Dynamic Metamorphosis: Investigating Temporal Shifts in Global Crude Oil Trade Networks

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ABSTRACT

The vast disconnect between crude oil supply and demand markets has given rise to a worldwide crude oil trading system. This paper constructs and analyzes global crude oil trade networks, employing various network analysis techniques and visualization methods. This study aims to delve into the patterns and abnormalities in the global crude oil market, offering insights into its evolution over the past decade. Based on the UN Comtrade Data from 2008-2023, we have constructed a weighted crude oil trade network. Through parameters such as Eigenvector Centrality, Betweenness Centrality and Global Clustering Coefficient we can arrive to certain conclusions regarding the evolving efficiency, criticality and robustness of economies and the trade relationships between nations and their primary crude oil trading partners. Through the lens of geopolitical tensions, such as the ongoing Russia-Ukraine conflicts and the 2008 Financial Crisis, this paper aims to understand the behavior of the global crude oil trade network. It delves deep into the intricacies of specific nodes within the network, analyzing how these events have reshaped trade relationships, altered centrality measures, and impacted overall network resilience and adaptability. By examining these critical junctures, the paper sheds light on the dynamic responses and structural changes within the crude oil trade network during periods of significant geopolitical and economic upheaval.

Introduction

Crude oil is an essential driving force for economic development. Its multifaceded uses in the industrial sector, from propeling vehicles to producing electricity, make it one of the most valuable natural resources in the world. Since the 1970s, the global crude oil market has undergone numerous changes. Crude oil trade networks are not only impacted by the relationship between demand and supply but also by geopolitics, fluctuations in crude oil prices and the state of the world economy. The robustness of global crude oil trade networks is a critical issue on the overall energy market. For all economies present in this trade network, trade stability is a major guarantee for economic stability. Studying the factors the influence this network and the abnormalities present in this network is of great significance for a comprehensive analysis of the state of the crude oil trade patterns.

The traditional powerhouses of the Middle East and Western industrialized nations have historically wielded unchallenged authority over the global crude oil trade. In 2000, OPEC (Organization of the Petroleum Exporting Countries) implemented the "price band" policy to effectively manage crude oil supply, ushering in a four-year period of market stabilization. However, the landscape shifted dramatically after the US subprime mortgage crisis and the European debt crisis, with international crude oil prices reaching their zenith in 2012. In recent years, there has been a noticeable surge in the trade volume share of Southeast Asian countries within the global crude oil market. Since 2020, the world's crude oil market has been undergoing significant adjustments fueled by factors such as the COVID-19 pandemic and global environmental concerns. This period of flux has been marked by a series of transformative policy shifts, including OPEC's production cut agreement, the rise of the US shale gas revolution, European energy restructuring efforts, and the rapid economic ascent of emerging East Asian economies. At the heart of the crude oil market's instability lie concerns over energy security and the expanding influence wielded by major oil corporations and international/regional oil entities. To mitigate the risks stemming from supply and demand fluctuations, nations are actively seeking out new trading partners to bolster their resilience in the face of crude oil supply disruptions.

Previous academic research on international crude oil trade networks has explored several aspects, encompassing demand and supply dynamics, geopolitics, the emergence of new technology, and most importantly, a thorough network analysis. Conducting such an in-depth analysis on the evolving efficiency and robustness of global crude oil trade networks will allow us to understand the transmission efficiency and the stability of the network, and thereby provide policy recommendations for maintaining the oil market stability. For the economy of a nation, this study can also be used as a guide for avoiding market risks. For a specific trade relationship, when a new trade policy is implemented, if the criticality of trade relationships increases in subsequent years, it can be considered that the trade policy promotes the contribution of trade connection to network efficiency; otherwise, the trade policy may not promote or even inhibit trade.

