vector Autoregression framework to examine the synchronous behavior of variables, considering the magnitude of shocks. Our findings reveal varying degrees of linkage at the lower, median, and upper quantiles of the conditional distribution. The results show that extreme events, such as the COVID-19 pandemic and the Russia-Ukraine war, significantly amplified spillovers across logistics markets, while the impact of the Israel-Hamas conflict was more regionally contained. Regional clustering and geographical proximity play a crucial role, with stronger interconnections observed among neighboring countries, such as the US and Canada, and Germany and France. The US stands out as a dominant transmitter of shocks, while countries in Asia and Oceania tend to be net receivers, highlighting their vulnerability to external disruptions. These results underscore the need for quantile-based risk assessments in regulatory frameworks and risk management strategies to better manage asymmetric risk transmissions during global crises.

IMPACT STATEMENT

The current study makes significant theoretical contributions to understanding interdependence and risk transmission in the global logistics industry, particularly under extreme market conditions. By employing the Quantile Vector Autoregression (QVAR) approach, we move beyond traditional mean-based analyses, which often overlook the critical behavior of markets during crises. Our focus on tail-risk spillovers highlights how extreme positive and negative shocks exert a much stronger influence on market dynamics than median shocks, advancing the literature on market interdependencies by introducing a more nuanced perspective on risk transmission during periods of stress and stability.

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1. Introduction

The importance of logistics and transportation in ensuring the smooth movement of people and goods has grown in recent decades due to the increased international trade. Companies are heavily reliant on these sectors as they facilitate the timely distribution of products and services. Yet, this sector has been significantly prone to global supply chain disruptions caused by various events such as the COVID-19 pandemic and the geopolitical tension (e.g. the Russia-Ukraine conflict and the ongoing Israel-Hamas conflict). This disruption is exemplified during the COVID-19 pandemic and translated into border restrictions, quarantine policies, and falling demand. The latter lockdowns and travel restrictions made it difficult not only for businesses to obtain necessary raw materials and components, but also have further limited the movement of goods and people. The consequence of economic recession forced many

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companies to reduce operations or temporarily shut down ended up reducing the demand for logistical services. However, the pandemic has also caused a surge in online shopping, leading to an increased need for eCommerce logistics services (Ho et al., 2021). Unfortunately, this increased demand has caused delays and congestion in the supply chain. Despite these difficulties, the industry has made progress by adopting automation and digitalization to reduce dependence on human labor and improve productivity.

The recent geopolitical tensions, such as the conflicts between Russia and Ukraine and Israel-Hamas, have caused significant disruptions with extensive geopolitical and economic consequences. These disruptions have particularly affected supply chains in the food, energy, and construction sectors, leading to increased costs of logistics services (Toygar & Yildirim, 2023). According to Chopei Viktoriia et al. (2024), the occupation of Ukrainian territory and the destruction of logistics infrastructure have created significant challenges in maintaining logistics operations in conflict-affected regions. These events have also had a profound impact on the geopolitical landscape, shaping Ukraine's integration efforts with Europe and causing significant shifts in trade relations across Europe (Melnikova, 2023). The ongoing conflict between Israel and Hamas has introduced another level of intricacy to global logistics. In this vein, border closures, restricted trade routes, and security concerns result in disruptions in critical sectors and exacerbate regional instability, affecting both the logistics industry and the broader economy in the region (Hokayem, 2023; Rivlin, 2024). These events stressed the significance of taking into account the potential risks associated with global trade and transportation in strategically vital regions (Ti & Kinsey, 2023).

The logistics industry is a major contributor in facilitating the connection between production and firm operations, hence promoting socioeconomic growth and establishing a notable impact on the global economy. Recent global major events, however, have heightened the weaknesses in the business and underscored the significance of examining its interdependence. Understanding the transmission of shocks within the logistics industry during crises is essential for portfolio managers and policymakers. To date, researchers attempted to evaluate the impact of global disruptions. Yet, there remains a notable gap in research focusing on how these events affect the logistics industry. This research examines the emerging role of logistics markets in the context of recent significant events including as the COVID-19 pandemic, the Russia-Ukraine conflict, and the Israel-Hamas war. Precisely, the focus of this study is to evaluate and compare the logistics equity indexes of 17 nations, both developed and emerging, and examine the interrelationships among them. Our research contributes to two key areas: (1) understanding the influence of these global crises on logistics markets, and (2) exploring the interconnectedness of these markets. This work offers a fresh perspective on the global interconnection within the logistics industry not only in the light of growing international commerce continues to grow, but also emphasize the logistics sector's vulnerability to geopolitical events and underscore the importance of understanding how shocks are transmitted within the industry during such periods. It is a widely held view that the lockdown policies during COVID-19 pandemic posed significant challenges to logistics. More particularly, logistics companies faced strict import and export restrictions, decreased demand for passenger travel, and changes in customer relationships (Mitrkęga & Choi, 2021; Perkumiene et al., 2021). Equally, recent geopolitical tensions (the Russia-Ukraine war and the Israel-Hamas conflict) has exacerbated these challenges by disrupting energy and food supply chains, increasing logistics costs, and damaging critical infrastructure. The tensions have also led to broader geopolitical shifts that have impacted global trade routes. These crises stress the vulnerability of logistics sector to geopolitical events and underscore the importance of understanding how shocks are transmitted within the industry during such periods.

The existing literature on the interconnectedness between the global shipping markets and other financial sectors is extensive and focuses particularly on volatility spillover, specifically within the shipping industry. This literature can be divided into three primary strands. The first strand focuses on how information is transmitted between spot markets and freight market derivatives, particularly in shipping markets. In the seminal work of Kavussanos and Visvikis (2004), the authors suggest that Forward Freight Agreements (FFAs) help discover information faster than spot markets. In a following work, Kavussanos et al. (2014) stressed that derivatives like FFAs and futures contracts play a critical role in transmitting information and predicting spot market behavior. Similarly, Yin et al. (2017) reveal that forward contracts play a significant role in predicting spot rate fluctuations in the dry bulk shipping market and help improve market participants' risk management strategies. By employing a vector-autoregression (VAR)

model Yang et al. (2022) highlight the critical role of secondhand ship prices as better indicators of market conditions than newbuild prices due to their immediate availability for operation, showing that these derivative-like markets reflect economic changes more swiftly than traditional asset markets. In a second strand, various studies have assessed the efficacy of fluctuations in oil prices and its influence on shipping rates, particularly in the tanker market. Sun et al. (2018) assess the connection between the volatility in oil price markets and dry bulk forward freight agreements. They have ascertained the use of dynamic conditional correlation-based models for hedging strategies (see also, Sun et al., 2020). Using GARCH models, Gavrilidis et al. (2018) highlight that oil price shocks excessively affect smaller tankers. Recently, Riaz et al. (2023) and Maitra et al. (2021) extended this analysis by using spillover index methodologies to reveal heightened linkages between crude oil prices and freight rates or the logistic sector, especially during extreme market events like the global financial crisis and the COVID-19 pandemic. The latter significant spillover effects on logistics firms' stock returns, underscoring the importance of commodity prices in shaping the economic environment of logistics and shipping industries, which further underscore the need for sophisticated risk management strategies in times of economic uncertainty. New findings amongst shipping markets provide further evidence that climate policy uncertainty can significantly influence shipping markets, particularly during extreme market conditions. According to Meng et al. (2023), there is a bidirectional and asymmetric spillover between carbon finance and dry bulk shipping. This asymmetry reveals the stable yet crisis-prone interdependencies between these markets. Chen et al. (2024) further highlight the role of climate policy uncertainty in exacerbating the spillover effects between carbon, energy, and shipping markets. Their findings indicate that conventional shipping and energy industries are more vulnerable to volatility in carbon markets when climate concerns are severe.

Third strand of the literature focuses on modeling the volatility of shipping freight rates and possible spillovers across different market segments (Drobetz et al., 2012; Tsouknidis, 2016). Utilizing a value-at-risk (VaR) approach, Yang et al. (2022) measure risk spillover effects in the dry bulk shipping market. Their findings ascertain how external shocks from related markets drive volatility across vessel types. Ju et al. (2024) employ time-frequency analysis to investigate bidirectional spillover effects between freight markets and shipping supply chains. They reveal that volatility spillovers differ across market segments, depending on both long-term trends and short-term cyclical fluctuations.

Despite the extensive research in the literature, there is a dearth of comprehensive analysis in the logistics sector literature about the interdependencies across industries. The latter results in a substantial lack of knowledge of the sector and its widespread effects. With exception of the work of Maitra et al. (2021) which explored the topic using dynamic equicorrelation and spillover index, the data used does not include the recent COVID-19 pandemic. Besides, several studies have shown that the pandemic heightened volatility in financial markets (Lyócsa & Molnár, 2020), and increased the transmission of tail risk (Alqaralleh, 2024; Alshater et al., 2023; Guo et al., 2021). Moreover, research has revealed that the pandemic's impact on oil and stock market volatility surpassed that of the 2008 global financial crisis (Zhang & Hamori, 2021).

Given this setting, studying the interconnectedness of logistics indices is a critical area of research in the field of economics. This research is of great significance, especially in regard to security and the creation of policies. This area gained momentum in light of the global economic slowdown resulting from the pandemic that has presented significant challenges globally. The uncertainties in the global economy, along with the adoption of lockdown measures, have profoundly affected the global supply chain and caused substantial disruptions, as noted by McKee and Stuckler (2020). However, The ongoing worldwide disturbance in the financial and economic domains, triggered by the COVID-19 pandemic, exhibits notable distinctions from other crises, such as the global financial crisis. Regulators and investors must fully understand the implications of lockdown measures on logistics markets. This study examines not just the COVID-19 pandemic but also the conflicts between Israel and Hamas, as well as Russia and Ukraine. The volatility in the market has been attributed to these events, and the logistics sector has been particularly impacted. Moreover, the market sentiment is influenced by geopolitical events, which subsequently affect traders' risk assessments. Enhanced portfolio creation and hedging techniques may be achieved by gaining a more profound comprehension of the logistics industry's risk propagation and directional spillovers. Policymakers must comprehend market spillovers, connections, causes, and procedures to effectively stabilise global markets during periods of crisis. On top of that, prior research has

mostly focused on traditional indicators of interconnectivity, such as correlations and the spread of market disruptions, which may not comprehensively reflect the interdependencies within the financial system during times of strain. By employing quantile-based measurements, it is possible to distinguish the level of interconnectivity at distinct quantiles and detect transmission patterns at the top, middle, and lower extremities of the data.

In this study, we use quantile-based spillover measures to analyze the connectedness of the logistics industry in 17 countries. We use daily data from 1 June 2016, to 14 August 2024, and examine both positive and negative shocks, focusing on differences in connectedness across the left, median, and right tails of the conditional distribution. We also assess the variation in tail-dependence over time and the impact of major economic events. The data, sourced from DataStream, includes daily stock returns for the following countries: US, Canada, Australia, Germany, Japan, India, France, Taiwan, Norway, Hong Kong, Singapore, Korea, Malaysia, New Zealand, Denmark, Thailand, and Brazil. By studying the connectedness of the logistics industry during various market states, our findings can inform risk management strategies and improve policymaking decisions.

This study has confirmed the varying degrees of connectedness across global logistics markets, with European and American countries, especially the United States, consistently acting as net transmitters of spillovers. In contrast, Asian and Oceanic nations often serve as net receivers, leaving them more vulnerable to external shocks. The TCI surged during significant global events like the COVID-19 pandemic and the Russia-Ukraine war, and, to a lesser extent, the Israel-Hamas conflict, reflecting increased market interdependence and heightened spillovers. Although the TCI gradually declined during the global economic recovery, it remained elevated in the upper and lower quantiles, indicating sustained sensitivity to extreme market conditions. This elevated TCI in the extremes suggests that return shocks spread more rapidly at the tails than at the median, underscoring the importance of using quantile-based analyses to fully capture spillover dynamics during crises. The study also shows that connectedness is highly dynamic, surging during crises and easing as volatility decreases, though it remains elevated at the extremes. This pattern underscores the vulnerability of global logistics markets to extreme events, which amplify spillover effects and heighten market risks. These insights carry significant implications for regulators, investors, and portfolio managers in the logistics industry. The study underscores the importance of focusing on extreme events and implementing flexible risk management strategies that address the time-varying and asymmetric nature of risk transmission. By adopting these approaches, stakeholders can more effectively navigate the volatile and interconnected global logistics landscape, ultimately improving market stability and resilience against future disruptions.

