



Dual nature of spillovers: Contemporary and lagged connectedness in oil shocks, geopolitical risk, and EURO financial stress

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ABSTRACT

We employed the novel R² decomposed connectedness approach to analyze the interplay among oil market shocks, geopolitical risk, global economic conditions, and EURO financial stress. Our findings demonstrate significant interconnectedness, characterized by moderate contemporaneous and lagged spillover effects. Our findings exhibit that geopolitical risk threats propagate shocks to countries such as Austria, Denmark, Finland, France, Germany, Netherlands, Spain, Sweden, and the UK. In contrast, global economic conditions and other factors serve as recipients of those shocks. Furthermore, our time-varying measures unveil fluctuations in interconnectedness during pivotal events such as wars, financial crises, and shifts in OPEC policies.

1. Introduction

Oil market shocks often coincide with periods of heightened geopolitical tensions and uncertainty in major oil-producing regions (Cunado et al., 2020; Xie et al., 2023). Given that geopolitical risks, such as conflicts in these regions, can disrupt global oil production and supply and induce sharp volatility in oil prices (Xie et al., 2023). In turn, this results in higher energy costs for countries and businesses, which can dampen global economic activity and tighten global financial conditions (Jiménez-Rodríguez et al., 2022). In such cases, net energy-importing countries, such as those in the EURO-zone, could experience sudden increases in oil prices due to geopolitical events, which may pose significant economic challenges. For example, these higher oil prices could lead to rising inflation, weaken the eurozone's trade balance, and impact its terms of trade. In that regard, recent oil market shocks, such as the Russia-Ukraine conflict, were a great example, and they had strained the public finances of peripheral eurozone countries like Italy, exacerbating economic downturns and triggering financial stress (Sheng et al., 2023). Thus, these shocks have contributed to elevated inflation and

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economic disruptions, causing financial distress in the EURO-zone (Liadze et al., 2023).

It should be noted that financial stress in major EURO-zone economies such as Germany, France, Italy, and the UK can affect oil price volatility and global economic activity (Hoque et al., 2023). Given their position as significant oil consumers with large economies, the economic weakness and financial instability in these nations can dampen global oil demand. This impact can spread globally through trade and financial market linkages. Consequently, there is an intricate connection between geopolitical risks, the oil market, global economic conditions, and financial stress in eurozone countries. Hence, a deeper understanding of these connections is needed over time to inform investors, financial institutions, and policymakers.

Several interrelated economic and financial theories support their interconnectedness and spillover mechanisms. For example, geopolitical theory and energy economics assert that geopolitical risks, such as political instability and military conflicts, have a major impact on oil market dynamics. They trigger demand, supply, and inventory shocks (Bouoiyour et al., 2019; Gong et al., 2023). These risks increase uncertainty in oil prices due to factors such as currency devaluation and inflation. This uncertainty affects investors' risk aversion levels and influences corporate cashflows (Bigerna, 2024; Yang et al., 2023). In turn, these price changes can lead to economic and financial instability (NguyenHuu & Örsal, 2023). Additionally, the contagion theory of Forbes and Rigobon (2002) shows the pass-through impact of geopolitical uncertainty on financial markets. This uncertainty stems from unpredictable political events that increase volatility and risk (DeGhetto, 2024; Salisu et al., 2023). It can cause structural shocks, such as sudden shifts in demand and supply, which lead to greater market volatility and capital flight (Acemoglu et al., 2016; Khraiche et al., 2023). High geopolitical risk may also spark sanctions and conflicts, which force investors to rethink their portfolios and affect commodity markets (Liu et al., 2021; Phan et al., 2019). On the other hand, financial stress can disrupt regulatory frameworks and oil supply chains. This disruption can lead to major price shocks that affect global trade and might cause realignments between OPEC and non-OPEC countries. These structural shocks can result in sudden changes in the oil market.

This study examines three main strands of literature related to stress. The first area explores the connection between geopolitical risk (GPR) and oil price shocks, as seen in studies by Bouoiyour et al. (2019), Cunado et al. (2020), Li et al. (2023), Liu et al. (2021), Meng and Li (2024), Mignon and Saadaoui (2024), Qin et al. (2020), and Yang et al. (2023). The second area examines how GPR relates to financial stress, covered by Bajaj et al. (2023), Del Gaudio (2023), Fiorillo et al. (2023), Long et al. (2021), NguyenHuu and Örsal (2023), Olalere Mukuddem-Petersen (2024), Phan et al. (2022), and Shahzad et al. (2023). The third area investigates the interactions between financial stress and oil price shocks, discussed in studies by Ahmed and Sohag (2025), Anand et al. (2023), Apostolakis et al. (2021), Dagher and Hasanov (2023), Hoque et al. (2025), Elsayed et al. (2024), Nazlioglu et al. (2015), Qin (2020), Sohag et al. (2023), and Wan et al. (2015). Together, these studies reveal important links among geopolitical risks, the oil market, global economic conditions, and financial stress.

These connections can be conceptualized as operating through several transmission channels. First, the inflation and monetary policy channel holds that oil price shocks will increase inflation, possibly compelling central banks to raise policy rates, thereby increasing the cost of borrowing and leading to financial stress. Second, through the trade and terms-of-trade channel, energy-importing countries such as the Eurozone suffer the adverse effects of oil price spikes, with trade balances deteriorating, national income declining, and fiscal pressures rising. Third, the risk sentiment and financial contagion channel suggests that geopolitical risks and financial stress in core economies may also result in generalized flight-to-safety and correlated selloffs across markets. Lastly, the supply chain and real activity channels imply that global trade can be affected by geopolitical actions and oil supply shocks, which in turn affect the economic health of the whole world and, in turn, corporate earnings and financial stability. By combining the decomposed measures of these underlying drivers, our empirical model captures the specific signatures of these channels and determines their speed and persistence.

The existing literature has already established a high degree of interconnectivity within the oil-geopolitical risk-finance nexus. Studies by Apostolakis et al. (2021) and Maghyereh and Ziadat (2024) have documented the transmission of shocks between oil markets and financial stress. Meanwhile, other papers, such as those by Shahzad et al. (2023) and Del Gaudio (2023), have identified the relationships between geopolitical risk and financial instability. Moreover, the recent research by Hoque et al. (2025) presents an in-depth study of oil shocks, the global economic situation, and economic strain in South and Southeast Asian markets, which is closely aligned with our set of variables. Nevertheless, one fundamental weakness remains across these studies and other studies that use connectedness models (e.g., Diebold & Yilmaz, 2012, 2014): they yield a single aggregate measure of spillovers. While informative, combining effects into a single metric obscures a crucial aspect of financial decision-making: the timing of risk transmission. Providing, we argue that the distinction between an instantaneous market shock and a propagating shock in a system with a delay is critical for a portfolio manager hedging exposure or a central bank considering intervention, as the former necessitates immediate liquidity and hedging, and the latter requires anticipatory policy changes. As a result, the existing methodologies, while fundamental, leave a knowledge gap regarding the time profile of shock propagation (such as contemporaneous and lagged) within the oil-geopolitical-financial stress nexus. Thus, contemporaneous and lagged interrelations among these variables need to be fully understood, as they are critical factors for successful real-time risk management and informed policy intervention in the future. Additionally, the existing still lacks a comprehensive examination that integrates the decomposed oil shocks, disaggregated geopolitical risk (threats versus acts), global economic states, and an extensive collection of European financial stress indices.

Furthermore, in current studies, there is a tendency to use composite indices, thereby obscuring underlying dynamics. For example, treating geopolitical risk (GPR) as a homogeneous variable fails to distinguish between market anxiety generated by geopolitical threats (GPRT) and the actual economic disturbances caused by geopolitical acts (GPRA). Similarly, analyzing oil price shocks in aggregate, rather than unravelling the demand-, supply-, and risk-driven shocks, obscures the causes and eventual economic effects. To accurately trace these transmission channels, it is crucial to conduct a comprehensive analysis that simultaneously integrates these decomposed factors, such as specific oil market shocks, disaggregated GPR, global economic conditions, and a granular set of European

financial stress indices. This approach is especially vital for the Eurozone, which is not only a highly vulnerable net energy importer but also possesses a heterogeneous financial structure.

Considering these research motives and the existing gaps in the literature, this research paper examines the interrelationships among geopolitical risks, the oil market, the global economy, and financial stress in eurozone nations. In this undertaking, we employ the R^2 -decomposed connectedness methodology, as formulated by Balli et al. (2023) and Naeem et al. (2024), which accounts for both contemporaneous and lagged connectedness. While previous studies have touched on the transmission mechanisms in the oil and financial markets (Zhang et al. (2023); Benlagha et al., 2022), they failed to distinguish between immediate and delayed spillovers. By isolating these temporal dimensions, our framework provides novel insights that empower market participants to react swiftly to immediate shocks or anticipate delayed effects, thereby optimizing risk management and hedging strategies. Moreover, the R^2 decomposition technique is less computationally intensive than connectedness methodologies suggested by Diebold and Yilmaz (2012) and Diebold and Yilmaz (2014), because it does not require normalization.

Additionally, several studies highlight that connectedness and transmission mechanisms can vary during crisis events (e.g., Hoque, Sahabuddin, & Bilgili, 2024; Hoque et al., 2023). For example, Hoque et al. (2025) indicate that the Global Financial Crisis of 2008/09, the oil market shocks of 2014/15, the COVID-19 pandemic, and periods of war have changed the shock transmission mechanisms of the nexus between the oil-geopolitical-FSI mechanisms. Similarly, Billah et al. (2025) show that the COVID-19 pandemic and war periods have disrupted shock transmission mechanisms across financial markets. Ahmed and Sohag (2025) show different disruption during Russia-Ukraine and global geopolitical tensions. Therefore, to accurately capture these temporal variations and structural shifts, we conduct a subsample analysis focusing on periods before the 2001 crisis, before the global financial crisis, after the global financial crisis, and during the Russian Ukrainian war.

These interconnected gaps are the direct focus of our research, enabling us to present not only methodological but also empirical contributions. To begin with, we shall add a new time dimension to the spillovers analysis using the R^2 -decomposed connectedness model by Balli et al. (2023). This is a unique way of measuring the ratio of shock transmission: instantaneous (contemporaneous) and delayed (lagged). This decomposition is no longer limited to the aggregate spillover measures of traditional models (e.g. Diebold & Yilmaz, 2012, 2014) but offers actionable intelligence on the velocity of financial contagion. As a debate example, the fact that lagged effects (35.83) are more dominant than contemporaneous ones (30.29) indicates that the system is susceptible to the existence of propagating shocks rather than instantaneous response-a vital fact in the establishment of a short-term crisis response policy and a long-term stabilization strategy.

Second, we provide a more intertwined and detailed analysis of the European case. In contrast to the literature that is aimed at a single transmission channel (e.g., the oil-FSI in Apostolakis et al., 2021 or GPR-FSI in Shahzad et al., 2023), we combine the four oil market shocks, geopolitical risk (threats and acts), global economic conditions, and an overall set of nine European financial stress indices. This enables us to distinguish between net transmitters and receivers in this multifaceted system, which demonstrates, for example, that geopolitical threats (GPRT) are transmitters and geopolitical acts (GPRA) are receivers, a fact that is obscured when we analyze this multifaceted system using a composite GPR index.

Third, our network analysis, contingent on the crisis, will provide dynamic information. We overcome the challenge of identifying how connectedness changes under crisis conditions to demonstrate that the directional roles of variables (e.g., WEC, GPRT) and the nature of shock transmission become fundamentally different in contemporaneous and lagged spaces across various crises (dot-com bubble, GFC, Russia-Ukraine war). This provides a more dynamic and detailed view of financial contagion than the static or fully aggregated network plots used in the literature.

Additionally, the interconnectedness quantified in this study is theorized to proceed through several primary channels of transmission. The inflation and monetary policy channel assume that the effect of oil price shocks is an increase in inflation. Thus, central banks may be forced to tighten monetary policy, which increases the cost of borrowing and may induce financial stress. Concurrently, the trade and terms-of-trade channel highlights that, as a net energy importer, the Eurozone experiences deteriorating trade balances during oil price spikes, which ultimately weakens national income and exacerbates financial stress. In addition, the risk sentiment and financial contagion channel dictates that geopolitical risks and financial stress originating in core economies can trigger a generalized flight-to-safety, spilling over into other markets and driving correlated selloffs. Lastly, the supply chain and real activity channels imply that geopolitical actions and oil supply shocks interfere with global trade. In contrast, oil demand shocks indicate a change in the health of global economies, thus influencing corporate profits and financial stability. By integrating these transmission channels, our empirical model yields critical insights into the relative speed and persistence of contemporaneous and lagged spillovers, as derived from the framework's decomposition. Ultimately, our empirical findings offer a critical resource for market participants, policymakers, governments, and international organizations, equipping them to navigate complex financial environments and formulate robust risk-mitigation strategies during periods of heightened uncertainty.

