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Systemwide directional connectedness from Crude Oil to sovereign credit risk

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ABSTRACT

This study examines the spillovers from Crude Oil price fluctuations to sovereign credit risk, proxied by CDS spreads for 16 oil exporters and importers belonging to G20. Besides measuring shocks from Crude Oil to sovereign risk, it also examined the system-wide impacts of CDS shocks to understand their magnified impacts within a system. Furthermore, the study finds the channels that have the potential to act as a carrier of shocks from Crude Oil to sovereign risk considering four country-specific and two global factors. Our study deployed Generalized Impulse Response Functions and Generalized Forecast Error Variance Decomposition for being independent of ordering. Additionally, DCC-GARCH has been applied to test the robustness of the results. Our results highlight higher spillovers to oil-exporting countries from Crude Oil when compared to oil importers, irrespective of their development stage. Interestingly, developed countries are severely impacted by net system-wide shocks from developing and oil-exporting countries. Moreover, Global factors play a dominant role in carrying the shocks from Crude Oil to sovereign risk of countries. Stock market indices are important among important domestic factors that act as carriers of shocks, and VIX is robust amongst global variables. Our results are valuable to Regulators, policymakers, portfolio managers, banks, and financial institutions for proactively planning their respective policies.

1. Introduction

The increasing global debt accompanied by deteriorating fiscal statements of a large number of countries has become a global issue and raised concerns about sovereign credit risk and the financial sustainability of these countries. These concerns become daunting due to increased economic and financial interlinkages between countries that expose these countries to systemic risk. An example of this kind of episode has been the Global Financial Crisis (GFC), where the problem initiated by a financial institution has been transmitted to the entire financial system across the globe. The result of such a crisis has brought up Credit Default Swaps (CDS)[1] (Alam et al., 2019) into the spotlight that witnessed a massive surge. Usually, the increased magnitude of credit spreads gauges the increased levels of credit risk in an economy (Lahiani et al., 2016; Shahzad et al., 2017). An economic event not only brings exponential changes in the credit spreads but also results in heavy volatilities in the commodity prices, especially Crude Oil, as witnessed during GFC. As per UNDP, high volatile prices of commodities lead to macroeconomic instabilities, volatilities in export earnings, forex reserves, and

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[1] CDS is a credit derivative contract that protects bondholders against bond issuer defaults. The protection is promised in return for a premium called CDS spreads. A higher perceived risk of default would lead to higher CDS spreads and vice-versa.

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countries' economic growth (UNDP, 2011).[2] Though volatile oil prices pose a challenge to all countries, its impact can be severe on oil-reliant countries as a substantial part of their revenues and expenses depends on Crude Oil. Moreover, the intensity of volatility determines the deterioration of economic fundamentals that further determines the likelihood of sovereign default. Numerous finance news articles have recently highlighted the increasing costs of CDS to a multi-month high for Italy and Saudi Arabia.[3] Similar stories are published for various other oil exporters. Higher CDS spreads, indicating increased sovereign risk, can be precarious as it can result in a rising debt cost to sovereigns reverberating to non-sovereign borrowings. Moreover, sovereign risk is a critical determinant for the macro-economic dynamics of a country and can ruffle the entire financial system.

Fluctuations in Crude Oil prices can be alarming to oil-reliant nations and affect their debt servicing capabilities as an integral part of their revenues, expenditure, and forex reserves dependent on Crude Oil prices. An increasing oil price may increase the oil exporter's cash flows, strengthen their currency against the USD, and increase purchasing power parity. Increased PPP gives trade surplus to exporters with cheap imports; hence, an appreciation in forex reserves and sovereign wealth is recorded, which improves the nation's economic strength and debt-serving capacity. The opposite holds for oil importers. Does it raise a critical question about the quantum of spillover of oil price variations to the sovereign credit risk of such countries? Literature has recorded the jumps from Crude Oil prices to sovereign risk (Shahzad et al., 2017) and mentioned it to be time-varying and country-specific (Sabkha et al., 2019). The relevance of oil price shocks and their impact on financial assets are well documented (Kilian and Park, 2009; Arouri et al., 2012; Malik and Umar, 2019); however, less attention is devoted to spillovers from Crude Oil price fluctuations to sovereign credit risk. Critically, the spillovers from Crude Oil to sovereign do not pause in one country. However, these can propagate to other connected countries as a part of the system due to boundless globalization. Therefore, this study addresses another question of the systemic impacts of these spillovers amongst various sovereign markets. The prevalence of systemic impacts can never operationalize in isolation; some channels become the instrument in such transmission. Chuffart and Hooper (2019) mentioned the role played by global and country-specific factors in CDS spread determination. This study conveys the role of country-specific and global factors in Crude Oil spillovers to sovereign risk to determine critical factors. It provides an essential source of shock transmission for sovereign risk to account for the relevance of Crude Oil against other factors.

An examination into these queries is of value to its stakeholders, including oil-dependent sovereigns and the countries connected to oil-reliant countries through economic, financial, or other mediums. Our findings are helpful to energy regulators, banking regulators, policymakers, financial investors, and portfolio managers. As Crude Oil and oil stocks are welcomed by investors in their portfolios, understanding the mechanism through which Crude Oil shocks are transmitted to one sovereign, and the system has significant implications for diversification, risk mitigation, and international portfolio management. Additionally, identifying factors that channel the spillovers of Crude Oil prices to sovereign instabilities can be valuable to policymakers and Regulators, enabling them to be proactive in their policies. Most importantly, directional predictability from Crude Oil for oil-dependent countries is relevant to the sovereign, as increased riskiness makes their debt more expensive. A predictiveness of sovereign default risk is of even higher interest to banks and financial institutions as these have a large portion of their reserves parked in sovereign securities. A report by IMF[4] (Balcilar et al., 2018) (2019) mentions that declining oil prices severely impact local banks of Sub-Saharan African oil-exporting countries that become illiquid, and the value of their assets depreciates, leading to a rise in NPAs. Besides, the Sovereign risk premium serves as a benchmark for non-sovereign borrowings; hence, this study is helpful to non-sovereign borrowers.

Crude Oil upheavals sometimes make their impact visible in the long run, where the short run seems unaffected by the Crude Oil price moves or vice versa. Moreover, measuring system-wide connectedness is a more complex and non-linear phenomenon. There are numerous methods used to measure such issues in literature, such as NARDL (Lahiani et al., 2016), Wavelet Coherence Framework (Yang et al., 2017), Cointegration (Hammoudeh et al., 2013), Multivariate regression quantile (Bouri et al., 2018), GARCH-Copula CoVar (Wang et al., 2020). However, we deployed Generalized Impulse Response Functions and Generalized forecast error variance decompositions (Diebold and Yilmaz, 2012) to study risk transfer in the short run and long run from Crude Oil price fluctuations for G20 nations.[5] A Global Vector Autoregressive (GVAR)[6] model (Pesaran et al., 2004) is built as instrumental for global and country-specific variables of sample countries. The methodology is chosen as it is invariant to order. It also records shock dependence connectedness captured in the VAR disturbance covariance matrix and cross-variable dependence captured in VAR coefficients (Pesaran et al., 2004; Singh et al., 2018). Besides, the method is most often used to measure system-wide spillover studies (Pavlova et al., 2018; Singh et al., 2018). Additionally, Multiple Regression Models have been used to lay the foundation for our study, and DCC-GARCH is used to check robustness. Literature outlined non-linear and asymmetric effects of Crude Oil price returns and volatilities on exporting and importing countries (Bouri et al., 2018; Ngene et al., 2019). Our sample G20[7] Countries are a mix of developed and developing and are among major oil exporters and importers, which enables us to capture the differentiating impact of oil price

[2] UNDP 2011. Human Development Report 2011: Sustainability and Equity – A Better Future for All.

[3] https://www.reuters.com/article/us-health-coronavirus-cds-idUSKBN20W1KJ.

[4] https://www.imf.org/en/Publications/WP/Issues/2019/06/17/Coping-with-Falling-Oil-Prices-The-Different-Fortunes-of-African-Banks-46955.

[5] G20 nations contribute approximately 80% of the world's GDP and 75% of global trade. Besides, more than half of the G20 nations have a debt to GDP ratios above 60%, and their credit ratings have seen a downside recently, which seems a vital contributor to an increase in sovereign risk.

[6] Under the GVAR model, country-specific small dimension models are estimated that include domestic variables and their cross-section averages of foreign variables. The resultant coefficients can be solved as one extensive system in the second step.

[7] India, Canada, and Saudi Arabia are not included in the study due to the unavailability of CDS data for these countries for an entire sample period. European Union is not considered for it enjoys the status of a collaborative pact amongst countries and would not be justified to take it at par with individual nations.

fluctuations for exporters and importers and developed and developing nations.

The rest of the paper is structured and organized into five sections. Section 2 deals with a brief review of contemporary literature and gap identification. Section 3 deals with data and its sources. Section 4 explains the research methodology framework adopted for carrying out research. Section 5 discusses the findings of Regression, GIRFs, and GFEVD outcomes, along with the robustness of results and implications of the study. Section 6 concludes the research and its findings.

