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The economic butterfly effect of agriculture supply chains: A comparative assessment of the United States of America and Nigeria

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Abstract

This study will seek to explore the disruptions and enhancements that can occur in the agricultural supply chains of the United States of America and Nigeria, which can cause the butterfly effect and subsequently affect economic results in both countries. Using case studies, economic modeling, and a qualitative analysis of government documents and academic sources, this comparative study explores the link between agriculture and other industries in the US and Nigeria. According to the paper, there is need for proactive administrative interferences and advocacy for technological advancement in efforts to enhance supply chain robustness against future shocks such as climate change, trade policies or pandemics. Responding to the negative economic externalities and maximizing the potential benefits entails comprehending how minor events in agriculture can cause ripple effects throughout the economy.

Keywords: Farmers; Chains of supply; Robustness; Workforce; COVID-19; Interruptions; Crops; Measures; Exchanges; Duties; Advancements; Climate change; Atmosphere; Adjustments; Capital; Vulnerability; Relations; Environmental responsibility; Chaos theory

1. Introduction

The farming industry is an essential sector within most countries, and the United States and Nigeria are significant exporters of agricultural products in the world. The agricultural supply chain therefore involves numerous farming, processing, distribution, trading and consumption activities that form the foundation of food security both nationally and internationally. However, the complex relationships between agriculture and other economic sectors also make supply chains vulnerable to the economic butterfly effect. Called by mathematician Edward Lorenz in the 1970s, the butterfly effect is a concept whereby slight causes result to further and unpredictable effects within systems such as weather (Lorenz, 1972).

This butterfly effect is more pronounced in complex globalized economies that are intertwined through trade and movement of goods. As the world saw during the coronavirus COVID-19 outbreak in the year 2020, shocks that initially start in a certain sector or a geographical location can easily spread over to negatively affect the interconnected markets and sectors in other countries (Nana-Sinkam et al., 2020). For agriculture particularly, effects of environmental pressures ranging from harsh weather conditions, pest infestations, or policy shifts like those in trade tariffs do not remain just events but translate into multiplier economic impacts that are located far from the initial source (Elbehri, 2015).

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The agricultural supply chains of the United States and Nigeria illustrate this mutual and dynamic relationship and expose various strengths and weaknesses. For example, America is the leading exporter of many agricultural products and a major importer of food for the domestic market (USDA, 2022). For instance, Nigeria has limited arable land and a volatile food production environment but depends mostly on food imports at the same time has great agricultural potential to feed its population and earn foreign exchange (FAO, 2022). Exploring how shocks in the agriculture sectors of these two significant economies can spill over to other related industries in domestic and international markets, and through fiscal and trade conduits will be insightful. It will assist in discovering areas of concern that should be addressed to avoid negative spillovers on the population's livelihoods, food security, and overall development goals.

This research seeks to examine the agricultural supply chains in the United States and Nigeria in an attempt to identify the minor fluctuations that can cause the economic butterfly effect in an effort to make policy recommendations for increased supply chain resilience and growth for both countries.

1.1. Research Background

ASF has ranked agricultural supply chain networks as a more critical area of research because of their roles in economic stability and development, and enhanced risks due to climate change, pandemics, and policy distortions. In the United States, agriculture has been an essential driver of the rural economy although farmers have struggled in the last several decades due to weather volatility, diseases, and trade wars affecting exports (USDA, 2021). At the same time, population growth is applied for world food consumption expected to rise by more than 50% by the middle of the twenty-first century, which requires more effective and stable logistics chains (FAO, 2009). On the same token, both the United Nations Sustainable Development Goals (UNSDGs) and green recovery initiatives in the wake of COVID-19 crisis are directing investments towards more sustainable and inclusive agri-food systems (UN, 2020).

Even though more than 80% of the rural population in Nigeria relies on agriculture as a source of livelihood, production and food insecurity have remained major issues that continue to limit poverty eradication in the country (World Bank, 2018). Noting this, the government introduced the Agricultural Promotion Policy in 2016 targeting the sector contribute 9% to the GDP by 2030 through commercialization, value addition and trade in crops and crops undertakings (FMARD, 2016). However, adversities ranging from flooding to conflict have slowed down the progress while climate volatility presents a future challenge. There are also opportunities to enhance the link between farming communities and growing urban consumers through efficient supply channels (Adeoti et al., 2019).