This study makes several significant contributions to the existing literature on the connectedness of international logistics markets. Firstly, it builds on the understanding that market linkages can vary substantially during bearish, normal, and bullish (El Khoury et al., 2024). Using the quantile-based vector autoregressive (QVAR) method, the study analyzes volatility across these markets. This investigation applies VAR models within quantile regression to explore the interdependencies between extreme positive and negative shocks in the logistics markets. By focusing on the highest and lowest points in the distribution of shock sizes (i.e. the 95th and 5th percentiles), the study effectively captures the interconnectedness linked to these exceptional shocks, providing deeper insights than solely focusing on the median quantile. Through the analysis of tail risk propagation, the study gains a more comprehensive understanding of the intricate network of interdependencies. Secondly, the volatility spillover in the logistics sector is evaluated using the net-pairwise volatility spillover index. This broader perspective offers additional insights into how shocks spread across markets. Thirdly, analyzing the impact of the pandemic on the interdependence of global logistics markets enriches the existing body of knowledge by providing a unique analysis of the pandemic's significant consequences on the logistics industry. Finally, the study's division into three key periods (COVID-19, the Russian-Ukraine conflict, and the Israel-Hamas conflict) also highlights the varying intensity and persistence of these shocks, demonstrating how different crises impact the network of logistics markets in distinct ways. The study's results provide a detailed understanding of the complex connections within these highly volatile and often controversial markets. These findings are particularly relevant for researchers, professionals, and policymakers in the logistics industry, as they emphasize the importance of accounting for extreme risks and understanding the intricate network of interdependencies within these markets. The segmentation of

the sample into these three critical periods also allows stakeholders to assess the long-term implications of each event on the global logistics landscape.

The study's practical results might have a substantial impact on ship owners, investors, and regulators, among other actors in the logistics business. This study aims to provide insights into the risk factors and spillover effects in logistics markets, with the goal of improving portfolio diversification and hedging strategies in times of economic instability, the transfer of instability from one market to another can offer useful insights into the potential of market downturns. This enables both individuals and regulatory agencies to take proactive steps to lessen the adverse impacts. For example, those working in the maritime business might modify their routes and trading methods according to the discoveries made in this research. Likewise, Investors, such as portfolio managers and traders, can enhance their decision-making in relation to their portfolios by taking into account the dynamic spillover effects across logistics. This insight may be of great help to regulators in formulating efficient regulations to mitigate critical consequences during market stress. Furthermore, the study highlights the need to include extreme occurrences in risk management plans and emphasises the need to acquire a more thorough comprehension of the interaction between logistical indicators.

From a modelling perspective, the observation that return spillovers exhibit distinct behaviour at the lower and upper quantiles suggests that relying just on average measures may not sufficiently capture all the interconnectedness within the system. During periods of economic uncertainty, disregarding this issue might lead to insufficient or ineffective stabilisation measures. Investors in the logistics business should also take into account the practical consequences. Hence, in times of market duress, traders must adapt their assessments and risk management strategies accordingly. Furthermore, traders and portfolio managers must possess the adaptability to adjust their positions in response to shifts in market dynamics caused by alterations in pairwise return spillovers.

In the following sections, we will lay out the econometric modeling framework in [Section 2](#), describe the data in [Section 3](#), present the results and findings in [Section 4](#), and conclude the paper in [Section 5](#).

2. Econometric modelling framework

The quantile connectedness approach is employed to analyze the co-movement among variables, accounting for the strength of shocks. Unlike traditional mean-based VAR models that focus on average relationships, this technique captures the impacts of both extreme positive (higher quantile) and negative (lower quantile) structural shocks, rather than just regular market conditions (median quantile). The joint quantile approach further assesses whether the magnitude of connectedness shifts based on market states (bearish, bullish, and normal). This model is particularly well-suited to capture the complexities of risk transmission in the logistics sector during extreme market conditions, such as those seen during the COVID-19 pandemic and the Russia-Ukraine conflict, where market shocks propagate differently across varying periods of stress and stability.

2.1. Quantile VAR model

In reference to the influential research conducted by Koenker and Bassett (1978), the τ^{th} conditional quantile of one logistics series y_n on a vector of explanatory variables x_n at every quantile ($\tau \in (0, 1)$) can be represented as

$$Q_\tau(y_t|x_t) = x_t\beta(\tau) \quad (1)$$

In [Eq. \(1\)](#), the dependence relationship at every quantile ($\tau \in (0, 1)$) of y_n and the x_n is denoted by $\beta(\tau)$ can be estimated through the following:

$$\hat{\beta}(\tau) = \underset{\beta(\tau)}{\operatorname{argmin}} \sum_{t=1}^T \left(\tau - 1_{\{y_t < x_t\beta(\tau)\}} \right) |y_t - x_t\beta(\tau)| \quad (2)$$

Accordingly, the VAR process of order P then be given as follows:

$$y_n = c(\tau) + \sum_{\tau=1}^P \beta_i(\tau) y_{n-\tau} + \varepsilon_t(\tau); \forall n = 1, \dots, N \quad (3)$$

where the n -dimensional endogenous vector an at time t is represented by y_n , and the n -dimensional intercept term at the quantile τ is $c(\tau)$. A matrix of n -dimensional lag coefficients at quantile τ is represented by $\beta_i(\tau)$, while the n -dimensional residual term at quantile τ is represented by $\varepsilon_t(\tau)$.

Given that the error term $\varepsilon_t(\tau)$ fulfils the population quantile limit of $Q_\tau(\varepsilon_t(\tau)|y_{t-1}, \dots, y_{t-p}) = 0$, the estimated values of y at each conditional quantile τ may be estimated as

$$Q_t(y_t|y_{t-1}, \dots, y_{t-p}) = c(\tau) + \sum_{\tau=1}^P \hat{\beta}_i(\tau) y_{n-\tau} \quad (4)$$

2.2. Quantile spillover model

Once the quantile vector autoregression QVAR(p) is determined, its quantile vector moving average representation QVMA(∞) is then constructed using Wold's theorem as follows:

$$\sum_{\tau=1}^P \beta_i(\tau) y_{n-\tau} + \varepsilon_t(\tau) = c(\tau) + \sum_{i=1}^{\infty} \Psi_i(\tau) \varepsilon_t(\tau) \quad (5)$$

Where $\beta_i(\tau)$ is an $N \times N$ dimensional QVAR coefficient matrix.

According to Pesaran and Shin (1998) (also see (Chatziantoniou et al., 2022)), we may use the h -step-ahead forecast to compute the Generalised Forecast Error Variance Decomposition (GFVD). To do this, we need to create the related shocks in the following manner.

$$\theta(h)_{ij} = \frac{(Y(\tau))_{jj}^{-1} \sum_{h=0}^H ((\Psi_h(\tau) Y(\tau))_{ij})^2}{\sum_0^H ((\Psi_h(\tau) Y(\tau) \Psi'_h(\tau))_{ii})} \quad (6)$$

The estimated contribution of the variation within a market and the variance across different markets in Eq.6 is then normalized so it provides a measure of pairwise connectedness at each quantile τ from logistic industry in the country (i) spillover to country (j) at horizon H as follows:

$$\tilde{\theta}_{ij}(h) = \frac{\theta(h)_{ij}}{\sum_{j=1}^N \theta_{ij}}; s.t \sum_{j=1}^N \tilde{\theta}_{ij}(h) = 1 \text{ and } \sum_{i,j=1}^N N^g_{ij,t} (K) = N \quad (7)$$

Eq. (7) may be utilised to evaluate the level of interconnectedness in the time-based domain. Likewise, one can borrow from the spectral decomposition method of Stiasny (1996) to consider the connectedness relationship in the frequency domain. To the latter end, consider the frequency response function of the form $\Psi(e^{-i\omega}) = \sum_{h=0}^{\infty} e^{-i\omega h} \Psi_h, i = \sqrt{-1}$. The spectral frequency of the series y_t at each frequency (ω) can be given as a Fourier transformation of the QVMA(∞) as follows:

$$S_y(\omega) = \sum_{h=0}^{\infty} E(y_t y'_{t-h}) e^{-i\omega h} = \Psi(e^{-i\omega h}) Y_t \Psi(e^{+i\omega h}) \quad (8)$$

From Eq. (8) one may conclude that the frequency GFVD is nothing but a combination of both spectral density and the GFVD. Viz

$$\theta(\omega)_{ij} = \frac{(Y(\tau))_{jj}^{-1} \left| \sum_{h=0}^H (\Psi(\tau)(e^{-i\omega h}) Y(\tau))_{ij} \right|^2}{\sum_0^H (\Psi(\tau)(e^{-i\omega h}) Y(\tau) \Psi'(\tau)(e^{-i\omega h}))_{ii}} \quad (9)$$

Eq. (9) is then normalized as

$$\tilde{\theta}_{ij}(\omega) = \frac{\theta(\omega)_{ij}}{\sum_{j=1} \theta_{ij}} \quad (10)$$

where $\tilde{\theta}_{ij}(\omega)$ is the fraction of the j^{th} series' spectrum at a specific quantile τ that is attributable to a shock in the j^{th} series.

Subsequently, information on the transmission of effects within particular quantile may be calculated using the same methodology as in (Diebold & Yilmaz, 2012, 2014), with comparable explanations. These measurements include the following

The net pairwise directional connectedness (NPDC) is as follows:

$$NPDC_{ij}(d) = \tilde{\theta}_{ij,t}(d) - \tilde{\theta}_{ji,t}(d) \quad (11)$$

Total directional connectedness from others, given as:

$$FROM(d) = C_{i \rightarrow j,t}(d) = \frac{\sum_{i,j=1, i \neq j}^N \tilde{\theta}_{ij,t}(d)}{\sum_{j=1}^N \tilde{\theta}_{ij,t}(d)} * 100 \quad (12)$$

Total directional connectedness to others, given as

$$TO(d) = C_{i \leftarrow j,t}(d) = \frac{\sum_{i,j=1, i \neq j}^N \tilde{\theta}_{ji,t}(d)}{\sum_{j=1}^N \tilde{\theta}_{ji,t}(d)} * 100 \quad (13)$$

The net total directional connectedness can be obtained as follows:

$$NET(d) = FROM(d) - TO(d) \quad (14)$$

3. Data

In this study, our dataset consists of the daily closing price of seventeen logistics indices¹ in from 1 June 2016 to 14 August 2024, collected from DataStream. Dictated by data availability, the countries included are the US, Canada, Australia, Germany, Japan, India, France, Taiwan, Norway, Hong Kong, Singapore, Korea, Malaysia, New Zealand, Denmark, Thailand, and Brazil.

The 17 countries in this study were selected based on their economic significance in global logistics, geographic diversity, data availability, and market characteristics. Key players like the US, Germany, and China, major hubs for international trade, were included to capture the dynamics of the most influential markets. Geographic diversity across North America, Europe, Asia, and Oceania ensures that regional variations and responses to global crises are well-represented. Reliable high-frequency data on logistics indices were a priority, ensuring robust analysis. Finally, the inclusion of both developed and emerging markets allows us to examine how different economic structures and vulnerabilities influence spillovers in the logistics sector.

Table 1. Descriptive statistics of daily returns of the logistic indices.