2. Related studies

There are two tranches of research in the literature regarding sovereign credit risk. The first tranche investigates the determinants of sovereign risk, and most scholars have described the influential role of global and country-specific variables at different time points (Rodrigues et al., 2015; Yorovaya et al., 2016; Pavlova et al., 2018; Sabkha et al., 2019). However, the different studies have considered discrete economic and financial factors relevant and assumed different global and country-specific factors for their study. Fong et al. (2018) have considered Real GDP Growth, Inflation Rate, Net exports to GDP, Leverage of Banking sectors, and foreign investments as domestic factors that explain Sovereign Risk, while VIX, COMM, MOVE, and foreign exchange expectations as global factors. In another study, Lahiani et al. (2016) considered Libor, Federal fund rate, T-Bill Rate, VIX, and WTI as explanatory variables. Likewise, discrete combinatory economic and financial factors have been chosen by different studies. Commonly, Exports and Imports, Political stability, MSCI world Index, Crude Oil, Local stock market Index, sectoral indexes, SMOVE, and Housing Index are amongst few factors that scholars have paid attention to (Guo et al., 2011; Hammoudeh et al., 2013; Shahzad et al., 2017; Hkiri et al., 2018; Pavlova et al., 2018; Sabkha et al., 2019; Chuffart and Hooper, 2019).

The second tranche deals with the connectedness between sovereign markets or oil markets and other financial markets such as stock markets (Tiwari et al., 2020), Forex Markets (Alam et al., 2019), Bond markets (Demirer et al., 2020), commodity markets (Balcilar et al., 2020), amongst CDS indexes (Fonseca and Ignatieva, 2018). Literature has evidence on linkages between Oil prices and Sovereign risk, although it is still young and needs further examination (Bajaj et al., 2022). Using the VAR-GARCH-in mean model, Wegner et al. (2016) have proved that a positive shock to Crude Oil prices lower the CDS spreads of oil-producing countries using nine oil-exporting countries. Likewise, Shahzad et al. (2017) studied Directional predictability from oil implied volatility to CDS spreads of four GCC Markets and five other oil-exporting countries. They found significant direction predictability from oil to CDS spreads for most oil-exporting countries, especially during a highly volatile period. Pavlova et al. (2018) examined spillovers from oil prices in oil-exporting countries and recorded the existence of spillovers to 4%–31%. Where Crude Oil price fluctuations impact oil-exporting, researchers have examined its impact on oil-importing countries. Oil price Volatility and returns have non-linear and asymmetric causal effects on the SCR of oil importers and exporters (Ngene et al., 2019). Oil exporters are more sensitive to positive oil shocks, whereas importers are more sensitive to adverse oil shocks (Bouri et al., 2018). They also show that low volatility of the oil market predicts low sovereign risk at various quantiles and lags and vice versa.

Additionally, in 2019, Bouri et al. highlighted that the relationship between the CDS Spread of oil exporters with oil prices is negative; it is less pronounced for MENA oil importers. They used a cross-quantilogram approach and reported asymmetric effects of oil prices across quantiles. Wang et al. (2020) mentioned that extreme oil returns are risky for developed and emerging countries. Further, they added that oil importers behave differently to extreme oil returns per their economic stability. Also, upward oil returns have a higher intensity of spillover to CDS spreads than downward oil returns, specifically for oil exporters. Using wavelet analysis, Yang et al. (2018) found time-varying linkages and increasing co-movement between CDS spreads of G7 and BRICS nations with increasing Crude Oil prices.

Interestingly, Sun et al. (2018) have outlined that sovereign CDS of emerging markets causes higher spillovers to stock markets than developed markets. In contrast, developed markets cause more significant spillovers from stock markets to CDS markets. They also pointed out that CDS and commodity markets dominate during specific periods while stock markets are always dominant. Chen et al. (2020) worked on the interconnectedness of 27 Sovereign markets of European countries using causality analysis and Network Graphs. They found that the network varies with market conditions and is unstable. The network becomes complex and more connected during the turbulent period. Similarly, Bostanci and Yilmaz (2020) have shown network connectedness of sovereign credit risk of developed and developing countries and found that developing countries play a significant role in shock transmission.

Where cross-market spillovers have been focused on one side, the other studies the spillover between sectoral CDS. Hammoudeh et al. (2013) studied transmission amongst US credit and market risk measures focusing on four oil-related sectors. They recorded the responsiveness of oil-related CDS to VIX in the long and short run. Lahiani et al. (2016) examined short and long-run linkages between the CDS of banks, insurance, and financial service sectors. They found long, and short-run asymmetric changes in CDS spreads to changes in federal funds and T-bills rate. They do not find any impact of WTI on the short-run dynamics of the bank and financial service sector CDS. US short-term interest rates are more sensitive to credit events than to WTI. Using the NARDL approach, Shahzad et al. (2017) have found the asymmetric nonlinearity between industry CDS index spreads of 10 US industries in the long and short run. They observed Crude Oil as one contributor to such linkage along with equity prices, VIX, and Bond rates with higher contributions than Crude Oil. They also mentioned that positive and negative shocks to macroeconomic variables have a different impact on industry CDS spreads. Balcilar et al. (2020) have analyzed spillover effects across oil-related CDS, oil markets, and financial market risk for the US during and after the subprime crisis. They found oil market is the primary source of risk transmission to oil-related CDS, whereas bond markets transmit the highest risk to stock markets. Further, oil price shocks are more significant for oil-related CDS than demand and supply shocks.

It is natural to expect severe structural changes in return and the transmission of volatility from oil to sovereign markets during global crises. Noteworthy, Studies have captured this time-varying behavior and intensified spillovers from Crude Oil to sovereign markets during the crisis. A few such studies include Guo et al. (2011), who found that apart from own shocks, shocks from the stock market and oil market are the driving force behind credit default and stock market variation during the crisis. Additionally, an increased sensitiveness of CDS volatility to oil market conditions during risky regimes has been documented by (Sabkha et al., 2019). They also found dissimilarities between the explanatory power of exogenous variables during the turbulent and tranquil regime. On the contrary, Bouri et al. (2017) found that some significant commodity exporters and importers lack commodity spillover to CDS. They suggest that other macroeconomic variables contribute to volatility in sovereign CDS. There is a direct impact of oil price fluctuations on CDS spreads in Venezuela. However, the Russian CDS spread is impacted indirectly through forex as it has a flexible exchange rate system (Chuffart and Hooper, 2019). They also mentioned that determinants of CDS spreads do not have the same impact in times of crisis and calm. Da Fonseca et al., 2016 found that future negative jumps have a higher impact than positive jumps while explaining CDS Spreads during the crisis.

A careful examination of literature outlined time-varying linkages between oil prices and sovereign risk. Additionally, the spillovers from oil to sovereign markets are different for countries caused of their economic and financial connections with other countries. We, through this study, are trying to contribute to the existing literature on Crude Oil and sovereign market linkages in 3 ways:

1. We focus on measuring the intensity of Crude Oil shock spillover for G20 nations in the short and long run.
2. We would be examining the circulation of Crude Oil shocks in the system, i.e., system-wide spillover amongst sovereign markets.
3. We would be capturing other global and country-specific channels along with Crude Oil that contributes to the systemic spillover between countries and becomes a medium for such transmission.

Since literature has used numerous methods to study connectedness issues, we rely on GIRFs and GFEVD (Diebold and Yilmaz, 2014) to study short and long-run risk transfer. To resolve the issue of dimensionality, we exploit the Global VAR model (Pesaran et al., 2004). The methodology is chosen because it is invariant to order and records shock dependence connectedness captured in the VAR disturbance covariance matrix and cross-variable dependence captured in VAR coefficients (Pesaran et al., 2004; Singh et al., 2018). Besides, the method is most often used to measure system-wide spillover studies (Pavlova et al., 2018; Singh et al., 2019, Singh et al., 2019).

3. Data collection and sources

Our primary interest is understanding the spillovers between Crude Oil and CDS, for which Monthly data for Crude Oil and 5-year sovereign CDS has been sourced from Bloomberg from January 2008 to December 2019. Further, we have collated the monthly data for four country-specific variables (Stock Market Index, 10-year bond yield, Inflation, Real Effective Exchange rate) and two global variables (Volatility Index (VIX), Federal Funds Rate) to meet another objective. Notably, REER measures the currency's value against the weighted average of a basket of currencies. Since we are trying to capture systemic impacts, it would be a better proxy to capture exchange rate effects than the foreign exchange rate considered in the literature (Pavlova et al., 2018; Chuffart and Hooper, 2019). These factors are chosen based on literature and data availability. Data for Stock Market Indices, 10-year bond yield, CBOE VIX, and Federal funds rate have been sourced from Bloomberg. Monthly data for inflation is taken from the database of the International Monetary Fund, and the real effective exchange rate has been collected from the Federal Reserve Bank of St. Louis. The monthly data results in 144 data points per country per year for each variable. Total data points collected are 11,232 per country (720 per country per variable except for inflation and Bond Yield, which is available for 15 countries) for country-specific variables and 144 for global variables resulting in 432 data points. Logarithmic conversion of the entire data has been done to stabilize the variation in data.

