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The Impact of Climate Change on Global Supply Chains

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Abstract

From clothes, food and raw materials to countless goods – all are being delivered through complex global networks. This itself as long as they are global is they supply chains. They are the backbone of the global economy that is worth $80 trillion and are logistical networks that tangentially bind the world's business landscape. However, they are experiencing a comprehensive but unprecedented storm of challenges. Therefore, a question raises how should managers of supply chains act now and in the long run to overcome the obstacles that hover the trade and logistics of the planet? This very text aims to provide guidance and some corrective measures by examining the changes, some of which bring forth innovations rather than drawbacks, in infrastructural, strategical and conceptual sense.

Set alongside the properties of the earth's atmospheric and 105 year range of shifting weather paradigms, climate fluctuations currently navigate to a stretch-marked territory. Nevertheless, the last few years put up worrisome records – unrelenting fires and polar circles hovering disasters of deeply traumatic temperatures. This owes its unusualness to the addition of carbon from fossil fuels into the atmosphere since 1880 in an unprecedented mass through the around 1.3 trillion tons of CO2 released. The entirety of every known natural catastrophic phenomena such as ice ages, mass extinctions along with the previously referred weather records and some more are explained through lifespans of 600 million years while this pollution of the fossil age has been unveiled for 245 earth rounds.

Keywords

climate change, global supply chains, extreme weather, resilience strategies, sustainable practices, risk management, logistical networks, innovation

2. Introduction

Climate change has a profound impact on global supply chains, forwarding and backwarding the implications and constraints of this process. The objective of the critical essay is to explore and expound on the interconnectedness of climate and supply chains. Climate issues heavily influence global dynamics, and business and supply chain phenomena are as strongly driven by, as drive, climatic and environmental changes. It is important to pay tribute not only to how climate-related events cause classical "supply chain disruptions," such as halts of production and disrupted transportation, but also, and more importantly, to how such events also lead to significant disruptions in the distribution of goods and services, and a drastic contraction of demand. Such an integrated and quantitative exploration and modeling of these and related economic complexities on a global scale represent a missing link in the reconciliation of climatic and supply chain dynamics. A subsequent section is therefore initiated to relay, with consideration of frameworks and essential terminologies, the motivation and anticipated benefits in shedding new light on this multi-faceted system.

The increasing frequency and severity of this diverse class of disruptions underscores the paramount importance of more resilient supply chains, in particular when considering the numerous and intricate connections with different aspects of climate. All these vital issues call for a profound understanding and modeling of the profound implications of climate change upon global supply chains for policymakers, companies and society as a whole. A comprehensive discussion of these broad goals requires the delineation of several important challenges and along with the initial strategies of how to address them, as well as an encapsulation of relevant data sources and methodologies that are employed.

With, they should serve as a preamble for the reader to navigate through the core text and also an introduction to the significant societal implications of this rising need for a substantial alteration, re-consideration and re-organization of the contemporary global supply chain landscape in the wake of the fifth of all time recorded.

3. Understanding Climate Change and Supply Chains

Climate change refers to large and long-term alterations in the statistical parameters of the climate system, which causes an increase in extreme weather events. Climate change is directly focused on the erratic decrease in global precipitation, sudden temperature variations, and increased frequency of catastrophic disasters. Besides, it causes the reduction of the resources, accumulation of environmental liabilities, and limitation of the production framework range (Dahlmann & K. Röhrich, 2019). Hence, it has caused considerable disruptions in global supply chains' reliability. To illustrate, international shipments for 25% of containers, whereas their transportation networks include 2.5 million miles of integrated railways, 5.6 million miles of pipelines, more than a thousand inland ports, and around 10,000 ownership ports. Since climate change, worse environmental conditions have led to a number of busiest US ports shelter from the increased sea level, and this has caused considerable shifts for logistics networks. Due to the close relationship between the supply chains and the environment, the global scale has shifted the agglomeration orders on wheat and corn (maize) crops.