	US	CAN	AUS	DEU	JPN	IND	FRA	TWN	NOR	HKG	SGP	KOR	MYS	NZL	DNK	THA	BRA
Mean	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Median	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Standard deviation	0.01	0.01	0.01	0.02	0.01	0.02	0.01	0.02	0.02	0.01	0.01	0.02	0.01	0.01	0.02	0.01	0.02
Range	0.23	0.24	0.27	0.25	0.19	0.23	0.32	0.20	0.19	0.16	0.18	0.23	0.18	0.27	0.22	0.26	0.39
Minimum	-0.12	-0.13	-0.17	-0.14	-0.09	-0.16	-0.16	-0.12	-0.11	-0.06	-0.09	-0.13	-0.09	-0.17	-0.13	-0.13	-0.23
Maximum	0.11	0.11	0.10	0.11	0.09	0.07	0.17	0.09	0.08	0.09	0.08	0.11	0.09	0.11	0.09	0.13	0.16
Skewness	-0.53	-0.88	-1.07	-0.34	0.19	-1.27	-0.36	-0.34	-0.63	-0.20	-0.24	-0.03	-0.18	-1.50	-0.38	-0.03	-1.38
Kurtosis	9.61	16.70	26.50	8.72	6.61	11.10	23.50	5.82	3.99	3.60	12.30	6.06	9.39	32.80	3.79	27.40	17.90
N	2235																

This table presents the descriptive statistics of the daily returns from 1 June 2016 to 14 August 2022 for 17 countries. Country code as explained in Table 2.

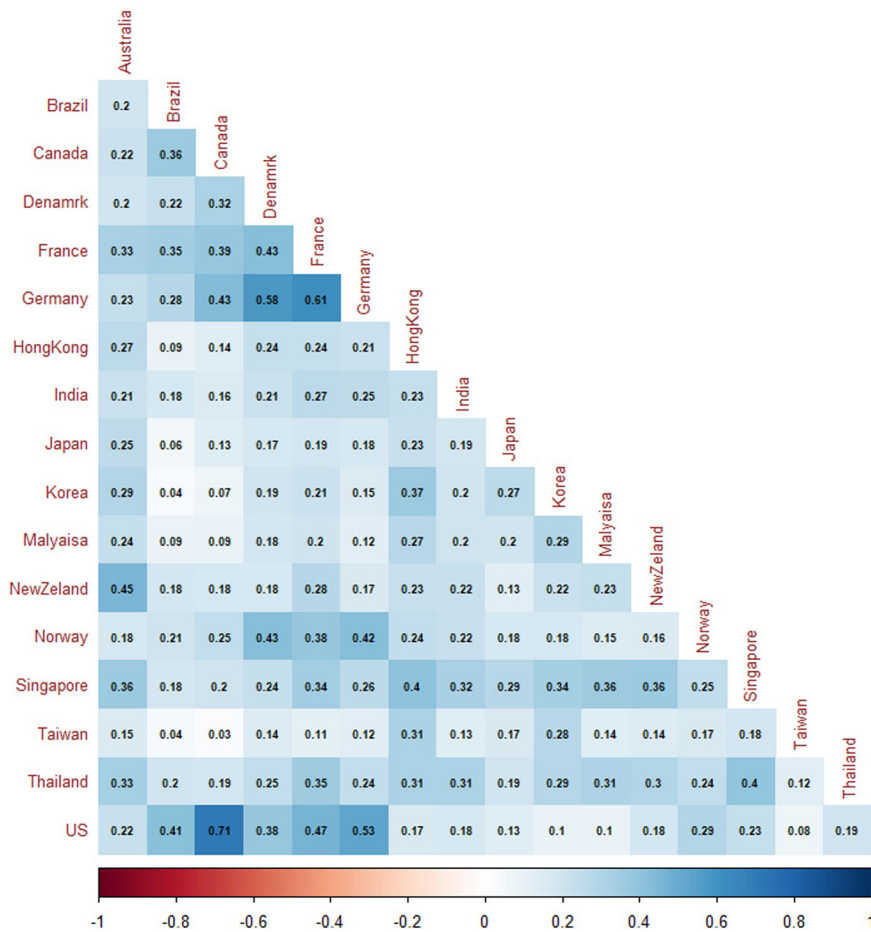


Figure 1. Correlation Heat Map: This figure reports the heatmap of the pairwise correlations between each of the logistic indices. Blue (red) denotes a positive (negative) correlation, while the colour refers to the intensity of the correlation.

Our analysis aimed to capture not only the impact of the COVID-19 pandemic but also the conflicts between Israel and Hamas, as well as Russia and Ukraine on the connectedness network of these indices.

Table 1 presents the descriptive statistics of the 17 indices, measured as logarithm first differences. The average means are close to zero for all countries, and the standard deviation values are similar and low, indicating that this industry is characterized by low fluctuations regardless of geographical location. Additionally, all indices display negative skewness and excess kurtosis exceeding three, suggesting sudden extreme negative returns and a peaked distribution with fat-tails. The Jarque-Bera test suggests that no series is normally distributed, consistent with the statistical results of skewness and kurtosis. The stationarity tests using Augmented Dickey Fuller (ADF) and Phillips-Perron (PP) unit root tests (Dickey & Fuller, 1979; Phillips & Perron, 1988), although not reported, reject the null hypothesis of the presence of a unit root and, hence, suggest that all series are stationary.

The correlation heat map is seen in Figure 1. Notably, the logistics indices of the US and Canada exhibit a very strong positive correlation (0.71), reflecting the close economic ties and integrated logistics networks between these two nations. Similarly, the indices of Germany and France show a strong positive correlation (0.61), which can be attributed to the robust economic connections within Europe. Other countries, such as Denmark and Germany (0.58), also demonstrate a significant level of co-movement. On the other hand, weaker correlations, represented by lighter shades, are seen between countries like Brazil and Japan (0.06), indicating less direct economic or logistical interdependence between their logistics markets. This heatmap reveals insightful information about the varying degrees of interconnectedness between global logistics markets, with certain regional clusters showing stronger correlations due to shared economic or geographical ties.

4. Empirical results

This section is devoted to the presentation and discussion of connection findings stemming from the connectedness analysis based on a quantile VAR (QVAR) model among the considered logistics indices. We begin by providing an average measure of the interdependence of these indices over the entire sample period. The dynamic evolution of TCI over time is then shown, which is useful for analyzing its response to various economic and political events during the sample period. Results are reported for the median, extreme lower, and extreme upper quantiles for comparison. We have also included net total connectedness results to better understand each index market's role (i.e. whether it is a net transmitter or receiver of shocks). Finally, the discussion and implications revolve around a dynamic analysis that examines the relationship between connectedness and specific events. This approach helps us better comprehend how the network's connectedness evolves over time.

4.1. Static connectedness analysis

Table 2 presents the connectedness measures among the logistics indices for the full sample period, calculated at the median ($\tau = 0.05$) using the quantile VAR model. The main diagonal elements represent each index's contribution, while the off-diagonal elements indicate the contribution 'from' or 'to' other indices. The rows show the effect each index receives from other indices in the system, while the columns show the effect of one specific index on all other indices.

Table 2 reports the static connectedness measures calculated for the full sample period, focusing on the median ($\tau = 0.5$) quantile in Panel B. The off-diagonal elements reflect the spillovers 'from' and 'to' each index, with rows representing the effects received by each index and columns showing the spillovers transmitted by each index. The results show a TCI of 46.5%, indicating a moderate level of return spillovers across the logistics markets. The US has the highest contribution to return spillovers (87.1%), followed closely by Germany (78.7%) and France (75.1%), highlighting their central role within the global logistics network. In contrast, Malaysia (26.5%) and New Zealand (26.7%) contribute the least to spillovers. Notably, India (36.4%) and Brazil (34.4%) are the least affected by external shocks, suggesting a degree of insulation from global market dynamics. Net connectedness results, presented at the bottom of Panel B in Table 2, further reveal that most European and American countries are net transmitters of shocks. Specifically, the US is the largest net transmitter (31.7%), followed by Germany and France, both contributing around 20%. Meanwhile, countries such as Australia, Japan, India, Taiwan, Hong Kong, Singapore, Korea, Malaysia, and New Zealand are net receivers of return spillovers. The largest net receivers are New Zealand and Japan, with net spillovers of approximately -15%, indicating their vulnerability to external shocks.

To understand how the intensity of shocks impacts connectedness, we extend the analysis to the lower ($\tau = 0.05$) and upper ($\tau = 0.95$) quantiles in Panels A and C, correspondingly. The TCI at the extreme lower and upper quantiles increases significantly to 72.4% and 72.8%, respectively, compared to 46.4% at the median, confirming that severe shocks amplify the transmission of returns across markets. These findings align with the contagion effect hypothesis, which posits that during periods of market stress, correlations between markets tend to increase, leading to more pronounced spillovers (Londono, 2019). However, the TCI at the extreme lower quantile does not exceed that at the extreme upper quantile. It is important to note that the contributions to others (TO) and contributions from others (FROM) are more substantial in both the lower and upper tails compared to the median. Interestingly, while the largest transmitters remain consistent across quantiles—the US, Germany, and France—there are some shifts in the net roles of countries when moving from the median to the tails of the distribution. The US, Canada, Germany, France, and Denmark remain net transmitters in all quantiles, whereas Australia, Japan, India, Taiwan, Korea, Malaysia, Thailand and New Zealand remain net receivers in all quantiles. Yet, Norway shifts from being a net receiver at the median to a net transmitter in both the lower and upper quantiles. Similarly, Singapore and Hong Kong, which are net receivers in the median and lower quantiles, become net transmitters at the upper quantile. The latter stressed that these economies play a more active role in transmitting shocks to other markets under more favorable market conditions. By

Table 2. Return spillovers in the quantile VAR.