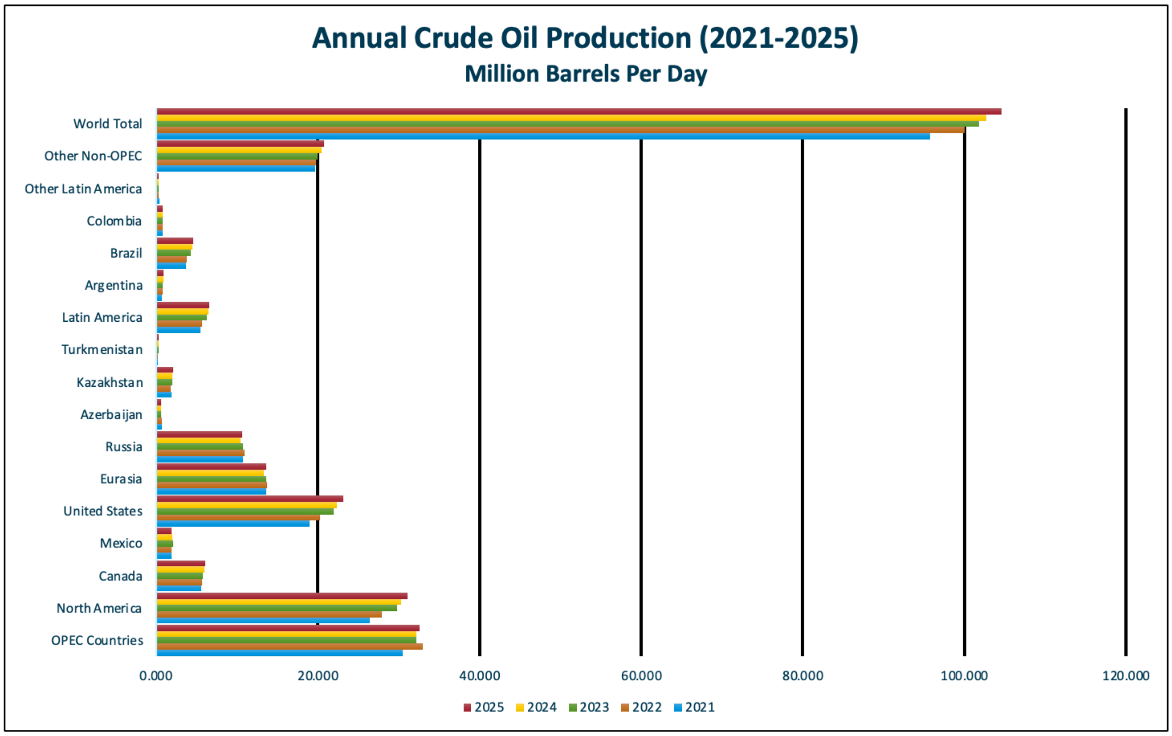

Figure 1. Annual crude oil production (2021-2025)

In 2022, global crude oil production surged by a remarkable 5.4%, marking a significant leap from the modest 1.6% growth witnessed in 2021 and surpassing the average growth rate of 1.3% observed during the 2010-2019 period. Over the past year, the bulk of this surge in global crude oil production was concentrated in the Middle East, which saw a staggering increase of 13%, notably driven by robust expansions in Saudi Arabia (+16%), the United Arab Emirates (+15%), Kuwait (+8.1%), and Iran (+5.9% despite facing sanctions).

Moreover, North America experienced a notable uptick, with production climbing by 6.5% in the US and by 2.6% in Canada. Latin America also contributed to the global upswing, recording a 3.9% increase, primarily fueled by a robust 3.9% growth in Brazil, while production remained steady in Mexico.

Despite facing Western sanctions, Russia saw its crude oil production continue to rise, albeit at a more moderate pace of 2.1%. However, production faced headwinds in Africa, declining by 1.6%, primarily due to a significant 14% drop in Nigerian production, partially offset by an 11% increase in Algerian production. Similarly, production dipped in Asia by 0.9%, despite a 2.7% rise in China, as production contracted notably in Indonesia (-7%), Malaysia

(-8.6%), and Thailand (-19%). Meanwhile, the downward trend persisted in Europe, with a notable 5.3% decline, driven by a 4.1% decrease in Norway and a substantial 7.5% drop in the UK.

Literature Review

The topological characteristics of the global crude oil trade network have attracted numerous scholars and researchers. The theoretical models proposed by K Bhattacharya et al. (2008) and M Barigozzi et al. (2010) play a vital role in promoting further research on the topological features of the global crude oil trade network. Some researchers have even narrowed their scope to regional trade networks.

P Giudici et al (2019) performed an in depth analysis on Asian trade networks and even arrived to the conclusion that Asian trade networks can be divided into two overlapping communities, in which diverse economies play diverse roles. Some scholars have even performed research on specific network features. F Dablander et al (2019), for example, performed an analysis on the importance of nodes in trade networks as a whole, with a primary focus on node centrality indexes such as node degree, betweenness centrality and closeness centrality.

Further delving into papers that conduct an analysis of trade networks from the lens of network parameters, Gao et al (2015) discusses important parameters such as degree distrubution and community stability. Du et al (2017) discusses the relative importance of economies in a network through the lens of centrality measures, by consutrcting import and export crude oil trade networks. Zhong et al (2017) also examines key players in a fossil fuel trade network through the lens of centrality measures. Chen et al (2012) achieved significant results when discussing the importance of essential nodes and weighted edges in a network.

Data and Methodology

Collection of Data

The global crude oil trade data present in this paper has been sourced from the UN Comtrade Database, with the HS (Harmonized System) Code for crude oil being 2709. HS 2709 includes petrolium oils and oils obtained from bituminous minerals, crude. A few trade data points and trading nations could not be identified in this database, however the absence of this data had no effect on the overalls results and the conclusions drawn. Since the data present in the database comes directly from the trading parties, there are incosistencies.

The countries/regions selected for this study are the top 15 global crude oil exporters. Alongside these 15 major trading nations, certain economies that are vital to the overall global economy have also been included. Some of these additions include Australia, Italy, Denmark, Netherlands and even the ASEAN (Association of Southeast Asian Nations) region. With the data present on UN Comtrade and our understanding of the top crude oil exporters, we have constructed two independent databases for two different time frames – 2008 to 2013 and 2018 to 2023. These time frames, taken a decade apart provide us with a plethora of valuable information regarding the crude oil trade landscape across the top trading countries. Through parameters such as each country's primary trading partner, trade value ($) and net weight (kg) we have constructed two networks that reflect the trade networks of those specific time frames.

Construction of Data Set

Through the crude oil trade data on UN Comtrade (HS Code 2709), we chose the export data and created a data set of the top 15 crude oil exporters, alongside eight other additional countries/regions that whose data will provide us with a better understanding of the overall global crude oil trade network. The data set constructed include the trade value

($) and net weight exported (kg), which will contribute towards the weight of the edges in the network. Using this data set, we were able to calculate the values of certain valuable parameters.

The global crude oil trade network is a complex system. As long as there is a trade relationship in the network, there is an edge in the network. Due to globalization, there are many complicated trade relationships in the overall crude oil trade network. There are two types of crude oil trade networks – weight and unweighted networks.