The 16 countries considered for the study include Australia, Brazil, Mexico, Russia, South Africa, Argentina, China, France, Germany, Indonesia, Italy, Japan, South Korea, Turkey, the UK, and the USA.[8] The countries selected are a mix of developed and developing countries[9] and oil exporters and oil importers.[10] Additionally, the cross-border balance of payment amongst each country's pair and GDP PPP 2018 (in USD) has been fetched to construct the weights to determine country-specific foreign variables from WITS World Bank's Database from 2008 to 2019. Logarithmic conversion has been done for each year's balance of payment value for each country pair.

4. Research methodology

Since our sample has large number of additional local and global variables, the kind of problem that we are dealing with is having the dimensionality problem, i.e., 'Curse of Dimensionality' which arises when the number of variables chosen becomes relatively large than the available time dimensions which make it impossible to achieve unrestricted VAR even with a small number of variables (Bussiere et al., 2009). In such scenario Global Vector Autoregressive (GVAR) model serves as an alternative to overcome such

[8] The USA became a net exporter in 2020, and Our study considers data till 2019. Therefore, It is considered a net oil importer for our study. For details, https://www.eia.gov/energyexplained/oil-and-petroleum-products/imports-and-exports.php.

[9] We have categorized countries as developed or developing according to the criteria given by the world bank, i.e., Gross National Income (GNI) per capita as per GNI of 2018. We have considered High-Income countries ($12,376 or More) as developed countries, whereas Lower ($1026 to $3995) and Upper Middle-income ($3996 to $12,375) economies are considered developing economies.

[10] The countries are divided between exporting and importing countries based on net oil exports or imports.

dimensionality problem (Pesaran et al., 2004). Under the GVAR model, country-specific small dimension models are estimated that include domestic variables and their cross-section averages of foreign variables. The resultant coefficients can be solved as one extensive system in the second step. The foreign specific variable has been computed as the weighted average of the corresponding variable of other nations, with a fixed weight computed based on the average balance of payment from the year 2008-to 2019, defined as.

4.1. Foreign specific variable $(x_{it})^{*} = \sum_{j=0}^{N} (w_{ij}^{*} \ x_{it})$ (1)

Where w_{ij} is the weight computed from the average balance of payment, here (ij) reflects the share of country "j" in net trade exports of the country "i". The matrix computing the Balance of trade between countries (i and j) can be defined as

$$
\begin{array}{lllll}
 & x_1 & x_2 \ldots\ldots & x_N & \text{Balance of Trade} \\
x_1 & 0 & d_{12} \ldots\ldots & d_{1N} & \sum_{j=1}^{N} d_{1j}, j \neq 1 \\
x_2 & d_{21} & 0 \ldots\ldots & d_{2N} & \sum_{j=1}^{N} d_{2j}, j \neq 2 \\
\vdots & \vdots & \vdots & \vdots & \vdots \\
x_N & d_{N1} & d_{N2} \ldots\ldots & 0 & \sum_{j=1}^{N} d_{Nj}, j \neq N
\end{array}
$$

Hence, the corresponding weight can be computed as

$$\text{Wij} = \frac{d_{ij}}{\sum_{j=1}^{N} d_{ij}} \tag{2}$$

Using an inter-country balance of trade data serves the purpose of capturing the shock propagation from country-specific and global variables to one country and then passed on to another via the trade channel with the country-specific variable acting as the medium $\{g_i \rightarrow x_i \rightarrow x_j\}$. Noteworthy, all the global and foreign-specific variables have been chosen as weakly exogenous for all the country-specific models. The lag order has been based on the Akaike information criterion (AIC).

4.2. Generalized Impulse response function

The methodology was introduced by Koop et al. (1996). The GIRF is based on the definition.

$$\text{GIRF (xt; ult, n)} = \text{E}\left(\text{xt+n} \mid \text{uilt} = \sqrt{\sigma_{ii,ll}} \ \text{It}-1\right) - \text{E}(\text{xt+n} \mid \text{It}-1) \tag{3}$$

where I_{t-1} is the information set at time t-1, $\sigma_{ii,ll}$ is the diagonal element of the variance-covariance matrix Σ_u which corresponds to the lth equation in the ith country, where "n" is the horizon. Thus, the shock of one standard error on the jth variable at time step t + n can be illustrated for the lth equation as:

$$\text{GIRF (xt; ult, n)} = \frac{e'_j * A_n * G_0^{-1} * \sum_u e_l}{\sqrt{e'_l * \sum_u e_l}} \quad \text{where n} = 0, 1, \ldots 2; \text{ l, j} = 1, 2, \ldots \text{k} \tag{4}$$

For our study, we have given a shock to Crude Oil to capture its impact on the CDS of countries. Further, we have given a shock to CDS to understand its composition explained in section 4.2. This would aid us in measuring the magnitude of shock spillover from Crude Oil to CDS and understanding the role of other country-specific and global variables in shock transmission.

4.3. Generalized forecast error variance decomposition

In the Generalized Forecast Error Variance Decompositions (GFEVD) framework, the forecast error variance equations can be decomposed to see how much variance is caused by self for a variable 'i' and how much is contributed by the rest. Utilizing the concept, Diebold and Yilmaz (2012) derived a set of connectedness measures and deployed them to different levels of granularity from pairwise to system-wide "FROM," "TO," "NET," and "TOTAL" connectedness values (for details, please see Diebold and Yilmaz, 2012)

$$C_{FROM(i \leftarrow \blacksquare)}(H) = \frac{\sum_{j=1 \ i \neq j}^{N} \widetilde{\vartheta}_{ij}^{g}(H)}{\sum_{i,j=1}^{N} \widetilde{\vartheta}_{ij}^{g}(H)} \times 100 = \frac{\sum_{j=1 \ i \neq j}^{N} \widetilde{\vartheta}_{ij}^{g}(H)}{N} \times 100 \tag{5}$$

$$C_{TO \ (\blacksquare \leftarrow i)}(H) = \frac{\sum_{j=1 \ i \neq j}^{N} \widetilde{\vartheta}_{ji}^{g}(H)}{\sum_{i,j=1}^{N} \widetilde{\vartheta}_{ji}^{g}(H)} \times 100 = \frac{\sum_{j=1 \ i \neq j}^{N} \widetilde{\vartheta}_{ji}^{g}(H)}{N} \times 100 \tag{6}$$

$$C_{i\ (NET)}(H) = C_{\blacksquare \leftarrow i}(H) - C_{i \leftarrow \blacksquare}(H) \tag{7}$$

$$C_{TOTAL}(H) = \frac{\sum_{i,j=1\ i\neq j}^{N} \widetilde{\vartheta}_{ij}^{g}(H)}{\sum_{i,j=1}^{N} \widetilde{\vartheta}_{ij}^{g}(H)} = \frac{\sum_{i,j=1\ i\neq j}^{N} \widetilde{\vartheta}_{ij}^{g}(H)}{N} \tag{8}$$

4.4. DCC-GARCH

Though we estimated GIRFs and GFEVDs, we corroborated our results using DCC-GARCH as a robustness test. DCC-GARCH model examines the time-varying conditional volatility and works in two steps by estimating individual GARCH parameters in the first step and conditional volatilities between the individual parameters in the second step. A DCC GARCH (1,1) model is written as:

$$Y_t = \mu_t + \varepsilon_t \quad \frac{\varepsilon_t}{F_{t-1}} \sim N(0, H_t) \tag{9}$$

$$\varepsilon = H_t^{1/2} u_t u_t \sim N(0, I) \tag{10}$$

$$H_t = D_t R_t D_t \tag{11}$$

where F_{t-1} stands for all information up to t-1. $Y_t,\ \mu_t,\ \varepsilon_t,\ and\ u_t$ are the vectors that represent time series, conditional mean, error term, and standardized error terms, respectively. Furthermore, $H_t, R_t D_t = diag\left(h_{11t}^{\frac{1}{2}}, \ldots\ldots\ldots\ldots\ldots, h_{NNt}^{\frac{1}{2}}\right)$ are N*N dimensional matrix that gives time-varying conditional variance-covariance matrix, dynamic conditional correlations and time-varying conditional variances.

4.5. Multivariate regression

We lay the foundation of our study by checking for the influence of chosen variables on the CDS spreads of selected countries. The study is based on linear regression by the Ordinary Least Square (OLS) method. The equation for regression used is expressed as:

$$CDS_i = \alpha + \beta^* BY + \delta^* REER + \gamma^* SMI + \varrho^* Inf + \theta^* WTI + \pi^* VIX + \varphi^* FFR + \varepsilon_i \tag{12}$$

where,

$$CDS_i = Credit\ Default\ Spread\ of\ country\ i, \alpha = constant$$

5. Result analysis

5.1. Preliminary statistics

First, we have dealt with the missing data values by filling them with the trend forecast feature in excel. With the help of scatter plot graphs, we found a few outliers. However, we decided to retain the values as removing or replacing these variables may cause data to lose sensitive information and manipulate the results. Therefore, we decided to retain the variables with not too extreme values. For Bond yields, we converted negative numbers to their absolute values while taking their logarithmic conversions.

