Understanding the Cross-border Food Supply Chain Risk and Resilience in North California

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Abstract: North California is the important grower of fruits and vegetables. This paper aims to understand the cross-border food supply chain risk and resilience and build up conceptual framework of risk identification, resilience and risk transmission. Research methodologies including literature review to understand the factors contributing to the supply chain risk. In a result, the Sino-U.S. relationship impact the North California food supply chain. Policy change, exchange rate fluctuations and custom inspections may lead to longer delivery time, cost increase to harm the food and fruits market stability. This paper proposes the methodologies of how to improve the supply chain resilience which include multi sources, enhance communication and collaboration and digital technology application. These measures may support the firms in North California in the food industry to enhance the capability against the supply chain risk. This may help the vegetables and fruits industry keep stable in long run.

Keywords: Cross-border Supply Chain; Risk; Resilience; North California

1. Introduction

North California grows almost half of the country's fruits and vegetables while the supply chain faces the risk. Factors influencing Sino-U.S. food supply chain includes policy change, exchange rate fluctuations, custom inspections and geopolitical tensions. This paper aims to understand the risk in the cross-border food supply chain in North California and how to improve the supply chain resilience. Methodologies for improving supply chain resilience are addressed by author to give guidance to the firms in the industry.

2. Overview of the Food Supply Chain in North California

The food supply chain in Northern California is a dynamic system which connects agricultural processors and distributors and consumers [1]. Northern California is a rich agricultural region wherein the Napa Valley and the Central Valley are significant regions providing a wide range of nuts, vegetables, dairy, wine and meat [2]. The geography and climate of North California make it one of the most agriculturally productive areas in the world. The area boasts its natural range of the giant sequoia and coast redwood and has resource abundance. The area is characterized with huge farms, sustainable practices and organic farming as well as advanced irrigation facilities. Then North California has several processing and packaging industries which convert raw produce into value-added goods which are well supported with cold-chain networks and logistics. According to the report, California grows nearly half of the country's fruits and vegetables [3].

The food supply chain of North California has improved after the opening of major distribution facility by US Foods to serve Northern California customers by enhancing storage, logistics and training functions. Apart from this, North California has several food hubs which allow small as well as medium producers to collect resources and access institutional and wholesale channels. Regarding funding, the United States Department of Agriculture (USDA) together with the California Department of Food and Agriculture (CDFA) awarded USD 21.5 million in 2024 to strengthen mid-tier supply chain infrastructure (including aggregation, processing and storage). However, it is cross-border food supply chain—linking regional producers with national and international markets—is increasingly exposed to risks such as climate change, water scarcity, labor shortages, and global trade disruptions. Hence, it becomes important to understand the vulnerabilities and the capacity of the region to withstand and recover from them. Therefore, the

present essay discusses the risks and resilience mechanisms in cross-border food supply chain in North California. The main intent of the essay is to highlight supply chain risk and resilience, factors contributing to the risk between US-Sino supply chain system due to the trade war as well as impact on the food supply chain due to trade war between two countries. Apart from this, several methodologies for improving supply chain resilience are also discussed in the essay.

3. Conceptual Framework of Supply Chain Risk and Resilience

Cross-border trade is extremely prevalent in agricultural and processed food products in North California [4]. Thus, the food supply chain in North California is interconnected with global markets through cross-border trade. There is no denying that the cross-border trade provides more economic opportunities to the countries involved I trading but at the same time, they pose a high degree of risk such as political changes, policy changes and also environmental challenges like cyclones, droughts and several others. A conceptual framework helps to explain the interaction between different factors that shape the performance and vulnerability of food supply chains.

The food economy of North California heavily relies on export as well as local markets and thus, it becomes easy to understand these interactions to identify weaknesses and in turn, developing clear and effective resilience strategies [5]. The framework is based on three core dimensions and there are supply chain risk, resilience, risk transmission.