The rest of the paper is organized as follows. In section 2, we detailed the dataset and method. In the following section, we presented and discussed empirical results. In the final section, we conclude the study, highlighting practical and policy implications.

2. Data and methods

This study utilizes data from geopolitical risk indices developed by Caldara and Iacoviello (2018), specifically focusing on two

sub-indices: Geopolitical Threats (GPRT) and Geopolitical Acts (GPRA) which have been obtained from Matteo Iacoviello's website.¹ The World Economic Conditions (WEC) indicator is sourced from Baumeister's (2020) website.² Additionally, four fundamental oil market shocks, as identified by Baumeister and Hamilton (2019), are considered: oil supply shocks (OSS), economic activity-driven shocks (EAS), oil consumption demand shocks (OCDS), and oil inventory demand shocks (OIDS). The study's scope encompasses nine major European countries (Austria, Germany, Denmark, Spain, Finland, France, United Kingdom, Netherlands, and Sweden) for which financial stress indices³ are acquired from DataStream and ECB website.⁴ To enhance comparability and reduce dimensionality, the GPRT and GPRA scores are rescaled by dividing them by 100.⁵ The study analyzes monthly data spanning from February 1985 to March 2023.

Table 1 provides summary statistics. The results reveals right-skewed distributions for the financial stress indices and geopolitical risk indicators, indicating non-normality in the data. The oil market shocks exhibit mixed skewness (both left and right), while the economic conditions indicator is left-skewed. Furthermore, all series exhibit leptokurtic kurtosis. The Jarque-Bera test statistic confirms the non-normality of the data. Additionally, all series are characterized by stationarity, autocorrelation, and ARCH errors. A significant correlation exists among many series, as indicated in Table 2, at the 5% significance level. Consequently, the adoption of a rolling-window vector autoregressive (VAR) model with contemporaneous effects proves to be a suitable modeling approach for this study.

2.1. R^2 decomposed connectedness approach

This paper employs a new technique, R^2 decomposed connectedness, introduced by Balli et al. (2023), to investigate the aggregate, contemporaneous, and lagged spillover effects of oil market shocks, geopolitical risk, global economic conditions, and EURO financial stress. Unlike traditional methods, this approach clarifies both immediate and delayed spillovers, which matters in this context. Immediate spillovers illustrate how markets interact and adjust to one another right away (Elsayed et al., 2025; Esmailpour Moghadam & Sharifbagheri, 2025). Delayed spillovers show how past events influence current market behaviors Balli et al. (2023). This distinction is essential for understanding the timing and impact of geopolitical risks and oil market shocks on financial stress.

The method broadens the connectedness frameworks by Diebold and Yilmaz (2012) and Diebold and Yilmaz (2014) as it combines the generalized forecast error variance decomposition (GFEVD) with the decomposition concept of Genizi (1993), so that the connectedness measures can be more precisely and cost-effectively estimated since the normalization issue is prevented.⁶ In particular, the R^2 value of a multivariate regression model lies in the range of 0 to 1, so scaling is not required to find the correlation with the row sums, and the row sums are automatically kept within a functional range (Naeem et al., 2024):

$$y_t = \sum_{i=0}^p B_i y_{t-i} + u_t \quad u_t \sim N(0, \Sigma)$$

Here, y_t , y_{t-i} , and u_t represent $K \times 1$ dimensional demeaned vectors at time t , and B_i and Σ are $K \times K$ dimensional matrices where $\text{diag}(B_0) = 0$. This means that the left-hand side (LHS) variable is not included in the right-hand side (RHS) variables. If $p = 0$, the model simplifies to the contemporaneous R^2 decomposed connectedness approach of Naeem et al. (2023). Additionally, the model can be formulated as $y_{k,t} = b_k x_t + u_{k,t}$, where $x_t = [y_t, y_{t-1}, \dots, y_{t-i}, \dots, y_{t-p}]$ is a $K(p+1) \times 1$ dimensional vector and b_k is an $1 \times K(p+1)$ dimensional vector with zero on the k th position.

The total R^2 value in bivariate linear regressions (BLRs) is equal to the R^2 goodness-of-fit measure in a multivariate linear regression (MLR) only if all independent variables on the right-hand side (RHS) are uncorrelated. Therefore, it is crucial to determine a mapping that converts the correlated series $x_{k,t}$ into orthogonal series. PCA can be used with as many latent factors as there are right-hand side (RHS) variables. The R^2 decomposition for a multiple linear regression (MLR) can be computed using the following formula:

$$\begin{aligned} R_{xx} &= V\Lambda V' = CC' \\ C &= V\Lambda^{1/2}V' \\ R^{2,d} &= C^2(C^{-1}R_{yx})^2 \end{aligned}$$

Let V and Λ be $\text{diag}(K_g, K_p, \text{ and } K_{p-1})$ with dimensions $[K(p+1) - 1] \times [K(p+1) - 1]$. The matrices $[K(p+1) - 1]$ represent the eigenvector, eigenvalue, and Pearson correlation matrices. Additionally, R_{yx} and $R^{2,d}$ represent the $[K(p+1)-1] \times 1$ Pearson correlation

¹ <https://www.matteoiacoviello.com/gpr.htm>.

² <https://sites.google.com/site/cjsbaumeister/datasets>.

³ The CLIFS consists of six financial stress indicators that are mostly based on the market. These indicators cover three areas of the financial markets: equities, bonds, and foreign currencies. Also, when putting the sub-indices together, the CLIFS takes into account how market categories move together. More details on CLIFS can be found in the study of Duprey (2017).

⁴ <https://data.europa.eu/data/datasets/country-level-index-of-financial-stress-clifs-clifs?locale=en>.

⁵ The Geopolitical Risk (GPR) index was divided by 100 solely to standardize the scale of the regressors and ensure numerical stability in the estimation of coefficients. Hence, the topology of the connectedness network is unaffected by this rescaling.

⁶ The normalization issue is that when the row sums of the Generalized Forecast Error Variance Decomposition are greater than 1, they need to be scaled to fall in the range of 0 to 1. This approach to R^2 connectedness also naturally limits the range of values, eliminating the need for such normalization. This issue and why the R^2 connectedness framework can prevent it are better described in Naeem et al. (2024).

Table 1
Descriptive and unit root test.

Abbreviation	Full Name	Mean	Variance	Skewness	Ex.Kurtosis	JB	ERS	Q(10)	Q2(10)
Oil Market Shocks									
OSS	Oil Supply Shocks	-0.086	1.78	-1.639***	12.089***	2993.973***	-2.446**	6.455	6.956
EAS	Economic Activity Driven Shocks	-0.019	0.504	-2.171***	23.265***	10688.854***	-9.481***	1.022	119.626***
OCDS	Oil Consumption Demand Shocks	-0.002	14.489	-0.372***	1.539***	55.743***	-5.463***	3.456	18.679***
ODS	Oil Inventory Demand Shocks	-0.071	1.162	0.265**	0.443*	9.120***	-4.574***	4.819	6.352
Geopolitical Risk									
GPRT	Geopolitical Threats	1.03	0.198	3.050***	13.875***	4383.989***	-5.338***	504.467***	301.324***
GPRA	Geopolitical Acts	0.982	0.557	5.923***	48.743***	48018.059***	-5.767***	450.295***	231.198***
World Economic Condition									
WEC	World Economic Conditions	0.018	0.216	-3.330***	23.294***	11201.173***	-5.691***	433.333***	106.089***
Panel D: European Countries' Financial Stress Indices									
Austria		0.129	0.008	1.371***	1.684***	197.665***	-4.329***	1030.379***	764.827***
Germany		0.130	0.008	1.457***	2.356***	267.893***	-4.829***	784.293***	621.997***
Denmark		0.116	0.007	1.933***	4.920***	747.048***	-5.098***	682.654***	535.301***
Spain		0.123	0.008	1.892***	3.968***	573.604***	-4.380***	876.360***	583.314***
Finland		0.173	0.019	1.897***	4.230***	616.051***	-2.426**	1608.075***	1513.318***
France		0.128	0.008	1.704***	3.274***	426.116***	-2.674***	766.065***	658.987***
United. Kingdom		0.121	0.008	1.945***	4.889***	744.994***	-4.138***	995.775***	952.615***
Netherlands		0.102	0.007	2.417***	7.600***	1548.273***	-4.805***	756.404***	514.570***
Sweden		0.129	0.012	2.255***	6.006***	1076.416***	-3.200***	1229.509***	1084.861***

Note: GPRT- Geopolitical Threats, GPRA- Geopolitical Acts, WEC- World Economic Conditions, OSS- oil supply shocks, EAS- economic activity driven shocks, OCDS- oil consumption demand shocks, OIDS- oil inventory demand shocks. Country name demonstrates Country Wise Financial Stress indices. The Ljung-Box Q(10) and Q2(10) Statistic tests for the null hypothesis of no autocorrelation in given series and squared series, respectively. ERS are Elliott-Rothenberg-Stock Unit Root Test. ***indicates statistical significance at the 1% level. ** indicates statistical significance at the 5% level. * Indicates statistical significance at the 10% level.

Table 2
Pearson correlation matrix.

	GPRT	GPRA	WEC	OSS	EAS	OCDS	OCDS	Austria	Germany	Denmark	Spain	Finland	France	UnitedKingdom	Netherlands	Sweden
GPRT	1	0.55	-0.15	0.07	-0.09	-0.03	-0.05	-0.08	0.19	0.02	0.05	0.12	0.18	-0.06	0.14	0.13
GPRA	0.55	1	-0.16	0.06	-0.03	-0.04	0	-0.14	0.1	-0.02	0.01	-0.04	0.06	-0.02	0.11	0.02
WEC	-0.15	-0.16	1	0.04	0.23	0.02	0.01	-0.12	-0.26	-0.22	-0.24	-0.11	-0.4	-0.35	-0.19	-0.27
OSS	0.07	0.06	0.04	1	-0.14	-0.28	0.02	0.09	0.08	0.02	0.06	0.01	0.1	0.06	0.07	0.08
EAS	-0.09	-0.03	0.23	-0.14	1	0.07	-0.02	-0.07	-0.06	-0.08	-0.06	-0.03	-0.08	-0.07	-0.03	-0.06
OCDS	-0.03	-0.04	0.02	-0.28	0.07	1	-0.39	-0.06	-0.04	-0.02	-0.06	-0.02	-0.08	-0.02	-0.11	-0.03
OCDS	-0.05	0	0.01	0.02	-0.02	-0.39	1	0.03	0.02	0.06	0.01	0.01	-0.06	0.04	0.02	-0.02
Austria	-0.08	-0.14	-0.12	0.09	-0.07	-0.06	0.03	1	0.55	0.46	0.54	0.48	0.54	0.38	0.34	0.58
Germany	0.19	0.1	-0.26	0.08	-0.06	-0.04	0.02	0.55	1	0.59	0.49	0.38	0.67	0.45	0.54	0.57
Denmark	0.02	-0.02	-0.22	0.02	-0.08	-0.02	0.06	0.46	0.59	1	0.57	0.44	0.6	0.56	0.41	0.58
Spain	0.05	0.01	-0.24	0.06	-0.06	-0.06	0.01	0.54	0.49	0.57	1	0.48	0.7	0.48	0.44	0.57
Finland	0.12	-0.04	-0.11	-0.04	-0.03	-0.02	0.01	0.48	0.38	0.44	0.48	1	0.51	0.17	0.22	0.67
France	0.18	0.06	-0.4	0.1	-0.08	-0.08	-0.06	0.54	0.67	0.6	0.7	0.51	1	0.5	0.58	0.65
UnitedKingdom	-0.06	-0.02	-0.35	0.06	-0.07	-0.02	0.04	0.38	0.45	0.56	0.48	0.17	0.5	1	0.38	0.5
Netherlands	0.14	0.11	-0.19	0.07	-0.03	-0.11	0.02	0.34	0.54	0.41	0.44	0.22	0.58	0.38	1	0.34
Sweden	0.13	0.02	-0.27	0.08	-0.06	-0.03	-0.02	0.58	0.57	0.58	0.57	0.67	0.65	0.5	0.34	1

Table 3
Overall transmission between oil market shocks, geopolitical risk, global economic condition, and EURO financial stress.