All the variables are checked for their statistical significance, and the results are briefly examined in this section. Interestingly, CDS returns of all markets are volatile in the same range irrespective of their oil dependency and development status. Stock market indices for all the countries are volatile, but the instability of China, Italy, and Turkey is higher than in other countries. A negative mean REER of all countries except for China, Indonesia, and the USA, implies a depreciation of their currencies. However, the developing countries and oil exporters are showing comparatively higher negative returns than developed countries barring China and Russia. The standard deviation shows good stability in the REER of Germany, France, Italy, and the USA, whereas the REER of Russia has been highly volatile. There is a downward movement in bond yields of all countries except for Russia, South Africa, Japan, and Turkey, with abysmally low positive returns. Notably, the Bond yields of Japan are highly volatile among all other markets, followed by France and Germany. Oil exporting markets have recorded low volatility in their bond yields. The mean values indicate an almost similar rise in inflation in all countries. All global factors remained negative throughout, but the value is meager with high volatility. The skewness and Kurtosis of all the variables reflect the skewness of data. The non-normalcy of data is confirmed with the Jarque-Bera test. ADF results show that all logarithmic return series are stationary at a level. It is also observed that Crude Oil negatively correlates with the CDS of all the countries. Intuitively, Crude Oil's correlation is comparatively higher for oil-exporting countries than oil-importing countries.

5.2. OLS regression coefficients

As a first step, we used Multiple Regression Analysis to lay the foundation of our model. Though we have chosen the variables based on literature, we examined their role using a simple regression model. Appended Table 1 shows the regression estimates for all the control variables considered in the study. Theoretically, a positive shock to oil prices would increase the revenues of oil-exporting countries, thereby enhancing the public finances and their creditability. Higher paying capacity would boost the investor's confidence in the economy resulting in falling CDS spreads. The vice-versa would hold for oil-importing countries. Hence, a negative relationship between Crude Oil and CDS is anticipated for oil-exporting countries, and a positive relationship is expected for oil-importing countries accordingly. Surprisingly, the coefficients of Crude Oil are negative for all countries except for Germany, France, and the USA. However, the coefficients are significant for a few countries, viz. Brazil and Mexico among the oil-exporting nations, whereas Japan, Italy, Turkey, Australia, and South Africa, are among oil importers.

Alternately, developed economies do not share as significant relationships with WTI as those of developing economies, with a few exceptions. Where the CDS of a country is impacted by Crude Oil, we find that VIX plays a significant role for all countries' CDS but few oil importers, i.e., Italy, Germany, France, UK, and Australia. VIX is a measure of fear; theoretically, increasing fear should increase the CDS spreads in the country and vice versa. Regression coefficients show that VIX has positive coefficients for all oil-exporting countries and mixed signs for oil-importing countries. In addition to VIX, another critical global factor influencing CDS is the Federal funds rate, which can proxy the benchmark rate for spread calculation. Our regression coefficients show that the Federal funds rate does not significantly determine CDS spreads for oil exporters and developing countries. However, in the inverse direction, it is significant for a few oil importers and developed economies, such as Australia, France, Germany, Japan, and the UK. The Stock Market Index is usually considered a leading indicator of the country-specific variables that stipulates the economy's health in advance. A falling stock market index can be followed by increasing CDS spreads.

Similarly, an increase in a country's REER index would reflect the sovereign's strength and result in declining CDS. Our regression coefficients outline that Stock Market Index and REER are the factors that are negative and significant for most of the countries, irrespective of them being oil importers, exporters, and their development stage. Similarly, Bond yields are positive and significant for most developing countries with non-significant estimations for developed economies. The significance of Bond yields is a mix for oil exporters and importers. Logically, increasing bond yields are followed by rising CDS spreads, holding for developing countries. Inflation also increases CDS spreads for a sovereign as rising prices would reduce the purchasing power of a sovereign. Noteworthy, inflation does not play a crucial role in the CDS spreads for all countries but Italy, South Africa, and the USA. Our regression results highlight the significance of all the factors for one or more country models; however, at the time of a sudden shock to one country, the impact of these independent variables can be accelerated from the one that regression estimated here. To understand the immediate and long-term impact of shocks on CDS, we have calculated the Generalized Impulse response functions and generalized forecast error variance decompositions discussed in the following sections.

5.3. Generalized Impulse Response Functions of one standard error shock to Crude Oil price

Table 2[11] in the appendix exhibits the Generalized Impulse Response Functions of credit default swaps for one standard error shock simulated in Crude Oil. Noteworthy, a negative relationship between Crude Oil and CDS is anticipated for oil-exporting countries, and a positive relationship is expected for oil-importing countries accordingly. Surprisingly, the impulse responses show a negative response for most countries, irrespective of whether it is an oil-exporting or importing countries. This result resonates with the outcome of Bouri et al. (2020), who mentions the adverse relation of CDS spread in oil-exporting countries, and the relations are less pronounced for oil importers in their study. These responses remained for two consecutive periods and started correcting after that. Though all countries respond negatively, the impulse responses of oil-exporting countries are more vigorous. They range from 5.55% to 7.42% compared to oil-importing countries, ranging from 0.93% to 6.07%. However, the negative responses of oil-exporting countries have witnessed a faster recovery in period one than oil-importing countries. The results are in tandem with the theory concerning oil-exporting countries but not for oil-importing countries. This may be attributed to oil reserves, sovereign wealth funds (Naifar et al., 2017), and other resources available to these nations. Furthermore, when the countries are categorized as developed and developing nations, no heterogeneity behavior toward changing Crude Oil prices is observed. When the countries are categorized as oil-exporting and importing countries, we see that oil-exporting countries are more sensitive to Crude Oil shocks than oil-importing countries. Notably, an episode around the 2014 oil crisis, where the credit rating of Russia was downgraded to Baa 3 by Moody's, BBB- by Fitch, and Standard and Poor's cut the ratings to Junk status,[12] Russia's CDS inflated even higher than the countries with lower credit ratings having less dependency on Crude. Likewise, ratings for Mexico, Brazil, Argentina, and many other oil exporters were downgraded. Although Brazil and Argentina are relatively diversified economies, their lower fiscal strength makes them a high receiver of shocks; as a result, Argentina defaulted in the same period, and Brazil got a hit indirectly due to a decline in royalties of their oil fields.

The GIRFs of CDS to Crude Oil shocks established a quantifiable response. We have checked for the Impulse Responses of all chosen country-specific and global variables to Crude Oil shocks to determine if these can be possible channels of the shocks from Crude Oil to CDS. Undoubtedly, countries try to offset the impact of Crude Oil price changes by adjusting interest rates. The federal funds rate, regarded as the marginal cost of borrowing, usually sees an upside (downside) to a positive (negative) shock in Crude Oil price, which is generally followed by other countries. We found a shock to Crude Oil is giving an immediate impact of 3.27% on the Federal Funds Rate. However, this effect is only contemporaneous, and the federal funds rate settles from period two. VIX, a fear index, respond negatively to the Crude Oil shock. Our GIRFs show VIX responds inversely to one standard deviation shock to Crude Oil, which is

[11] We took a forecast horizon of 60 periods; due to space constraints, we have not shown GIRF graphs, and also, the responses are shown for contemporaneous moves and further two period moves.

[12] https://www.reuters.com/article/russia-cds-idUSL6N0VC2E220150202.

Table 1
Regression Coefficients for domestic and global factors for CDS where BY=Bond Yield, REER = Real Effective Exchange Rate, INF=Inflation, SMI= Stock market Indices, FFR= Federal Funds Rate, WTI= Crude Oil, VIX=Volatility Index.