Lower Quantile; TCI =72.46																		
	US	CAN	AUS	DEU	JPN	IND	FRA	TWN	NOR	HKG	SGP	KOR	MYS	NZL	DNK	THA	BRA	FROM
US	25.71	11.99	2.94	8.14	3.54	2.96	6.95	2.29	4.61	3.63	3.80	2.72	2.77	2.78	6.61	3.17	5.39	74.29
CAN	12.93	27.34	3.50	6.39	3.88	2.90	6.27	2.41	4.15	3.51	3.77	2.74	3.14	3.12	5.58	3.41	4.94	72.66
AUS	5.29	5.22	26.91	5.16	4.79	3.35	6.23	3.33	3.98	4.17	4.69	4.14	3.65	6.01	4.32	4.46	4.29	73.09
DEU	8.11	5.62	3.27	24.03	3.37	3.60	10.19	2.71	6.35	3.69	3.73	3.24	2.65	2.44	9.14	4.10	3.78	75.97
JPN	6.36	5.37	4.75	5.08	26.89	3.73	5.39	3.88	4.51	4.22	5.21	4.45	3.89	3.15	5.01	4.27	3.86	73.11
IND	4.54	3.90	3.71	4.94	4.24	32.14	4.99	3.51	4.23	4.70	5.10	3.47	3.96	3.35	4.22	4.98	4.01	67.86
FRA	7.25	5.77	4.20	10.15	3.33	3.43	24.70	2.61	5.72	3.76	4.06	3.38	2.96	3.42	6.41	4.01	4.83	75.30
TWN	4.71	3.51	3.86	4.43	4.37	3.38	4.27	30.56	4.64	6.93	4.97	5.57	3.75	3.68	4.57	3.16	3.62	69.44
NOR	5.55	4.64	3.52	7.24	3.75	3.54	6.37	3.56	27.77	4.45	4.20	3.74	3.31	2.86	7.34	3.99	4.16	72.23
HKG	5.58	4.43	4.05	5.17	4.00	3.79	5.16	5.29	4.79	23.78	6.62	5.55	4.23	3.30	5.08	4.96	4.22	76.22
SGP	5.39	5.44	4.73	5.03	4.75	4.21	5.25	3.83	4.10	6.77	25.06	4.53	4.68	4.14	3.96	4.84	4.20	74.94
KOR	5.21	4.02	4.30	4.81	4.27	3.40	5.26	4.86	4.60	6.44	4.92	26.43	4.69	3.43	4.80	4.63	3.91	73.57
MYS	4.62	4.30	3.98	4.19	4.58	4.08	4.68	3.80	3.75	5.08	5.47	4.70	29.51	3.50	4.54	5.19	4.03	70.49
NZL	5.55	5.27	6.66	4.60	3.45	3.26	5.40	3.77	3.65	4.40	5.07	3.60	3.81	28.95	4.08	4.40	4.07	71.05
DNK	7.29	5.55	3.18	9.86	3.73	3.35	6.65	2.97	6.80	4.33	3.56	3.39	3.24	2.80	25.55	3.90	3.84	74.45
THA	4.00	3.66	4.81	4.93	3.99	4.56	4.96	2.88	4.31	5.77	5.39	4.59	4.66	3.80	4.58	29.52	3.59	70.48
BRA	6.59	5.75	3.66	4.77	3.05	3.81	5.86	2.58	4.63	3.56	4.09	3.07	3.25	3.55	4.64	3.72	33.40	66.60
TO	98.98	83.53	65.13	94.89	63.10	57.37	93.89	54.28	74.83	75.42	74.66	62.86	58.64	55.32	84.89	67.18	66.76	1231.74
NET	24.68	10.87	-7.96	18.92	-10.02	-10.49	18.59	-15.15	2.60	-0.80	-0.27	-10.70	-11.84	-15.73	10.45	-3.29	0.15	
Middle Quantile; TCI =46.49																		
	US	CAN	AUS	DEU	JPN	IND	FRA	TWN	NOR	HKG	SGP	KOR	MYS	NZL	DNK	THA	BRA	FROM
US	44.61	15.80	1.25	8.62	1.24	1.44	6.34	0.85	2.66	1.86	1.88	0.68	0.87	1.13	5.31	1.37	4.09	55.39
CAN	17.41	48.92	1.84	5.37	1.74	1.22	4.99	0.85	2.23	1.58	1.74	0.68	1.20	1.31	3.83	1.68	3.42	51.08
AUS	4.59	4.45	52.55	3.66	2.47	1.69	5.78	1.46	2.07	2.45	2.66	2.35	1.47	4.55	2.24	2.72	2.83	47.45
DEU	9.02	4.83	1.29	41.81	1.15	2.34	12.24	0.94	5.42	1.86	1.93	1.06	0.91	0.78	9.99	2.34	2.09	58.19
JPN	6.01	4.08	2.67	3.24	54.68	1.78	4.10	2.53	2.55	1.94	3.16	2.40	2.17	1.05	3.16	2.23	2.24	45.32
IND	2.59	1.72	1.50	2.88	1.83	63.56	3.20	1.33	2.34	2.69	3.68	1.20	1.60	1.79	2.00	3.56	2.52	36.44
FRA	7.28	4.84	2.32	12.54	1.44	2.29	44.08	1.05	4.63	2.02	2.26	1.33	0.99	1.55	5.98	2.37	3.03	55.92
TWN	3.02	1.84	1.65	2.45	2.42	1.49	2.33	61.58	2.33	5.94	2.71	3.73	1.77	1.50	2.00	1.28	1.94	38.42
NOR	3.73	2.75	1.40	7.22	1.56	2.14	5.59	1.82	53.71	2.50	2.08	1.58	1.22	1.23	6.83	2.14	2.51	46.29
HKG	4.56	2.98	2.43	3.78	1.64	2.33	3.98	4.38	2.98	47.58	5.60	4.32	2.32	1.44	3.14	3.19	3.34	52.42
SGP	3.89	2.91	2.78	3.30	2.78	3.07	3.90	2.66	2.04	6.07	50.49	2.88	2.75	2.38	1.96	3.83	2.31	49.51
KOR	4.01	2.16	2.45	3.18	2.34	1.29	3.39	3.50	2.35	5.56	3.48	55.20	2.35	1.37	2.61	2.68	2.08	44.80
MYS	3.16	2.63	1.56	2.51	2.25	2.05	2.93	1.77	1.73	3.18	3.33	2.33	60.61	1.44	2.71	3.57	2.27	39.39
NZL	4.32	3.78	5.03	2.70	1.42	1.64	3.62	1.97	1.84	2.05	3.00	1.24	1.69	58.48	2.07	2.85	2.30	41.52
DNK	6.52	4.14	1.44	11.48	1.52	1.78	6.29	1.42	6.20	2.37	1.87	1.76	1.29	1.28	46.60	1.99	2.05	53.40
THA	1.96	1.63	2.81	2.87	1.92	3.22	3.10	0.99	2.25	4.07	4.01	2.36	2.84	2.09	2.38	59.65	1.85	40.35
BRA	5.10	3.66	1.97	2.91	0.81	1.84	3.39	0.74	2.57	1.43	1.85	0.97	1.11	1.90	2.33	1.87	65.55	34.45
TO	87.18	64.20	34.39	78.72	28.54	31.61	75.17	28.25	46.19	47.56	45.25	30.88	26.53	26.79	58.53	39.68	40.88	790.33
NET	31.79	13.12	-13.06	20.52	-16.79	-4.83	19.24	-10.17	-0.10	-4.85	-4.27	-13.92	-12.85	-14.72	5.13	-0.67	6.43	
Upper Quantile; TCI =72.89																		
	US	CAN	AUS	DEU	JPN	IND	FRA	TWN	NOR	HKG	SGP	KOR	MYS	NZL	DNK	THA	BRA	FROM
US	23.99	11.71	2.99	8.20	3.63	3.29	7.04	2.61	4.84	3.90	3.85	2.76	3.14	2.99	6.52	3.15	5.40	76.01
CAN	12.69	25.94	3.51	6.35	4.04	3.12	6.31	2.50	4.34	3.74	3.94	2.69	3.48	3.09	5.79	3.40	5.09	74.06
AUS	5.18	5.21	26.43	5.08	4.85	3.36	6.25	3.65	3.85	4.37	4.85	4.24	3.80	6.04	4.35	4.51	3.98	73.57
DEU	8.32	5.87	3.52	23.31	3.10	3.96	9.99	2.84	6.08	3.95	3.95	3.16	2.62	2.72	9.03	3.88	3.70	76.69
JPN	5.90	5.07	5.13	4.72	27.00	4.06	5.39	4.32	4.45	4.20	5.32	4.44	4.11	3.33	5.03	4.18	3.33	73.00
IND	4.59	3.88	3.61	4.67	4.50	31.43	4.97	3.45	4.30	4.67	5.30	3.38	4.12	3.33	4.37	5.23	4.20	68.57
FRA	7.36	5.84	4.27	9.87	3.50	3.79	23.87	2.80	5.64	3.90	4.10	3.50	3.02	3.31	6.57	3.96	4.68	76.13
TWN	4.27	3.38	4.10	4.30	4.54	3.42	4.02	30.34	4.71	6.96	5.01	5.70	4.11	3.97	4.38	3.32	3.46	69.66
NOR	5.43	4.38	3.29	7.21	3.75	3.84	6.40	3.99	27.60	4.60	4.25	3.69	3.37	2.69	7.39	4.13	4.01	72.40
HKG	5.47	4.28	4.35	4.98	3.87	4.09	5.35	5.31	4.65	23.73	6.36	5.52	4.09	3.58	5.31	4.74	4.31	76.27
SGP	5.01	4.20	4.81	4.83	4.74	4.38	5.44	4.32	4.04	6.75	25.53	4.65	4.41	4.38	3.81	4.96	3.74	74.47
KOR	5.00	3.90	4.58	4.78	4.47	3.33	5.05	5.14	4.34	6.57	5.16	26.49	4.58	3.49	4.83	4.57	3.70	73.51
MYS	4.80	4.46	4.02	4.08	4.26	4.35	4.69	3.88	4.11	5.10	5.15	4.74	29.05	3.57	4.72	5.08	3.94	70.95
NZL	5.61	5.11	6.65	4.40	3.60	3.26	5.16	4.23	3.70	4.36	5.14	3.37	3.60	28.76	4.18	4.47	4.38	71.24
DNK	6.69	5.40	3.51	9.46	3.62	3.86	6.72	3.31	6.95	4.55	3.64	3.53	3.36	2.84	24.61	3.82	4.13	75.39
THA	4.09	3.72	4.58	4.58	3.98	4.96	4.93	3.13	4.21	5.73	5.45	4.57	4.65	3.67	4.39	29.83	3.55	70.17
BRA	6.70	5.74	3.60	4.71	2.91	3.86	5.74	2.78	4.54	3.57	3.98	3.22	3.27	3.72	4.96	3.80	32.90	67.10
TO	97.13	82.15	66.53	92.22	63.33	60.94	93.45	58.25	74.75	76.92	75.46	63.18	59.71	56.71	85.62	67.20	65.62	1239.18
NET	21.12	8.09	-7.05	15.53	-9.67	-7.63	17.32	-11.40	2.35	0.66	0.98	-10.34	-11.24	-14.52	10.24	-2.97	-1.48	

Notes:.

(1) The findings based on a QVAR model with window length (200), (H = 100) step-ahead generalised forecast error variance decomposition approach and has a lag length of order one (BIC).

(2) According to the ISO 3166 international standard, the country code is: US: United State; CAN: Canada; AUS: Australia; DEU: Germany; JPN: Japan; IND: India; FRA: France; TWN: Taiwan; NOR: Norway; HKG : HongKong; SGP: Singapore; KOR: Korea; MYS: Malaysia; NZL: NewZeland; DNK: Denmark; THA: Thailand; BRA: Brazil.

contrast, Brazil acts as a net transmitter at the lower quantile but shifts to a net receiver in the median and upper quantiles.

Together, the static connectedness, during normal market conditions, demonstrates that although there are substantial spillovers among logistics indices, the degree of interconnection is manageable. During severe crises time, however, the logistics sector becomes vulnerable to contagion. The latter is especially stressed during periods of recent worldwide crises, which have the potential to disrupt supply networks and distribute hazards internationally. These static results also emphasises the fluidity of global logistics markets, where areas alternate between acting as net transmitters and recipients depending on market conditions. This highlights the necessity for adaptable policies from policymakers and business leaders to alleviate the impacts of market shocks. The results also indicate that in times of severe market conditions, market correlations become stronger, resulting in intensified spillover effects. The implications for risk management in the logistics sector are significant, since traditional diversification measures may prove less successful during periods of market stress. Hence, it is imperative for enterprises and governments to give priority to enhancing the robustness of supply chains by taking into account the increased interdependence during times of crisis.

4.2. Time-varying analysis

The results thus far reveal significant asymmetries in spillovers between the lower (left tail) and upper (right tail) quantiles, as compared to the median quantile, emphasizing the inadequacies of using median or average connectedness measures to accurately reflect spillovers during periods of market turbulence. This finding underscores the necessity for a dynamic, quantile-sensitive analytical framework to fully capture these variations across different market conditions. To this end, Figure 2 displays the time-varying connectedness analysis using a rolling window approach based on QVAR offering insight into the shifting interactions among logistics indices across the median, lower, and upper tails of the distribution. The TCI across all quantiles—median, lower, and upper—follows a similar broad trajectory throughout the sample period. At the median quantile, the TCI fluctuates widely, ranging from approximately 25% to 70%, with distinct periods of heightened values. The most pronounced increase in TCI occurred from January 2020 to early 2021, during the outbreak of the COVID-19 pandemic, where the TCI surged to nearly 70%. This surge corresponds to the massive escalation in volatility spillovers across logistics markets as the pandemic severely disrupted global supply chains, triggering a sharp drop in aggregate demand and a corresponding rise in market uncertainty and fragility. Another significant, albeit smaller, rise in the TCI is noted during the Russia-Ukraine conflict, during which the TCI peaked at around 50%. This geopolitical strife and the resulting disruptions to trade—particularly in energy and commodities—contributed to heightened spillovers within logistics indices during this period. Such tensions increased volatility in global markets, amplifying the transmission of shocks across the global logistics network.