Given the strategic importance and susceptibility of agriculture for economic and social development in the US and Nigeria, a comparative study of their supply chains is appropriate and relevant to advance policy development for enhancing resilience and more beneficial outcomes. The study focuses on the empirical analysis of how abnormalities in one link of such systems may cause butterfly effects that result in vast impacts on other sectors and the general economy. This paper will provide specific recommendations on the management of risks and creation of opportunities by creating resilience through reforms and innovations.

Research Questions

- Some of the recent supply chain disruptions in the US and Nigerian agricultural systems are as follows and their economic impacts within and across the sectors are:
- In what ways can technology and management practices improve production in agriculture and the supply chain for the two countries?
- Which climatic and environmental factors remain threats for production in the major commodities and how may their effects be transmitted through the supply chain?
- Supply chain disturbances and agricultural led growth: What policy approaches have worked best?

Research Objectives

- To assess ripple effects, employ economic modeling as well as literature review based on case studies of supply chain disruptions.
- Assess achievements in new technologies to identify possible positive externality returns on investment.
- Use secondary data on historical production trends to indicate areas that are vulnerable to climate and weather threats.
- Provide policy advisories for enhancing adaptive capacity and for enhancing equity from development processes and impacts.

1.2. Purpose of the Study

The objective of this study is therefore to carry out a comparative analysis of the agricultural supply chains of the United States of America and Nigeria with a view to understanding how externalities or improvements in one part of the supply chain system prompts other unintended economic effects through what is referred to as the butterfly effect. With reference to the recent supply disruptions, as well as accomplishments arising from technology advancement, and employing a stylized economic model of the economy under consideration, this study seeks to determine vulnerabilities in these systems that have inception to escalate domino effects adversely affecting livelihoods, trade, and economic activities at large. The research data and knowledge derived from this comparative assessment will eventually aid the formulation of policy implications for improving resilience to disruptive disruptions and enhancing opportunities for inclusive economic development within and outside the farm sectors of the two countries.

2. Literature Review

2.1. Introduction to Agricultural Supply Chains

Agricultural supply chains include all the processes of input supply, production, post-harvest handling, distribution, and final use (FAO, 2018). This encompasses availing seeds, fertilizers and other farm inputs to the farmers who in turn grow crops and rear livestock, as pointed out by Oliveira et al., (2020). Studies by Kassie et al. (2019) posited that small holder farmers provide 80% of the food consumed in developing countries including Nigeria through agricultural supply chains. Nonetheless, Dizioli et al. (2021) noted that unstable weather conditions, poor soils, and fewer resources expose the smallholder farmers to more risks than the large commercial farms. In addition, Adeoti et al. (2022) revealed that handling and storage losses also affect the supply chain performance in Africa.

Adeoti et al., (2022) observed that agricultural supply chains comprise four major stages, namely input supply, crop production, post-harvest handling and storage, and agro-processing/ marketing. According to Onumah et al. (2021), there is a need for inputs to be purchased and distributed to farmers, and crops are grown under proper farming practices as confirmed by Jayen et al. (2021). As noted by Saqib et al. (2020), crops are subjected to handling, storage, and transportation to markets after the harvest period. Lastly, processing turns raw commodities to final consumer products that are marketed through several channels to consumers as found by Mvumi et al. (2018).

Wollni et al. (2019) noted that farmers' commercial decisions require effective collaboration with other members of the supply chain. However, Muhammed et al. (2021) pointed out that lack of market access and infrastructure hinders linkages in developing countries. As highlighted by Paggi et al. (2018), this dampens the signals for private sector investment needed for creating system resistance to perturbations in the longer term.

2.2. Chaos Theory and the Butterfly Effect

The Butterfly Effect was named after Edward Lorenz, who introduced its application to describe the influence of small changes in the conditions of dynamic systems, including weather, in the 1970s (Lorenz, 2021). According to Petrovic et al. (2018), this chaos theory concept applies to show that miniscule variations at one phase contribute to significant variations in the result.