An unweighted crude oil trade network, in year t, which is represented by the adjacency matrix A. The row and column of each of the matrix elements represent the import and export relationships, respectively. The matrix element a_{ij} = 1 indicates that crude oil from nation i is sold to nation j. This notation is essential in calculating certain centrality measures, which will provide us with an understanding of the importance of nodes in the trade network. Secondly, a weighted crude oil trade network, in year t, is represented by the matrix W. The matrix element $w_{ij} = v_{ij}$ indicates that crude oil is exported from nation i to nation j, and the trade volume of this trade transaction is v_{ij}, which is the edge of the edge in the network.

Using the notations above for the weighted trade network, the total export volume of economy i in a weighted trade network is as follows

$$V_i^{Export} = \sum_{j=1}^{N} v_{ij}$$

Here, N is the number of nations in the trade network.

Before delving into our analysis of certain network parameters and the conclusions derived, an observation of the two trade networks we have obtained is vital. A visual and color-coded representation of the two trade networks is present below:

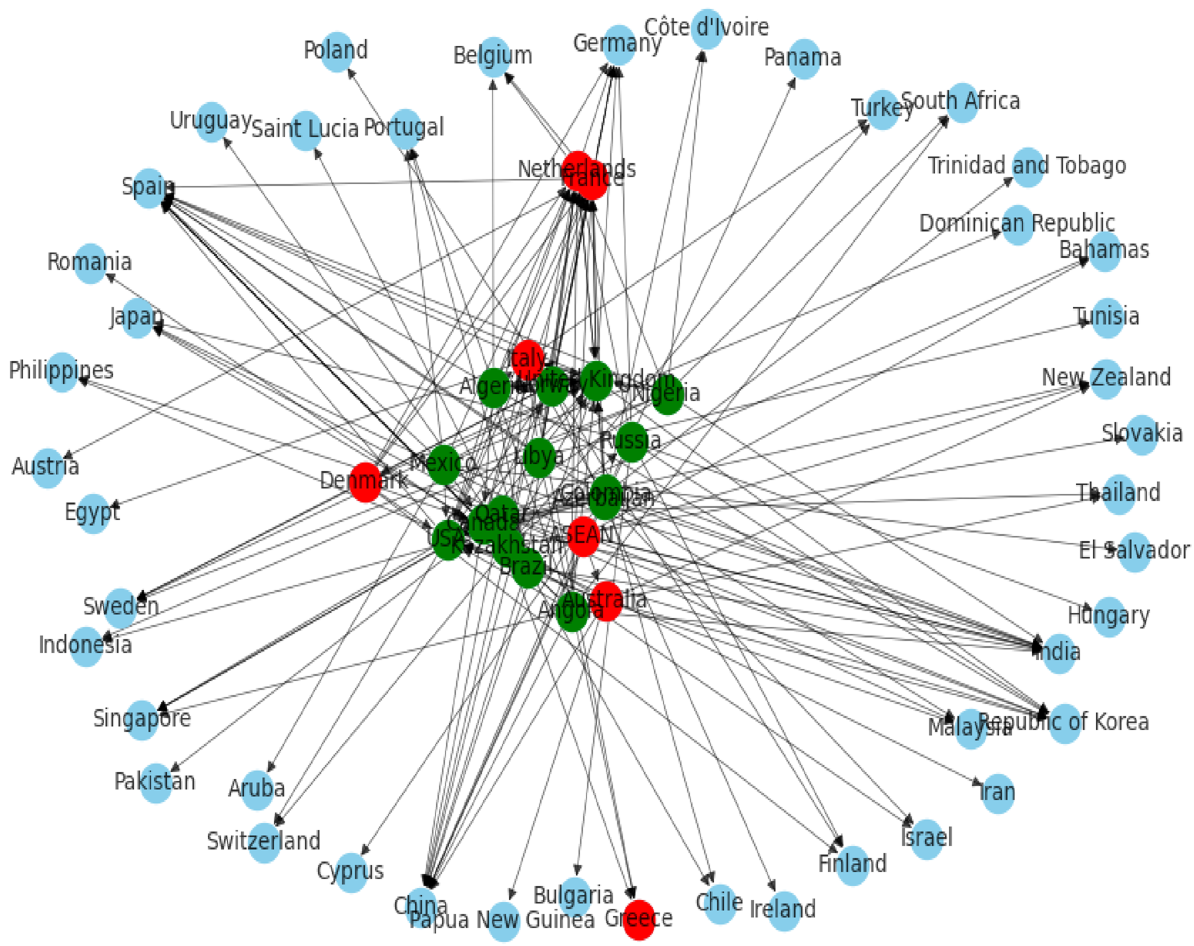

Figure 2. Crude OTN Obtained (2008-2013)

