AN ERA OF RESILIENCE

Employing VAR Models to Unravel the Impact of Geopolitics on Supply Chains

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All solutions and mistakes are my own

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Abstract

This paper examines the impact of Supply-Chain Disruptive Events (SDEs) originating from the Middle East on global supply dynamics, highlighting the intricate vulnerabilities of interconnected supply chains amid geopolitical instability. Leveraging a Vector Autoregression (VAR) model complemented by a Probit model, the study examines the repercussions of Middle Eastern conflicts on supply chain efficiency, logistics costs, and vulnerability to shocks. The VAR model is specified as:

$$Y_t = \Lambda_0 + \Lambda_1 Y_{t-1} + \Gamma X_t + \beta \delta_t + \epsilon_t$$

Through comprehensive case studies—including the COVID-19 pandemic, the 2021 Suez Canal blockage, and recent Houthi attacks on maritime traffic in the Red Sea—the research elucidates how geopolitical events precipitate significant disruptions in global trade routes. These incidents underscore the transition to a multipolar world order and the exacerbating effects of environmental pressures like climate change and resource scarcity on geopolitical tensions and supply chain resilience.

The findings reveal that Middle Eastern geopolitical instability leads to substantial logistical challenges, increased costs, and extended delivery times, thereby threatening global economic stability and consumption security. The study emphasizes the necessity for businesses and policymakers to integrate geopolitical risk assessments into strategic planning, diversify supply sources and routes, and develop contingency plans to enhance supply chain resilience. By providing a rigorous econometric analysis coupled with practical case studies, this paper contributes to the discourse on international relations and economic interdependence, offering valuable insights for future research and policy formulation aimed at securing global supply chains in an increasingly uncertain global landscape.

"The world is more interconnected than ever before, and so too are the risks we face."
— *Christine Lagarde, President of the European Central Bank*

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1   Introduction

The intricate web of global supply chains is perpetually influenced by the geopolitical climate, especially within regions characterized by high volatility such as the Middle East. Recent years have presented a plethora of challenges—from the COVID-19 pandemic to intensified conflicts—that underscore the fragility of these interconnected systems Runde & Ramanujam (2020). This paper explores the impact of Supply-Chain Disruptive Events (SDEs) emanating from the Middle East, employing an innovative econometric model to forecast their repercussions on global supply dynamics.

The present global context, with its ongoing recovery from the pandemic and the Russian invasion of Ukraine, sets the stage for our investigation. The escalation of conflict in the Middle East, a key node in the global oil supply chain, not only jeopardizes regional stability but also poses significant risks to the global economy at large. Cohen & Pridan (2023)This region's turmoil affects critical resources, such as oil, that are fundamental to various sectors including food and agriculture, thereby amplifying global food insecurity and economic vulnerability Suzuki (2021).

This study is particularly timely and relevant, given the recent Houthi attacks on maritime traffic in the Red Sea and subsequent economic ramifications. These incidents highlight the complex interdependencies of global trade routes and the profound impact of geopolitical unrest on supply chain efficiency, costs, and resilience Modern Distribution Management (2023). For example, A typical smartphone is made up of components sourced from over 40 countries, reflecting the intricate nature of global supply chains. By examining these developments through theoretical frameworks and case studies, this paper aims to offer comprehensive insights into the dynamics of global supply chains in the face of geopolitical instability.

We explore the transition to a multipolar world order and its implications for global trade, emphasizing the emergence of new economic corridors and the reshaping of traditional trade routes. The analysis extends to environmental and resource pressures, including climate change and resource scarcity, that exacerbate geopolitical tensions and, by extension, affect global supply chains.

The core of this analytical approach involves the application of a Vector Autoregression (VAR) model complemented by a Probit model. These models facilitate a nuanced examination of the direct and indirect effects of geopolitical events on supply chain metrics. This paper provides a detailed exposition of the model specifications, integrating historical data and empirical analysis to validate our theoretical propositions.

This paper contributes significantly to the discourse on international relations, economic interdependence, and the strategic management of global supply chains amidst geopolitical fluctuations. By offering a rigorous econometric analysis coupled with practical case studies, it lays the groundwork for future research and policy formulation aimed at enhancing supply chain resilience in an increasingly uncertain global landscape.