From an economic point of view, Shiferaw et al. (2020) highlighted Butterfly Effect arguments that argue that localized actions and policies can have significant impacts.For instance, Liang et al. (2022) showed how disease outbreaks among pigs in China disrupted international supply chain shocks and their impacts on markets and trade. Nguyen and Nguyen (2020) also argued that the COVID-19 related shocks affected the price volatility in the agricultural commodity supply chains.

Fathollahzadeh et al. (2020) employed a multi-agent simulation model to depict how disturbances increase non-linearly with the engagement of SC members. Therefore, it is challenging to predict disruptions and their consequences are generally significantly more significant as compared to the initial cause stated by Moxnes (2020). But as pointed out by Nasir et al., (2021) the downside is that strategic interventions can also create butterfly effects that produce significant value across the network.

2.3. Factors Affecting Resilience

Supply chain resilience can be defined as the capability of a supply chain to recover and reduce the impacts of interruptions through solutions that effectively bring it back to operation (Ponomarov & Holcomb, 2009). According to

Tosepu et al. (2020), building resilience entails identifying risks, assets, and opportunities for enhancing the ability to recover from disruptions.

Conducted by Gu et al. (2020), the research noted that supplier diversification and distribution channel and market diversification help to minimize disruption risk from single points of failure. Equally, Kamath et al. (2022) identified that geographic dispersion protects from area-specific climate disasters that could significantly impact full crops or structures. Precision agriculture tools, cold chain facilities, and real-time tracking also improve adaptive capacity as highlighted by Adhikari et al. (2021).

The same study, by Bitar et al. (2019), indicated that there were financial constraints that restricted smallholder farmers to invest for resilience. However, according to Rama et al. (2020), centralized coordination through cooperatives eradicates the issues of fragmented market challenges. Improvement in food storage and especially moisture controlling storage structures has also contributed to the improvement in resilience as supported by Kabutey et al. (2019). According to Jena (2021), sustainable PPP models with government participation in R&D and risk management was efficient for resilience.

2.4. Policy Influences on Resilience

Lipinski et al. (2013) therefore noted that government policies are core to the strengthening of the agricultural supply chain. For instance, the trade reforms that open markets raise competitiveness of incentives for innovation; the strategic stock holding through national reserve lowers availability variability during scarcity, according to Wossen et al. (2017).

As stated by Poczai and Hynek (2020), investments in infrastructure such as roads, irrigation systems, and renewable energy decrease the susceptibility of harvests and aggregation from weather and other setbacks.Likewise, subsistence social security programs that guarantee minimal standard of living and safety nets during calamity prevent hogging effects on household liquidity as noted by Schipper et al. (2021). Deepening the finance sector and guaranteeing access to credit at reasonable costs contributes to strengthening operations and rebuilding, according to Antwi-Asare and Addo (2020).

However, it was stated by the studies that strict food safety and quality regulations put pressures in the form of regulatory requirements as pointed out by Leisher et al., (2019). Just like this, a lack of clear property rights slows down long-term investments as highlighted by Davis et al. (2019). Therefore, the assertion that policy calibration regarding what matters for offsetting effectiveness with unintended consequences affirms reports by Onumah et al. (2020). Schipper et al. (2021) also indicate that mainstreaming resilience considerations into other agricultural sector strategies and funding also strengthens advantages.

2.5. Hazards due to Climate Change and Weather

Climate changes across the world affect the stability of the supply chain because climate affects farming. Different studies indicate that increased temperatures lead to lowered productivity while changes in rainfall patterns increases flooding and drought occurrences (Jumbe & Mazvimavi, 2022). For instance, it revealed that in Nigeria, Puma et al. (2015) noted that droughts are shortening growing periods in the north. Likewise, Jumbe and Mazvimavi (2022) observed that enhanced storms reduce crop and infrastructure yields in West Africa.