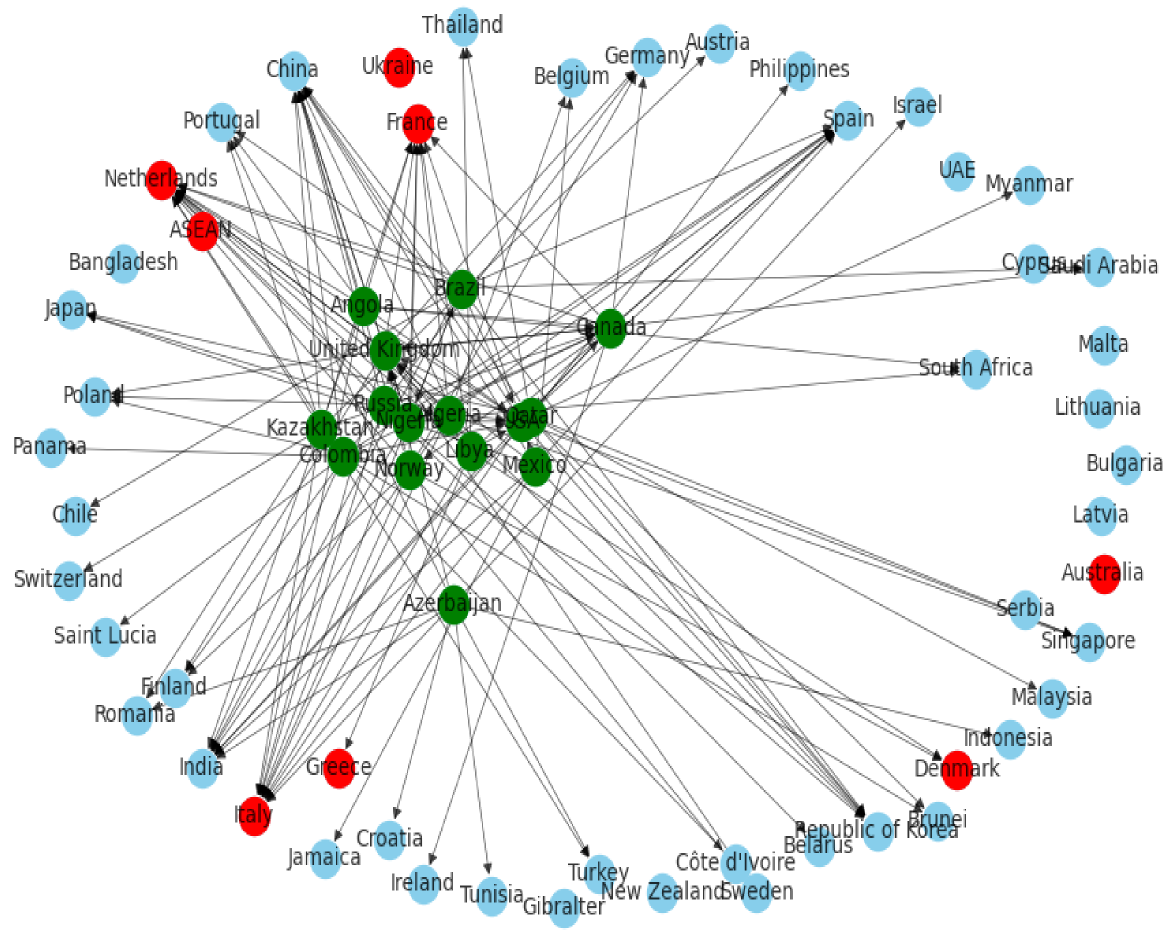

Figure 3. Crude OTN Obtained (2018-2023)

A visible change in the structure of this vast trade network can be observed. The green nodes represent the top 15 crude oil exporters, while the red nodes indicate other major economies and regions that were initially considered essential to the network but may not be as significant as previously thought. The blue nodes represent other trading partners connected to these primary nodes.

Quantifiable Parameters

Centrality Measures

Centrality is a crucial concept in graph analytics and deals with distinguishing important nodes in a graph. It recognizes nodes that are important among the whole list of other nodes in the graph.

Eigenvectors are used in network analysis primarily to identify influential nodes and rank them based on their connections to other high-scoring nodes. They are also instrumental in community detection, where the eigenvectors of matrices like the adjacency matrix reveal clusters within the network. On the other hand, betweenness centrality measures the importance of nodes based on the number of shortest paths that pass through them, highlighting nodes that act as critical bridges or connectors within the network. While eigenvector centrality focuses on node influence through connectivity, betweenness centrality emphasizes the node's role in facilitating communication across the network.

Eigenvector centrality calculates the centrality of a vertex based on the centrality of the connected vertices around it. A vertex with a high value of eigenvector centrality is linked to many other vertices with high eigenvectors. In the case of the global crude oil trade network, the countries with more important trading partners will have higher eigenvector values. The formula to calculate eigenvector centrality is as follows:

$$AX = ZX$$
$$Z_i x_i = a_{1i}x_1 + a_{2i}x_2 + a_{3i}x_{3 \ldots +\, a_{ni}x_n}$$
$$C_{(e)i} = Z_i$$

Here, A is an n × n adjacency matrix composed of a_{ij}, X = $(x_1, x_2, x_3, \ldots\ x_n)^T$ denotes the degree centrality of each vertex, and Z_i is the eigenvector centrality value, while a_{ij} denotes the contribution of vertex i to the status of vertex j. The eigenvector centrality of vertex i is denoted by $C_{(e)i}$. This paper uses the weight edge attribute as connection strength to calculate eigenvector centrality.

Betweenness centrality, on the other hand, describes the importance of a vertex as a mediator in the network. It is a study of the bridge effect of a node. Therefore, as the degree of betweenness centrality for a node increases, so does its potential for control over the other countries in the trade network.

Mathematically speaking, betweenness centrality as a network parameter can be stated as the number of counts with which a point lies in between the shortest paths linking other nodes in the trade network. This measure is based upon the assumption that transactions only take place along the shortest paths connecting other pairs of nodes in the network.

Betweenness centrality can be mathematically represented as:

$$a_{ij}(p_k) = \frac{m_{ij}(p_k)}{m_{ij}}$$

Where m_{ij} is the number of edges/connections between points i and j in the network. $m_{ij}(p_k)$ is the number of edges/connections between points i and j that contain point p_k.

Network Density

As the most used network description metric, network density compares the actual number of edges in the network to the theoretical maximum number of edges in the network and depicts the overall closeness of vertex relationships in the network. Generally, the larger the network density, the more edges the network has, and the denser the network; conversely, the sparser the network. The formula to calculate network density is as follows:

$$D = \frac{2E}{N(N-1)}$$

Here, E is the number of edges in the network where links exist between the vertices, and N is the number of vertices in the network.