	Intercept	BY	REER	INF	SMI	FFR	WTI	VIX	Adj R2	SE	F-Statistics
Brazil	0.0058	0.6921***	−0.5966*	−0.0193	−1.1993***	−0.0099	−0.1823*	0.1482***	0.6277	0.0979	35.2016***
	(0.0161)	(0.1974)	(0.3247)	(2.91)	(0.1787)	(0.0229)	(0.0998)	(0.0435)			
Mexico	−0.0017	0.781	−1.6430***	0.5473	−1.1396***	−0.0205	−0.2838***	0.2259***	0.6173	0.0973	33.7261***
	(0.0115)	(0.5768)	(0.3718)	(2.3168)	(0.2283)	(0.0473)	(0.1016)	(0.0443)			
Russia	−0.0188	0.6135**	−0.8224**	2.8453	−1.3104***	−0.0354	−0.1838	0.1486***	0.5969	0.1162	31.0390***
	(0.0144)	(0.2454)	(0.3261)	(1.8933)	(0.1789)	(0.0264)	(0.1292)	(0.0509)			
Argentina	0.0085	–	−0.4883	–	−0.3133	−0.081	−0.4134	0.3312***	0.1094	0.296	4.4895***
	(0.0257)		(0.7063)		(0.2459)	(0.0673)	(0.2895)	(0.1243)			
China	−0.0073	−0.0986	1.8552*	−0.4051	−0.9132***	−0.005	−0.2136	0.2766***	0.4753	0.1291	19.3768***
	(0.0116)	(0.2705)	(0.9478)	(2.2607)	(0.1408)	(0.0297)	(0.1291)	(0.0539)			
Indonesia	−0.0033	0.6804***	−0.5344	0.9466	−1.0050***	−0.0282	−0.1113	0.1966***	0.5835	0.1062	29.4231***
	(0.012)	(0.1868)	(0.4709)	(1.9861)	(0.234)	(0.0245)	(0.1072)	(0.046)			
South Africa	0.0184	1.0156***	−1.6209***	−3.8266*	−0.6433***	−0.0114	−0.2050**	0.1157**	0.5442	0.0948	25.2168***
	(0.0129)	(0.2044)	(0.2742)	(2.2066)	(0.2248)	(0.0215)	(0.1029)	(0.0443)			
Turkey	−0.0029	1.0579***	−0.7348***	0.694	−0.6478***	−0.0279	−0.1430*	0.0941***	0.7239	0.0768	54.1796***
	(0.009)	(0.1026)	(0.238)	(0.7376)	(0.1084)	(0.0175)	(0.0737)	(0.0326)			
Australia	−0.0012	−0.0873	−1.1417*	−1.8493	−1.9021***	−0.0775**	−0.2935*	0.034	0.3971	0.1424	14.3607***
	(0.0196)	(0.1724)	(0.6198)	(8.4649)	(0.4007)	(0.0336)	(0.1559)	(0.0687)			
France	0.0012	−0.018	−8.7197***	2.0186	−2.6083***	−0.1114***	0.1962	−0.0225	0.4264	0.1514	16.0799***
	(0.0135)	(0.0276)	(1.9496)	(4.2041)	(0.3645)	(0.0348)	(0.159)	(0.0782)			
Germany	0.0086	−0.0665*	−5.1997***	−2.6438	−1.9176***	−0.1396***	0.1391	−0.0332	0.2765	0.179	8.7510***
	(0.016)	(0.038)	(1.9569)	(4.6267)	(0.3633)	(0.041)	(0.1772)	(0.0867)			
Italy	−0.0093	0.5254***	−5.7334***	13.4793**	−1.6199***	−0.0568*	−0.3101**	−0.0165	0.5302	0.1368	23.8897***
	(0.0128)	(0.108)	(1.6835)	(5.3819)	(0.2252)	(0.0307)	(0.1441)	(0.0634)			
Japan	0.0076	0.0112	−0.8572	−4.827	−1.2237***	−0.0880**	−0.2574*	0.1237*	0.2906	0.1482	9.3099***
	(0.0125)	(0.0206)	(0.6798)	(4.0924)	(0.3185)	(0.0341)	(0.149)	(0.0695)			
South Korea	0.0041	0.1402	−0.1107	0.4058	−1.3842***	−0.0226	−0.0904	0.1532***	0.4226	0.1067	15.8444***
	(0.01)	(0.1062)	(0.4479)	(2.6862)	(0.2322)	(0.0256)	(0.1102)	(0.0474)			
UK	−0.0012	−0.0954	0.7274	−2.5136	−1.7451***	−0.0773**	−0.1592	−0.0092	0.1826	0.1628	5.5307***
	(0.0165)	(0.1123)	(5.6531)	(5.0598)	(0.4963)	(0.0368)	(0.1778)	(0.0853)			
USA	0.0349**	−0.0857	−3.6100***	−10.6321**	−2.6060***	−0.0181	0.2363	−0.2346**	0.162	0.1692	4.9205***
	(0.0161)	(0.1593)	(1.3648)	(4.3317)	(0.546)	(0.0386)	(0.2048)	(0.0935)			

Table 2
Contemporaneous and first two period Generalized Impulse Response Functions of Global and Domestic Factors to one standard error shock to Crude Oil.

		Brazil	Mexico	Russia	Argentina	China	Indonesia	SouthAfrica	Turkey	Australia	France	Germany	Italy	Japan	SouthKorea	UK	USA
CDS	**0**	−0.0555	−0.0602	−0.0742	−0.0571	−0.0476	−0.0316	−0.0389	−0.0293	−0.0607	−0.0259	−0.0093	−0.0371	−0.0526	−0.0394	−0.0347	−0.0102
	1	−0.0209	−0.0120	−0.0380	−0.0611	−0.0197	−0.0087	−0.0138	−0.0065	−0.0138	−0.0181	−0.0377	−0.0148	0.0091	−0.0167	−0.0189	−0.0244
	2	−0.0062	−0.0074	−0.0020	−0.0125	−0.0083	0.0009	0.0002	0.0009	−0.0130	−0.0089	−0.0135	−0.0121	0.0001	−0.0013	−0.0218	−0.0161
Bond Yield	**0**	−0.0002	0.0064	−0.0122	–	0.0073	0.0001	0.0051	−0.0024	0.0327	0.0041	−0.0105	0.0114	0.0108	0.0133	0.0310	0.0282
	1	−0.0015	0.0040	−0.0056	–	0.0093	0.0058	0.0026	0.0044	0.0093	0.0975	0.0374	0.0205	0.1087	−0.0085	0.0050	0.0115
	2	−0.0001	0.0012	−0.0012	–	0.0042	0.0030	0.0043	0.0026	−0.0001	−0.0132	0.0360	0.0014	0.0408	0.0119	−0.0002	0.0071
Inflation	**0**	0.0000	−0.0003	−0.0007	–	−0.0007	−0.0006	0.0002	0.0008	0.0001	0.0010	0.0007	0.0005	0.0001	0.0003	0.0004	0.0007
	1	0.0001	−0.0004	−0.0012	–	0.0000	0.0000	0.0006	0.0012	0.0002	0.0005	0.0009	0.0005	0.0005	0.0009	0.0006	0.0019
	2	0.0000	−0.0004	−0.0015	–	−0.0003	0.0000	0.0007	0.0004	0.0003	0.0004	0.0000	0.0003	0.0005	0.0002	0.0004	0.0010
Real Effective Exchange Rate	**0**	0.0094	0.0052	0.0058	−0.0034	−0.0029	−0.0009	0.0047	0.0020	0.0064	0.0014	0.0012	0.0008	−0.0041	0.0044	0.0003	−0.0043
	1	0.0057	0.0038	0.0133	−0.0011	−0.0030	0.0008	0.0052	0.0010	0.0049	0.0005	0.0011	0.0005	−0.0056	0.0022	0.0002	−0.0031
	2	0.0013	0.0009	0.0056	0.0011	−0.0015	0.0013	0.0008	0.0000	0.0004	0.0002	−0.0002	0.0000	−0.0030	0.0001	−0.0001	−0.0001
Stock Market Index	**0**	0.0223	0.0157	0.0276	0.0336	0.0127	0.0102	0.0191	0.0108	0.0097	0.0125	0.0101	0.0149	0.0158	0.0193	0.0122	0.0165
	1	0.0073	0.0038	0.0043	0.0067	0.0063	0.0061	0.0007	0.0051	0.0078	0.0033	0.0044	0.0055	0.0040	0.0026	0.0039	0.0069
	2	−0.0014	−0.0013	−0.0060	−0.0041	−0.0041	0.0002	−0.0015	−0.0010	−0.0001	0.0011	0.0009	0.0009	0.0039	−0.0014	−0.0007	0.0028
Federal Funds Rate	**0**	0.0327															
	1	0.0283															
	2	−0.0012															
Volatility Index	**0**	−0.0544															
	1	−0.0118															
	2	−0.0039															

enormous on impact (−5.44%) that settles down quickly until period 4.

The GIRFs of country-specific variables have been shown in Table 2. Expectedly, all the chosen variables respond to one standard error shock to Crude Oil. REER is sensitive to Crude Oil shocks. Crude Oil is denominated in US Dollars, and an increase in oil prices would result in a decline in purchasing power of USD. Our results show the decline in REER of USA by 0.43%. The declining power of the USD is advantageous for other countries when their exchange rate is expressed in terms of the USD. Table 2 shows REER of oil-exporting countries is positively sensitive to Crude Oil shocks ranging from 0.52% to 0.94%, barring Argentina, which is sensitive, but its REER decreased by 0.34% to a shock to Crude Oil. Argentina's domestic economic issues might contribute to the peso's depreciation. Owing to a history of intemperate borrowings with insufficient fiscal and monetary restrains, the country fell into default for the ninth time.[13]

With an increase in oil prices, the REER of oil-exporting countries witnesses an appreciation that undercuts their trade competitiveness with expensive exports and cheaper imports for non-oil sectors, referred to as the Dutch Disease Phenomenon. It is often difficult to reconstruct the lost competitiveness when prices of Crude Oil fall. Therefore, the regulatory institutions try to offset these adverse effects by adjusting the interest rates that have a domino effect on inflation, aggregate demand and supply, and overall economic growth. Noticeably, the REER of all oil-exporting countries started correcting in period one. However, it further increased for Russia due to the highest contribution of Crude Oil exports to its GDP. On the flip side, oil importers are also sensitive to Crude Oil shocks, but the degree of response varies from a low of −0.09% to a high of 0.64%. Logically, an increase in oil prices depletes the forex reserves of an importing country; therefore, we expected a fall in their REER which is holding for China, Japan, and Indonesia, with REER falling by −0.29%, −0.41%, and −0.09% on impact respectively. The REER is positive for other oil importers, though the change is relatively lower than for exporters. South Korea, South Africa, and Australia show the highest positive sensitivity amongst oil importers. A fall in USD must also strengthen the currency of oil importers, which may have counterbalanced the loss due to depleting forex reserves.