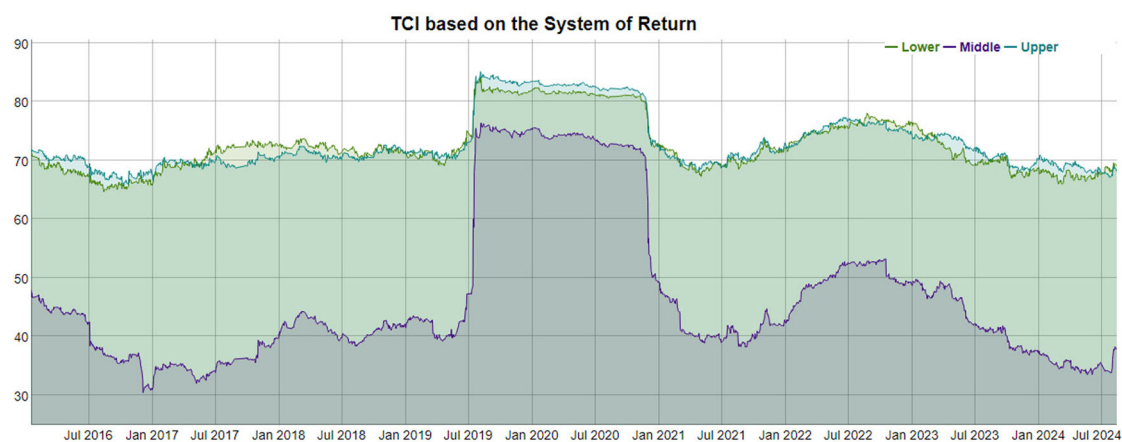


Figure 2. TCI based on the system of return. Total spillover based on the system of return measurement with window length (200) and forecast horizon ($H=100$) trading days.

As the global economy began to rebound from the pandemic-induced recession, the TCI within the median quantile gradually receded, dropping to as low as 25%. However, despite the decrease in the median TCI, the TCI in the lower and upper tails remained significantly elevated. The TCI in the left and right tails is higher, but exhibits a slightly narrower range, oscillating between 45% and 75%. This sustained elevation in the tails indicates that logistics indices remained highly sensitive to extreme market conditions, even as overall volatility eased. The consistently high TCI in the tails suggests a continued susceptibility to both positive and negative shocks, reinforcing the view that extreme events—whether upward or downward—can enhance interconnectedness within global logistics markets. Interestingly, the alignment of patterns in both the lower and upper tails suggest a degree of symmetry in spillovers under extreme market conditions. Positive shocks in upper-tail spillovers tend to coincide with increases in lower-tail spillovers, and the reverse holds true for negative changes. This symmetry implies that during periods of systemic stress, logistics indices become more tightly interconnected, facilitating the swift spread of shocks in both upward and downward directions. Consequently, periods of increased fragility, where negative shocks spread easily, are also accompanied by an enhanced transmission of positive shocks. Thus, in times of heightened stress, the logistics network becomes highly responsive, transmitting shocks rapidly regardless of direction.

While recent trends highlight significant global crises, the ongoing Israel-Hamas conflict (October 2023 through August 2024) has yet to produce a dramatic impact on the Total Connectedness Index (TCI) when compared to previous crises like the COVID-19 pandemic or the Russia-Ukraine conflict. The slight uptick in the TCI observed towards the end of 2023 and into 2024 might suggest potential delayed effects as the conflict continues, but thus far, the conflict has not triggered the same level of global disruption in logistics. This implies that the conflict, while critical on a regional scale, may not yet be extensive enough to induce a systemic response in the global logistics network. However, continued monitoring and further data will be essential to determine if delayed spillover effects might still emerge as the situation develops.

This symmetric behavior of spillovers during periods of market stress has critical implications for risk management and policymaking in the logistics sector. The persistent elevation of TCI in the tails highlights the enduring vulnerability of logistics markets to extreme events, even when median volatility declines. Policymakers and market participants must recognize the potential for extreme shocks to quickly propagate throughout the network, necessitating robust contingency planning and strategic interventions to mitigate the impact on global supply chains.

4.3. *Connectedness network connectedness*

Figure 3 offers a depiction of the magnitude and directionality of connectedness within global logistics markets, shedding light on the complex web of spillover dynamics. The use of color and size variations—yellow for net transmitters, blue for net receivers, and the size of nodes and thickness of edges—effectively visualizes the varying degrees of influence and spillover intensity among different logistics indices.

Broadly, the visualization illustrates the heterogeneity of return spillovers transmitted from one country to another. The considered indexes can be classified as strongly connected, moderately connected, or weakly connected, as indicated by the size of the edges.

One interesting finding is the prominent role of France and the United States as major contributors to global shocks within the considered global logistics network. In detail, France and the US demonstrate their positions as central hubs in the logistics ecosystem with a far-reaching impact on smaller economies by regularly transmitting shocks to other markets, such as New Zealand and Japan, which appear as significant receivers during normal times. Another important finding is that the strength of spillovers weakens market turbulence, suggesting a shift towards more isolated, risk-mitigating behavior within individual markets. This latter emphasises the need for adaptive strategies that can accommodate such shifts in interconnectedness during periods of stress. Most striking was the strongest return spillovers were between US and Canadian logistics stocks, while the weakest are between India and Hong Kong.

Of interest here is the strong clusters of spillover connections between geographically proximate countries. For instance, in Asia, countries such as Singapore, Korea, Taiwan, Malaysia, and Hong Kong are

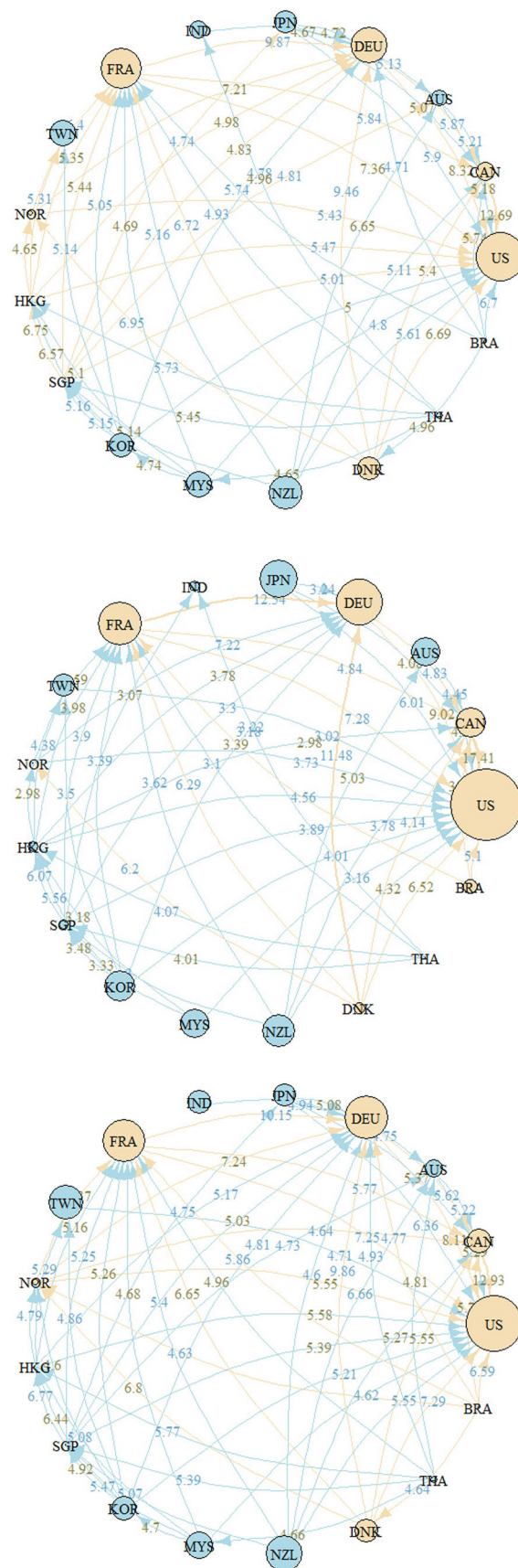


Figure 3. The degree of pairwise weighted directional connectedness of a system that consists of the closing daily return. The colours on the borders indicate the source of the connections. The colour yellow (blue) indicates the transfer (reception) of spillover effects from one market to another within the entire system. The size of each figure reflects the level of total directional connectedness. The size of the link corresponds to the level of risk associated with interactions between different markets.

tightly interconnected. A possible explanation for the latter might be shared trade routes and regional integration. Similarly, in Europe, Germany, France, Denmark, and Norway form a strongly interconnected cluster, reflecting their robust economic ties and highly integrated logistics networks. The close economic relationship between the US and Canada is particularly striking, with strong spillovers reinforcing the depth of their integrated logistics markets. Less robust linkages between nations, such as India and Hong Kong, suggest a decrease in direct economic and logistical links, leading to a reduction in the transfer of benefits. The establishment of regional blocs, such as the Americas and Oceania, highlights the importance of physical closeness and regional economic collaboration in shaping the spread of effects. These clusters highlight the importance of understanding the interconnection of regional logistics as a critical factor in improving the resilience of global supply chains.

Figure 4 effectively underscores the varying roles countries play in the global logistics network, particularly in terms of net directional spillovers. At the conditional median, three distinct groups emerge. The first group, including countries such as the US, Canada, Germany, France, and Norway, consistently acts as net transmitters of shocks, meaning they frequently drive volatility across other markets. The second group, which includes nations like Japan, Korea, Malaysia, and New Zealand, primarily functions as net recipients, absorbing spillovers from the first group. The third group, characterized by fluctuating roles, can alternate between being net transmitters and net receivers, depending on the broader macroeconomic landscape and external factors. However, the behavior of net spillovers changes significantly during extreme events. In such periods, the defined roles of countries as transmitters or receivers become less predictable. Specifically, in periods of financial stability, the United States and European nations often exhibit a net transmitter of shocks, whereas Asian countries generally acting as net receiver of shocks. By contrast, in times of crisis, Asian countries alternate between contributing and receiving shock.

The recent events, including the COVID-19 pandemic (early 2020 to early 2021) and the Russia-Ukraine conflict (early 2022 to early 2024), exemplify how global crises heavily disrupted global supply chains and intensified volatility across the logistics network. More recently, the Israel-Hamas conflict from October 2023 to August 2024 further influenced these dynamics, driving additional fluctuations in the logistics sector.

Together, a country's role as either a net transmitter or receiver of spillovers is fluid and highly contingent on global events and market conditions. This dynamic nature highlights the need for continuous monitoring of spillovers, particularly during periods of significant volatility or geopolitical unrest, to better manage risks and capitalize on emerging opportunities within the logistics industry.

4.4. Sensitivity analysis

Robustness of the total spillover indices was validated through two distinct sensitivity analyses. The first sensitivity test examined the impact of varying rolling window sizes and forecast horizons by employing a 300-day rolling window and a 150-day forecast horizon. The results, depicted in Figure 5, demonstrate that the spillover patterns remain consistent, suggesting that the interconnectedness between markets is resilient to changes in the rolling window size or forecast horizon.

The second test focused on the influence of different extreme quantile selections on the estimation outcomes. After adjusting the extreme quantile parameters and re-estimating the model, Figure 6 illustrates that the connectedness between the considered indices remains stable, irrespective of the chosen extreme quantile. This finding reinforces the robustness of the connectedness analysis, showing that the spillover effects are reliable across different methodological adjustments.

5. Impact of recent global crises on logistics market connectedness

The analysis, so far, reveals that market connections exhibit asymmetry, with interconnections strengthening during periods of higher returns. However, during times of market stress and increased volatility, shock transmission becomes more efficient. This phenomenon occurs as negative or positive shocks in one logistics market help to diffuse or cushion the impact on others, aligning with economic theory which posits that volatility shifts across quantiles due to changing investor behavior and market dynamics.