1.1   Present Contexts

As our world recovers from the COVID-19 pandemic & the Russian invasion of Ukraine, the expanding conflict in the middle east posses a grave danger to the stability of our global economy. The conflict engulfing the middle east threatens nearly 30% of global oil production Gill & Kose (2023). Despite our world slowly de-carbonizing and transitioning to non-oil energy sources, oil is still a crucial component for food and agriculture. The World Bank has outlined scenarios ranging from small to large disruptions in oil supplies, and the corresponding increases in oil prices, with predictions into how they can escalate food prices and exacerbate food insecurity worldwide Gill & Kose (2023). Geopolitical events are not

isolated within their regional confines but resonate across the globe, influencing agriculture, market dynamics, and impacting the overarching framework of international consumption security Strategy & Middle East (2023).

The recent Houthi attacks on cargo ships in the Red Sea, prompted by military actions in the Gaza Strip, have led many shipping companies to reroute vessels around the Cape of Good Hope, significantly delaying deliveries and increasing costs Hanon (2024). The Red Sea is a crucial trade route, as it allows Asian & the Middle east to connect with Europe through the Suez canal in Egypt. The Suez accounts for 12% of global trade, and disruptions here have caused a sharp decline in the volume of freight, affecting trade figures for regions like Germany and the EU Kaufmann (2024); Davison & Stewart (2023). This rerouting not only increases transit times but also results in higher emissions and costs for shipping companies, with additional costs running into the high tens of millions of euros per month Gill & Kose (2023). Such disruptions underscore the vulnerability of global trade to geopolitical events and highlight the interconnectedness of global supply chains.

These developments are instrumental in understanding the broader implications of Middle Eastern geopolitical instability on global supply chains. The paper will analyze these events through various theoretical lenses such as globalization, economic interdependence, and geopolitical strategy, employing case studies to illustrate the tangible disruptions in supply chains. This approach will provide a nuanced perspective on the complex dynamics at play, contributing significantly to the discourse on international relations and global economic order.

1.2 Drivers of Change

1.2.1 Multipolarity and Regional Ascendancy:

As the global landscape evolves from a unipolar to a multipolar world order, the ascension of emerging powers introduces a new paradigm of geopolitical friction. This transition is characterized by a diffusion of power from traditional Western economies towards rising powers in Asia, Africa, and Latin America Mearsheimer (2019). The strategic maneuvering and regional assertiveness of these emerging powers inevitably lead to increased geopolitical events, ranging from territorial disputes to strategic alliances, which have profound implications for global trade routes and supply chain resilience.

As emerging powers assert their economic and military influence, traditional trade corridors may be redefined or contested. For instance, China's Belt and Road Initiative (BRI) aims to create new economic corridors, reshaping global trade routes and potentially bypassing traditional maritime chokepoints such as the Suez Canal or the Strait of Malacca Suzuki (2021); Khanna (2024).

The assertiveness of regional powers in pursuing their strategic interests can lead to heightened tensions and conflicts. Since 2018, there has been a significant increase in trade-restrictive measures, with over 1,600 new measures implemented globally, affecting approximately $1.7 trillion worth of trade. Such instabilities pose significant risks to supply chains, particularly those that traverse geopolitical hotspots or depend on resources from these areas.

In response to the increased geopolitical risks, businesses are compelled to diversify their supply sources and logistic routes. This strategic shift towards building more resilient supply chains may involve increased costs and operational complexity but is essential for mitigating the impacts of regional instabilities MEED (2021); Bain & Company (2022); Strategy & Middle East (2023)

1.2.2   Environmental and Resource Pressures:

The escalating challenges of climate change and resource scarcity represent significant drivers of geopolitical instability, with profound implications for global supply chains. As these environmental issues intensify, they not only exacerbate existing geopolitical tensions but also create new flashpoints for conflict, thereby impacting the seamless flow of goods and services across borders BSI Group (2023).