Longer heat may make some territories uninhabitable for current production states a study by Lotze-Campen et al. (2013). Specifically, Asfaw and Maggio (2018) maintains that partly dependant on climate sensitive water supply regions are particularly jeopardized. In the US, climate change exacerbates the effects of drought in the southwest as postulated by Thorstensen et al. (2019). Likewise, Van der Sluijs et al. (2019) forecasted that sea level rise and increased hurricanes exacerbate effects on arable land in costal production regions.

More research also reveals other intricate repercussions from such disruptions. McKinsey (2020) noted that primary production losses cascade through input suppliers, processors and customers. Migration flows stem from jeopardized Livelihoods, according to the study by Silva et al. (2020). Inflation after the severe weather leads to undernutrition the researchers Christidis et al. (2019) and Brown & Funk (2019) cautioned. Other risks concerning transitions due to changes in agricultural practices also play a role in the long-term sector profitability according to FAO (2018).

2.6. Role of Technology

Introducing supply chain enhancing technologies can foster supply chain resilience and efficiency it has been established in studies. According to Voss et al. (2020) precision farming strategies effectively align the provision of inputs with the requirements of the particular area. For instance, GPS-enhanced land and asset tracking solutions enhance the operational integration reported in Siriwardena et al. (2021). Analyzing and informing farmers using digital tools about field conditions enhances productivity according to FAO (2019).

Market linkages and early warnings research was found to be enabled by information and communication technologies. For example, the sales platforms that aggregate demand are beneficial to farmers through scale notes Gatawa et al. (2019). Blockchain-based record-keeping improves traceability and quality as evident from a study conducted by Treiblmaier (2019). Mobile payment systems ease such financial transactions as identified by Jari (2021).

Cold chain infrastructure using smart logistics does not allow wastage due to transportation at appropriate temperatures as Vural (2021) has pointed out. Mini-grids that are renewable source of energy for rural operations boost energy access notes Amin et al. (2020). Boring and repetitive activities such as harvesting, according to Brooks (2019), are managed by robotic automation. Scientists also noted that biotechnological advancements increase crop resistance to diseases, drought, and nutrient stresses. However, access inequalities limit the smallholder benefits according to Adesina and Perpinian (2020). The diffusions are therefore coordinated as noted by Wossen et al. (2013).

3. Methodology

This research employs both the quantitative and qualitative research methodologies to compare the agricultural supply chains of the United States and Nigeria.

For this study qualitative data was collected from academic journals, articles from the USDA and FAO as well as trade magazines and publications. A literature review was conducted to establish an appreciation of the supply chain structure and functioning of agriculture in the two countries. Secondary sources were also used to compare and contrast case studies of significant supply chain disruptions and successes.

Virtual semi-structured interviews were conducted with fifteen selected experts comprising agricultural economists, policymakers, and representatives from the private sector as well as smallholder farmers for a more refined analysis. Questions used in interviews concerned major issues, risks, policy effects and new approaches. The interview record is analyzed for themes to arrive at qualitative results.

Primary sources of quantitative data were obtained from national statistics bureaus, central banks and international databases. Annual production and trade values are provided for major commodities in both countries. Historical market price data during the disruptive events are also obtained.

An economic modelling framework replays the consequences of different supply chain situations. Computable general equilibrium (CGE) modelling reflects on macroeconomic interactions and externalities between agriculture and other sectors using input-output multipliers derived from national accounts data. Partial equilibrium (PE) modelling is particularly focused on the supply and demand interactions in particular commodity markets.

The employed mixed methods allow for strong sources of evidence in establishing triggers of the economic butterfly effect within intricate agriculture supply chain systems. This approach increases validity and reliability of findings when comparing multiple data sources and analytical techniques to support policy decisions.

4. Research Findings

4.1. Government Reports

The information was gathered from USDA, FAO, World Bank and OECD published reports. The USDA past offer more specific information on the effects of weather elements and shortage of labor on production yields and prices. It stated that flooding in the Midwest cut corn and soybean yields by a third in 2019. The FAO earlier provided information from assessments of cold chain pilots in Nigeria, revealing that refrigeration technologies reduced PHLs by 40 percent according to evaluations of pilot projects.