	GPRT	GPRA	WEC	OSS	EAS	OCDS	OIDS	Austria	Germany	Denmark	Spain	Finland	France	United Kingdom	Netherlands	Sweden	FROM
GPRT	16.55	20.86	5.5	2.7	1.72	1.3	1.22	2.43	3.23	3.07	3.91	3.37	2.72	2.73	4.85	2.72	62.34
GPRA	23.99	22.15	5.25	1.61	1.49	2.22	0.94	2.79	2.34	1.74	2.92	1.84	2.62	2	2.9	2.06	56.7
WEC	4.56	3.78	19.24	3.66	12.44	3.55	1.51	3.65	4.33	5.13	2.97	2.29	5.16	7.31	2.93	3.32	66.58
OSS	2.69	1.81	3.78	1.51	3.33	14.27	2.23	3.44	3.47	3.36	3.02	2.44	3.65	2.16	3.43	3.33	56.43
EAS	2.08	3.74	7.6	3.78	6.38	4.39	2.8	2.89	3.01	3.01	2.3	2.16	3.13	4.22	2.54	2.66	50.33
OCDS	1.62	2.4	2.45	12.66	2.17	3.54	14	2.18	3.63	2.82	1.67	2.42	2.47	2.11	2.5	2.59	57.69
OIDS	2.18	3	2.42	4.36	2.1	15.69	4.14	2.35	1.99	2.42	2.46	1.87	2.14	2.05	2.12	1.93	49.08
Austria	2.15	2.7	3.67	2.42	2.04	1.3	1.37	20.17	6.9	5.11	7.99	7.76	8.47	3.89	6.07	6.15	67.99
Germany	3.43	1.64	4.68	2.43	1.87	2.71	1.04	5.97	15.72	7.49	6.97	7.01	9.39	3.94	7.95	6.67	73.19
Denmark	2.4	1.34	5.46	2.03	1.42	1.1	1.17	5.03	7.94	10.97	8.64	8.55	8.67	11.17	6.77	6.8	78.49
Spain	3.58	2.08	3.08	1.15	1.48	0.9	0.82	8.13	7.01	9.42	14.01	8.26	13.28	4.77	6.64	6.4	77
Finland	2.6	1.28	1.97	1.31	0.92	0.84	0.69	8.79	7.32	8.84	9.44	19.06	8.04	5.2	6.3	10.62	74.16
France	2.18	1.04	5.52	1.87	2.05	1.16	0.92	7.78	10.15	8.2	12.53	6.79	9.51	5.55	7.83	7.89	81.46
United Kingdom	1.74	1.51	5.42	1.21	2.2	1.24	0.91	4.22	4.76	11.19	5.2	5.08	6.32	16.8	5.26	8.24	64.51
Netherlands	6.18	2.3	2.23	1.76	1.85	1.63	0.8	5.61	8.9	7.05	7.21	7.04	8.13	4.41	18.19	5.12	70.22
Sweden	2.33	1.19	3.45	1.95	1.17	1.15	0.83	6.72	7.95	7.2	6.68	10.07	8.49	7.25	5.37	14.36	71.8
TO	63.7	50.68	62.48	44.89	38.25	53.46	31.26	71.97	82.92	86.06	83.9	76.96	92.68	68.77	73.46	76.51	1057.95
IncOwn	80.25	72.83	81.72	46.4	44.64	57	35.4	92.14	98.64	97.03	97.91	96.03	102.18	85.58	91.65	90.87	TCI
NET	1.36	-6.02	-4.11	-11.54	-12.08	-4.23	-17.82	3.98	9.73	7.58	6.9	2.81	11.21	4.27	3.24	4.71	66.12
NPT	6	4	10	3	1	4	1	10	13	12	10	8	13	8	9	8	

Note: The results obtained from R^2 decomposed measures are based on a 120-Month rolling-window VAR model with a lag length of order two (AIC). GPRT- Geopolitical Threats, GPRA -Geopolitical Acts, WEC- World Economic Conditions, OSS- oil supply shocks, EAS- economic activity driven shocks, OCDS-oil consumption demand shocks, OIDS- oil inventory demand shocks. Country name demonstrates Country Wise Financial Stress indices.

Table 4
Contemporaneous Transmission between Oil market shocks, Geopolitical Risk, Global Economic Condition, and EURO Financial.

	GPRT	GPRA	WEC	OSS	EAS	OCDS	Austria	Germany	Denmark	Spain	Finland	France	United.Kingdom	Netherlands	Sweden	FROM
GPRT	0	15.81	2.28	0.89	0.38	0.43	0.41	0.73	1.17	1.36	1.03	0.91	0.72	2.01	0.92	30.41
GPRA	15.95	0	1.91	0.49	0.51	0.61	0.28	0.75	0.68	0.53	0.9	0.62	0.59	0.96	0.63	25.95
WEC	2.14	1.88	0	1.31	2.45	0.37	0.35	1.2	1.48	1.95	1.13	0.82	2.37	0.73	1.23	21.62
OSS	1.23	0.61	1.67	0	0.94	11.1	1.23	1.24	1.37	1.56	1.03	1.09	1.18	1.32	1.28	27.59
EAS	0.58	0.8	3.53	1.01	0	0.99	0.49	1.05	1.15	0.82	0.78	0.69	1.39	1.13	0.85	16.45
OCDS	0.61	0.78	0.67	11.12	0.92	0	13.24	0.86	1.65	0.85	0.57	0.72	0.76	1.26	0.94	35.74
ODS	0.7	0.51	0.7	1.43	0.51	14.08	0	0.75	0.69	0.96	0.85	0.6	0.81	0.56	0.79	24.87
Austria	0.6	0.62	1.17	0.88	0.54	0.49	0.22	0	3.08	2.38	3.84	3.41	4.03	3.49	2.36	28.58
Germany	1.01	0.47	1.46	0.96	0.64	1.14	0.26	3.13	0	4.2	3.83	3.74	5.41	4.63	3.06	35.85
Denmark	1.12	0.41	1.94	0.83	0.32	0.41	0.44	2.39	4.17	0	4.19	4.74	4.75	4.2	3.09	38.5
Spain	1.24	0.78	1.03	0.48	0.3	0.24	0.25	3.79	3.71	4.23	0	3.81	2.11	3.44	2.58	35.11
Finland	0.91	0.38	0.68	0.53	0.25	0.28	0.18	3.42	3.53	4.61	3.84	0	2	3.28	3.66	30.84
France	0.79	0.42	2.22	0.79	0.62	0.39	0.33	4.04	5.4	4.87	7.14	3.3	3.12	4.5	3.79	41.72
United.Kingdom	0.62	0.54	2.46	0.43	0.91	0.57	0.46	1.54	1.93	5.63	2.31	2.18	0	2.14	3.43	28.35
Netherlands	1.92	0.79	0.7	0.8	0.65	0.86	0.2	3.43	4.64	4.17	3.53	3.35	2.19	0	2.54	34.31
Sweden	0.79	0.43	1.18	0.89	0.31	0.6	0.34	2.41	3	3.08	2.56	3.71	3.34	2.35	0	28.75
TO	30.2	25.25	23.6	22.84	10.26	32.57	18.69	30.73	37.66	41.18	37.85	33.72	43.93	36.02	31.14	484.63
Inc.Own	30.2	25.25	23.6	22.84	10.26	32.57	18.69	30.73	37.66	41.18	37.85	33.72	43.93	36.02	31.14	TCI 30.29
NET	-0.2	-0.7	1.98	-4.75	-6.18	-3.18	-6.18	2.15	1.81	2.69	2.74	2.88	2.22	1.71	2.39	
NPT	5	4	7	3	1	2	0	13	9	11	13	13	10	9	13	

Note: The results obtained from R^2 decomposed measures are based on a 120-Month rolling-window VAR model with a lag length of order two (AIC). GPRT- Geopolitical Threats, GPRA -Geopolitical Acts, WEC- World Economic Conditions, OSS- oil supply shocks, EAS- economic activity driven shocks, OCDS-oil consumption demand shocks, OIDS- oil inventory demand shocks. Country name demonstrates Country Wise Financial Stress indices.

Table 5
Lagged Transmission between Oil market shocks, Geopolitical Risk, Global Economic Condition, and EURO Financial Stress.

	GPRT	GPRA	WEC	OSS	EAS	OCDS	OIDS	Austria	Germany	Denmark	Spain	Finland	France	United. Kingdom	Netherlands	Sweden	FROM
GPRT	16.55	5.05	3.22	1.81	1.34	0.87	0.81	1.7	2.06	1.71	2.55	2.35	1.82	2.01	2.84	1.8	31.93
GPRA	8.03	22.15	3.34	1.12	0.98	1.62	0.66	2.04	1.66	1.21	2.02	1.31	2	1.41	1.93	1.43	30.75
WEC	2.43	1.9	19.24	2.35	9.98	3.18	1.16	2.45	2.85	3.18	1.84	1.47	2.94	4.93	2.2	2.09	44.96
OSS	1.46	1.2	2.11	1.51	2.39	3.16	1	2.2	2.1	1.8	1.99	1.35	2.47	1.43	2.11	2.06	28.85
EAS	1.5	2.94	4.07	2.77	6.38	3.4	2.31	1.84	1.86	2.19	1.52	1.47	1.94	2.83	1.42	1.81	33.88
OCDS	1.01	1.62	1.78	1.54	1.25	3.54	0.76	1.32	1.97	1.97	1.1	1.69	1.68	1.35	1.24	1.65	21.94
OIDS	1.47	2.49	1.72	2.92	1.59	1.61	4.14	1.59	1.3	1.46	1.6	1.27	1.23	1.24	1.56	1.14	24.22
Austria	1.55	2.07	2.5	1.54	1.5	0.81	1.15	20.17	3.82	2.73	4.16	4.35	4.44	2.42	2.58	3.8	39.41
Germany	2.43	1.17	3.21	1.47	1.22	1.57	0.78	2.83	15.72	3.29	3.14	3.27	3.99	2.03	3.32	3.61	37.33
Denmark	1.28	0.92	3.52	1.2	1.1	0.7	0.73	2.64	3.77	10.97	4.45	3.81	3.91	5.68	2.57	3.71	39.99
Spain	2.35	1.29	2.05	0.67	1.18	0.66	0.58	4.34	3.29	5.19	14.01	4.45	6.17	2.66	3.19	3.81	41.89
Finland	1.68	0.9	1.29	0.78	0.66	0.56	0.51	5.38	3.79	4.23	5.59	19.06	4.75	3.2	3.02	6.96	43.31
France	1.39	0.63	3.29	1.08	1.43	0.77	0.59	3.74	4.75	3.33	5.39	3.49	9.51	2.43	3.33	4.11	39.75
United. Kingdom	1.12	0.97	2.96	0.78	1.3	0.67	0.46	2.68	2.83	5.56	2.89	2.9	3.1	16.8	3.12	4.82	36.15
Netherlands	4.26	1.51	1.53	0.96	1.2	0.77	0.6	2.18	4.26	2.88	3.68	3.69	3.59	2.23	18.19	2.58	35.91
Sweden	1.54	0.76	2.28	1.06	0.86	0.55	0.49	4.31	4.95	4.13	4.12	6.35	4.72	3.92	3.02	14.36	43.05
TO	33.5	25.43	38.88	22.05	27.99	20.89	12.58	41.24	45.26	44.88	46.05	43.24	48.74	39.78	37.44	45.37	573.33
Inc.Own	50.05	47.58	58.12	23.57	34.37	24.44	16.71	61.41	60.98	55.85	60.06	62.31	58.25	56.59	55.63	59.73	TCl 35.83
NET	1.57	-5.32	-6.08	-6.79	-5.89	-1.05	-11.64	1.83	7.92	4.89	4.16	-0.07	9	3.63	1.53	2.32	
NPT	6	5	9	4	1	4	1	9	13	11	10	8	13	9	9	8	

Note: The results obtained from R2 decomposed measures are based on a 120-Month rolling-window VAR model with a lag length of order two (AIC). GPRT- Geopolitical Threats, GPRA -Geopolitical Acts, WEC- World Economic Conditions, OSS- oil supply shocks, EAS- economic activity driven shocks, OCDS-oil consumption demand shocks, OIDS- oil inventory demand shocks. Country name demonstrates Country Wise Financial Stress indices.

and R^2 contribution vectors, respectively.