Global Clustering Coefficient

The closeness between a vertex and its neighbors is usually described in terms of clustering coefficients. The coefficient used to describe the overall clustering pattern of the network is called the global clustering coefficient, which can be applied in directed and weighted networks. The global clustering coefficient is based on triplets, the total number of closed triplets in the network, and returns a number between 0 and 1. A larger global clustering coefficient indicates a greater tendency to cluster within the network.

Results

A Renewable Shift

As mentioned previously, network density is the number of edges/connections in the network relative to the total number of edges/connections that are capable of taking place. The network density values provide substantial tangible information and enable us to draw significant conclusions regarding the shifts in energy use within these trade networks.

As per the data collected on UN Comtrade, the network densities calculated for the two time periods are as follows:

2008 – 2013: **0.044**
2018 – 2023: **0.033**

Network density reflects the number of actual connections relative to the number of possible connections in the network. A decrease in density in the crude oil trade network might indicate fewer transactions and trade relationships in the crude oil sector. This could be due to a variety of factors, including a shift in energy policies, increased adoption of renewable energy sources, or a global move towards sustainability.

As countries and companies pivot towards renewable energy to meet environmental goals and reduce carbon footprints, they might reduce their reliance on crude oil, thereby diminishing the trade network density of crude oil. Concurrently, the renewable energy sector might experience an increase in trade network density, indicating more transactions and stronger trade relationships as the sector grows. However, this is a complex relationship and would require additional data on renewable energy trade networks and other influencing factors to arrive to a concrete conclusion.

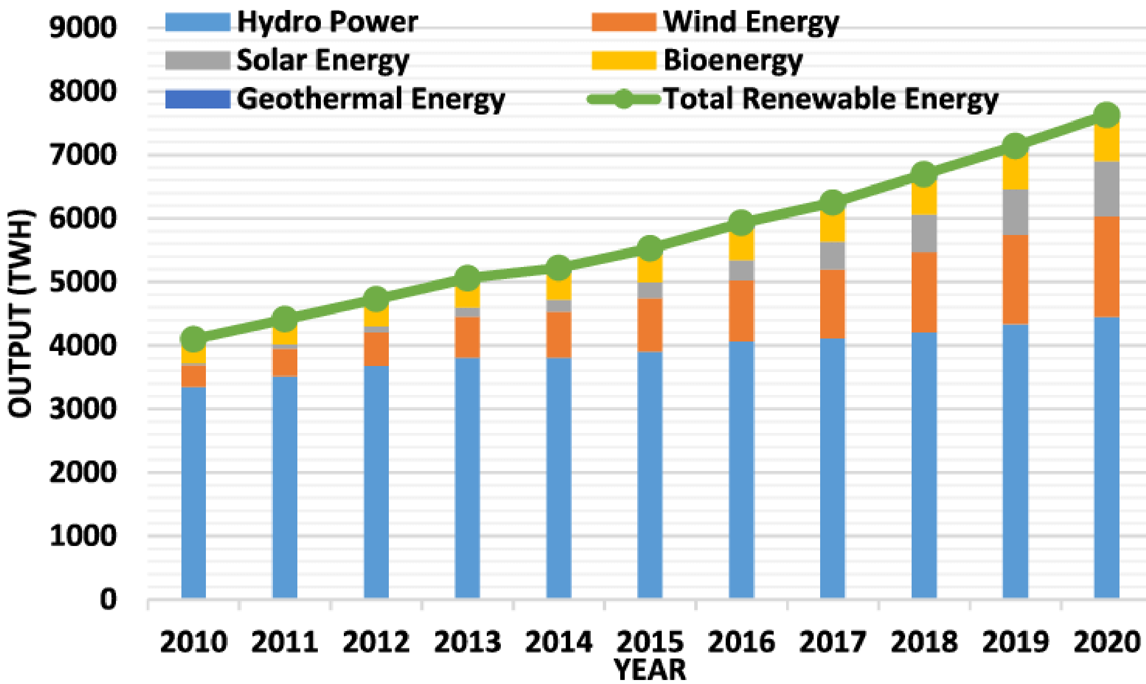

Figure 4. Shift towards renewable energy sources

This decrease in network density represents a reduction in overall cohesion of the network. This decrease might suggest that certain countries or regions are engaging in less crude oil trade with other countries. This could be explained by shifts in demand and supply dynamics, changes in production capabilities, or alterations in geopolitical relationships between countries. This decrease in network density could also possible imply a dilution of trade relationships, with few countries dominating the trade network. Thus, this implies a higher level of concentration in the crude oil trade, with the already existing major trading nodes playing an even more important role in the network.

Geopolitical Shifts

Supply Disruptions

Geopolitical conflicts or tensions in major oil-producing regions, such as the Middle East, can disrupt supply chains. This can lead to temporary shortages, increased volatility in oil prices, and a need for countries to seek alternative suppliers. The direct impact of these disruptions is often a sharp fluctuation in commodity prices and heightened market volatility. For example, political tension in oil-producing regions can cause crude oil prices to spike, affecting a wide range of industries dependent on this resource. These shifts in commodity prices reflect the market's immediate response to geopolitical risks and uncertainties but they can create a long-term ripple effect in adjacent markets that can continue long after the initial crisis is resolved.

Price Fluctuations

Political instability, sanctions, and changes in government policies significantly influence the volatility of crude oil prices. Regional conflicts and political upheavals in key oil-producing areas, such as the Middle East, can disrupt production and export operations, reducing global oil supply and driving up prices. For instance, conflicts in Iraq or Libya often led to production cuts, while changes in government can alter energy policies, impacting oil production and exports.