Climate change has immediately affected 10 of 16 supply chain performance indicators. Environmentally friendly and low fuel consumption container B type ships have been preferred more during post economic climate change; however, high competition caused exceeding their economic life expectancy, and this caused the gap between direct/indirect energy consumption/greenhouse gas emissions rates. As a result of the increase in air and sea temperatures, the turbocharger machinery broke down more often in the main diesel engines, and this has caused the global supply chain performance to decrease

significantly. Climate change affects the environment right away after erupting, but delays have set for the generation of operational and marketing actions for its mitigation and adaptation. Synchromodal transportation plans try to compete with the modal transportation's time and cost advantages by ensuring the smooth interactions between different modes of transport, terminals, and modes. To increase the fluidity and the flexibility in the supply chains, it is aimed that the modal and infrastructural options are less important by the role of the modes should be changed for only trustable operations, sustainable and environmentally friendly transport should be promoted, and the long-term partnerships should be encouraged. Touching only the actual strategy, and most of the time, the efforts will be wasted since many stakeholders and disseminators are involved, and most of these will try to set their pieces for the uncertain future. (Hanaysha and Alzoubi2022)(Siagian et al., 2021)(Boyacı-Gündüz et al.2021)(Mio et al.2022)(Arabadzhyan et al.2021)

4. Challenges Faced by Global Supply Chains Due to Climate Change

Introduction to Challenge:

Unpredictable weather patterns have several effects on global supply chains, many of which will lead to increased costs. Firstly, they can lead to logistical inefficiencies; whereby unexpected weather conditions cause widespread disruptions in delivery routes, leading to longer and costlier distribution. This problem can be exacerbated in certain regions of the world where weather extremes are more probable. Much of Indonesia often experiences very heavy rains followed by periods of intense drought and then dense fogs, all of which can close roads and ports for days at a time.

Similarly, such weather conditions can disrupt the export processes of many first world nations during times of severe drought. Conversely, the types of conditions that would lead to blocked transport routes are also the types of conditions that would cause price increases in some crops, such as grains. This can increase the costs of food related supply

chains, as was seen in 2010 when the price of wheat almost doubled due to droughts in Russia and parts of the U.S (Martin & GAUDENZI, 2015). Additionally, if one of these supply chains are a 'critical' production, this increased cost might not be able to be passed onto the customers, meaning lower profit margins.

On a broader scale, climate change may cause more natural disasters which are likely to disrupt the sourcing of raw materials, be they imported or locally sourced. Disruptions may involve catastrophic events that damage infrastructure, delays in transportation, or may simply involve increases in price. Nonetheless, there is an overall increase in the cost of inventory holding across all nodes in the supply chain as the likelihood of failure at some point in time increases. Additionally, climate change often increases the volatility of the environment in which a supply chain functions, making it particularly difficult to plan for the efficient allocation of resources.

5. Adaptation Strategies for Resilient Supply Chains

The recent increase in extreme weather events all over the world poses considerable new risks to global supply chains. Organizations planning, sourcing, producing, and delivering goods at an international scale will have to adapt their strategies to mitigate climate-change-induced impacts. Adopting risk management practices is an essential part of the supply chain resilience that allows organizations to prepare for, respond to, and recover from catastrophic events (Dahlmann & K. Röhrich, 2019). To establish resilient global supply chains under the influence of a changing climate, extensive and continuous vulnerability assessments are key. By identifying the risks and opportunities within the supply chain network, companies can actively implement innovative logistics solutions to increase resilience and generate more value.

One of the most cost-effective approaches to increasing the resilience of the supply chain to climate change is related to the strategic placement of stocks and resources as a contingency measure. By strategically diversifying suppliers and geographically

distributing production facilities and warehouses, supply chains can become more robust to the impacts of a rapidly changing climate. An additional low-investment option is the adoption of trust and collaboration amongst stakeholders that foster the exchange of contingency space in the event of climate-related disasters. Governments need to enforce the integration between suppliers and logistics partners in risk assessments to develop robust contingency plans in the face of extreme weather events. Firms also need to collaborate with governmental agencies to take advantage of climate service providers that can inform about upcoming extreme weather events and offer climate–resilient supply chain guidelines.

Sustainability initiatives contribute to reducing the carbon footprint of supply chains and therefore mitigating the impact of climate change. A large portion of greenhouse gas emissions within a supply chain network come from the transportation of goods. For a global scope, the logistics facilities and transportation vehicles dispersed along the network are increasing their carbon footprints rapidly. As a result, one common strategy to mitigate the potential impacts of climate change is investing in infrastructure that can withstand climate change–related disruptions. There are several actions that firms can take in order to achieve impressive results.