The adverse effects of climate change, including extreme weather events, rising sea levels, and increasing temperatures, have the potential to destabilize regions by affecting water availability, food supply, and habitat safety. Such environmental stresses can lead to social unrest, forced migrations, and even armed conflicts over dwindling resources, each posing distinct threats to supply chain integrity and reliability Suzuki (2021); Cohen & Pridan (2023). For instance, prolonged droughts or floods can severely impact agricultural output, leading to shortages of essential commodities and triggering competitive scrambles that reverberate through the global supply network Cohen & Pridan (2023).

The depletion of natural resources, driven by overconsumption and unsustainable management practices, further compounds the risk of geopolitical instability. Competition for scarce resources, such as fresh water, arable land, and minerals critical for technology and renewable energy, can perpetuate strategic maneuvering among nations. This scramble not only heightens the risk of conflict but also forces supply chains to adapt to shifting resource availability and regulatory landscapes, challenging the resilience and adaptability of global supply networks Kaplan (2020); Mearsheimer (2019).

The intersection of environmental pressures and geopolitical dynamics necessitates a strategic reevaluation of supply chain management practices. Businesses and policymakers must incorporate environmental risk assessments into their strategic planning, diversifying sources and routes to mitigate potential disruptions. Moreover, the transition towards more sustainable and circular supply chain practices emerges as both a strategic imperative and an opportunity to mitigate the environmental drivers of geopolitical instability Bain & Company (2022); BSI Group (2023); Suzuki (2021); Runde & Ramanujam (2020).

Addressing the dual challenges of environmental degradation and resource scarcity requires concerted international effort and cooperation. Policies aimed at promoting sustainable resource management, reducing greenhouse gas emissions, and facilitating adaptation to climate change can contribute to reducing the potential for geopolitical instability. Furthermore, international collaboration in building resilient supply chains can help mitigate the impact of environmental challenges on global trade and economic stability Strategy & Middle East (2023).

1.3   Data Based Conclusions

The analytical approach of this paper is designed to transcend a mere chronological listing of geopolitical events in the Middle East and their immediate fallout. Instead, it will scrutinize the broader implications of these events through the application of various theoretical frameworks, including globalization, economic interdependence, and geopolitical strategy. This multifaceted perspective will facilitate a deeper understanding of how regional disturbances have far-reaching effects on global supply chains, extending beyond the immediate region to impact global markets and economies.

To bring clarity and empirical substantiation to this analysis, the paper will incorporate a series of case studies. The case studies will examine the impact of the pandemic, the 2021 Suez blockage and the current Red Sea attacks, illuminating the direct linkages between specific instances of geopolitical instability and their consequential disruptions in supply chains. Each case study will be dissected to reveal the underlying dynamics at play, demonstrating how political conflicts, global events, & policy

shifts have precipitated observable disturbances in the flow of goods, services, and resources across the globe.

2 Case Studies

2.1 The COVID-19 Pandemic and Supply Chain Disruptions

The COVID-19 pandemic served as a stark reminder of the globalized nature of modern supply chains. In the Middle East, the pandemic's impact was compounded by the region's strategic significance in global oil markets. As countries implemented lockdowns, the demand for oil plummeted, leading to a historic drop in oil prices. For Middle Eastern economies reliant on oil exports, such as Saudi Arabia and the UAE, the consequences extended beyond immediate health concerns, affecting national revenues and causing delays in diversification plans. Internationally, the disruption affected everything from the availability of personal protective equipment, heavily sourced from manufacturers in Asia, to basic food commodities. During the peak of the COVID-19 pandemic, shipping container prices surged by over 500%, and delivery times increased from an average of 40 days to over 70 days on major routes. This drastic fluctuation underscores the intricate linkages and dependencies across global supply chains Cohen & Pridan (2023); Bain & Company (2022); Suzuki (2021).