Economic sanctions imposed by major economies, such as those on Iran and Venezuela, severely limit these countries' ability to trade oil, tightening global supply and raising prices. Financial sanctions can further disrupt trade by restricting access to international financial systems, exacerbating supply constraints.

Government policies, including regulatory changes, production quotas set by organizations like OPEC, and subsidies for alternative energy sources, also play a crucial role. Stricter environmental regulations can increase production costs, leading to higher prices, while coordinated production cuts by OPEC can stabilize or increase prices. Market speculation and investor behavior in response to geopolitical events add another layer of volatility, with traders buying or selling oil futures based on anticipated impacts.

In Table 1 below, we can see a decline in the dominance of countries such as the USA and the UK in terms of eigenvector and betweenness centrality. This can be attributed to decline in the dominance of these nation's currencies, as Russia and Saudi Arabia begin to eye the Chinese Yuan for oil trade. The fall in the dominance of these countries' currency is clearly visible by the fall in their centrality values.

Trade Routes and Logistics:

Geopolitical shifts can affect key trade routes. For example, conflicts in the Suez Canal, a critical chokepoint for global oil transportation, can hinder the movement of oil tankers, affecting global supply and logistics. International energy markets depend on reliable transport routes. Blocking a transit point, even temporarily, can lead to substantial increases in total energy costs and world energy prices.

The importance of the Suez Canal as a vital trade link is underscored by its efficiency in connecting major trade routes. However, approximately 12% of the world's seaborne oil and significant quantities of LNG transit the Red Sea, with disruptions prompting companies like Maersk and Hapag-Lloyd to halt voyages through the area. These disruptions lead to increased energy prices, delayed product availability, and potential inflation. The Grand Bonanza's voyage, costing around $5.7 million, exemplifies the financial burdens imposed by these geopolitical shifts, prompting reassessments of shipping routes and strategies. As European refiners face higher import costs and U.S. refiners find new opportunities, the global oil market adapts to these challenges, with shifting trade dynamics, increased freight rates, and the need for strategic navigation through geopolitical uncertainties.

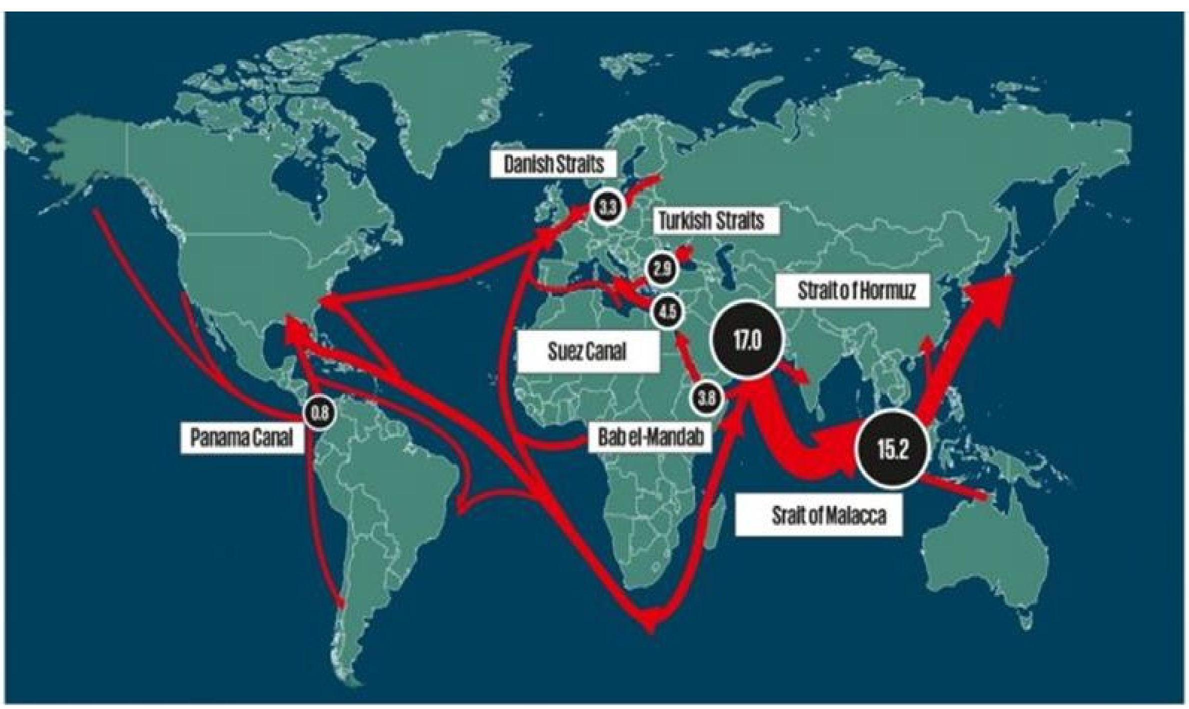

Figure 5. Maritime routes crucial for world oil trade (All estimates made are in millions of barrels per day)

Economic Sanctions and Trade Restrictions

Imposition of economic sanctions on oil-exporting countries can limit their ability to trade oil, affecting global supply and altering trade patterns. This can force other countries to find new sources of oil. This will be further delved into in the following subheading, as the sanctions imposed on Russia are further analyzed.