R_{xx} represents Pearson correlation coefficients among the right-hand side (RHS) variables, while R_{yx} represents Pearson correlation coefficients between the left-hand side (LHS) and RHS variables.

The initial $K-1$ values of $R^{2,d}$ indicate the concurrent contributions of R^2 , while the remaining values indicate the delayed contributions of R^2 . Hence, the total vector sum of $R^{2,d}$ is equivalent to the MLR R^2 measure used to assess the goodness-of-fit. Afterwards, we aggregate the $R^{2,d}$ contribution of K multiple linear regressions (MLRs) to form a $K \times K(p+1)$ dimensional $R^{2,d}$ decomposition matrix, denoted as $[R_0^{2,d}; \dots; R_i^{2,d}; \dots; R_p^{2,d}]$.

$R_0^{2,d}$ represents the contemporaneous spillovers ($R_C^{2,d}$), while ($R_L^{2,d} = R_1^{2,d} + \dots + R_i^{2,d} + \dots + R_p^{2,d}$) (the sum of lagged values) represents the lagged spillovers.

In the connectivity approach of Diebold and Yilmaz (2012, 2014), $R_C^{2,d}$ and $R_L^{2,d}$ complement the scaled GFEVD matrix. As a result, the total connectedness index (TCI) equals the average R^2 of the k MLRs:

$$TCI = \frac{1}{K} \sum_{k=1}^K R_k^2$$

The range of R_k^2 , which is between zero and one, also applies to TCI, thereby addressing the issue of connectedness normalization (Lastrapes & Wiesen, 2021; Chatziantoniou & Gabauer, 2021; Gabauer, 2021). Our proposed methodology enables the examination of both contemporaneous and lagged TCI.

$$\begin{aligned} TCI &= \frac{1}{K} \sum_{k=1}^K R_k^2 \\ &= \left(\frac{1}{K} \sum_{k=1}^K \sum_{j=1}^K R_{C,k,j}^{2,d} \right) + \left(\frac{1}{K} \sum_{k=1}^K \sum_{j=1}^K R_{L,k,j}^{2,d} \right) \\ &= TCI^C + TCI^L \end{aligned}$$

where TCI^C and TCI^L denote the contemporaneous and lagged TCI, respectively. The aforementioned concept can also be extended to encompass total directional connectedness to and from others, as well as net total directional connectedness measures.

3. Empirical discussion

3.1. Averaged dynamic connectedness

Our study analyzed the transmission and connection of oil market shocks, geopolitical risk, global economic conditions, and EURO financial stress. The findings reveal a high degree of connectedness among these factors, with 66.12% of the variance in the left-hand side (LHS) variables explained by the right-hand side (RHS) variables (see Tables 3–5). This suggests a tightly coupled system in which shocks spread rapidly, creating significant systemic risk. Additionally, this rapid propagation of shocks supports notion of contagion theory. These findings highlight the level of spillover among oil market shocks, geopolitical risk, global economic conditions, and EURO financial stress. These findings are partially supported by Hoque et al. (2025, 2026), and Maghyereh and Ziadat (2024) for a higher level of spillover among oil price shocks, global economic conditions, and financial stress. Additionally, this also supports NguyenHuu and Örsal (2023) for their evidence on GPR and Mignon and Saadaoui (2024) for their evidence on GPR and OIL. Additionally, our findings also confirm the theoretical assertions of geopolitical theory, energy economics theory, and contagion theory.

The disaggregation of the Total Connectedness Index (TCI) reveals that 35.83% of its value is attributable to lagged interdependencies, compared with 30.29% to contemporaneous dynamics. This implies that the spillover of shocks among oil markets, geopolitical risk, and financial stress is stronger in the long term than in the short term. Although this observation contradicts the strong form of the Efficient Market Hypothesis (EMH), it is consistent with models of informational burdens and heterogeneous participants. It also exposes the role played by structural frictions and concrete institutional mechanisms. Additionally, policymakers and market participants may require time to fully understand the complex second-round shocks. For example, a geopolitical threat (GPRT) can have a contemporaneous effect on oil prices. However, its ultimate effects on company profits will be delayed, as supply chains and subsequent central bank policy responses play out over several months. This delayed transmission indicates a gradual diffusion of information across distinct market segments and highlights operational lags within real economic channels. Thus, economic agents, like investors and policymakers, do not always respond quickly to new information. Instead, they take time to evaluate the implications of these shocks. For instance, geopolitical events or financial crises may initially trigger a quick market response, but their longer-term effects can be more significant. Additionally, these results are consistent with previous research on the topic (see Abdel-Latif & El-Gamal, 2020; Gençyürek, 2023; Xie et al., 2023) and provide a new dimension to the connectedness of these factors with contemporaneous and lagged spillover.

The FROM and TO connectedness measures exhibit significant differences between their contemporaneous and lagged counterparts. Certain variables, such as GPRT, GPRA, OSS, EAS, and the WEC, exhibit higher lagged FROM measures than their

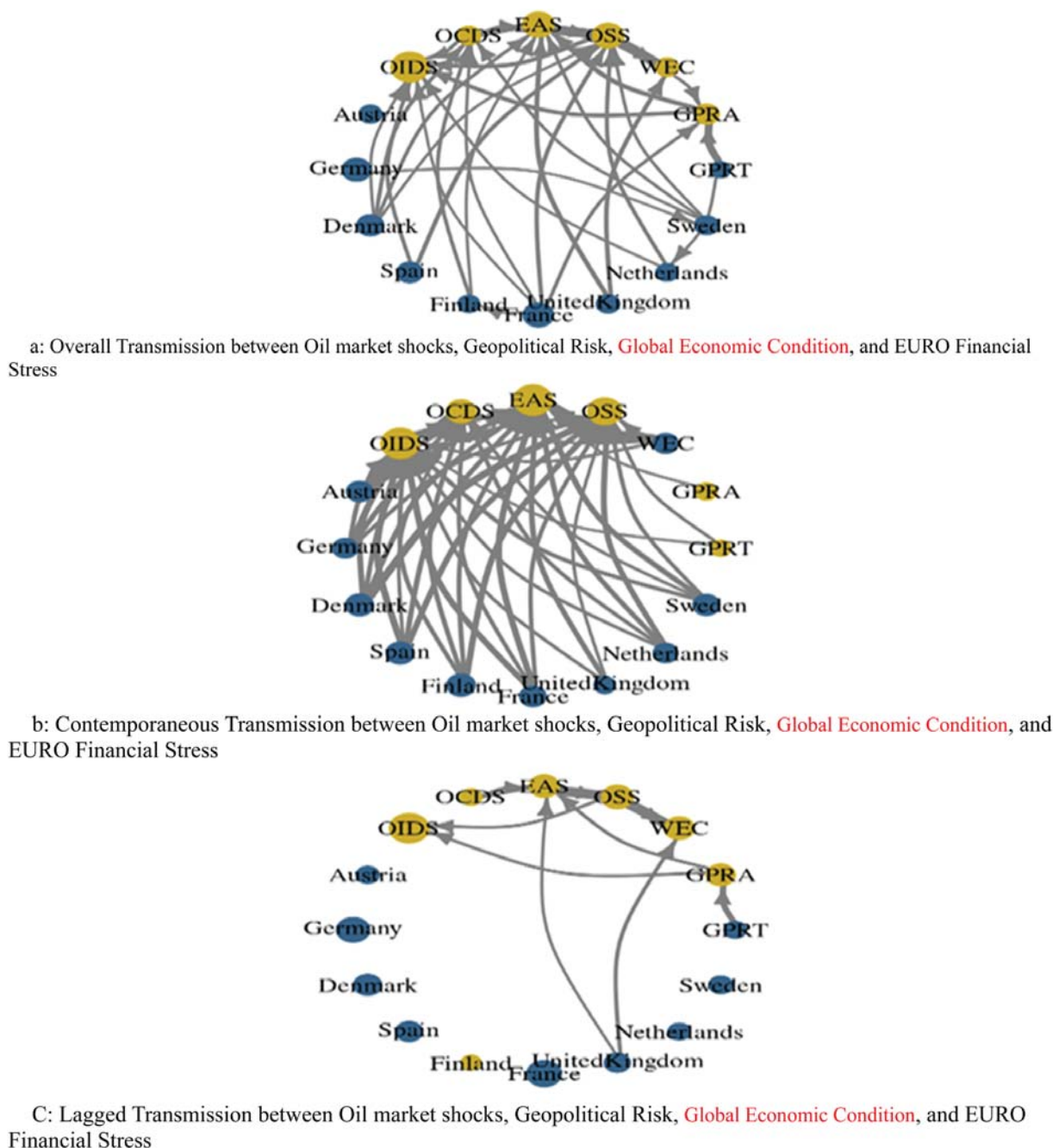


Fig. 1. Overall, Contemporaneous, and Lagged between Oil market shocks, Geopolitical Risk, Global Economic Condition, and EURO Financial Stress.

Note: R^2 decomposed measures are based on a 120-Month rolling-window VAR model with a lag length of order two (AIC) and H Step 10. We chose rolling windows of 120 months and a lag length of two, based on the Akaike Information Criterion (AIC). This choice is ideal for capturing long-term trends while also addressing shorter-term changes. The 120-month window allows us to include a significant historical context, leading to a thorough analysis of structural changes in market dynamics. The lag length of two captures immediate and short-term effects without adding too much noise, achieving a balance between precision and clarity.

contemporaneous measures, indicating a stronger influence of past values and interdependencies. Conversely, all financial stress indices, except for France, exhibit lower lagged FROM measures than their contemporaneous measures, implying a more prominent role of immediate interactions and dynamics. Examining both immediate and lagged relationships is crucial in understanding the transmission and interdependencies among the variables. These findings validate the importance of considering contemporaneous and lagged connectedness, as suggested by Balli et al. (2023).

In addition to this, we have found that GPRT (1.36%), Austria (3.98%), Germany (9.73%), Denmark (7.58%), Spain (6.9%), Finland (2.81%), France (11.21%), Netherlands (3.24) Sweden (4.71%), and the United Kingdom (4.27%) are all net shock transmitters. GPRA (−17.82%), OIDS (4.88%), WEC (−4.23%), OSS (−11.54%), EAS (−12.08%), OCDS (−20.19%) are shock receivers. Fig. 1a also shows

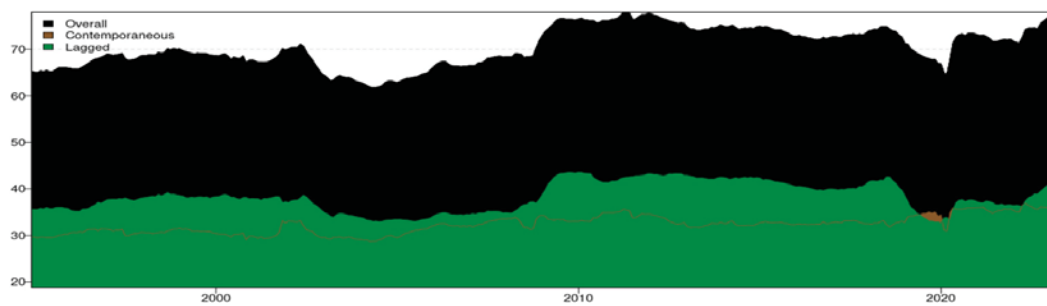


Fig. 2. Dynamic Transmission between Oil market shocks, Geopolitical Risk, Global Economic Condition, and EURO Financial Stress.

similar roles with dense network. On the economic side, this split of GPR implies that geopolitical threats (GPRT) broadcast uncertainty. The fact that nations such as Germany and France have consistently been net transmitters of financial stress is not merely a matter of their large economies but also of their central positions in the European financial system. With the largest economy in Europe and one of the main holders of European debt, Germany passes on stress through its cross-border exposures via banks. It serves as a reference point for regional risk perception. Besides, France's role is enhanced by its large, internationally active banking industry with significant exposure to international commodity trade finance (see Fig. 2).