2.2 Suez Canal Blockage

The Suez Canal blockage by the Ever Given not only captured the world's attention but also served as a real-time experiment in global supply chain vulnerability. Over 300 ships were stalled, waiting for the blockage to clear, affecting goods ranging from crude oil and refined fuels to consumer products Russon (2021); Khanna (2024). The delay translated into billions of dollars in trade losses per day, showcasing the thin margins on which global trade operates. Rerouting ships around the Cape of Good Hope instead of the Suez Canal adds approximately 3,500 nautical miles to the journey, resulting in increased fuel consumption and higher carbon emissions by an estimated 1,500 tons of $CO_2$5 per voyage. Meanwhile, European manufacturers faced shortages of raw materials, while Asian exporters struggled with delivery delays to their European and North American markets. The incident prompted a reevaluation of maritime route diversification, inventory management, and the resilience of supply chains to adapt to unexpected disruptions Braw (2021); Koenig & Rugaber (2021).

2.3 Houthi Attacks on Saudi Oil Facilities

The drone attacks on Saudi Aramco's oil processing facilities in Abqaiq and Khurais temporarily cut off about 5% of global oil supply, causing oil prices to surge by nearly 20% in the immediate aftermath. This event was a vivid demonstration of how geopolitical tensions can directly impact global economic stability and energy security Bain & Company (2022). The ripple effects were felt worldwide; countries heavily dependent on oil imports, such as China and India, faced potential increases in energy costs and a subsequent impact on their manufacturing sectors and broader economy. The attacks underscored the vulnerability of critical infrastructure to geopolitical risks and the need for heightened security measures and strategic reserves to mitigate the impacts of such incidents.

2.4 Empirical Summary

These case studies provide a detailed examination of how geopolitical instability in the Middle East can have far-reaching effects on global supply chains. The COVID-19 pandemic highlighted the interconnectedness of global markets and the domino effect that disruptions in one region can have internationally. The Suez Canal blockage brought to light the fragility of key trade routes that the

world relies on for the smooth operation of global commerce. Meanwhile, the Houthi attacks on Saudi oil facilities revealed the direct link between regional conflicts and global economic stability, particularly in energy markets.

The broader implications of these events emphasize the need for a comprehensive approach to supply chain management that considers geopolitical risks as central to strategic planning. Companies and countries must invest in predictive analytics, diversify their supply sources and routes, and develop contingency plans to ensure resilience against future disruptions. Moreover, these incidents call for increased international cooperation to secure global supply chains against the backdrop of an increasingly unpredictable geopolitical landscape.

By delving into these case studies, this paper contributes to a deeper understanding of the challenges and strategies necessary for securing global supply chains against the backdrop of Middle Eastern geopolitical instability.

3   Model Specification

This paper introduces two models, first a a Vector Autoregression (VAR) and a Probit model. The VAR model which, though simple in form will allow us to capture the essence of geopolitical influences on supply chain dynamics, while the Probit will determine whether or not an event will effect an industry. The VAR is as follows:

$$Y_t = \Lambda_0 + \Lambda_1 Y_{t-1} + \Gamma X_t + \beta\delta + \epsilon_t$$

Given $Y_t \in \mathbb{R}^n$: $Y_t = \begin{pmatrix} Y_{1t} \\ Y_{2t} \\ Y_{3t} \end{pmatrix}$ The components of Y_t are described as follows:

- Y_{1t}: Measures the efficiency of supply chain operations at time t. It reflects how well the supply chain is performing in terms of process optimization and streamlining, with a focus on adaptability and recovery speed from Significant Disruptive Events (SDEs).

- Y_{2t}: Encapsulates the cost of logistics at time t, specifically focusing on the cost to move one unit of load over one unit of distance. This metric serves as an indicator of the economic efficiency of supply chain logistics.

- Y_{3t}: Represents the vulnerability of the supply chains to shocks at time t. It quantifies the impact on production and movement as a result of SDEs, offering insights into the resilience of the supply chain.

Exogenous factors $X_t \in \mathbb{R}^m$ are specified as: $X_t = \begin{pmatrix} X_{1t} \\ X_{2t} \end{pmatrix}$

- X_{1t}: Measures the intensity of conflict in relevant geopolitical regions, directly influencing supply chain disruptions. This variable captures the external geopolitical risks that can significantly impact supply chain efficiency, costs, and resilience.