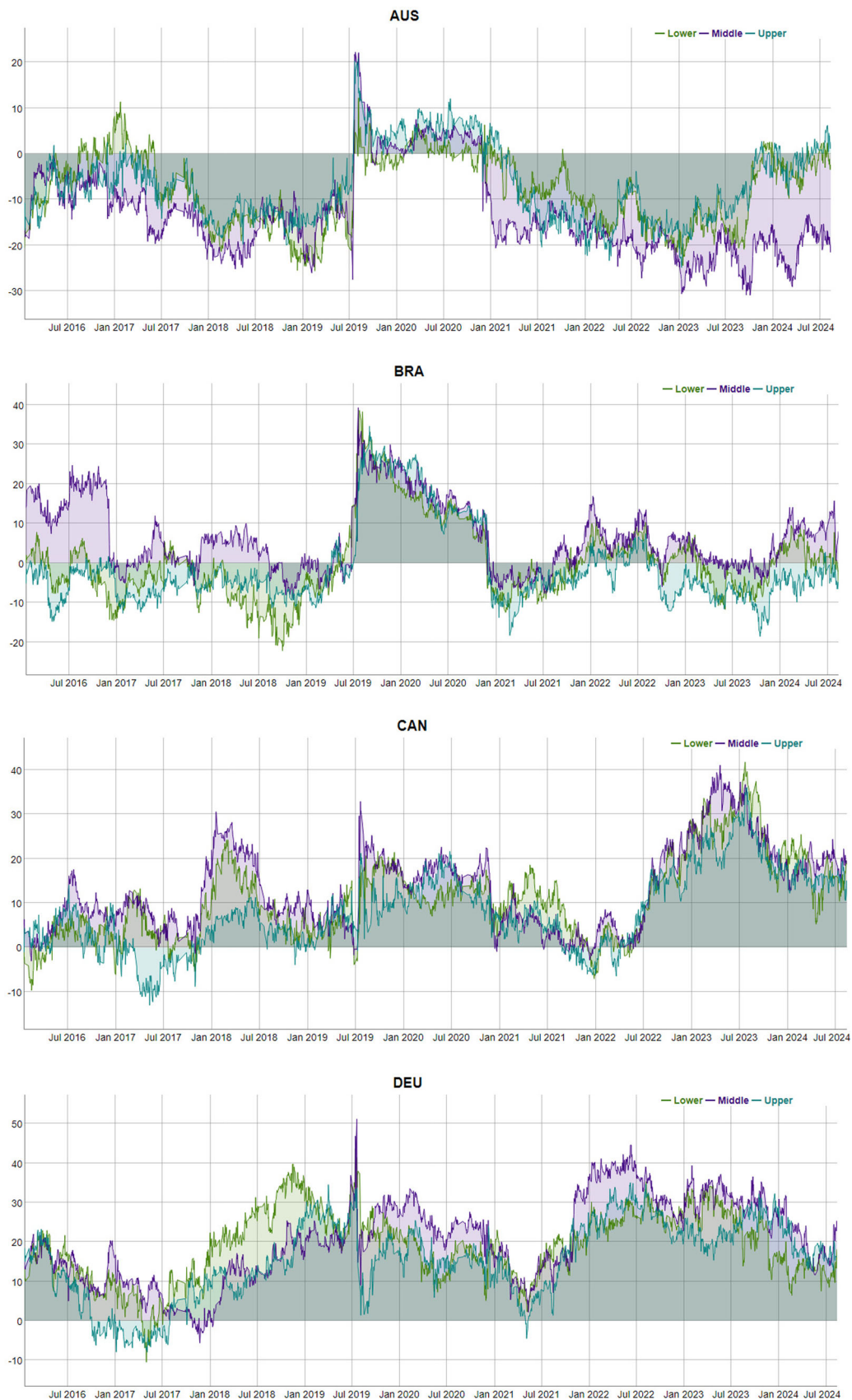


Figure 4. Net directional spillovers in the quantile VAR (median, lower and upper quantile).



Figure 4. Continued.

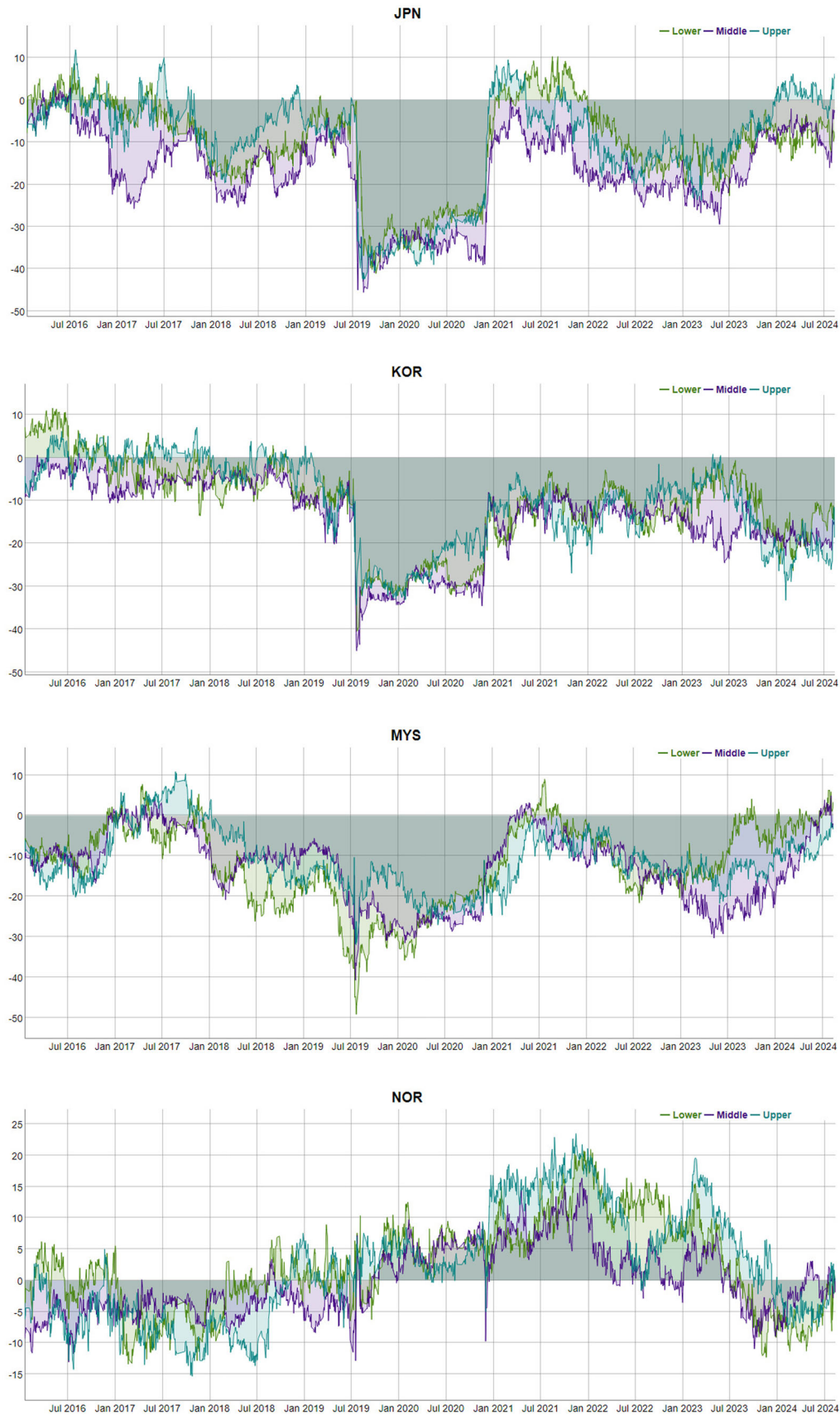


Figure 4. Continued.

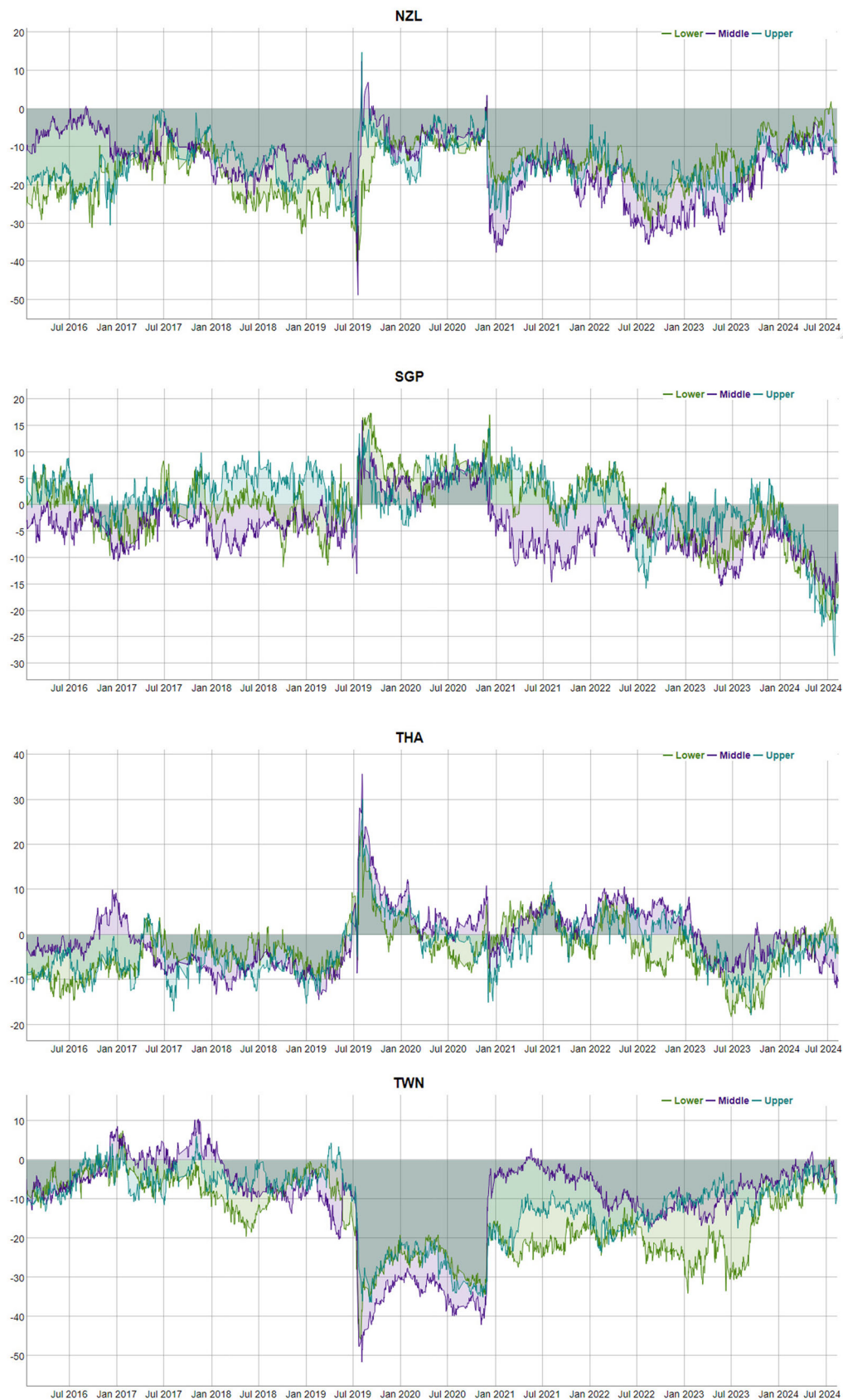


Figure 4. Continued.