On the other hand, the Netherlands is frequently a recipient, despite its large economy. This is explained by its open and highly leveraged financial system, as well as the dominance of large multinational corporations (e.g., in energy and agriculture), which makes its financial stress index more vulnerable to global shocks transmitted by core economies and commodity markets. Furthermore, the presence of net shock transmitters, such as financial stress in Germany, France, Finland, and the Netherlands, shows how connected global economies are. These economies, due to their size, trade volume, and financial influence, can spread economic disruptions. Shocks that start in these countries, whether from policy changes, geopolitical events, or market fluctuations, can ripple through interconnected supply chains and financial systems, affecting both regional and global markets. Additionally, WEC, GPRA, and OCDS, as shock receivers, are vulnerable to the EURO and oil markets. For instance, a high dependency on oil imports or sensitivity to commodity demand can worsen the effects of price shocks or geopolitical disruptions.

Moreover, when comparing the net transmission roles in the contemporaneous and lagged periods, we observe a shift in the behavior of certain variables. Specifically, WEC, which were identified as net shock receivers in the overall analysis, now act as net shock transmitters in the contemporaneous period. This implies that new information about the health of the global economy constitutes a direct informational shock that reprices an asset in real time. Its reversal to a receiver over time demonstrates that the global economy is eventually subject to the lagged impacts of the previous financial and oil shocks. This highlights WEC could facilitate predictability of oil market (Lv. and Wu, 2023) and financial stress. In the same period, GPRT shifts from a net shock transmitter to a net shock receiver in the overall analysis. Additionally, in the lagged connectedness, Finland become net receiver. These contrasting roles in net shock transmission underscore the complex dynamics among the variables. Consequently, this reinforces the necessity of incorporating both contemporaneous and lagged effects to fully understand the propagation of systemic shocks. In addition, the network plots in Fig. 1b and c highlight that transmission of spillover effects was strong and integration in the contemporaneous period. This suggests that shocks originating in one economy were more likely to spread to others simultaneously, rather than with a delay, due to the high degree of integration among the economic networks. Additionally, Fig. 1c shows that financial stress indices, except for the UK, are not integrated with oil market shocks, geopolitical risk, and the global economic condition.

3.2. Time varying connectedness

The time-varying connectedness analysis presented in Fig. 1 demonstrates that the financial-oil-geopolitical system is inherently dynamic. Specifically, the network experiences dramatic fluctuations in response to distinct economic regimes and exogenous crises. We noted persistently high overall connectedness, revealing the contemporary global financial system's inherent vulnerability to contagion. This has an immense economic impact, as the advantages of international portfolio diversification are likely to be lost during periods of systemic crisis. The changing rates of contemporaneous versus lagged connectedness also give an efficient dynamic map of market efficiency and absorption capacity. The high contemporaneous spillovers indicate periods of intensive information processing, typically panics, while the sustained lagged spillovers suggest that the market is being digested and that secondary ripple effects are long-lasting.

We observed higher overall connectivity during oil market events, such as OPEC production cuts in 1998/99, 2001, 2007/08, and 2016/17; the oil price revolution from 2014 to 2016; and ongoing supply disruptions from 2021 to the present. These events support the idea of increased connectedness driven by supply-side shocks in commodity markets, consistent with the oil shock hypothesis (Hamilton, 1983). This theory suggests that sudden changes in oil supply, often due to cartel decisions or geopolitical tensions, worsen inflation, disrupt global trade balances, and increase volatility in equity, currency, and bond markets (Baumeister et al., 2022; Baumeister & Hamilton, 2019; Kilian, 2014; Ma et al., 2025). Additionally, the financial channel manifested as the sharp devaluation of assets in the energy sector and in high-yield bonds, which strained the balance sheets of the exposed banks and funds. At the same time, the trade and terms-of-trade channels caused severe recessions in oil-producing emerging economies, such as Russia and Venezuela, which reduced their demand for European exports and the value of European banks' claims against these countries. The prevalence of

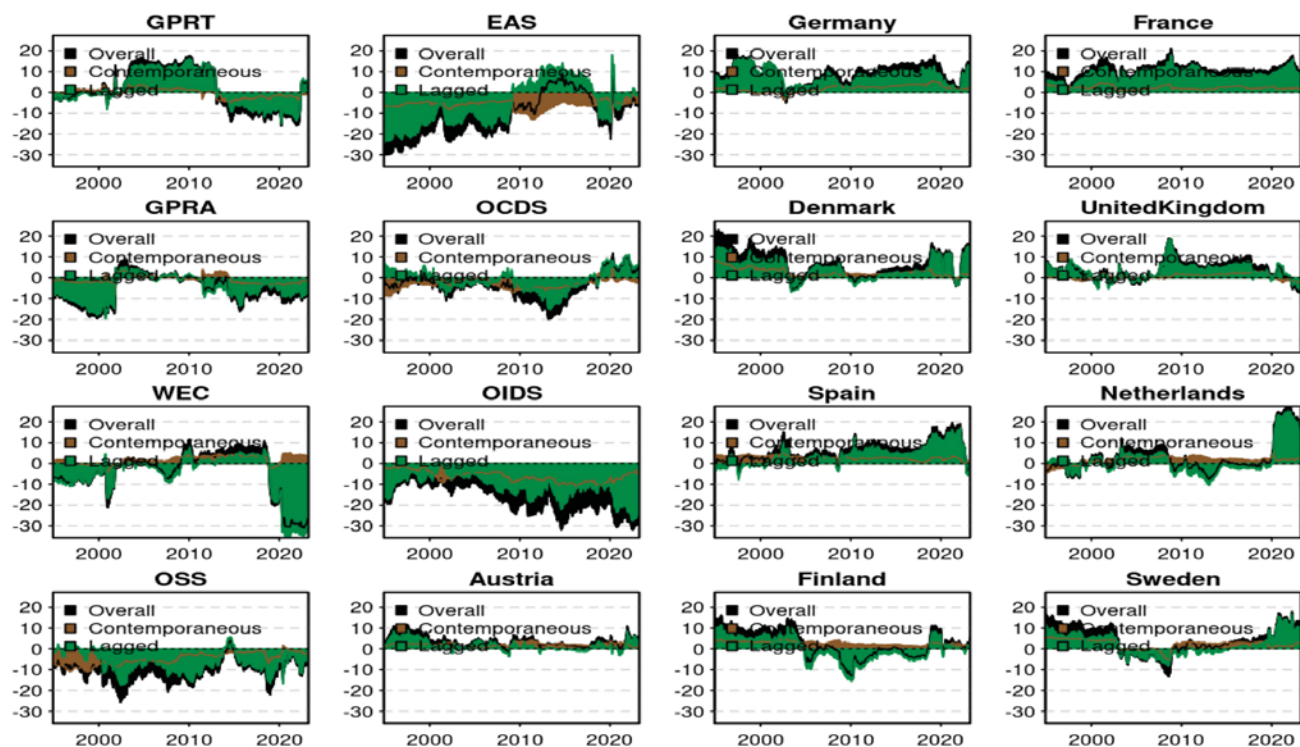


Fig. 3. Dynamic net directional roles of Oil market shocks, Geopolitical Risk, Global Economic Condition, and EURO Financial Stress.

Note: R2 decomposed measures are based on a 120-Month rolling-window VAR model with a lag length of order two (AIC) and H Step 10.

lagged spillovers during this period is economically significant. It indicates that the initial price shock was less detrimental than the subsequent wave of corporate defaults, fiscal constraints in oil-exporting nations, and the credit risk repricing that unfolded over the following years. Similarly, the disruptions starting in 2021, driven by post-COVID demand surges and sanctions on Russian exports, have strengthened these connections. By intertwining energy security with broader supply chain vulnerabilities, these shocks have triggered coordinated spikes in inflation and commodity prices in advanced economies.

Furthermore, spikes in connectedness are clear during geopolitical events, such as the 1990-91 Gulf War, the 9/11 attacks, the 2003 Iraq War, the 2011 Arab Spring, the 2016 Brexit referendum, and the 2022 Russia-Ukraine war. These event-driven connectedness fits with the contagion models of [Forbes and Rigobon \(2002\)](#). For example, the recent Russia-Ukraine war has combined energy sanctions with food supply shocks. This situation has pushed wheat and natural gas prices to record highs. The economic reason behind this is the export disruption of key commodities in a central region, which directly spreads inflationary shocks to other countries and forces them to urgently reconsider their energy security and supply chain resilience due to imports. This illustrates the spread of geopolitical risks along global value chains ([Acemoglu et al., 2016](#)), but our breakdown introduces a crucial time dimension. A primary example is the Russia-Ukraine war, which triggered an immediate surge in energy prices. However, its most profound economic impact was not the initial shock but the entrenched core inflation that necessitated prolonged monetary tightening by the ECB and the BoE. This policy shift ultimately manifested as a strong lagged spillover, tightening financial conditions across Europe long after the initial energy spike. This is the most important transmission process between geopolitics and financial stress.

In addition, financial crises such as the 1997 Asian Financial Crisis, the 2000-01 dot-com bubble burst, the 2001 Eurozone debt stress, the 2008-09 Global Financial Crisis (GFC), the 2011-12 Eurozone sovereign debt crisis, and the COVID-19-induced economic turmoil highlight these patterns. These events relate to the financial accelerator model of [Bernanke et al. \(1999\)](#), which shows how negative shocks increase leverage and credit constraints, causing widespread effects across borders and asset classes. Moreover, the most significant Euro financial stress occurred during the 2010-12 sovereign debt crisis, which was associated with renewed increases in overall and current connectedness.

Besides these crisis-related reasons, the heightened connectedness from 1997 to 2009 likely resulted from broader changes in global financial systems. The economic impact is that financial liberalization and the adoption of the Euro have created a more integrated system. These developments have fundamentally transformed global market dynamics. Transmission shocks are no longer merely exogenous responses to specific triggers; rather, the integrated architecture of the contemporary financial network generates endogenous co-movements. This structural evolution facilitates synchronized market responses that occur either in conjunction with, or independently of, documented geopolitical events. These shifts transpired alongside broader globalization trends, which heightened interdependencies by reducing frictions in information diffusion, capital mobility, and cross-border asset integration. A primary catalyst for this structural transition was the wave of financial liberalization during the 1990s and early 2000s, which significantly reshaped the institutional frameworks of both emerging and developed economies. Another significant change was the introduction of the EURO in 1999, along with technological advancements that further supported these findings. Additionally, the 2008-09 GFC