Similarly, the response of Stock Market Indices of oil-exporting countries is comparatively higher than oil-importing countries ranging from 2.76% to 3.36%. Indeed, there are expectations of rising indices on the positive shock to Crude Oil for oil exporters and a reverse trend for oil importers as rising oil prices will increase the cost of production and reduce profit margins for many companies constituting an Indices.

Bond Yields are another essential indicator reflecting investors' confidence in the sovereign. A positive shock to Crude Oil increases the revenues of oil exporters, indicating positive moves in macro-economic factors of a country such as high GDP, high forex reserves, strong currency, etc. In turn, this attracts the investors to sovereign bonds, raises the bond demand, and reduces the bond yields. Our results reflect a negative effect on oil exporters' bond yields barring Mexico, which shows a positive move in bond yield. Russia's Bond yields show more sensitivity relative to other oil exporters, i.e., its yield is declining to 1.22%. This can be attributed to its significant issues by oil and gas companies.

On the contrary, oil-importing countries witnessed an increase in their bond yield due to Crude Oil shocks. Australia, the UK, and the US are the countries that have witnessed a significant change in their bond yields. Developed markets have more active and sizeable bond markets than developing countries. Surprisingly, China, Germany, Italy, and France see an increase in bond yields on impact, but the yield further increases in period 1. Rest the impact settles for all the countries in period 1. The USA is the most significant bond market, witnessing an increase of 2.82%. The impact of bond yield shows that developed markets are most sensitive to Crude Oil prices due to their sizable bond markets. Inflation is yet another critical factor that discounts the Crude Oil price fluctuations with an increase in the cost of production for oil-importing countries. Inflation in oil-importing countries is responding positively and is high in magnitude compared to oil-exporting countries for which the move is inverse in direction.

The GIRFs Table 2 appended shows that all the selected variables respond to Crude Oil price shocks and the significance of these factors for CDS as given by Regression coefficients (appended Table 1). It outlines the possibility for any of these variables to act as a potential channel of shock transmission from Crude Oil to CDS, examined in further sections.

5.4. Generalized forecast error variance decomposition

GIRF has made it clear that all the select variables respond to the oil price shocks immediately. These interesting findings have laid the foundation and opened the doors to dig into the medium to long-term effects of Crude Oil price fluctuations on the CDS of nations covered in the study. To understand the static view of such shocks, we have used generalized forecast error variance decompositions (Diebold and Yilmaz, 2012,2014) on Crude and country's CDS as a system with a forecast horizon of 60 periods. Table 3, the upper part briefs the spillover shocks received by each CDS. To understand the vulnerability of different countries to Crude Oil shocks, we have classified the shock spillover intensity into three categories, i.e., Low, Moderate, and strong. The classification is based on percentiles, i.e., the countries having spillovers above the 75th percentile of shocks to all countries (9.97%) are demarcated as high-intensity shocks, between 50th to 75th percentile (7.92%–9.97%) is demarcated as Moderate intensity, and below the 50th percentile (7.92%) is demarcated as Low-intensity shocks.

As observed, oil-exporting countries receive the highest spillovers from Crude Oil than importing countries, with Argentina being the only exception. On the strong receptor side, Russia is the highest receiver with a staggering 19.25% shock contribution from Crude Oil, followed by Mexico (14.01%) and Brazil (12.59%). It can be attributed to their balance of payments being more dependent on oil-

[13] https://www.bloomberg.com/news/photo-essays/2019-09-11/one-country-eight-defaults-the-argentine-debacles.

Table 3
Spillovers from Crude Oil to Country's CDS and System-wide spillover matrix for CDS.

SpilloverfromCrudeOil	Brazil	Mexico	Russia	Argentina	China	Indonesia	SouthAfrica	Turkey	Australia	France	Germany	Italy	Japan	SouthKorea	UK	USA	AverageSpillover
	0.1259	0.1401	0.1925	0.0658	0.0887	0.0604	0.0918	0.0432	0.1083	0.0452	0.0495	0.0550	0.0969	0.0911	0.0697	0.0529	0.0861

System-wide spillover matrix for CDS

	Brazil	Mexico	Russia	Argentina	China	Indonesia	South Africa	Turkey	Australia	France	Germany	Italy	Japan	South Korea	UK	USA	FROM
Brazil	0.2095	0.0500	0.0336	0.0227	0.0242	0.0150	0.0407	0.0460	0.0069	0.0018	0.0019	0.0016	0.0164	0.0392	0.0092	0.0017	0.3110
Mexico	0.0370	0.1509	0.0285	0.0212	0.0406	0.0097	0.0189	0.0104	0.0142	0.0005	0.0028	0.0025	0.0233	0.0175	0.0010	0.0037	0.2319
Russia	0.0155	0.0126	0.2343	0.0186	0.0242	0.0148	0.0256	0.0188	0.0106	0.0017	0.0039	0.0015	0.0128	0.0227	0.0035	0.0040	0.1908
Argentina	0.0011	0.0011	0.0118	0.6603	0.0039	0.0026	0.0036	0.0007	0.0024	0.0094	0.0056	0.0008	0.0015	0.0027	0.0019	0.0005	0.0496
China	0.0115	0.0278	0.0285	0.0146	0.2396	0.0171	0.0245	0.0131	0.0166	0.0003	0.0035	0.0002	0.0105	0.0225	0.0016	0.0031	0.1952
Indonesia	0.0117	0.0086	0.0283	0.0309	0.0280	0.2144	0.0334	0.0176	0.0245	0.0059	0.0037	0.0005	0.0050	0.0304	0.0013	0.0036	0.2334
South Africa	0.0249	0.0129	0.0312	0.0234	0.0292	0.0236	0.1538	0.0318	0.0129	0.0018	0.0034	0.0005	0.0073	0.1294	0.0011	0.0072	0.3405
Turkey	0.0438	0.0080	0.0316	0.0179	0.0218	0.0185	0.0486	0.2716	0.0090	0.0018	0.0025	0.0032	0.0028	0.0462	0.0041	0.0010	0.2606
Australia	0.0054	0.0006	0.0241	0.0213	0.0045	0.0042	0.0043	0.0034	0.3441	0.0038	0.0159	0.0030	0.0104	0.0047	0.0282	0.0057	0.1394
France	0.0113	0.0056	0.0322	0.0128	0.0011	0.0179	0.0236	0.0064	0.0094	0.2940	0.0550	0.0714	0.0118	0.0233	0.0287	0.0407	0.3513
Germany	0.0262	0.0140	0.0194	0.0104	0.0012	0.0018	0.0150	0.0029	0.0163	0.0599	0.4707	0.0148	0.0066	0.0154	0.0484	0.0011	0.2534
Italy	0.0017	0.0012	0.0285	0.0148	0.0020	0.0054	0.0195	0.0022	0.0093	0.0784	0.0211	0.3205	0.0056	0.0189	0.0152	0.0190	0.2428
Japan	0.0073	0.0139	0.0185	0.0126	0.0067	0.0006	0.0037	0.0022	0.0123	0.0075	0.0020	0.0010	0.4003	0.0041	0.0011	0.0081	0.1015
South Korea	0.0246	0.0128	0.0319	0.0230	0.0291	0.0236	0.1302	0.0318	0.0132	0.0017	0.0034	0.0005	0.0074	0.1500	0.0012	0.0073	0.3417
UK	0.0375	0.0188	0.0366	0.0174	0.0087	0.0093	0.0264	0.0146	0.0458	0.0372	0.0576	0.0170	0.0070	0.0254	0.3770	0.0230	0.3824
USA	0.0171	0.0251	0.0183	0.0068	0.0086	0.0107	0.0067	0.0245	0.0011	0.0448	0.0037	0.0078	0.0028	0.0078	0.0144	0.7271	0.2002
TO	0.2765	0.2128	0.4031	0.2685	0.2339	0.1749	0.4245	0.2263	0.2045	0.2564	0.1859	0.1264	0.1310	0.4102	0.1610	0.1297	**3.8255**
Net	−0.0345	−0.0190	0.2123	0.2189	0.0386	−0.0585	0.0840	−0.0343	0.0651	−0.0949	−0.0675	−0.1164	0.0295	0.0685	−0.2214	−0.0705	

based revenue, and a price increase would lead to inflated balances and vice versa. The rapid decline in oil price had hard hit the Russian Ruble in the past, coupled with the depreciation of the exchange rate against the dollar. The exports were deemed cheaper with a meager contribution to the economy.[14] However, diversification of the economic sector apart from oil has aided the economies of Mexico, Brazil, and Argentina to better manage dependency on oil shocks, thus leading to a relative fall in sensitivity to oil shocks (Pavlova et al., 2018). However, in the case of Russia, frequent sanctions proliferated domestic issues adding to the vulnerability of sovereign risk. Noteworthy, all oil-importing countries are receiving low to moderate spillovers from Crude Oil, barring Australia, which is vulnerable to oil shocks at 10.83%. Australia fulfills most Crude Oil requirements from Crude Oil imports[15] that add to its trade deficit, depreciation of forex rate, reduction in purchasing power, and ultimately weak fundamentals. Interestingly, moderate to high magnitude shocks are received by developing countries, whereas developed countries fall under the weak receiver category with France and Germany being the lowest receivers.