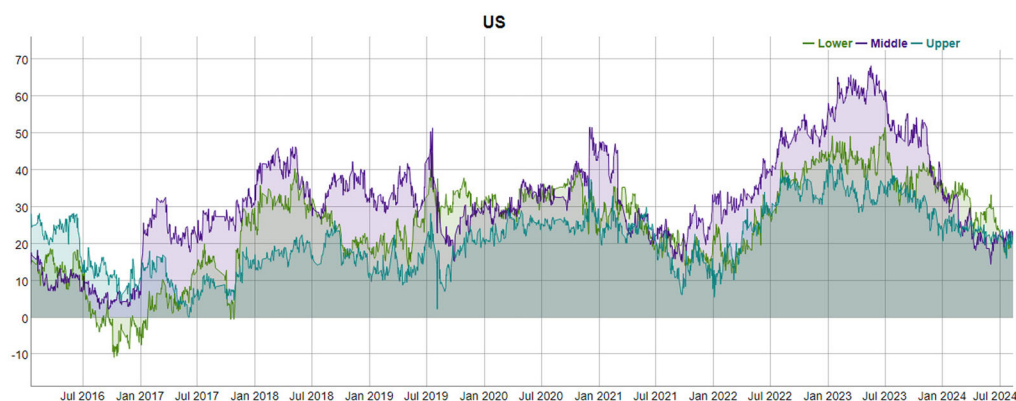


Figure 4. Continued.

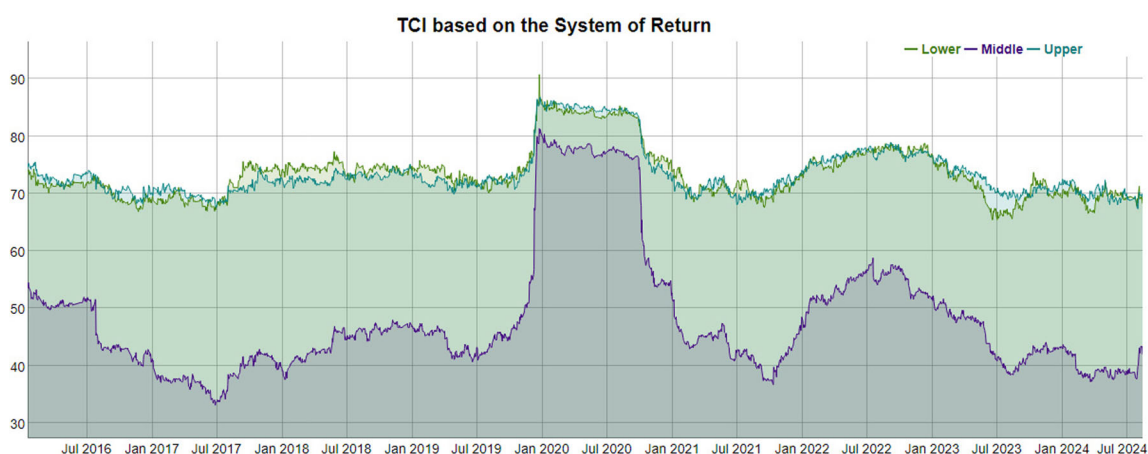


Figure 5. TCI based on the system of return. The Total spillover based on the system of return measurement with window length (300) and forecast horizon ($H=150$) trading days.

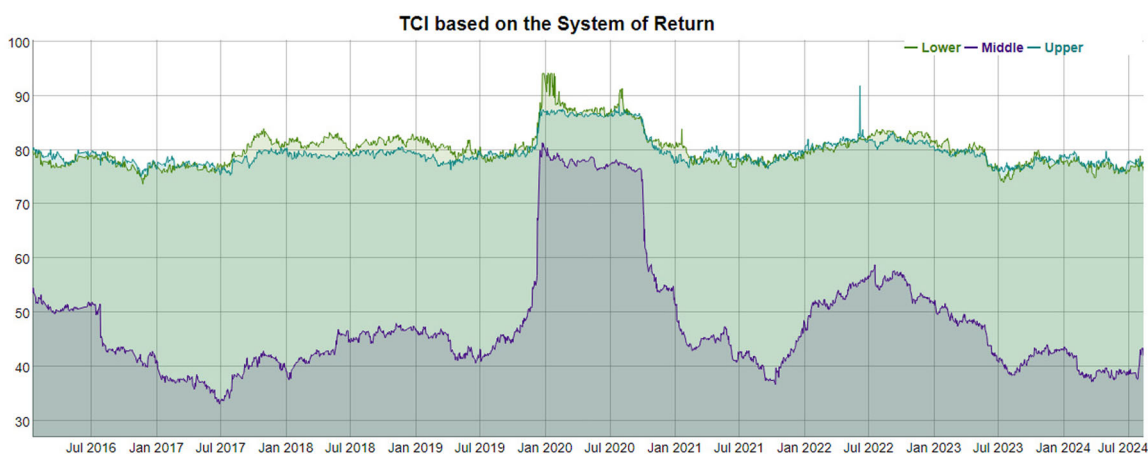


Figure 6. TCI based on the system of return. The Total spillover based on the system of return measurement at extreme quantile with window length (200) and forecast horizon ($H=100$) trading days.

This study aims to investigate the progression of market connectedness across logistics indices before, during, and after major global events, focusing on the COVID-19 pandemic, the Russia-Ukraine conflict, and the ongoing Israel-Hamas conflict. To explore these dynamics, we follow the work of Alqaralleh (2024) and examine the spillover network by selecting subsamples from the larger dataset,

corresponding to the periods of these significant crises. The COVID-19 pandemic, officially declared by the World Health Organization on 11 March 2020, provides the basis for our first subsample. According to Naeem et al. (2023) and Gunay and Kurtuluş (2021), the pandemic's economic disruptions are encapsulated in the period from 11 March 2020 to 10 March 2021, which is covered in Panel A. For the second subsample, we focus on the Russia-Ukraine conflict, which began on 24 February 2022, as identified by Abakah et al. (2022). This subsample extends to 17 January 2024, capturing a substantial portion of the ongoing conflict, and is analyzed in Panel B. The third subsample examines the Israel-Hamas conflict, which started on 7 October 2023 and continues to the most recent period, ending on 14 August 2024. This ongoing conflict is represented in Panel C. These subsamples enable a detailed analysis of how global logistics markets reacted to these transformative political and economic events, offering insight into the evolving interconnectedness and spillover dynamics during these periods.

Static connectedness analysis during these three crises shows a significant rise in the TCI amidst heightened uncertainty, as shown in Table 3. For instance, during the COVID-19 pandemic, the TCI reached 67.9%, indicating that over two-thirds of systemic variance in the logistics markets was attributable to interconnectedness. The Russia-Ukraine conflict, while also significant, recorded a slightly lower TCI of 64.2%. In contrast, the ongoing Israel-Hamas conflict shows a lower overall TCI of 56.9%, reflecting a more localized impact thus far. Despite the lower TCI during the latter two conflicts, extreme quantiles (lower and upper) still show strong market interrelations, demonstrating the heightened sensitivity to shocks in volatile conditions.

Table 3. Return spillovers in the quantile VAR.

Panel A: COVID-19 (11 March 2020–10 March 2021)																		
		US	CAN	AUS	DEU	JPN	IND	FRA	TWN	NOR	HKG	SGP	KOR	MYS	NZL	DNK	THA	BRA
COVID-19 ; TCI, L = 72.46 ; M = 67.97 ; U = 91.09																		
From	Lower	91.64	90.68	92.36	90.70	92.38	90.56	89.40	89.87	89.36	90.84	91.96	89.32	88.49	91.49	90.41	89.31	91.38
Others	Middle	73.08	68.16	74.05	71.45	73.62	66.67	68.90	60.91	64.48	68.44	75.55	64.71	57.28	72.60	66.62	63.78	65.25
	Upper	91.27	91.86	90.66	91.72	90.85	92.16	91.08	91.82	89.84	90.67	92.64	90.99	91.30	90.70	89.61	90.69	90.76
To	Lower	90.47	104.41	81.10	92.45	73.69	86.83	116.41	85.45	101.85	94.74	83.09	100.74	96.54	70.14	88.88	98.19	75.15
Others	Middle	100.32	79.92	53.82	84.94	53.78	55.36	122.63	52.26	63.74	74.99	69.41	48.57	53.46	44.81	72.10	69.00	56.41
	Upper	98.78	83.53	99.80	89.26	103.93	75.53	79.60	74.69	102.20	99.92	78.42	88.68	78.31	99.51	99.17	98.47	98.82
Net	Lower	24.68	10.87	−7.96	18.92	−10.02	−10.49	18.59	−15.15	2.60	−0.80	−0.27	−10.70	−11.84	−15.73	10.45	−3.29	0.15
	Middle	27.24	11.77	−20.23	13.49	−19.84	−11.31	53.73	−8.65	−0.74	6.55	−6.14	−16.14	−3.82	−27.78	5.48	5.23	−8.83
	Upper	7.51	−8.33	9.14	−2.46	13.08	−16.63	−11.49	−17.13	12.35	9.25	−14.22	−2.31	−12.99	8.82	9.56	7.79	8.06
Panel B: Russian-Ukraine conflict (24 February 2022–17 January 2024)																		
		US	CAN	AUS	DEU	JPN	IND	FRA	TWN	NOR	HKG	SGP	KOR	MYS	NZL	DNK	THA	BRA
From Others	Lower	91.13	91.07	91.17	90.62	91.02	89.70	91.84	91.07	91.57	91.06	92.16	90.46	91.38	90.69	90.99	89.93	89.46
	Middle	68.85	68.40	66.00	69.17	65.51	50.10	68.25	61.09	63.05	69.26	65.34	65.86	63.45	65.94	64.15	58.20	58.93
	Upper	91.27	91.86	90.66	91.72	90.85	92.16	91.08	91.82	89.84	90.67	92.64	90.99	91.30	90.70	89.61	90.69	90.76
To Others	Lower	96.10	92.94	84.32	98.10	84.35	93.59	87.97	85.35	85.36	95.59	82.72	99.65	77.97	86.26	96.53	96.39	102.14
	Middle	98.52	82.69	50.49	85.23	49.55	52.57	81.74	55.20	64.58	58.91	64.03	52.97	46.71	49.58	72.86	58.79	67.11
	Upper	98.20	95.10	81.55	90.34	77.37	85.92	85.16	84.91	97.57	87.04	94.16	97.30	84.36	84.54	84.58	106.91	85.49
Net	Lower	4.97	1.87	−6.85	7.48	−6.66	3.88	−3.88	−5.72	−6.20	4.53	−9.45	9.18	−13.41	−4.43	5.54	6.47	12.68
	Middle	29.67	14.29	−15.50	16.06	−15.96	2.48	13.49	−5.89	1.53	−10.35	−1.31	−12.89	−16.74	−16.36	8.71	0.59	8.19
	Upper	8.96	5.61	−8.92	0.15	−12.81	−1.37	−5.05	−3.68	8.80	−3.03	4.43	7.77	−4.66	−5.53	−5.27	18.75	−4.13
Panel C: Israel-Hamas conflict (7 October 2023 – 14 August 2024)																		
		US	CAN	AUS	DEU	JPN	IND	FRA	TWN	NOR	HKG	SGP	KOR	MYS	NZL	DNK	THA	BRA
From Others	Lower	87.77	89.53	89.35	85.33	88.54	88.54	88.01	87.96	87.81	89.38	86.48	88.13	85.75	86.84	88.54	87.58	89.28
	Middle	59.52	59.24	68.69	57.39	58.54	46.44	65.35	56.93	61.31	61.93	43.72	57.02	43.64	60.02	52.63	56.04	59.61
	Upper	87.85	87.00	86.28	85.91	86.85	83.75	88.94	87.14	87.25	87.33	85.95	88.82	85.45	86.80	87.13	87.26	87.21
To Others	Lower	94.79	68.34	91.79	106.18	84.17	78.84	98.66	87.68	98.81	85.98	58.71	94.52	110.02	88.58	72.87	92.29	82.62
	Middle	72.75	71.40	64.24	70.22	47.81	55.51	66.43	51.48	49.79	50.45	40.95	45.75	63.04	38.51	53.04	61.22	65.45
	Upper	88.86	97.05	114.41	86.06	82.97	86.09	84.37	76.33	80.20	94.90	68.51	86.88	94.84	88.02	69.33	83.29	94.78
Net	Lower	7.02	−21.19	2.44	20.85	−4.37	−9.70	10.65	−0.29	11.00	−3.40	−27.77	6.39	24.26	1.73	−15.67	4.71	−6.66
	Middle	13.23	12.17	−4.45	12.83	−10.73	9.07	1.08	−5.46	−11.53	−11.48	−2.77	−11.26	19.40	−21.51	0.41	5.18	5.84
	Upper	1.01	10.05	28.14	0.15	−3.88	2.34	−4.56	−10.81	−7.05	7.57	−17.44	−1.94	9.40	1.22	−17.79	−3.97	7.57

Notes:

(1) The findings were attained using a QVAR model with window length (100), (H = 50) step-ahead generalised forecast error variance decomposition approach and has a lag length of order one (BIC).