As per the data collected on UN Comtrade, the betweenness and eigenvector centrality values calculated for the two time periods are as follows:

Table 1. Countries With Top 10 Eigenvector Centralities

2008 - 2013		2018 - 2023	
Country	**EC Value**	**Country**	**EC Value**
Spain	0.419	Netherlands	0.414
Germany	0.394	Italy	0.297
United Kingdom	0.372	France	0.389
France	0.308	China	0.321
Netherlands	0.276	Canada	0.2009
Italy	0.236	United Kingdom	0.266
USA	0.230	Spain	0.249
Canada	0.221	Republic of Korea	0.225
Republic of Korea	0.204	India	0.156
Singapore	0.109	USA	0.170

There have been some significant changes in the EC values of countries over the course of 10 years. As can be seen from the table above, the UK, Spain, France, Netherlands, and Italy continue to be some of the countries that continue to maintain top-ranked EC values over the course of a decade. This means that those countries continue to be connected to a high number of important or hub nodes and are thus crucial for global crude oil trade.

Table 2. Countries With Top 5 Betweenness Centralities

2008 - 2013		2018 - 2023	
Country	**BC Value**	**Country**	**BC Value**
United Kingdom	0.036	Canada	0.027
USA	0.029	United Kingdom	0.018
Canada	0.0185	USA	0.013
Norway	0.0182	Nigeria	0.01
Italy	0.016	Brazil	0.005

In the following table, it is evident that countries such as the United Kingdom, USA and Canada continue to have high BC values over the course of 10 years. This signifies that these countries act as important meditators in global crude oil trade and their absence would have a significant impact on the overall trade network.

As an important European transit hub, the United Kingdom plays an increasingly important role as a bridge in the European Crude Oil trading system. However, with an increase in BC, we noticed a decrease in EC of the UK over the course of the 10 years, which strongly conveys how fragmented and diversified the global crude oil trade networks have become. At the same time, with the deepening of industrialization and an increase in national economic development needs, large developing countries such as India and China are expected to have a much higher demand for crude oil in the next 10-15 years, causing the overall crude oil trade network to shift eastwards. This could cause a shakeup in the overall crude oil trade network and cause some serious fluctuations in the centrality measures of high-ranking countries in the present date.

The 2008 Financial Crisis

The financial crisis began in the real estate market in 2006 as defaults on subprime mortgages increased. Initially, the damage was contained, but the crisis eventually spread throughout the economy, severely reducing economic activity. Despite the weakening housing market, commodity prices, including oil and gas, continued to rise for some time. However, the crisis eventually led to deflation and liquidation, driving all asset prices lower. Unemployment rose as companies reduced output due to falling aggregate demand, leading to decreased energy consumption and lower demand for oil and gas, further pressuring their prices.

The oil crises of the 1970s were a milestone for global economies and oil markets, leading to the adoption of neo-liberal policies and increased significance of oil markets. The 1980s saw relative stability, but the 1990s experienced price rises due to events like the Gulf War. By the late 1990s, oil prices began rising with global economic growth and increased demand. In the early 2000s, high demand, particularly in 2003, and geopolitical tensions such as the Iraq War, peaked oil prices at $53 per barrel in 2004. Prices continued to rise to historic highs of nearly $140 per barrel in mid-2008 before plummeting to $40 per barrel due to the global financial crisis. The severe recession in 2008-2009 reduced demand and prices. Supply disruptions, such as the 2011 Libyan production drop during the Arab Spring, caused significant market volatility. After four years of stability at around $105 per barrel, oil prices declined sharply since June 2014 due to increased global inventories, putting downward pressure on prices into 2015.

As can be seen in Figure 6 below, the Great Recession led to a major decline in the prices of crude oil, resulting in a decrease in trade volumes and disrupted trade links, which can be seen from a relatively lower global clustering coefficient in the 2008-2013 time period.