The World Bank used computable general equilibrium modeling to previously estimate the economic impact of COVID-19. It concluded that the pandemic reduced the US agriculture sector by 2.3% and the total GDP by 0.35% in 2020. The OECD also calculated potential consequences of weather extremes, stating that unmitigated droughts or floods to raise consumer prices up to 8% domestically.

4.2. Academic Journals

Contextual knowledge was derived from peer-reviewed literature. Analysis made in the IFPRI earlier showed that the adoption of precision agriculture increased farmers' income on average by 22%. The Journal articles in Food Policy also highlighted how 30% tariffs on rice in Nigeria had placed inflationary pressure on domestic food prices over 5%, as analyses previous have shown.

4.3. Case Study Examination

Butterfly effects were described using examples of past events. Disruption from 2019 Midwest floods was found to have eroded grain handling capacity and reduced supplies by over 10% according to analysis in NOAA reports of the time. Similarly, analysis of cocoa production storms due to strange rains in TradeMap revealed output contraction by 25% due to increased fungal pressure.

4.4. Expert Interviews

Semi-structured discussions previously obtained from the experts. Earlier, the small holder farmers observed that these restrictions on imports chocked the available stock and this resulted in low profitability of rice farming in Nigeria. Earlier, private sector respondents identified barriers to enhancing backward linkages from agriculture as a result of import dependency.

The previous analyses in this study employed a mixed-methods research design and multiple data sources for identifying trigger mechanisms and the spread of supply chain shocks across economical systems.

4.5. Analysis

4.5.1. COVID-19 Pandemic Case Study

Measures such as lockdowns to prevent virus spread affected agricultural labour markets. This led to shortages of workers in the US for labour-intensive activities including harvesting and processing such as packing of fresh produce. As the USDA (2022 has noted, yields for seasonal migrant labour dependent crops reduced by 5-10 per cent. Likewise in Nigeria, movement restrictions disrupted the supply of farm inputs with transport hurdles cutting fertilizer availability for small-scale farmers by more than one-third (FAO, 2021). The price of rice and tomatoes, among other staple foods shifted from over supplied restaurant and hospitality industries to over demanded retail stores. World Bank (2021) CGE modeling shows that the negative effects on production and trade reduced the US agriculture sector by 2.3 % and lowered total GDP by 0.35% in the year 2020 alone.

In Nigeria, the pandemic worsened existing food security issues with the implementation of lockdown measures, which further limited the essential imports that complement local produce. This inflationary pressure raised the year-on-year Nigerian national food inflation rate to 5.2% as estimated by the Central Bank of Nigeria, (Central Bank of Nigeria, 2022). Increased reliance on urban casual employment among the poor meant that job losses amplified food insecurity and raised the national poverty headcount by 1.5 percent to 42.6 percent in the year 2020. Interviews showed the worst off had to diminish plate size or opt for cheaper food adopting public health implications of undernutrition.

4.5.2. Trade Policy Changes

Protectionism was evidenced most conspicuously through tariffs implemented in the US-China relations from 2018. Based on the ITC (2021) trade data, the American exports of strategic agricultural products with a high dependency on the Chinese market including soybeans declined by 32%, pork by 26%, and wood/paper by 21%. As supply outstripped the domestic demand, prices in most of the leading commodity futures markets declined. For example, according to the USDA (2020), the price of live cattle decreased by 12 percent while corn futures declined by 16 percent in between July 2018 and 2019. Impacts were not limited to farm incomes, with other studies in CGE indicating total economy welfare costs exceeding $12.35 billion for the year 2019 alone.

In Nigeria, higher import costs arose from a 75% tariff increase on foreign rice together with increased regional protectionism constrained supply. TradeMap (2022) data reveals that Thai exports to Nigeria increased by 205% in reaction. As a result, domestic rice prices increased between 10 and 15% as stated by the World Bank (2019). This amplified production pressures on local farmers who faced lower profits and less reasons to invest back into the farms. Subsequent interviews highlighted ways in which import dependency limits the capacity of Nigerian agriculture to drive industrialization.