From Table 3, it is evident that there exists a long-term shock spillover from Crude Oil to oil-exporting and importing countries. The quantum is also high, with oil exporters receiving relatively highest spillovers. The picture is still elusive here. The spillover mechanism does not stop by hitting one country but further spills over to other countries linked through any economic or financial medium. To understand the enormous full-scale impact of Crude Oil spillovers on the sovereign risk of countries, we have analyzed the systemic impacts of such shocks. Importantly, feedback mechanism is observed in a systemic spillover system (Singh et al., 2018). It further leads to shock intensification in the system. On similar grounds, a possibility arises regarding shock intensification amongst CDS, though the shock origination traces to Crude Oil price fluctuations. Recently, Bostanci and Yilmaz (2020) highlighted that the most important transmitters of shocks related to sovereign credit risk are not necessarily the originators. Hence, understanding of systemic impacts of such spillover is critical as these proliferating shocks can be more detrimental to the economies than they appear. Here, we have constrained our system to the CDS of 16 oil-exporting and importing countries to understand the mechanism. Based on generalized forecast error variance decompositions, we have appended the spillover Index (Table 3). This table shows To, From, Net, and Total connectedness between the CDS of countries. 'To' connectedness shows shock transmission from the CDS of country 'i' to the CDS of all other countries, whereas 'From' connectedness shows shock transmission from the CDS of all other countries to country 'i'. Net connectedness is the difference of 'To' and 'From' connectedness of country 'i' that tells us whether a country is a net receiver or net transmitter. Total connectedness shows the total shock transmissions in the system, calculated by considering the average of either 'From' or 'To'. Noteworthy, the analysis here deals with interactions of CDS across all countries.

Further, we have demarcated the strong, moderate, and low receivers and transmitters based on percentiles. For net receivers, the countries receiving above 75th percentile, i.e., 9.489% are strong receivers, and countries receiving above 50th percentile and below 75th percentile, i.e., between 6.735% and 9.489% are moderate receivers, and countries receiving below 50th percentile, i.e., below 6.735% is low receivers. Similarly, the countries above 14.818% are strong transmitters for net transmitters, between 6.853% and 14.818% is a moderate transmitter and below 6.853% is low transmitters. For pairwise spillovers, above 2.492% is considered strong, between 1.285% and 2.492% are considered moderate, and below 1.285% are low-intensity shocks. From Table 3, it is evident that the CDS of most developed countries such as the USA, UK, France, and Germany are amongst the net receivers of shocks. Countries that received the lowest Crude Oil shocks are among the highest receivers of system-wide shocks. On the other front, oil-exporting countries held the position of net transmitters in the system, with Russia and Argentina being the highest transmitters. Notably, the oil exporters amongst the highest receivers of shocks from Crude Oil are prone to transmit the same shocks to other countries existing in the system. The strong and moderate-intensity shocks are given by developing countries, as shown by the pairwise shock spillover in Table 3. Brazil, Russia, Argentina, and South Africa emanate numerous strong shocks. Italy, France, the UK, and Germany have numerous weak to strong transmissions hitting them, implying shocks received by these countries from other countries in the system. Our findings are in tandem with the findings of (Sun et al., 2018; Bostanci and Yilmaz, 2020), who outlined that sovereign CDS of emerging markets causes higher spillovers. The UK is receiving 6.97% of shocks from Crude Oil directly; nonetheless, the UK is a net receiver of spillover with approximately 22.14% with major systemic shocks transmitted from Italy, Brazil, South Korea, and South Africa. Russia has been the EU's biggest trading partner and is transmitting strong shocks to Germany, Italy, and France. The USA, the largest economy, receives high-intensity shocks from France, Russia, Brazil, and Germany, along with moderate shocks from other countries.

The system seems complex, with multiple strong transmissions and reception of shocks that imply the presence of indirect spillovers in the system, which further multiplies the size of the Crude Oil shock and enlarges the threat. Importantly, these shocks are transmitted to interconnected countries via some financial and economic linkages. For example, the UK has a significant part of its FDI in Russia and shares longstanding trade relations that can be the possible channel that transmits the shocks from Russia to the UK. Identifying such channels that can act as carriers of the shocks to other countries in the system can help manage the stress. Identifying such channels and their contribution can be used for proactive policy decisions and provide time to manage the stress carried by such factors.

Two global and four domestic variables have been factored in the system already comprising CDS and Crude. Amongst the global variables, VIX and the Federal fund rate have been considered. On the other hand, domestic variables considered are viz. REER, Inflation, Bond Yield, and stock market index. GIRF results in Table 2 have already ascertained the short-run response of the chosen

[14] During the 2014 oil crisis, the impact on the Russian economy was devastating. The russian ruble declined by approximately 59% in 6 months from June to December 2014, and it began the year 2015 with the lowest PPP. Low oil prices made the imports dearer for Russia due to the lowest PPP resulting in high inflation and high-Interest rates of 17%. A sudden hike in interest rates can lead to a deep recession, as discovered by the USA in 1980.

[15] https://theconversation.com/australia-imports-almost-all-of-its-oil-and-there-are-pitfalls-all-over-the-globe-97070.

domestic and global variables to Crude Oil shock. To ascertain the medium to the long-term impact of Crude Oil shock on these factors, GFEVD is applied system-wide. Table 4, the upper half, shows the spillover shocks received from Crude Oil price fluctuations on domestic and global factors. Factors receiving shocks greater than 6.42% from Crude Oil are strong receivers, between 6.15% and 6.42% are moderate receivers, and lower than 6.15% are low receivers.

As we can observe, global variables are receiving low to high Crude Oil shocks, which further creates chaos for the receiving country and other countries via their bilateral linkages. Apart from shock proceeds from CDS to CDS, a possibility arises from shock propagation from global and domestic factors too. Table 4, the middle section, shows the shock spillover from global and domestic factors to CDS. Factors transmitting shocks higher than 3.43% to the country's CDS are strong transmitters; between 0.75% and 3.43% are moderate transmitters, and below 0.75% are low transmitters. On stimulating a shock to CDS, we received the contribution of all factors to CDS. Noteworthy, average values of all the factors are considered for computing the aggregates. As we can observe, VIX is the strong transmitter of shocks to CDS spreads of countries amongst global variables. Intuitively, the larger shocks received by VIX from Crude Oil can create a manifold impact on the CDS of other countries as shocks can be carried to CDS spreads of countries with high intensity.

On the contrary, despite receiving the lowest intensity shocks from Crude Oil, the federal funds rate is transmitting moderate spillover to CDS. For the domestic factors, though inflation is a strong receptor of spillover shocks from Crude Oil, it is a meagre contributor to spillover shocks to country CDS. However, the rest of the domestic factors, viz. SMI, REER, and BY surpass moderate to heavy spillover shocks to CDS, though shock reception from Crude Oil is on the lower side.

Notably, Stock market indices (SMI) play a significant role in the CDS spread for all the countries; it can be inferred that they can act as a supercarrier for the shocks arising from Crude Oil to the CDS of countries. Theoretically, a Crude Oil shock increases the cost to any economy and results in cost-push inflation. However, inflation was not playing any significant role while we measured impulse responses and regression; the same is empirically validated from the long-run dynamics computed via GFEVD. Notably, all countries are receiving shocks from all global and domestic factors with varying intensities, implying that all these factors can be carriers. Where country-specific factors receive low to strong intensity shocks from Crude Oil, they become potential carriers to pass on such shocks to CDS, but the intensity is lower.

Additionally, Global factors receive low to high-intensity shocks from Crude Oil, and at the same time, it can be translated to the CDS of countries with high intensity. Thus, CDS could be more vulnerable provided shock intensity to Global variables increases, which can be surpassed with greater intensity to CDS. Hence, we conclude that both global and domestic factors play a significant role as potential channels, but the role played by global factors is more prominent and dominant. Our findings advocate Longstaff et al. (2011), who mentioned the dominant role of global factors in explaining the CDS spreads/sovereign risk.

Table 4

Spillover from Crude Oil to Global and Domestic factors, Spillovers from Global and Domestic factors to Countries CDS and DCC-GARCH Estimates; here SMI=Stock Market Index, REER = Real Effective Exchange Rate, BY=Bond Yields, INF=Inflation, FFR=Federal Funds Rate, VIX= Volatility Index.