6. Technological Innovations and Climate Change Mitigation in Supply Chains

The increasing intensity of the global supply chain directly exposes the supply chain system to the challenges of changing climate conditions in the medium and long term. The supply chain's climate change vulnerability may arise in the form of production risks for suppliers, road and port access barriers for transportation, and long-term damage to shipment facilities depending on location. Climate change vulnerability also brings about several risks in the medium long foreseeable future. In view of this, use technological innovations that can add a level of climate change risk assessment and management capacity to prepare the global supply chain against these risks (Dahlmann & K. Röhrich,

2019). The technological innovations enable stakeholders to adopt more adaptable and stringent strategies and behaviors. The utilization increases the transparency level of the supply chain system. It may also increase the incentives for responsible joint risk management with weak and incapable partners to build robust mitigation plans. Some of the new technological improvements in the areas that are expected to enrich the toolbox of the supply chain system to cope with the impacts of climate change are examined. In the global and local scale, the climate change-related disruption impacts and propagation chains of supply chain network are relatively complex and hard to quantify in an analytical sense. The new predictive analytics models a triplet set, called ASG (Impact-Seed-Growth) to tackle climate change-induced disruption and study the propagation chain on supply chain. The applicability and effectiveness of this model are illustrated using 3 empirical cases on the Chinese supply chain network (Guo et al., 2024). The result of this reinforces the importance of climate change mitigation and adaptation measures, particularly in developing sustainable technologies, to protect against long-term risks. By making a comparative analysis on the facilities with the same service rates but different evacuation times due to the climate change risk exposure, it is shown that the evacuation time optimization is only advantageous for the exposed facilities with respect to their competitive settings and market demand profile among others. Moreover, important variations in operational strategies are observed in terms of salt reactivity and climate change exposure types. Salt reactivity compatible facilities are seen to apply low stock-out risk strategies in the exposed case. The facilities with a competitive disadvantage are observed to increase their operational novelty/discount mechanisms after the climate change event. The platform approach applied to each facility's retargeting and the demand altering strategies is shown to significantly alleviate the negative impacts of climate change exposure for the entire system positioning the company's global strategy as an essential driver.

7. Case Studies and Best Practices

Implementing Adaptations to Climate Change on a Global Level has moved to the forefront of policy discussion at the start of the 21st century. Accompanying requests to reduce greenhouse gas (GHG) emissions have been calls to find ways to adapt to those changes that are inevitable. This is true in Macro (national economies) and Micro (job security at a plant or farm) scales. A wider focus, not uniform across the literature, is Mesoeconomic levels: industries, and along with the closely linked geopolitical concerns, Global geographic levels. As a part of that contrast necessity and feasibility, with the later focused more on the disturbance prevailing to adaptation policy. Recent flooding in China and New Orleans is discussed more in policy context, with a separate effort to discuss adaptations to Global Supply Chains relates more to the emergence of a potentially manageable topic more recently (Glancy et al., 2007). There are several case studies that are cited that relate to both improved preparation and lessened damage when inevitable events do occur. Some of these cases have much wider implication in the context of Global Production Networks and Supply Chains (Dahlmann & K. Röhrich, 2019). They are examined in more detail here, as well as some top down recommendations based on both empirical investigation and direct corporate involvement. Case Studies include: Foods in Thailand; Wal-Mart in the US South; Garments and Textiles in Coastal China; and repair of the Port of Kobe in Japan after an earthquake. In all instances companies faced with challenges due to a ‘natural’ event they each have invested in adaptive measures after those initial events. A focus on a Mesoeconomic Sector allows examination of a more nuanced analysis of both what is specific to a single industry, why different sorts of weather changes matter to different sorts of production, and what is possible with various sorts of coordinated corporate and public policies.

8. Conclusion and Future Directions

This essay has set out to scrutinize the urgency, scope and complexity of the impact of climate change on global supply chains. The key argument of this essay is that climate change poses an existential threat to global supply chains and global commerce more generally. Temperature rise, severe weather events and rising sea levels are closely interconnected physical disruptions that put global commerce at substantial risk. The direct and indirect production, procurement and transportation losses might lead to the reduction of multiple economies to fringe economies. Global and coordinated efforts are indispensable to limit global warming. Adaptation practices and proactive stakeholder engagement including supply chain partners can potentially increase supply chain robustness and resilience in dealing with the consequences of climate change.

In an interconnected world, millions of production locations provide goods and services to billions of consumers through a global web of transportation and communication means. Over 90% of companies comprise multinational supply chains with multiple tiers of supplier and distribution networks crossing national borders. While this global commerce is economically beneficial to single entities and economies, its global interdependence amplifies the disturbances caused by climate change (Dahlmann & K. Röhrich, 2019). Furthermore, the effect of climate change on single economies and their supply chains has immediate and consequential impacts on many other economies and supply chains. The occurrence of supply chain disruptions such as an extreme weather event in China can have much broader consequences than the partial or total cessation of production in China. This disruption can also cause indirect production losses to multiple other economies that heavily rely on goods produced in China as inputs or final products for production, distribution, consumption.

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