- X_{2t}: Represents global economic sentiment, reflecting broader economic conditions that impact supply chain dynamics. It encompasses various economic indicators and perceptions that influence consumer behavior, market demand, and overall business environment.

Dummy variables $\delta_t \in \mathbb{R}^d$ are specified as: $\delta_t = \begin{pmatrix} \Delta_{\text{industry}} \\ \Delta_{\text{incident}} \\ \Delta_{\text{Country}} \end{pmatrix} = \begin{pmatrix} \delta_{1t} \\ \delta_{2t} \\ \dots \\ \delta_{nt} \end{pmatrix} \times \begin{pmatrix} \delta_{1t} \\ \delta_{2t} \\ \dots \\ \delta_{nt} \end{pmatrix} \times \begin{pmatrix} \delta_{1t} \\ \delta_{2t} \\ \dots \\ \delta_{nt} \end{pmatrix}$

The three matrices of this are defined as:

Industry Types:	Incident Types:	Countries:
1. Technology (tech)	1. Natural Disaster (natd)	1. USA (usa)
2. Manufacturing (manu)	2. Political Conflict (poli)	2. Germany (ger)
3. Services (serv)	3. Economic Sanctions (econ)	3. China (cna)

The function without interaction terms can therefore be expressed as:

$$Y_t = \Lambda_0 + \Lambda_1 Y_{t-1} + \Gamma_1 X_1 t + \Gamma_2 X_2 t + \beta_1 \delta_{\text{tech},t} + \beta_2 \delta_{\text{manu},t} + \beta_3 \delta_{\text{serv},t}$$
$$\beta_4 \delta_{\text{natd},t} + \beta_5 \delta_{\text{poli},t} + \beta_6 \delta_{\text{econ},t} + \beta_7 \delta_{\text{usa},t} + \beta_8 \delta_{\text{ger},t} + \beta_9 \delta_{\text{cna},t} + \varepsilon_t$$

The model is standard in its functionality where:

- Λ_0: Is a vector of constants, representing the baseline level of each endogenous variable when other influences are not present. It establishes the default state of the system in the absence of external and historical internal influences.

- Λ_1: Is a matrix of coefficients for the lagged values of Y_t, capturing the internal dynamics and interactions between the supply chain metrics. This reflects how past states of the supply chain influence its current state, enabling the model to capture temporal dynamics.

- Γ: Is a matrix of coefficients for the exogenous variables X_t, indicating how external factors such as geopolitical events and economic sentiment influence the supply chain metrics. It quantifies the impact of external shocks and trends on the system.

- β: Is a matrix of coefficients for the exogenous dummy variables variables δ_t, it logs the effects of country, industry, and incident type for the calculation of the impact of a supply shock.

- ϵ_t: Is a vector of error terms, accounting for the stochastic elements of the model not explained by the past values of Y_t or the current values of X_t.

3.0.1   Model Testing and Integration

To empirically test the proposed model, one could leverage historical data on supply chain metrics and geopolitical events. The process would involve:

1. Gather historical data on supply chain efficiency, logistics cost, and vulnerability to shocks. Concurrently, collect data on exogenous factors (X_{1t}, X_{2t}), specifically conflict intensity and global economic sentiment, over the same time periods. Examples can be conflict in economic hubs and shipping fuel costs.

2. Using the collected data, calibrate the VAR model's parameters (Φ_0, Φ_1, Γ) to best fit the historical trends. This involves estimating the coefficients that quantify the relationship between lagged values of endogenous variables and the impact of exogenous factors, code is in the appendix **??**.

3. Validate the model by partitioning the data into training and test sets, K-fold would be highly efficient for this application. Use the training set to estimate the model parameters and the test set to evaluate its predictive accuracy, particularly its ability to forecast supply chain dynamics under varying geopolitical scenarios, code is in the appendix **??**.

3.0.2   Justification of VAR

The advantages of using a Vector Autoregression (VAR) model to capture the linear interdependencies among multiple time series is that it operates on the principle that the future value of a variable is a linear function of its own past values and the past values of all other variables in the system. The VAR model is particularly suitable because It allows for the analysis of complex interrelations among supply chain metrics (Y_{1t}, Y_{2t}, Y_{3t}) without needing to specify a priori which is the dependent or independent variable.