(2) Refer to Table 2 for the explanation of abbreviations used in the table.

Throughout all three crises, the United States consistently emerged as the largest transmitter of spillovers, underscoring its influential role in the global logistics network. Asian countries, including Japan, Korea, Singapore, and Malaysia, frequently appeared as net recipients of spillovers, particularly during periods of extreme market volatility, highlighting the global flow of shocks from Western economies to Asian markets. Meanwhile, European countries alternated between being net receivers and transmitters of spillovers, depending on the geopolitical and economic context.

Together, The COVID-19 pandemic and geopolitical crises have severely affected logistics sectors worldwide. On one hand, the pandemic has caused interruptions in supply chains and fluctuations in market stability. On the other, the Russia-Ukraine war has indirectly impacted the logistics by affecting energy and commodities trading routes. Conversely, the Israel-Hamas war has mostly affected a specific geographical area. These incidents demonstrate the interconnectedness that emerges during crises, driven by international trade patterns, investor attitudes, and policy reactions. Effectively mitigating risks in the logistics business is of utmost importance, particularly as international commerce intensifies and crises become increasingly interrelated. Continuous surveillance and the formulation of risk mitigation plans are vital to guarantee resilience in the presence of forthcoming disruptions.

6. Conclusion

The existing literature on the logistics sector lacks a comprehensive analysis of the interdependencies across industries. This knowledge gap hinders our understanding of the sector and its broader impacts. In this study, we attempt to address this gap by examining 17 different countries and assessing how their international logistics sectors are interdependent. Taking into account the rationale and previous data that cross-market relationships are stronger during extreme events compared to typical periods, we evaluate the volatility transmissions by employing TVP-QVAR-based dynamic connectivity among the corresponding markets. This approach expands the mean-based VAR framework of connectivity to the quantile VAR level, enabling us to reveal the measures of connectedness at the highest, middle, and lowest quantiles of the conditional distribution.

The moderate interconnectedness during normal periods, as indicated by the TCI of 46.5%, suggests that while logistics markets do not operate in isolation, they possess a level of autonomy that allows for localized disturbances to be absorbed without triggering widespread global shocks. However, this balance is fragile and easily disrupted by global crises, such as the COVID-19 pandemic and geopolitical conflicts, which escalate spillovers and heighten vulnerabilities across markets. The sharp increase in TCI during extreme events illustrates the logistics network's susceptibility to contagion effects. The COVID-19 pandemic, with a TCI of 67.9%, demonstrates the profound impact of non-economic shocks, severely disrupting global supply chains and increasing volatility. Similarly, the Russia-Ukraine conflict, with a TCI of 64.2%, emphasizes the significance of geopolitical risks, especially in sectors like energy and commodities. The lower TCI of 56.9% during the ongoing Israel-Hamas conflict suggests that regional conflicts may not immediately induce global logistics crises, though their potential to escalate remains, particularly if key trade routes or markets are affected over time. The evidence the consistent role of major economies such as the US, Germany, and France as net transmitters of spillovers indicates their dominant position within the global logistics network, in which any policy changes or disruptions in these markets can have global repercussions. By contrast, net receivers' countries like New Zealand, Japan, Korea, and Singapore, remain vulnerable to external shocks. An implication of this is the possibility of the need for enhanced domestic resilience and diversified trade strategies. Of the more significant findings to emerge from this study is the dynamic nature of spillovers across different quantiles, where countries shift between being net transmitters and receivers depending on market conditions. The latter asymmetry further underscores the necessity for adaptive policies that can anticipate and respond to both positive and negative market shocks. In times of extreme market conditions, traditional diversification strategies may lose their effectiveness, calling for new approaches to risk management that prioritize supply chain diversification, regional resilience planning, and alternative risk mitigation mechanisms.

Moreover, the study suggests that both private companies and policymakers should prioritize building more resilient supply chains and strengthening international cooperation to mitigate the cascading

effects of global disruptions. Regional clustering, such as in Asia and Europe, presents opportunities for enhanced regional cooperation, which could serve as a buffer during global crises.

6.1. Theoretical and practical implications

The current study makes significant theoretical contributions to understanding interdependence and risk transmission in the global logistics industry, particularly under extreme market conditions. By employing the Quantile Vector Autoregression (QVAR) approach, we move beyond traditional mean-based analyses, which often overlook the critical behavior of markets during crises. Our focus on tail-risk spillovers highlights how extreme positive and negative shocks exert a much stronger influence on market dynamics than median shocks, advancing the literature on market interdependencies by introducing a more nuanced perspective on risk transmission during periods of stress and stability.

One of the primary theoretical contributions is the demonstration that shocks to logistics markets propagate differently across the various quantiles of the conditional distribution. Our findings reveal that extreme events—whether negative or positive—intensify market interconnectedness significantly more than median-level events, challenging the assumption that average connectedness measures sufficiently capture market behavior. This asymmetry in spillover effects, especially during crisis periods, underscores the need for extreme event modeling in the logistics sector. Additionally, we extend the application of the QVAR framework to the logistics industry, an area previously underexplored in the context of financial spillovers. This methodological innovation demonstrates the effectiveness of quantile-based connectedness measures in capturing the inherent volatility and risks in global logistics networks, particularly during crises such as the COVID-19 pandemic and the Russia-Ukraine conflict. By highlighting the critical role of tail dependencies, our study adds depth to the understanding of systemic risks and offers a robust framework for future research on interconnected markets.

These findings have significant implications for the stakeholders within the global logistics market. In this vein, the sharp rise in the Total Connectedness Index (TCI) during major global events like the COVID-19 pandemic and geopolitical conflicts highlights the urgent necessity for proactive regulation and enhanced oversight. Put differently, developing an early warning system should be a top priority for regulators to identify possible contagion risks and the intricate interconnections between logistics sector components. Further, they should enforce more stringent stress testing and risk management practices to ensure that firms within the logistics sector are better prepared to withstand both economic and geopolitical shocks. Furthermore, it is crucial to acknowledge that major industries such as the United States, Germany, and France have a substantial impact on the transmission of spillover effects. This underlines the significance of international regulatory collaboration in order to effectively handle the transfer of negative effects that have the potential to disrupt worldwide logistical networks.

From investor's perspective, the asymmetric behavior of market spillovers, particularly during periods of heightened volatility, signifies that the traditional diversification strategies may become less effective when spillovers intensify across the board. Consequently, more dynamic asset allocation strategies to adjust both stable and stressed market environments should be adopted, allowing investors to better navigate evolving global risks. In addition, portfolio managers should also adapt risk-adjusted strategies, consider alternative investments such as infrastructure or specialised logistics funds, and preserve flexibility in asset allocation. The insights gained from the identification of countries such as New Zealand and Japan as net receivers of shocks indicates that investments in these markets may be subject to higher risks during global crises. This latter may be of assistance to careful scrutiny of global conditions and their potential impact on investment returns in these regions.

The findings will be also of interest to traders as it provides insights into the timing and magnitude of spillovers across global logistics markets. On one side, traders could leverage the consistent identification of major economies like the US, Germany, and France as net transmitters of shocks (and thus often lead global trends during times of crisis) by identifying early signals of market stress in these countries and positioning themselves to capitalize on ensuing spillovers in other markets. On the other, traders should remain aware of the vulnerability of net receiver countries as they may experience more pronounced reactions to external shocks. This new understanding should help in creating opportunities for both hedging and speculative trading strategies during volatile periods.

Overall, the heightened interconnectivity during severe events strengthens the idea that participants within the logistics sector, including shipping companies, supply chain managers, and logistics service providers need to prioritise the establishment of supply chain resilience. It is essential to prioritise the allocation of resources towards operational redundancy, flexible routing, and contingency planning in order to ensure continuity. Geographical diversity is crucial for decreasing reliance on certain areas or trade channels. It is crucial to work together with policymakers to create strong and durable logistics infrastructure, particularly in areas that are prone to disruptions. This is necessary to ensure the long-term stability of the industry.

6.2. Practical implications for the maritime industry

There is clear evidence from 17 nations indicating the instability and increased risks in global logistics markets, particularly impacting the marine sector. An implication of this offers significant information for optimising operations, managing risks, and making strategic decisions. For instance, increased spillover intensity during crises could be of particular interest to maritime companies and offer insights to rerouting shipments away from conflict zones like the Black Sea during the Russia-Ukraine conflict. This reduces risks like delays, fuel cost fluctuations, and cargo losses. The maritime companies could also mitigate risks and ensure operational continuity by expanding operations to less correlated areas, like between Asia and South America. The latter is also strengthening regional partnerships, and thus further optimizing logistics, enhance supply chain resilience, and improving competitiveness.

The study also highlights the need for stronger risk management. As logistics markets become more interconnected during crises, adopting robust insurance policies and flexible contract terms, such as force majeure clauses, can help address disruptions. Preparing for both positive and negative shocks—whether demand surges or supply chain breakdowns—enhances resilience and allows for quick adjustments to shipping schedules.

The evolving nature of global logistics interconnectedness underscores the importance of advanced technologies for real-time monitoring and decision-making. Predictive analytics and machine learning tools can help maritime businesses anticipate disruptions and optimize operations. Digitalizing logistics processes, such as using blockchain for tracking, improves transparency and reduces inefficiencies, which is crucial during periods of market stress.

To summarise, it is imperative for the marine sector to enhance the robustness of its supply chain by expanding the range of suppliers, ensuring access to alternative ports, and establishing strategic alliances. It is crucial to work together with policymakers in order to create stronger and more durable logistical infrastructure, which is necessary for ensuring stability in the long run.

6.3. Study limitations and future research directions

Despite the valuable insights provided into the interdependence of logistics indices across 17 nations, it does have certain drawbacks. The analysis only took into account a restricted range of variables, excluding macroeconomic factors such as inflation rates, interest rates, and currency rates. In addition, particular variables related to sectors such as technological disruptions, labour market circumstances, and fuel costs were not taken into account. Subsequent studies might further investigate these variables to offer a more all-encompassing perspective on the elements that impact the logistics industry.

Being limited to the period from June 2016 to August 2024, this study lacks the ability to capture the intricacies of market dynamics within a single day. Consequently, it might fail to provide detailed insights into the behaviour of logistics markets during moments of increased volatility. Moreover, the analysis specifically concentrates on a certain group of nations, which may inadvertently exclude any regional differences in market behaviour that exist beyond the chosen sample.

The Quantile Vector Autoregression (QVAR) model employed in this study may not comprehensively reflect the complexities of logistics market interdependencies, particularly in the context of catastrophic occurrences. Incorporating frequency in the investigation might offer a more detailed understanding of how logistics markets react distinctively in different crisis periods.

Subsequent studies may explore the interdependence of logistics indices in various global crises, encompassing industries outside logistics, and constructing more dynamic models that accurately reflect changing market conditions in realtime.

Note

1. According to the Refinitiv business classification, this study uses logistics industry group, which is made of three industries: Courier, Postal, Air Freight & Land-based Logistics; Marine Freight & Logistics; and Ground Freight & Logistics.

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Authors' contribution

Huthaifa Alqaralleh: Methodology, Software, Formal analysis, Visualization, Writing – review & editing, Supervision. Rim El Khoury: Conceptualization, Validation, Investigation, Resources, Data curation, Writing – original draft, Writing – review & editing. Muneer M. Alshater: Conceptualization, Investigation, Writing – original draft, Project administration.

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Data availability statement

Used data will be made upon request.

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