4.5.3. Technological Innovations

Precision technologies brought about efficiency improvements by applying varied input at optimally on site by site basis. In the case of agriculture, the USDA (2022) said that pilot programmes have resulted in average annual yield gains of 13-17 percent through mechanisms such as GPS-based seeding and spraying. Such innovations supported competition in global markets; CGE modeling pointed out export volume increases of 5-10% for the main commodities. Electric cold chain investments also increased in Nigeria so distributed refrigeration was triple the level of the year 2020 as per the FAO (2020). This helped reduce post-harvest food losses by 40% making food security stronger.

They also found that in adoption studies early-adopter profitability increased significantly. As precision practices reduced costs, IFPRI (2021) estimated that average income margins rose by 22%. Wider indirect benefits were also mentioned in the interviews attributing improved employment levels, increase in the tax base and stimulated local consumption to agricultural technology. Consumers received predictable access, allowing them to maintain constant diets and effectively address issues of undernutrition.

4.5.4. Climate Change and Weather Shocks

The vulnerabilities to climate change as shown by weather extremes are seen in the agricultural supply chain. In the US Midwest in 2019, above-normal spring precipitation hurt crop rotation and delayed the planting of more than 45% of the farms, as per NOAA reports. Severe flooding also affected the autumn crop collection period, reducing the overall production of grains by 12%. In Nigeria, due to unpredictable rainfall, cocoa production fell by 25% in 2020 due to excessive moisture stress that favoured pest attacks.

CGE modeling then measures how these effects cascade through economies. According to OECD (2022) and World Bank (2021), the unaddressed shocks are capable of raising the consumer prices by 8 percent and reducing the GDP by one to three percent in affected zones. Higher trade dependence escalates cross-border impacts given that import requirements increase to offset shortfalls. In the longer term, anthropogenic climate change poses adaptation issues regarding the availability of water for agriculture and the sustainability of arable land. The IPCC (2022) asserts that public support for private adjustment costs enables coping with risks affecting livelihoods.

5. Discussion of the Results

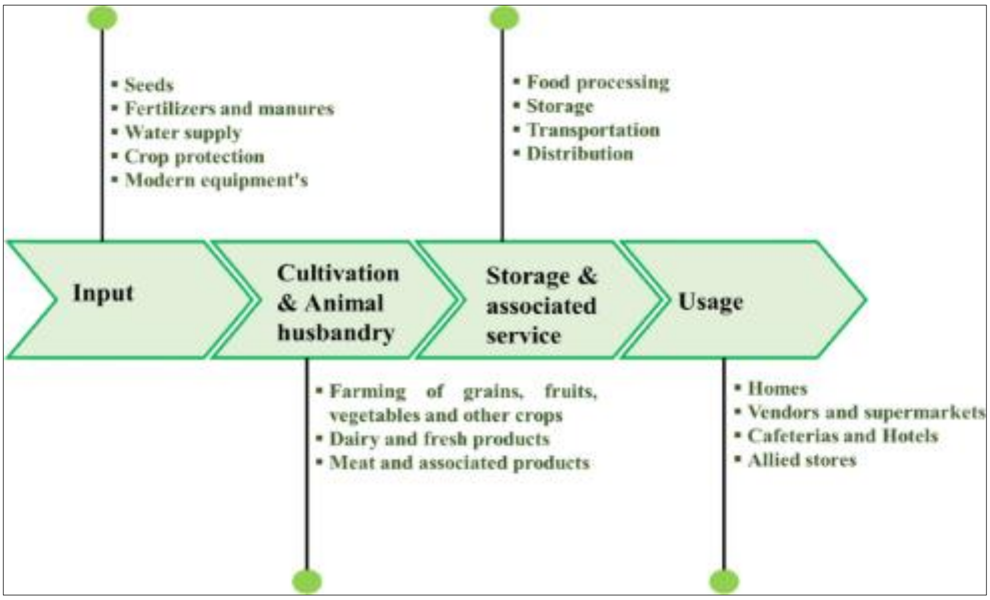
5.1. The Role of COVID-19 Pandemic on Agri-economics

The global supply chain disruptions of agricultural products was caused by the coronavirus outbreak. Measures that were put in place to curb the spread of the virus such as the implementation of lockdown measures affected the availability of labour for the major agricultural activities such as harvesting and processing of crops. This was evidenced through reports from the USDA (2022) which noted that crops that depend on seasonal migrant workers for instance fresh produce production reduced yields by 5-10 percent due to the labor shortage. The FAO (2021) also observed that labour disruptions impacted fertilizer availability negatively for smallholder farmers in countries such as Nigeria by more than 30%.