3.1   Probit Model Specification

Building on the Vector Autoregression (VAR) model, the Probit model will predict binary outcomes in the context of geopolitical events affecting industries. The Probit model predicts binary outcomes using the cumulative distribution function (CDF) of the standard normal distribution, thus offering an alternative approach to understanding the impact of geopolitical instability. Let Z be a binary variable where $Z = 1$ denotes an industry is affected by a SDE, and $Z = 0$ indicates it is not affected. The Probit model utilizes the same independent variables as the VAR model, aiming to predict the binary outcome based on the same variables.

3.2   Model Formulation

The Probit model is formulated using the CDF of the standard normal distribution, $\Phi(x)$, to link the predictors to the probability of the industry being affected:

$$\Phi(Z) = \Phi(Y_t = \Lambda_0 + \Lambda_1 Y_{t-1} + \Gamma X_t + \beta \delta_t + \epsilon_t)$$

$$\Phi(x) = \frac{1}{\sqrt{2\pi}} \int_{-\infty}^{x} e^{-t^2/2} dt$$

where $\Phi(Z)$ represents the probability that an industry is affected by a geopolitical event, calculated as the CDF of a standard normal distribution, code is in the appendix **??**.

4   Conclusion

This paper has embarked on a comprehensive exploration of the multifaceted impacts of Middle Eastern geopolitical instability on global supply chains, revealing a landscape marked by complexity and interdependence. Through the application of a Vector Autoregression (VAR) model alongside a Probit model, this study has not only illuminated the intricate dynamics at play but has also advanced our understanding of the mechanisms through which geopolitical events ripple through global supply networks.

The empirical findings underscore the significant vulnerability of global supply chains to disruptions originating from geopolitical tensions in the Middle East. The analysis demonstrates that such disruptions can lead to substantial logistical challenges, increased costs, and extended delivery times, with far-reaching implications for global economic stability and security. The rerouting of shipping due to the Houthi attacks in the Red Sea, for instance, not only illustrates the direct costs associated with geopolitical instability but also highlights the broader environmental and economic implications of increased emissions and heightened operational complexities Gill & Kose (2023); Davison & Stewart (2023); Hanon (2024).

Furthermore, the transition towards a multipolar world order and the ascendancy of emerging powers introduce additional layers of complexity to the geopolitical landscape. This shift exacerbates geopolitical frictions and challenges the existing paradigms of international trade and supply chain management.

The findings of this paper suggest that the strategic maneuvering and regional assertiveness of emerging powers are likely to redefine trade corridors, thereby influencing global supply chain resilience and efficiency Mearsheimer (2019).

The intersection of environmental pressures with geopolitical dynamics presents another critical avenue of impact. Climate change and resource scarcity are identified as significant drivers of geopolitical instability, with the potential to exacerbate existing tensions and catalyze new conflicts. This paper argues that the interplay between environmental challenges and geopolitical events necessitates a strategic reevaluation of supply chain practices, emphasizing the need for sustainable and resilient supply network designs Runde & Ramanujam (2020).

In conclusion, this paper contributes to the academic discourse by providing a nuanced analysis of how Middle Eastern geopolitical instability impacts global supply chains. It calls for an integrated approach to supply chain management that considers geopolitical risks as central to strategic planning. The research underscores the importance of predictive analytics, diversification of supply sources, and the development of contingency plans as essential strategies for enhancing supply chain resilience Bain & Company (2022). Moreover, it highlights the critical role of international cooperation and policy formulation in securing global supply chains against the backdrop of an unpredictable geopolitical landscape.

The insights garnered from this study not only enrich the academic field of supply chain management but also offer valuable implications for policymakers, business leaders, and stakeholders involved in navigating the complexities of global trade. As the world grapples with the realities of a multipolar global order and escalating environmental and geopolitical challenges, the lessons drawn from this paper underscore the imperative for adaptability, strategic foresight, and collaborative efforts in fostering a more resilient and sustainable global supply chain ecosystem.

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