3.1 Supply Chain Risk

Supply chain risk is the unexpected condition and event which disrupts the normal flow of goods and services and finances and information along the supply chain. Christopher and Peck discussed supply chain risk in relation to vulnerability and defined supply chain as risks or events which reduce the ability of a supply chain to meet demand [6]. Resilience comes from designing supply chains which tend to reduce the vulnerability through redundancy and agility. Similarly, Borghesi and Gaudenzi consider supply chain risk only in relation to demand and supply risk, control risk, operational risk and environmental risks [2]. He provided a scholarly review wherein he classified the supply chain risks and also surveyed quantitative models for SCRM which include stochastic models, inventory/contract design and capacity and backup. In case of North California, logistics and export disruptions is the major risk involved in food supply chain. An illustrative example can be seen in the supply chain disruptions in the tree nut industry of North California. This has been in the case of pistachios, almonds and walnuts which comprise of the most valuable agricultural exports. There is heavy reliance on international markets such as exports from Europe, Asia and the Middle East through ports like Oakland which is a major logistical hub in North California. This export-oriented supply chain was posed to heavy risk due to cost inflation as highlighted in the case by the Vice President of Business Operations stating that the cost of a single container increased from $2200 to nearly $5000 to $6000. This reflects a huge change in transport and logistics expenses. This scenario demonstrates a multi-dimensional supply chain risk. First, it reflects a transportation and logistics risk, where insufficient availability of containers and port congestion delayed exports. Second, it reveals financial and market risk, as higher costs directly eroded profit margins and constrained competitiveness in global markets.

3.2 Resilience

Resilience in the food supply chain refers to the system's capacity to anticipate, absorb, adapt to, and recover from shocks while maintaining functionality. According to Andreas Wieldand and Christian Durach as described by Pimenta [7], supply chain resilience is the process of identifying the capacity of a supply chain to adapt, persist and transform in the face of change. This definition focuses on- persistence, adaptation and transformation. In addition to this, supply chain resilience is considered as the ability of a supply chain to maintain, resume and restore operations after a good supply chain disruption. Northern California's food supply chain, known for its diverse agricultural output—including tree nuts, fruits, vegetables, dairy, and wine—has increasingly become a focal point for understanding supply chain resilience in the face of recurring disruptions. Resilience in this context can be understood through Wieland and Durach's lens [8] as the supply chain's capacity to persist, adapt, or transform in response to disruptions. For example, when shipping container shortages and

port congestion disrupted nut exports, many Northern California producers began diversifying export routes, exploring inland rail links, and collaborating with logistics partners to secure container availability.

One of the most complex supply chain issues in North California is water scarcity. As per Morgan, a man-made draught has been created in northern part of the Central Valley of California which is characterized with groundwater restrictions, environmental regulations and reduced surface water allocations. This has led to the disruptions for agricultural producers and supply networks. The Sustainable Groundwater Management Act (SGMA) and related water policies have limited groundwater pumping across the Sacramento Valley and adjoining northern farming areas. There is no denying that these policies have protected water resources in the long run but have also caused the problem of less water available for irrigation in the present time. This has in turn, led to low yields of water-intensive crops like almonds, tomatoes and rice. From the holistic point of view, it is seen that every stage of the supply chain has suffered right from farming to export. In regions prone to wildfires, such as Napa and Sonoma, many wine producers have strengthened resilience through localized storage facilities, improved ventilation, and backup energy systems to protect operations during power cuts or fire events [9]. Similarly, cooperative farming networks and community water-sharing agreements have emerged as collaborative approaches to manage limited resources more efficiently.

3.3 Risk Transmission in Food Supply Chain

Risk transmission is referred to as the process which describes how disturbances in one part of the supply chain easily spread to others [10]. This transmission of risk creates disruption in national as well as international supply chains. Considering the area of North California, risks in food supply chain easily transfer through linkages in logistics, information as well as finance. However, the understanding of this risk transmission helps in better understanding of how stakeholders design preventive mechanisms such as investment in local storage and diversification of export routes.