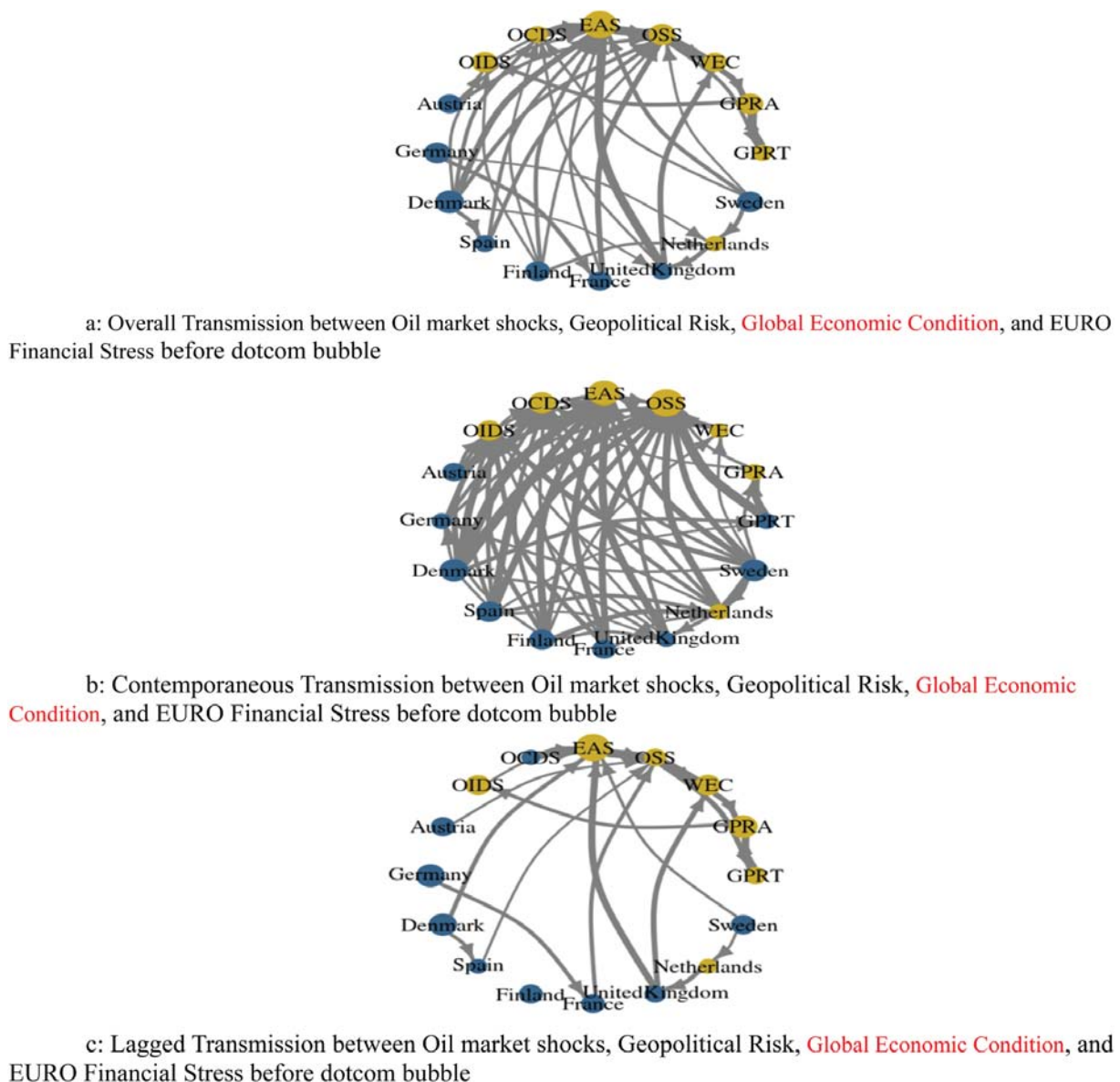


Fig. 4. Overall, Contemporaneous, and Lagged between Oil market shocks, Geopolitical Risk, Global Economic Condition, and EURO Financial Stress before dotcom bubble.

intensified these issues, as peripheral Eurozone countries like Ireland and Portugal underwent banking rescues that increased public debt. This led to a rise in credit default swap spreads and a quick drop in equity markets.

Moreover, in Fig. 3, we observe that fundamental oil shocks, geopolitical risk, and the Euro financial stress exhibit time-varying net directional roles in overall, contemporaneous, and lagged connectedness. These role transitions indicate economic implications, as there is a fixed transmitter or receiver of shocks. For example, a geopolitically neutral nation may become a shock absorber in the event of a financial crisis, serving as a core financial center, and then transition into a receiver in the case of a demand-side global recession. These variations in the net direction of connectedness are often triggered by significant events such as wars, financial crises, and policy changes by OPEC (Organization of the Petroleum Exporting Countries). These findings are supported by Shahzad et al. (2023), Hoque et al. (2025), and Hoque et al. (2026). Like their study, ours also exhibits contemporaneous and lagged connectedness.

3.3. Crisis dependent network

In order to understand the nature of the network, we conducted three subsample analyses focusing on the period before the 2000–2001 dotcom bubble and financial crisis, before the Global Financial Crisis 2008/09, after the financial crisis 2008/09, and during the Russia-Ukraine War, which are presented in Figs. 4–7, respectively. In Fig. 4, the connectedness among oil market shocks, geopolitical factors, global economic conditions, and Euro financial stress prior to the dot-com bubble is shown. Austria, Germany, Denmark, Spain, Finland, France, the United Kingdom, and Sweden act as transmitters across total, concurrent, and lagged connectedness. The fact that

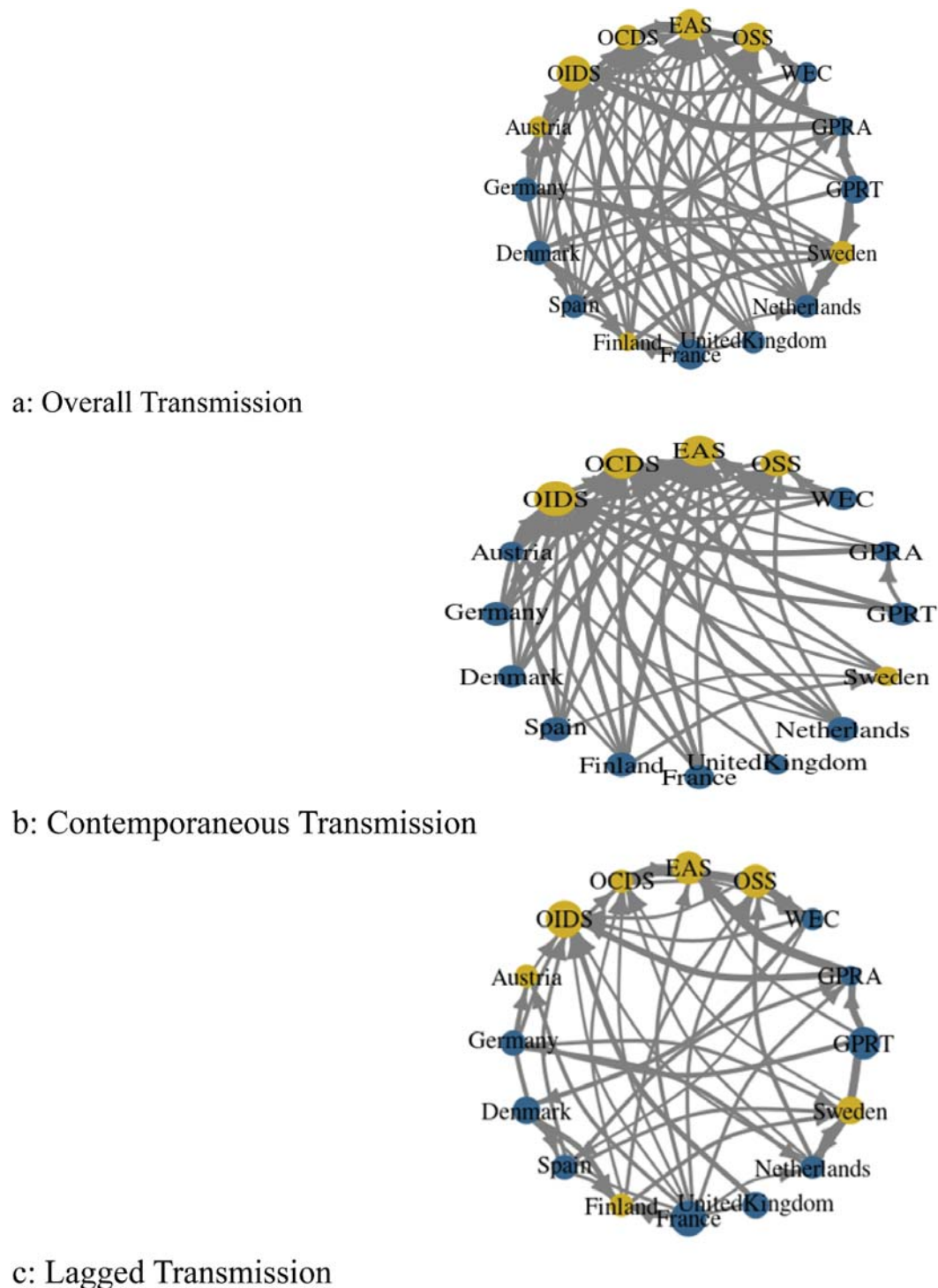
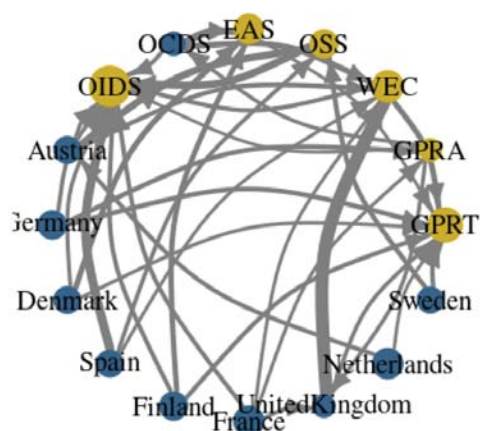


Fig. 5. Overall, Contemporaneous, and Lagged between Oil market shocks, Geopolitical Risk, Global Economic Condition, and EURO Financial Stress before Global Financial Crisis 2008/2009.

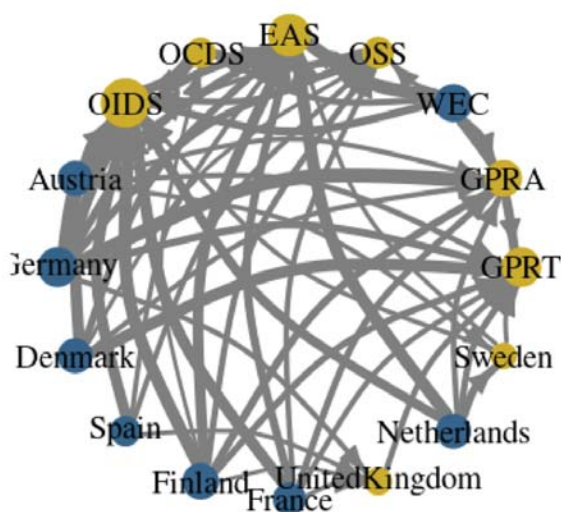
Note: R^2 decomposed measures are based on a 120-Month rolling-window VAR model with a lag length of order two (AIC) and H Step 10.

European financial systems acted as transmitters in the pre-crisis era reflects their status as stable, core capital markets. In a stable global environment, internal developments in these mature markets were the primary drivers of network-wide connectivity. In contrast, the Netherlands is a receiver in all three connectedness dimensions. Additionally, GPRT, GPRA, WEC, OSS, EAS, and OIDS serve as receivers in all three connectedness dimensions, except for OCDS, which acts as a transmitter in lagged connectedness.

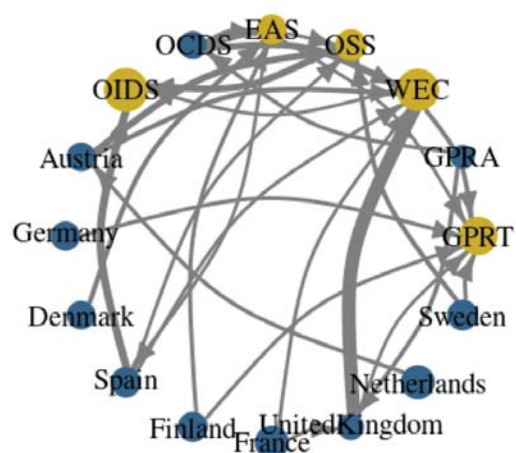
Fig. 5 shows the interconnectedness prior to the Global Financial Crisis of 2008/2009. In a sharp departure from the pre-dotcom era, GPRT, GPRA, and WEC transitioned from receivers to net transmitters across all dimensions. This signals a change in the sample dynamics: country-specific factors lost their leading role, and systemic risk became driven by synchronized global macroeconomic



a: Overall Transmission



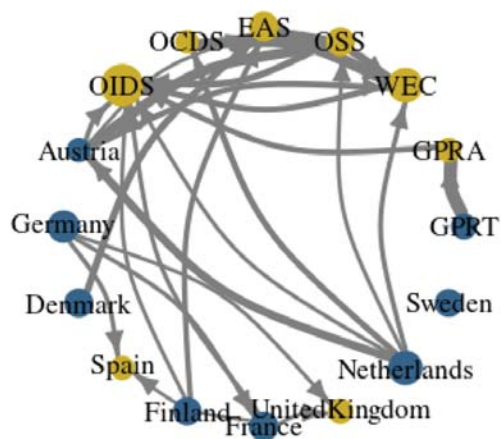
b: Contemporaneous Transmission



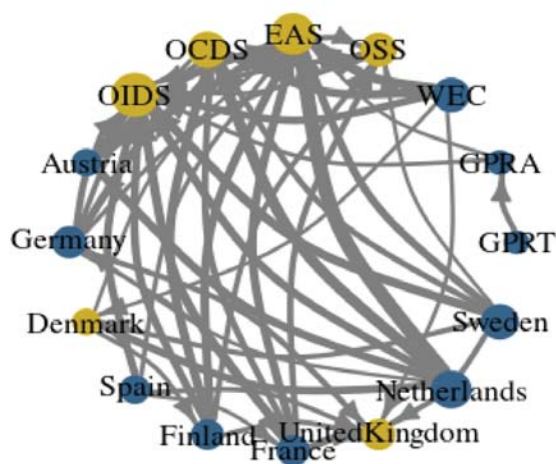
c: Lagged Transmission

Fig. 6. Overall, Contemporaneous, and Lagged between Oil market shocks, Geopolitical Risk, Global Economic Condition, and EURO Financial Stress after Global Financial Criss 2008/2009