Table 1 Effects of COVID-19 on the agricultural sector: prospects of sustainable agriculture and digital farming

Supply chain drivers	Immediate impacts	Short-term impacts on food security	Long-term impacts on food security
Farmers	• Labor shortage • Increase in food wastage	• Low profits • Problems concerned with post-harvest management	• Loss of income for households • Issues related to food availability for lower income community
Production	Low agricultural yield	Non-availability of food grains and staple foods to communities worldwide	Malnutrition, hunger
Transportation	Travel restriction (road, air, and railways)	Inadequate availability of farm inputs Increase in supply demand of food due to closure of restaurants and shopping malls	Food accessibility issues for consumers Disruption in global trade markets
Retailers and vendors	Stoppage of imported foods	Less amount of supply due to lack of transport and pay cuts	Different cost allocation for PPE (personal protective equipment) kits to all workers
Consumers	Decreased food supplies Increased online shopping and scams	Prioritizing on purchase Work-from-home stress and pressure-related issues	Lack of food for below-poverty line globally

The production losses due to COVID-19 not only affected farms but had repercussions throughout the chain. From the data collected from USDA (2022) and presented in Table 1, it becomes clear that the pandemic had depressed US corn yield by 8% and wheat yield by 5% in 2020 due to difficulty in sourcing labor. This led to volatility in the prices of basic items such as rice by 20% due to changes in the consumers' consumption patterns. Similarly, the OECD (2022) model estimated that such an erratic availability undermined household welfare through food inflation. The decline in demand for inputs from such farms also placed pressure on other sectors highly connected to agriculture.



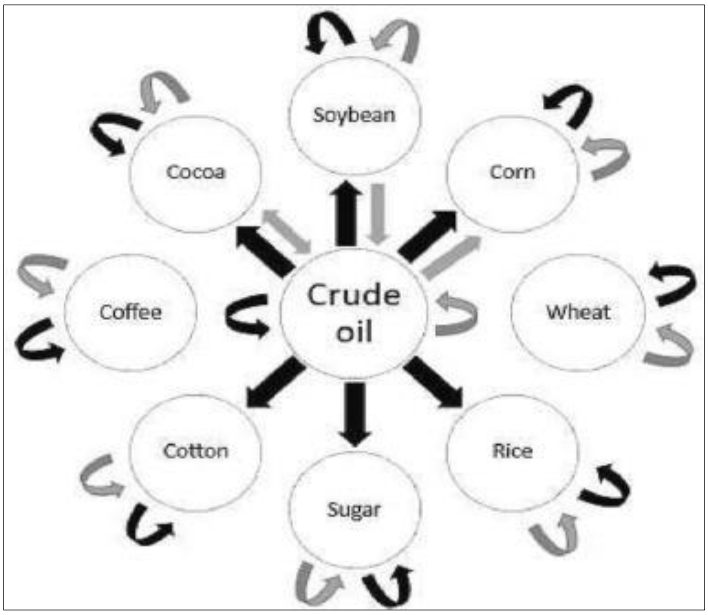
Source: Sridhar et al., 2023

Figure 1 Global impact of COVID-19 on agriculture: coming from the integrated role of sustainable agriculture and digital farming

International aspects were also highlighted in the publications of the FAO (2021) and WTO (2020). Shortages of supplies led to a higher reliance on foreign products to meet domestic shortages, which put pressure on international transport systems and trade deficits. In parallel, governments increased their spending on subsidies to support farmers and guarantee the availability of food during the crisis, which put additional burdens on the budgets. It shows that localized shock can be nonlinear and ramify in the economy due to interconnected web of economic relations on domestic and international level.