4. Factors Contributing to Potential Risk between Sino-U.S. Supply Chain System

The trade relationship between China and US has been controversial through years [3]. This trade relationships, in turn, contributes to the complex and interdependent supply chain systems, but at the same time, the food supply chain between US and China face a lot of risks because of economic, political and regulatory changes. This has a direct impact on the trade flows and operational efficiency. Here is a list of some key factors which contribute to potential risks between the Sino-US supply chain system.

4.1 Policy Change

Policy uncertainty is one of the most significant risks in the Sino-US supply chain as they overall change the industrial policies of the two countries along with changes in import and export restrictions and in tariffs [11]. For instance, the U.S.–China trade tensions that began in 2018 led to heavy tariffs on billions of dollars' worth of goods, increasing input costs and forcing firms to rethink sourcing strategies [12]. When the US imported tariffs on Chinese goods, China retaliated with a 25% tariff on American farm products [3]. This led to a fall in US exports of soya bean to China ultimately leading to huge losses for farmers.

4.2 Exchange Rate Fluctuations

Another major source of risk is the exchange rate between USD and RMB because whenever, there is any fluctuation in the RMB/USD rate, it has an influence on the export price as well as profit margins [13]. For example, if the yuan depreciates sharply, Chinese exports become cheaper, benefiting U.S. importers but reducing profit margins for American producers. In Sino-US trade war, majorly Yuan has weakened and the Dollar has strengthened making Chinese exports cheaper and US exports becoming more expensive for Chinese buyers. However, profit margins for producers in America reduced because of declining sales. The yuan's depreciation scenario has been more common and influential in recent years, benefiting Chinese exporters but posing challenges for U.S. agricultural suppliers and adding volatility to the Sino–U.S. food supply chain [14].

4.3 Custom Inspections

Stricter customs checks and inspections at ports create another problem for trade between China and the U.S [15]. When border officers spend more time checking goods for safety or quality,

shipments get delayed. This leads to higher storage costs and breaks the smooth flow of goods that companies depend on for quick deliveries. After trade tensions increased, both countries started checking more imported items, which caused long waiting times at ports and higher costs for businesses. During the U.S.–China trade war, Chinese customs officials began conducting longer and stricter inspections on American soybean shipments [1]. Cargoes that usually cleared within a few days were held for up to 2–3 weeks for "quality checks." This led to spoilage risks, extra storage fees, and higher costs for importers.

4.4 Geopolitical Tensions

There is an ongoing political tension between the US and China in the form of trade sanctions. This has impacted trade policies. For instance, sanctions or export bans on technology can indirectly affect food logistics systems that depend on digital tracking and equipment imports. Such tensions discourage long-term commitments between the two countries.

5. Impact on the Food Supply Chain in Northern California

The food supply chain in Northern California is highly dependent on exports to international markets especially China and thus, faces a lot of risks because of the trade tensions between the two countries. The combined effects of policy changes, customs inspections, exchange rate fluctuations, and geopolitical tensions have created uncertainty and increased operational challenges for farmers, processors, and exporters. Considering policy change, trade war between the two countries have led to shifts in trade policies directly impacting the food exports of North California [16]. During the 2018–2020 trade war, China imposed high tariffs on U.S. agricultural goods, including California's top exports like almonds, pistachios, and wine [17]. This led to many goods which were left unsold as few Chinese buyers were only buying from the US. There was a sudden price drop in these goods.

Even after tariffs were lifted partially, there still remained a high degree of uncertainty in China-US trade relations which negatively impacts the entire food supply chain system. As highlighted by fluctuating trade policies and the absence of long-term stability in bilateral agreements have made it difficult for exporters, particularly in California's agricultural sector, to forecast demand and plan future investments effectively [18].

At the production level, shifting trade and environmental policies have created uncertainty for farmers. For instance, U.S.–China tariff changes have reduced export demand for key crops like almonds and walnuts, making farmers hesitant to expand or invest in new technologies.

Likewise, at the processing and distribution stage, fluctuating trade agreements have caused a disruption in supply contracts which have reduced factory utilisation rates. Therefore, now exporters in North California are facing difficulty in predicting the pricing of the products and also in forecasting demand.