	SMI	REER	BY	INF	FFR	VIX
Average Shock spillover from Crude oil to Global and Domestic factors	0.06421	0.05881	0.04706	0.08589	0.01305	0.06419
Shock Spillover from Domestic and Global Factors to Country CDS						
	SMI	**REER**	**BY**	**INF**	**FFR**	**VIX**
Brazil	0.00882	0.00583	0.00588	0.00265	0.01597	0.12259
Mexico	0.00740	0.00446	0.00302	0.00241	0.01301	0.22650
Russia	0.00877	0.00412	0.00460	0.00291	0.01379	0.15193
Argentina	0.00284	0.00298	0.00316	0.00358	0.01146	0.05613
China	0.01051	0.00458	0.00422	0.00254	0.00640	0.15569
Indonesia	0.00838	0.00400	0.00474	0.00339	0.01886	0.16343
South Africa	0.00976	0.00466	0.00468	0.00225	0.00354	0.11433
Turkey	0.00956	0.00920	0.00988	0.00294	0.00553	0.06909
Australia	0.00616	0.00439	0.00483	0.00468	0.04351	0.17685
France	0.00721	0.00612	0.00540	0.00270	0.01418	0.10585
Germany	0.00624	0.00464	0.00495	0.00296	0.02806	0.06048
Italy	0.00744	0.00431	0.00841	0.00340	0.02124	0.09180
Japan	0.00625	0.00463	0.00421	0.00249	0.01979	0.15334
South Korea	0.00971	0.00460	0.00476	0.00191	0.00599	0.10388
UK	0.00506	0.00463	0.00558	0.00345	0.01551	0.07218
USA	0.00569	0.00648	0.00822	0.00387	0.01731	0.03305
Average Shock spillover from Global and Domestic factors to Country's CDS	0.00749	0.00498	0.00541	0.00301	0.01588	0.11607
DCC estimates to validate significance of short run and long run spillover						
	Estimate	**Std. Error**	**t value**	**Pr(> |t|)**		
[Joint] dcca1	0.00790	0.00229	3.45458	0.00055		
[Joint] dccb1	0.15574	0.00402	38.71206	0.00000		

5.5. Robustness check

Our study has used Regression estimates to validate the selection of variables for the study, followed by Generalized IRFs and FEVDs. The results of all these methods provide a robustness check to one another. We calculated the GIRFs of CDS to one standard error shock to domestic and global variables (amid space constraints, the graphs and table are not added; however, it is made available on request). We contrast the regression coefficients and the GIRFs response of CDS to all other variables to validate the estimates. Though Regression coefficients highlight the relationship between dependent and independent variables, impulse responses outline the response of the dependent variable to a shock to the exogenous variable. If regression coefficients state the inverse relationship between two variables, we expect the contemporaneous response of CDS to a shock to other variables also to be in the same direction. On comparing, we find the Regression coefficients are in line with impulse responses of CDS spreads to Crude Oil, i.e., all countries respond negatively to Crude Oil price moves except France, Germany, and the USA. The magnitude is high for oil-exporting countries compared to oil-importing countries, and developing nations respond higher than developed nations. The contemporaneous response of VIX for the countries is in line with significant regression coefficients. Similar is the response of CDS spreads to Federal Funds rate where on the impact the response of CDS is in the same direction of regression for all countries. We found the robustness in the inflation results for domestic factors as the contemporaneous responses agree with regression coefficients for all the countries except Brazil, France, Mexico, and South Korea.

The same is the case for the stock market index, where there is synchronization in two results for all countries. The responses of Bond yields are matched with regression coefficients verifying the estimations, with Japan as an exception. Similarly, the estimations for REER are also robust, with Australia, Indonesia, and South Korea as an exception. Since the sign contrast between the Impulse responses and Regression coefficients proved the robustness of estimations, we also contrasted these results with GFEVD, which provided yet another robustness to the results. VIX has significant regression coefficients for maximum country models; interestingly, VIX is found to be the most powerful transmitter and dominant carrier of shocks to the system. Likewise, SMI, significant for all country models, is receiving strong shocks from Crude Oil amongst domestic factors and is a moderate transmitter amongst domestic factors to CDS of countries, dominant carrier amongst domestic factors. Similarly, inflation that has significance for a few country models are receiving weak shocks from Crude Oil, and transmission to other countries is also weak. The result given by Regression, GIRF, and GFEVD is in alignment, which states the robustness of the results.

As another robustness test, we checked for the co-volatilities of all the series used in our study, i.e., four country-specific variables for 16 countries and two global variables. We have applied DCC-GARCH (1,1) model with multivariate normal distribution to obtain information on volatility spillover amongst all-time series. The parameters and p-values of joint DCC alpha and joint DCC beta report the residuals' impact and persistence. The estimates of joint DCC alpha and beta indicate persistence in the variances of analyzed time series for a longer time, which comes out to be significant. Table 4 bottom section exhibits the same. Our estimates of DCC GARCH support the outcome of GFEVDs. Hence, the estimates of Regression, GIRFs, GFEVD, and DCC-GARCH provide the robustness of our results.

5.6. Implications of the study

Our investigation is valuable for numerous stakeholders. Firstly, it is supreme to safeguard the creditability of a sovereign because reduced creditworthiness can result in raised cost of debt. For instance, in early 2010, Greece's sovereign debt was downgraded to junk status by credit rating agencies due to a high budget deficit that spiked their borrowing cost by 35%. The impact of Crude Oil price volatility on country CDS has emerged as a double-edged sword, with influence accompanied by shock propagation via domestic and global channels. It thus showcases the need to explore the usage of Crude as a risk-hedging tool against CDS, thus safeguarding the sovereign risk. The inverse relationship between sovereign risk and Crude Oil prices suggests a hedge position for oil and oil-related assets to minimize the detrimental effects of oil price fluctuations. Understanding its vulnerability to Crude Oil price fluctuations directly from Crude Oil and its system-wide impact can provide an insight into rebalancing the business portfolio and investment portfolio.

Most importantly, nations highly reliant on oil exports need to diversify their economies and exports. The need for diversification of the Russian economy has long been discussed in the news. Similarly, countries with import dependency should increase their forex reserves and more competitive exports in non-oil sectors to help cope with shocks from increased oil prices. Majorly, rebalancing a business portfolio is difficult due to the lack of resources; preparations for such a shock become mandatory, requiring a deep understanding of channels that influence the economy and act as carriers of such shocks. The identified channels, such as Federal rates, VIX, REER, Stock Market Index, etc., must be considered while framing policymaker and regulators' policies. The results have implications for countries' central banks seeking to manage oil-based inflation and exchange rates by changing interest rates and creating long/short positions in spot or futures markets. Besides, the Sovereign cost of debt is usually taken as a risk-free interest rate and serves as a benchmark for corporate borrowings; increased sovereign risk is inevitable for corporates and requires them to be ready to manage such shocks. Furthermore, Banks and Financial Institutions that park most of their money in government securities and credit holdings by oil and related companies, an apprehension of the increased sovereign risk could threaten the entire financial system via market interconnectedness. Hence, close monitoring of oil price volatility will aid in taking proactive measures to overcome the increased sovereign risk, hence safeguarding the fallout of the entire financial system.

6. Conclusion

The study investigated three crucial questions: firstly, whether the fluctuations in Crude Oil prices spill over to developed and developing oil-exporting and importing; secondly, if the spillovers are established, what would be the system-wide impact of such spillovers amongst sovereign CDS; thirdly, the contribution of global and country-specific factors in such spillovers is examined, and essential channels of spillovers are identified. The study took 16 economically significant countries (encompassing G20 group) as a sample with four domestic and two global factors along with Crude Oil and CDS. Firstly, we deployed a Multiple regression model for the theoretical underpinning. Secondly, we applied GIRFs to understand the immediate response of all factors to a Crude Oil shock. Thirdly, we employed GFEVD to calculate the medium to the long-term impact of Crude Oil shocks, CDS system-wide shocks, and the role of chosen variables. Lastly, we estimated a multivariate DCC-GARCH model to check the robustness of our results. Our regression estimates show the inverse relation of CDS spreads of all countries to the Crude Oil changes. However, oil-exporting countries are more sensitive to Crude Oil price changes than oil-importing countries. Regression estimates show that all the control variables play a significant role in CDS spreads in one or more countries. GIRF estimates of CDS spreads to Crude Oil shocks validate our regression result and show the negative response of CDS spreads to one standard error shock in Crude Oil prices. Similarly, GIRF estimates of all control variables to a shock in Crude Oil are in link with the regression results and show that all the variables respond contemporaneously to one standard error shock to Crude Oil. We find the existence of long-term shock spillover from Crude Oil to CDS spreads in all countries, where all the oil-exporting countries are getting strong spillovers from Crude Oil except for Argentina, which is getting low spillovers from Crude Oil. Australia is the strongest receiver of spillovers from Crude Oil among oil-importing countries. The system-wide spillover index amongst CDS spreads highlights that Russia and Argentina are the highest net transmitters of shocks, whereas the UK is the strongest net receiver of shock spillovers. Total spillover highlights the intensification of shocks being a part of the system. Further, Global factors dominate domestic factors in the transmission of shocks to sovereign CDS spreads. Furthermore, global and domestic factors transmit shocks to a country's CDS spreads in different intensities. Amongst the global factors, VIX dominates, whereas the domestic stock market index is the highest transmitter for most nations.

Author statement

Vimmy Bajaj: Methodology, Software, Data curation, Investigation, Writing – original draft, Writing-Review and Editing, Visualization. **Pawan Kumar**: Software, Writing-Review and Editing, Visualization, Supervision, Validation, Formal analysis. **Vipul Kumar Singh**: Conceptualization, Methodology, Validation, Resources, Writing-Review and Editing, Project administration The above-mentioned contribution is verified and agreed by all the authors before submission.

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