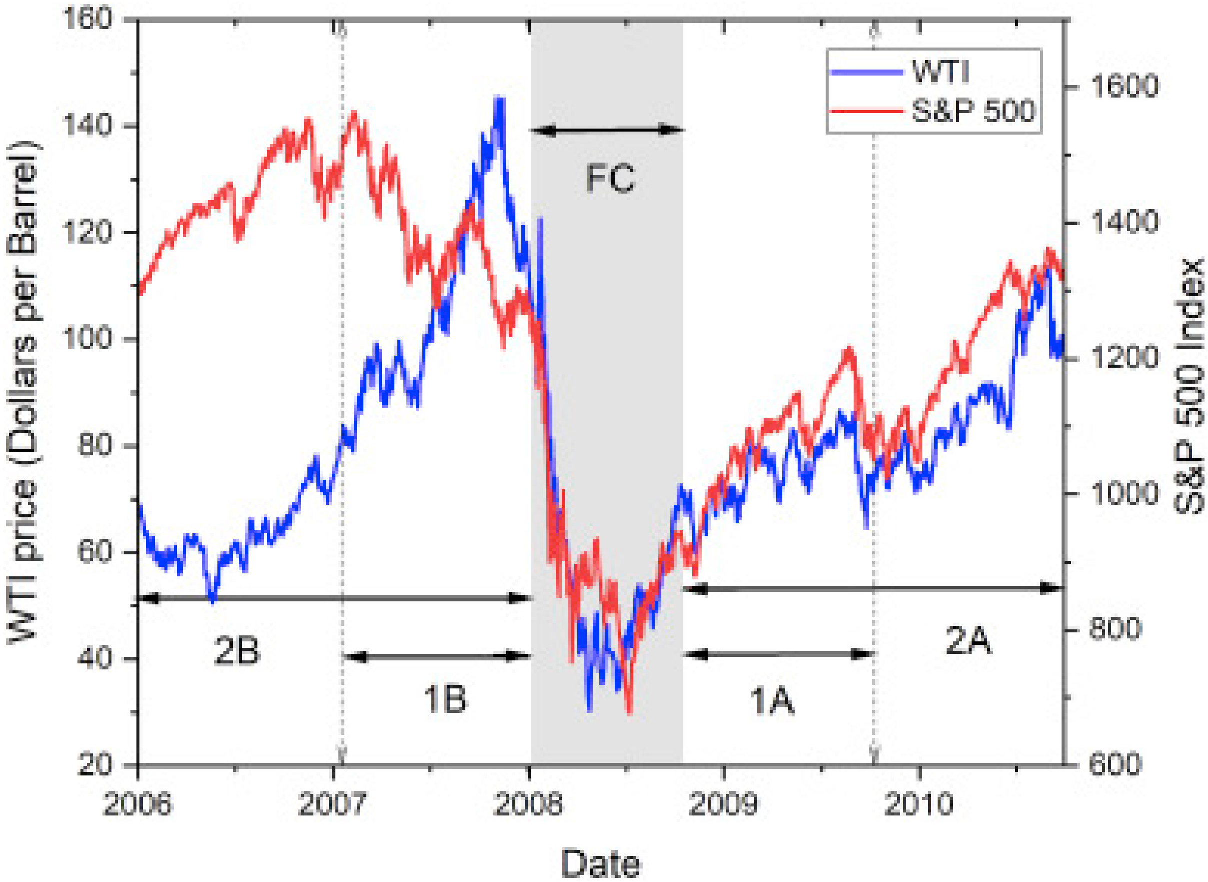

Figure 6. Deflation of crude oil prices following the Great Recession

This crisis also resulted in a change in key players in the crude oil trade network, as can be seen from the data collected under centrality measures. New countries with dominant EC and BC values emerged in 2018-2023, such as Brazil, Nigeria, and India, as is evident from Table 1 and Table 2. Overall, the crisis enhanced the network resilience, leading to a much more compact and coherent trade network, as can be seen by the lower network density and reduced number of nodes and edges in the more recent time period.

The Russia-Ukraine War

Since Russia's invasion of Ukraine in February 2022, Western governments have imposed a complex set of embargoes and sanctions on Russia's oil industry. While the US and its allies have long used sanctions as a tool of economic statecraft against oil exporters, the sanctions on Russia target one of the world's two largest exporters (the other being Saudi Arabia). Moreover, these sanctions come after two decades in which the US has imposed sanctions on other significant oil exporters, including Venezuela and Iran, limiting these countries' production and export capabilities too.

The Russia–Ukraine war accounts for 70.72% of the fluctuation in WTI crude oil prices and 73.62% of the fluctuation in Brent crude oil prices during the event window while also causing a fundamental shift in the long-term trend of crude oil prices.

We estimate that sanctions on Russian crude oil exports have reduced the import bill of buyers of sanctioned crude by as much as $22 billion over the past year, relative to where prices would have been without discounts to market benchmarks. This calculation excludes discounts on Russian refined product exports, also covered under the price cap, which would likely increase the discount substantially. Sanctions on Russian, Iranian, and Venezuelan crude have created a total discount of as much as $34 billion over the past year relative to traded benchmarks.

Sanctions have splintered the world oil market into "sanctioned" and "non-sanctioned" spheres. This imposes costs on sanctioned countries while offering benefits for countries such as China and India that transact in both sanctioned and non-sanctioned energy markets. Analysis of this partial splintering of the oil market provides new empirical evidence about the impact of current and potential future sanctions.

Conclusion

Implications

In this study, we collected crude oil trade data from two specific time periods that were a decade apart: 2008-2013 and 2018-2023. We utilized this trade data to quantify and create a network between top crude oil exporters and their trading partners, alongside certain other major global economies. Through an analysis of this network through the lens of network parameters such as centrality measures, network density, global clustering coefficient and even through geopolitical factors/situations that took place over the course of the decade such as the 2008 Financial Crisis and the Russia-Ukraine war, we can reach the following conclusions:

Firstly, more attention should be paid to the critical economies and trade relationships identified in the OTNs, because they will significantly affect the function of the OTN, such as the USA, China and Saudi Arabia. However fluctuations in their dominance should also be noted. This was seen by the fall in EC and BC values of the UK and USA, and an overall eastward shift in the OTN network towards developing economies such as India and China.
Secondly, to improve the robustness of the OTNs, economies need to establish more trade relationships, especially the relationship of higher criticality.

Thirdly, the economies that have more relationships and large volumes can enhance network efficiency. However, at the same time, such properties will increase the risk of a sudden reduction of robustness when deliberate attacks occur. Hence, such economies are highly vulnerable to cascading effects. Once such an economy has a problem, there will be a cascading effect affecting other economies and even the development of global oil trade. Since today's crude oil trade situation is changing rapidly, governments and policymakers need to be vigilant, making efforts to reduce the impact of sudden changes on the economy and trade, and seek a balance between network efficiency and robustness.

Areas for Future Research

Providing A New Metric for Further Exploration

A new metric can be provided to approach this complex trade network from a different angle and to further our research in this area. By obtaining detailed trade data on the political and economic indicators of various economies in the oil trade network, which can be combined with the trade values used in this current study, we can provide a new metric for measuring the weights of the trade relationships and to measure the efficiency and robustness of the network.

Trade Network for Other Commodities

The robustness and coherence indicators of the crude oil trade network proposed in this study can be applied to other trading systems, such as gas, coal and other commodity trading systems, to identify critical economies and trade relationships. There is a plethora of trade data for these commodities present on the UN Comtrade Database, where the entirety of the trade data for this study was sourced from.

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I was honored to present the findings of this study at the University of Cambridge, serving as the opening presenter at the CCIR Research Symposium. This opportunity to share my research with professors, colleagues and peers was both a privilege and a significant milestone in my academic journey.

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