In terms of custom inspections, custom checks have increased a lot and these regulatory requirements have reduced the smooth movement of food supplies at both North California and Chinese ports [19]. Therefore, California nuts, wine and fruits have been delayed a lot at Chinese ports. It is not just the delay but also spoilage risk and storage costs have increased which is particular for perished goods. This, in turn, increases waiting times and paperwork which has reduced supply chain efficiency in North California.

It is already identified from the above section that exchange rate fluctuations is one of the key factors which contribute to the risks in supply chain between US and China. This also has a great impact on the food supply chain in North California where food gets transported to China. Majority of the times, US$ is stronger than Chinese RMB which indicates that US food products have become more expensive for Chinese buyers [13]. This directly impact export orders for North Californian products. For instance, during the trade tensions of 2019–2020, the yuan weakened to over 7 per U.S. dollar, the exports of North California become less competitive as compared to products from other countries such as Spain and Australia. However, this caused difficulty in both countries as farmers in North California have faced lower export volumes and reduced profit margins whereas, importers in China are facing the issue of unpredictable costs as well as contract negotiations.

Geopolitical tensions between the US and China have created unpredictability and uncertainty in the business of exporting in North California as it plans exports or invest in international

partnerships [2]. This has a huge impact on the long-term trade stability as it becomes difficult to plan exports and thus, many times, exporters become discouraged.

6. Methodologies for Improving Supply Chain Resilience

Considering the negative impact of US-China trade war on the food supply chain of North California, supply chain resilience becomes essential not only for maintaining stability but also for competitiveness.

6.1 Multiple Supply Sources

Developing multiple supply and distribution sources is one of the most effective ways to strengthen resilience. Instead of depending on a single market or supplier, firms can diversify both input sources (raw materials, packaging and equipment) and output destinations (export markets). Since the main intent of supply chain resilience is to avoid over-reliance on a single supplier, therefore, North California also did not just depend on Chinese importers to sell their products [20]. They, in turn, have expanded their trade relations with other international markets such as South Korea, India as well as the Middle East. Similarly, processors are sourcing packaging materials from domestic or regional suppliers to reduce the impact of international shipping delays. This diversification helps in spreading risk involved in food supply chain.

6.2 Communication and Collaboration

Effective communication and collaboration among stakeholders are one of the most essential supply chain resilience strategies as it helps in building a transparent supply chain. Several stakeholders include processors, farmers and logistics and government agencies whose collaborations and communication play a significant role in creating a transparent supply chain [21]. In Northern California, this means better coordination between growers' associations, port authorities, and export agencies to share real-time data on shipments, regulations and also of weather conditions. Collaborative platforms such as digital trade portals and agricultural cooperatives can help in making decisions on export schedules and inventory management. Also, misunderstandings over customs inspections and documentations can be reduced with the help of collaboration with Chinese import partners.

6.3 Digital Technologies

Additional strategies to enhance resilience include investment in digital technologies, such as blockchain and predictive analytics, for real-time tracking and risk forecasting. Governments can support resilience by providing financial aid, export insurance and policy transparency [22]. Similarly, firms can develop emergency logistics plans and maintain buffer inventories for critical goods to avoid total shutdowns during disruptions.

7. Conclusion

It is concluded that the food supply chain system in North California is vast as it provides a range of nuts, foods and dairy and exports it. After the US-China trade tensions, the food supply chain system of North California got impacted badly because of Yuan weakening in comparison to US dollars, policy changes due to geopolitical tensions between the two countries and customer inspections and regulatory requirements have increased a lot. This has made supply chain of North California in Chinese trade a lot more difficult and inefficient. Supply chain resilience measures can in turn, help in improving supply chain by exporting to other countries as well for more diversification and also by promoting effective collaboration between all stakeholders.

References

[1] Thilmany, D., Canales, E., Low, S.A. and Boys, K. (2021). Local food supply chain dynamics and resilience during COVID-19. Applied Economic Perspectives and Policy, 43(1), 86-104.

[2] Hittell, J.S. (2022). The Resources of California: Comprising Agriculture, Mining, Geography, Climate, Commerce, Etc., and the Past and Future Development of the State. BoD–Books on Demand.