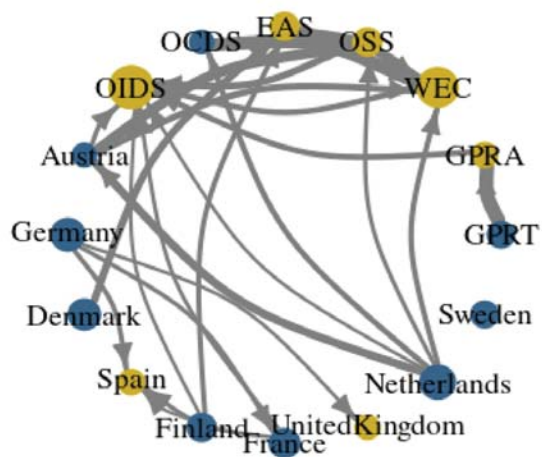
Note: R^2 decomposed measures are based on a 120-Month rolling-window VAR model with a lag length of order two (AIC) and H Step 10.



a: Overall Transmission



b: Contemporaneous Transmission



c: Lagged Transmission

Fig. 7. Overall, Contemporaneous, and Lagged between Oil market shocks, Geopolitical Risk, Global Economic Condition, and EURO Financial Stress during Russia-Ukraine War.

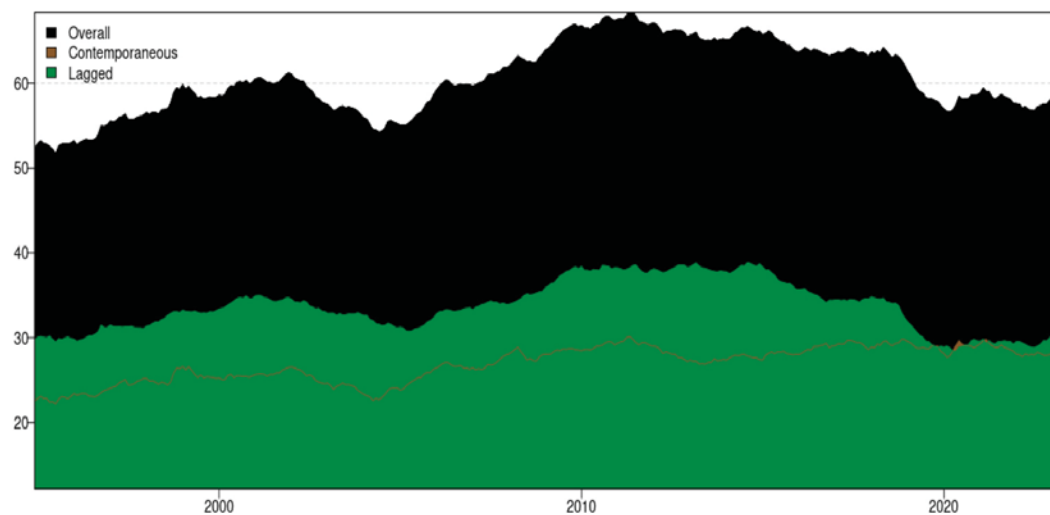


Fig. 8. Dynamic Transmission between Oil market shocks, Geopolitical Risk, Global Economic Condition, and EURO Financial Stress using Spearman Correlations.

cycles. Macroeconomic and geopolitical risks (WEC and GPR) become the dominant factors in the formation of systemic risk, which indicates a reassessment of the inherent risks of the entire market. In contrast, OSS, EAS, OCDS, and OIDS mainly act as receivers. Furthermore, major economies like Germany and France remained transmitters, whereas Finland exhibits a hybrid role, acting as a transmitter in the contemporaneous dimension but a receiver in others. This highlights the model's ability to capture heterogeneous responses among Nordic economies, distinguishing them from the central European core.

Fig. 6 shows the connections after the Global Financial Crisis of 2008/2009. The analysis reveals that GPRA serves as a transmitter in the lagged dimension. Other factors, such as GPRT, WEC, OSS, and EAS, mainly act as receivers. Notably, OCDS functions as a transmitter in both total and lagged dimensions, showing its important role. The economic narrative here is that, in the post-crisis environment of feeble global demand and deflationary pressures (the New Normal), oil demand shocks have become a fundamental indicator of the well-being of the global economy, thereby conveying stress. In contrast, Austria, Germany, Denmark, Spain, France, and the Netherlands primarily act as transmitters across all dimensions, highlighting their strong influence in the oil market. Finland shifted to a lagged transmitter role, while Sweden displayed mixed roles. This variation in country composition proves that the aggregate connectedness results are not driven by a single dominant country but are sensitive to how different economies (e.g., export-oriented vs. finance-oriented) process post-crisis deflationary pressures.

Fig. 7 shows what happened during the Russian-Ukrainian war. GPRT serves as a transmitter in both total and concurrent dimensions, while transitioning to a receiver in the delayed dimension. Herein lies the crisis lifecycle, in which geopolitical threats lead to an initial, overwhelming market shock, but their long-term impacts are, in turn, mediated by the lagged financial and economic impacts they induced, including long-term inflationary effects and central bank actions. On the other hand, OCDS always acts as a transmitter in all dimensions. GPRA has different roles in transmitting shocks, but OCDS always does. In all three dimensions, OSS, EAS, and WEC mostly operate as receivers. Furthermore, the country composition analysis reveals distinct vulnerabilities. Germany and France remained the main transmitters due to their centrality in the European energy grid and banking system. Conversely, Spain and the UK acted as net receivers, highlighting that peripheral European economies were recipients of the energy shock rather than originators.

In Figs. 4–7, ever-changing transmission and net directional roles in contemporaneous and lagged connectedness among oil market shocks, geopolitical risk, the global economic condition, and the Euro Financial Stress are shown. Before the dot-com bubble (Fig. 4), countries like Austria, Germany, and Denmark were always transmitters, while the Netherlands was always a receiver in all areas of connection. Before the 2008/2009 Global Financial Crisis (Fig. 5), on the other hand, GPRT, GPRA, and WEC all became transmitters, whereas Finland had mixed responsibilities. After the crisis (Fig. 6), GPRA became a lagged transmitter, whereas OCDS continued to serve as a transmitter. During the Russian-Ukrainian war (Fig. 7), GPRT once more served as a transmitter, while countries like Finland played different roles, showing how these ties are always changing. These results confirm that the network is dynamic rather than static. Specifically, it has transitioned from a region-centric system before 2000 to a macro-driven system leading up to the GFC, and eventually to a demand-sensitive energy nexus in the post-crisis period. Therefore, the dynamics between financial stress and risk shocks confirm that the R2-decomposed approach captures economic heterogeneity. Furthermore, past studies highlighted dynamic and frequency-connectedness network changes during crisis periods (Del, 2023; Shahzad et al., 2023; Hoque et al., 2025), which mainly exhibit lag dynamics; however, we present changing transmission and net directional roles in both contemporaneous and lag domains during crisis periods.

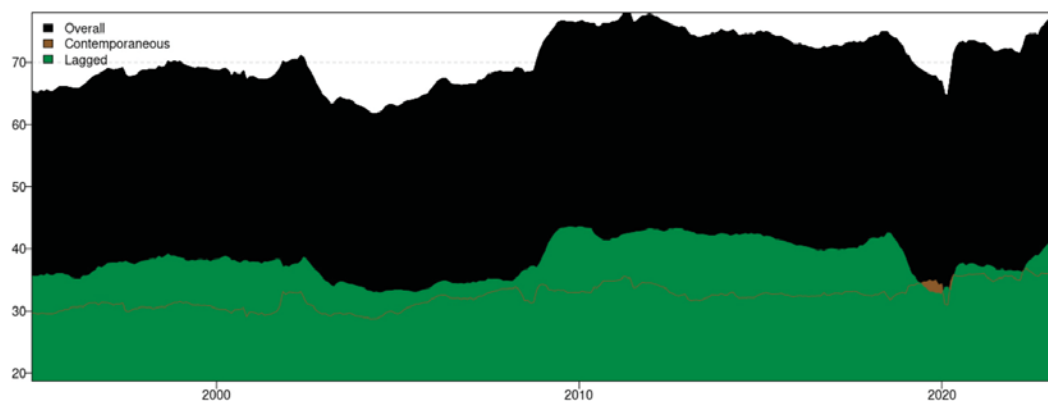
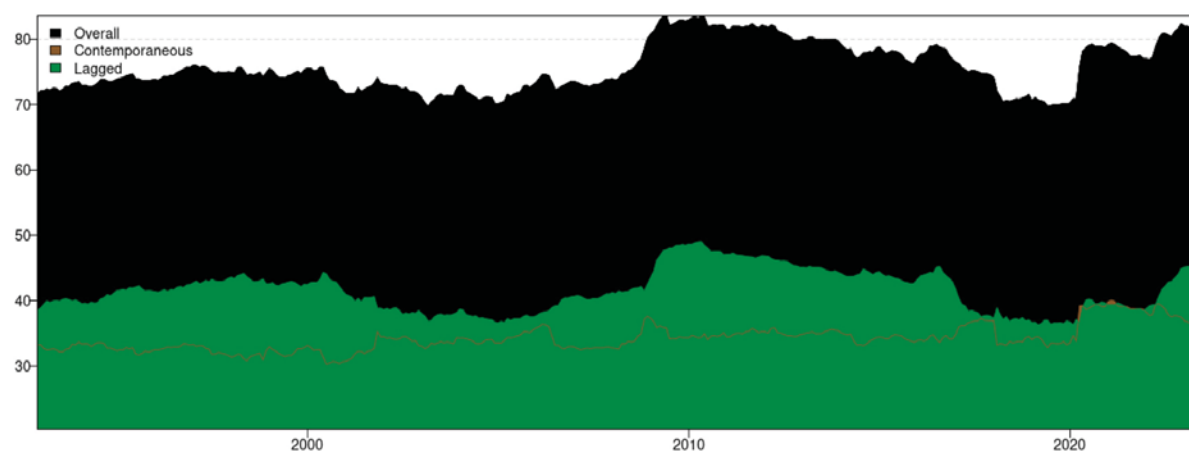


Fig. 9. Dynamic Transmission between Oil market shocks, Geopolitical Risk, Global Economic Condition, and EURO Financial Stress with rolling window 120, lag 2 and forecast horizon 12 step ahead.



a: Dynamic Transmission between Oil market shocks, Geopolitical Risk, Global Economic Condition, and EURO Financial Stress with rolling window 96, lag 2 and forecast horizon 10 step ahead.

Fig. 10a. Dynamic Transmission between Oil market shocks, Geopolitical Risk, Global Economic Condition, and EURO Financial Stress with rolling window 96, lag 2 and forecast horizon 10 step ahead.

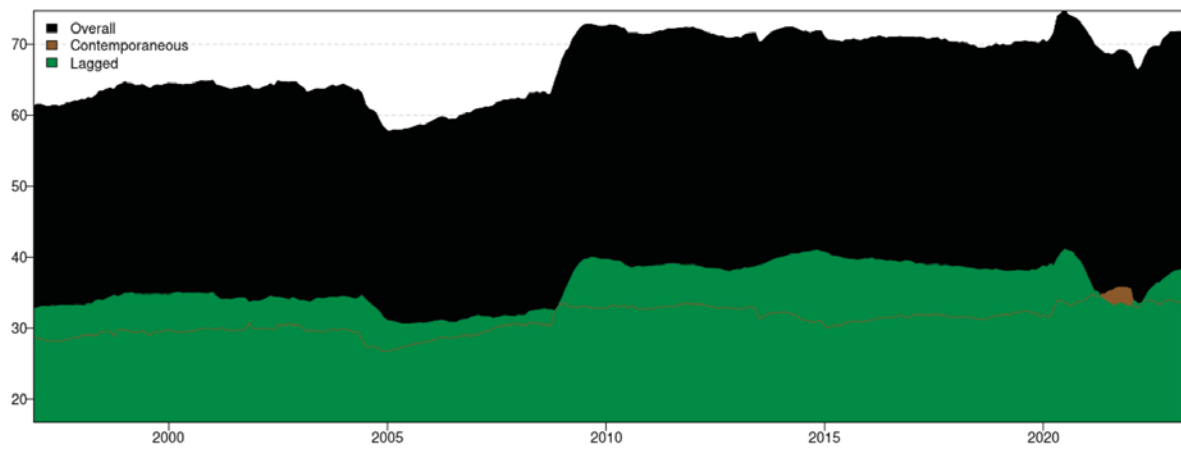
3.4. Robustness testing

3.4.1. Statistical metric invariance

To assess the robustness of our empirical results to alternative specifications, we first evaluated the sensitivity of the TCI to the choice of connectedness metrics. While our baseline R^2 -based connectedness approach uses Pearson correlation coefficients, we recalculated the TCI using Spearman rank correlations, as shown in Fig. 8. Despite minor scalar differences in the index's absolute magnitude, the dynamic patterns and structural breaks remain highly correlated with the baseline Pearson-derived TCI. This persistence suggests that, while there may be variation in the magnitudes of the connectedness measures, the overall trends are consistent across different correlation coefficients. This confirms that the system integration is driven by monotonic relationships between the variables and is not based on linear assumptions or outliers.

3.4.2. Temporal sensitivity and window selection

We subsequently addressed the bias-variance trade-off inherent in the choice of the rolling window size. As noted in the methodology, a 120-month window was selected to ensure estimation stability. However, we validated this against a shorter, more volatile window to ensure structural changes were not smoothed over. Figs. 9–11 present the connectedness results using a 12-step-ahead forecast horizon, a 96-month rolling window, a 144-month rolling window, and a lag order of 1, respectively. The 96-month (Fig. 10a) and 144-month window analyses (Fig. 10b) replicate the primary volatility spikes and trend shifts observed in the baseline 120-month model. This consistency confirms that our baseline specification successfully balances the trade-off between capturing structural changes (as evidenced by the 96- and 144-month windows) and maintaining sufficient observations for reliable inference.



b: Dynamic Transmission between Oil market shocks, Geopolitical Risk, Global Economic Condition, and EURO Financial Stress with rolling window 144, lag 2 and forecast horizon 10 step ahead.

Fig. 10b. Dynamic Transmission between Oil market shocks, Geopolitical Risk, Global Economic Condition, and EURO Financial Stress with rolling window 144, lag 2 and forecast horizon 10 step ahead.

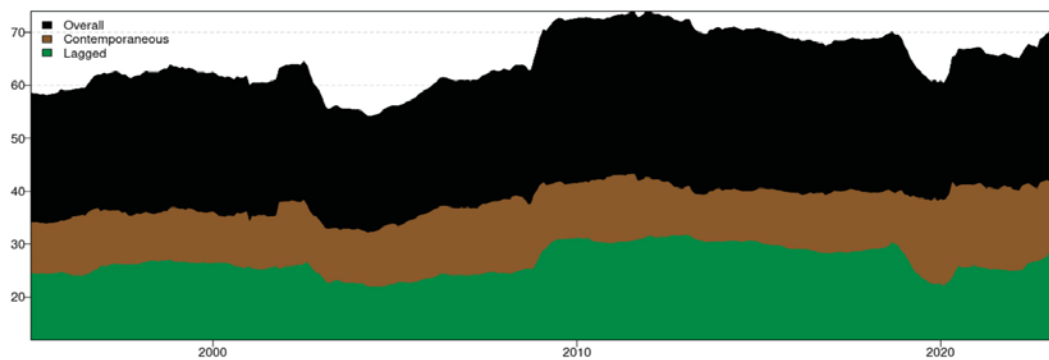


Fig. 11. Dynamic Transmission between Oil market shocks, Geopolitical Risk, Global Economic Condition, and EURO Financial Stress with rolling window 120, lag 1 and forecast horizon 10 Step ahead.

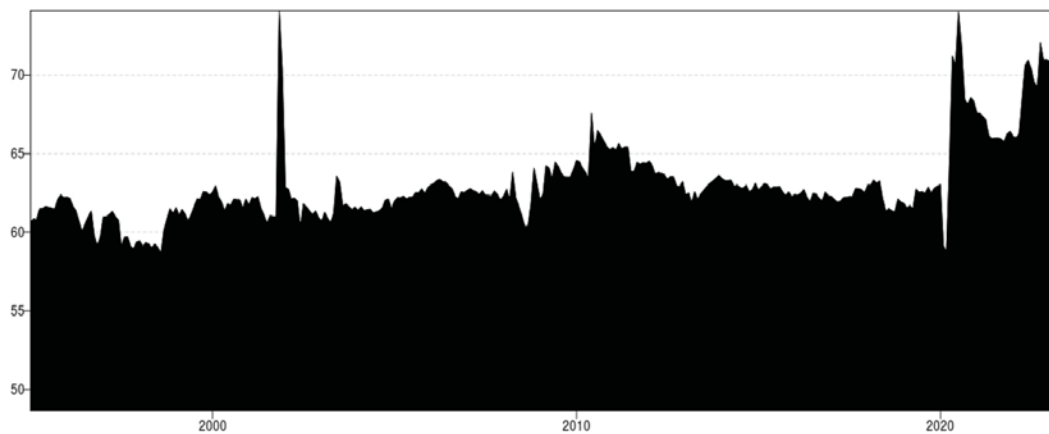


Fig. 12. Dynamic Transmission between Oil market shocks, Geopolitical Risk, Global Economic Condition, and EURO Financial Stress using DY Connectedness (2014).

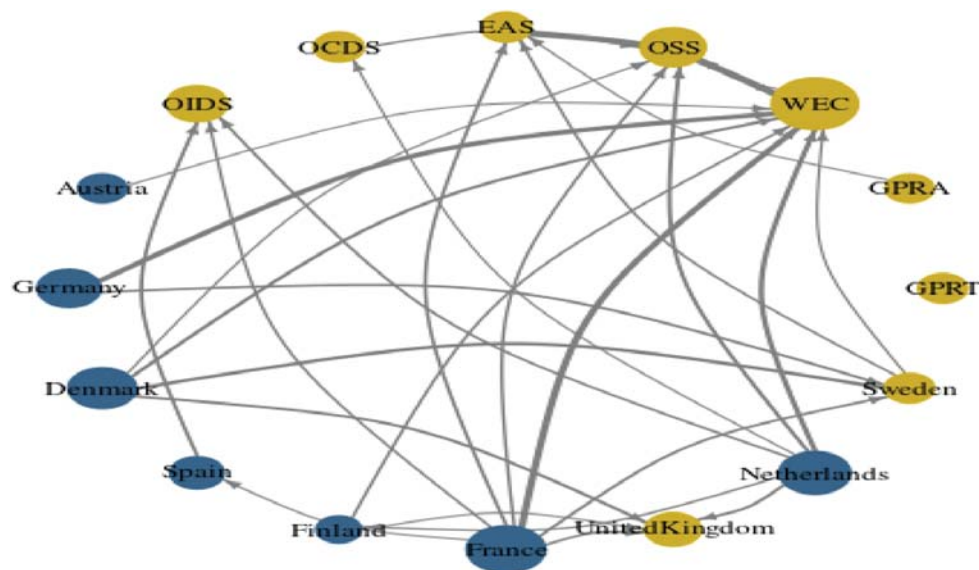


Fig. 13. Connectedness between Oil market shocks, Geopolitical Risk, Global Economic Condition, and EURO Financial Stress using DY Connectedness (2014).

3.4.3. Methodological consistency and compositional robustness

To address concerns regarding methodological dependence and country composition, we re-estimated the entire network using the FEVD approach of Diebold & Yilmaz (2014) with a lag of 2 (AIC) and a 10-step-ahead horizon. As shown in Figs. 12 and 13, the time-varying connectedness derived from the DY (2014) framework exhibits a high degree of co-movement with our R^2 -based TCI, particularly during key stress periods such as OPEC cuts, the 2008 Global Financial Crisis, and the Russia-Ukraine war. Importantly, the net directional roles remain stable across methods; the DY network confirms that Geopolitical Risk and Oil Market Shocks act as net transmitters, while the EURO financial stress indices largely remain net receivers. The fact that the network topology persists across these fundamentally different estimation techniques confirms that the results are driven by fundamental economic linkages rather than model-specific artifacts.

4. Concluding remarks

This paper employs a novel R^2 decomposed connectedness approach to investigate the transmission and connectedness of oil market shocks, geopolitical risk, global economic conditions, and EURO Financial Stress, considering overall, contemporaneous, and lagged effects. The findings unveil a significant level of overall connectedness, characterized by moderate contemporaneous and lagged connectedness, with lagged spillover exerting a stronger influence than contemporaneous spillover. Specifically, the results indicate that GPRT, along with Austria, Germany, Denmark, Spain, Sweden, the United Kingdom, Finland, France, and the Netherlands, primarily functions as a net shock transmitter, while GPRA, WEC, OIDS, OSS, EAS, and OCDS act as shock receivers.

Our findings are economically important, not only for their statistical soundness. The breakdown into contemporaneous and lagged spillovers can also provide a time map of the risk transmission, which is essential for strategic decision-making. For investors, the high degree of contemporaneous connectedness (especially in times of crisis), means that the diminished efficacy of traditional diversification strategies. This vulnerability requires a pivot towards resilience based on long-volatility approaches or safe-haven assets. It provides an opportunity to manage risks proactively. In such a case, investors can examine spillover dynamics in core markets (e.g., demand shocks in German financial markets or oil demand shocks) to predict lagged effects on peripheral European assets. This implies that real-time monitoring networks are insufficient. Thus, multi-period lag structures are necessary to enable risk managers to conduct stress testing and scenario analysis and capture the full delayed effects of initial shocks.

Additionally, the study's insights into the impact of geopolitical and financial shocks on market connectedness provide a framework for enhanced risk assessment, enabling policymakers to facilitate international cooperation and implement pre-emptive mitigation strategies. For example, European countries should work together to strengthen their strategic oil reserve policies among major importers. This could help them absorb financial shocks arising from events such as the Russia-Ukraine war, OPEC cuts, or geopolitical disruptions. Additionally, alongside energy-specific measures, tools for managing financial stability designed for closely linked economies could help limit financial spillovers from oil and geopolitical shocks. The European Central Bank and the Bank of England should require countercyclical capital buffers for banks with high exposure to commodity-linked assets. These buffers should be based on measures of interconnectedness similar to those used by Diebold and Yilmaz (2012). For instance, during periods of high interconnectedness (e.g., over 50%, as shown in Fig. 1 around 2008 or 2022), authorities could impose dynamic surcharges on systemically important financial institutions whose oil derivative portfolios exceed 10% of their total assets. They should also conduct more intense stress tests for scenarios involving 20% swings in oil prices or divergences in Eurozone yields. This approach is based on the financial

accelerator theory (Bernanke et al., 1999), which suggests that procyclical lending can worsen shocks. Moreover, the ongoing energy transition could significantly change these interconnectedness patterns. It may decouple oil shocks from the broader financial markets and reduce overall interdependencies. As green energy developments accelerate, supported by policies like the EU's Green Deal, renewable sources such as solar and wind, along with electric vehicles, could diminish oil's dominance. This could theoretically lower the transmission of shocks through a more diversified mix of energy sources, as discussed in the energy substitution literature.

These time-varying patterns have economic significance because they have a high predictive capacity for systemic risk. The regular increase in connectedness during a crisis is not just a statistical coincidence; it is empirical evidence of a shift in market regimes. As an investor, an increase in the TCI is a signal to reduce portfolio leverage and hold more non-correlated assets. Therefore, policymakers can leverage the lagged nature of oil shock transmission to implement proactive macroprudential measures. Such interventions could shield the real economy from the latent pressures of the credit cycle. Consequently, monitoring these decomposed connectedness measures in real-time enhances risk management and financial oversight. This approach allows for a critical distinction between transitory market volatility and the structural propagation of systemic contagion. Thus, authorities can better identify whether a shock requires immediate liquidity support or long-term solvency interventions.

Data availability

Data will be made available on request.

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