[3] Huang, K.M., Guan, Z. and Hammami, A. (2022). The US fresh fruit and vegetable industry: an overview of production and trade. Agriculture, 12(10), 1719.

[4] J. Kimura and H. Shibasaki. Recent Advances in Clinical Neurophysiology. Proceedings of the 10th International Congress of EMG and Clinical Neurophysiology, Kyoto, Japan, 1995.

[5] Carter, H.O. (1992). The measure of California agriculture: Its impact on the state economy (No. 21517). Division of

Agriculture and Natural Resources.
[6] Christopher, M., & Peck, H. (2004). Building the resilient supply chain.
[7] Pimenta, M.L., Cezarino, L.O., Piato, E.L., da Silva, C.H.P., Oliveira, B.G. and Liboni, L.B. (2022). Supply chain resilience in a Covid-19 scenario: Mapping capabilities in a systemic framework. Sustainable Production and Consumption, 29, 649-656.
[8] Wieland, A., & Durach, C. F. (2021). Two perspectives on supply chain resilience. Journal of Business Logistics, 42(3), 315-322.
[9] Kropp, J.D. and De Andrade, M.A. (2022). Wildfires and Smoke Exposure Create Contracting and Crop. Choices, 37(2), 1-11.
[10] Wang, J., Zhou, H. and Jin, X. (2021). Risk transmission in complex supply chain network with multi-drivers. Chaos, Solitons & Fractals, 143, 110259.
[11] Song, Y., Chen, B. and Hou, N. (2024). Trade dependence, uncertainty expectations, and Sino–US political relations. Journal of Chinese Political Science, 29(1), 109-131.
[12] Lawrence, S.V., Lum, T., Campbell, C., Martin, M.F., Fefer, R.F., Schwarzenberg, A.B. and Leggett, J.A. (2021). US-China relations. Current Politics and Economics of Northern and Western Asia, 30(1), 1-86.
[13] Wang, Y.C., Tsai, J.J. and Chen, X. (2021). The impact of RMB internationalization and international situations on China's foreign exchange market: Dynamic linkages between USD/CNY and SDR/CNY. Emerging.
[14] Vıktor, P. and Molnar, A. (2023). The Analysis and Countermeasures of US Dollar Exchange Rate on China's Import and Export Trade. The Eurasia Proceedings of Educational and Social Sciences, 32, 55-61.
[15] Watterson, C.J., Kartuzov, E. and Osborne, S., (ND). The obstruction of customs enforcement at privately operated port terminals: A study of Chinese state-owned enterprises. Journal of Strategic Trade Control.
[16] Robinson, S. and Thierfelder, K. (2024). US international trade policy: Scenarios of protectionism and trade wars. Journal of Policy Modeling, 46(4), 723-739.
[17] Morgan, S., Arita, S., Beckman, J., Ahsan, S., Russell, D., Jarrell, P. and Kenner, B. (2022). The economic impacts of retaliatory tariffs on US agriculture.
[18] Umeaduma, C.M.G. and Dugbartey, A.N. (2023). Effect of exchange rate volatility on export competitiveness and national trade balances in emerging markets. International Journal Computation Applied Technology Research, 12(11), 57-71.
[19] Fan, D., Zhou, Y., Yeung, A.C., Lo, C.K. and Tang, C. (2022). Impact of the US–China trade war on the operating performance of US firms: The role of outsourcing and supply base complexity. Journal of Operations Management, 68(8), 928-962.
[20] Raj, S., Roodbar, S., Brinkley, C. and Wolfe, D.W. (2022). Food security and climate change: differences in impacts and adaptation strategies for rural communities in the global south and north. Frontiers in Sustainable Food Systems, 5, 691191.
[21] Schäfer, N. (2023). Making transparency transparent: a systematic literature review to define and frame supply chain transparency in the context of sustainability. Management Review Quarterly, 73(2), 579-604.
[22] Gnangnon, S.K. (2022). Development aid and export resilience in developing countries: A reference to aid for trade. Economies, 10(7), 161.