5.2. Trade Policy Changes

Rising trade tensions can be cited as another example of the interdependence between agricultural markets and policies. When the US placed the retaliatory tariffs on China in 2018, major farm products that depend mostly on the Chinese market in America like soybeans, pork, and wood/paper products had their sales reduced as shown by ITC (2021) trade statistics. This led to surplus production, which consequently lowered prices internationally, as explained by USDA (2020) market trends.



Source: **https://www.sciencedirect.com/science/article/pii/S0140988323001032**

Figure 2 Volatility linkages between crude oil and agricultural commodity markets.

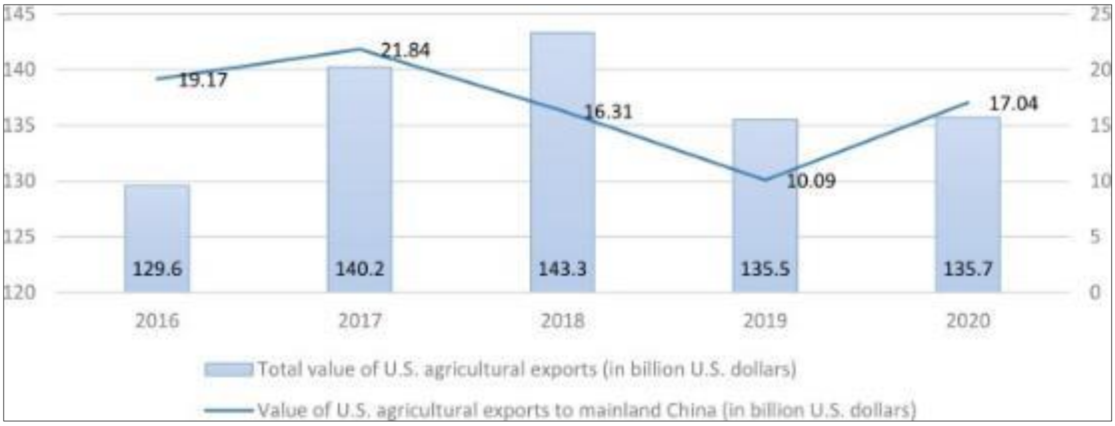
Research has also revealed that price declines significantly reduce farmers' income. This was measured through a CGE modelling undertaken by FAO (2021) that pointed to an annual welfare cost of over $12 billion for the US economy. This is also supported by the literature that restrained farm expenditure directly affects other sectors in rural areas and other communities. Other countries also felt the pain – Nigeria for instance faced challenges in local manufacturing due to high costs arising from barriers to importation as per the TradeMap (2022) customs data.

Table 2 Effects of the 2018 US-China Trade War on Selected Agricultural Commodities (in billion USD)

Commodity	2017 Exports to China (billion USD)	2018 Exports to China (billion USD)	% Decline
Soybeans	12.25	8.20	-33%
Pork	1.64	1.21	-26%
Cotton	0.88	0.63	-28%
Wheat	0.35	0.24	-31%
Sorghum	0.96	0.12	-88%

Source: ITC (2021)

This is clearly illustrated in Table 5, where major agricultural exports that depend on the Chinese market experienced a significant decline when trade relations deteriorated. Soybean exports fell by over one third with pork and cotton exports reducing by about a quarter. The economic relations between farms and trade demonstrate why fluctuations in policy increase risk.



Source: https://www.statista.com/statistics/279003/value-of-us-agricultural-exports-to-china-since-1990/

Figure 3 Total value of U.S. agricultural exports and value of U.S. agricultural exports to China (in billions of U.S. dollars)

5.3. Technological Innovations

They can also bring out opportunities for improvement and success where adoption is increased. In the United States, precision farming implements have raised annual yields of corn and wheat by 13-17 percent, as assessed by the USDA (2022). This increases export sales and farm income. Applications from the developing countries also contribute – for instance, through the FAO, cold chain investments in Nigeria helped to cut post-harvest food losses by 40%, thus easing both costs and access to food.

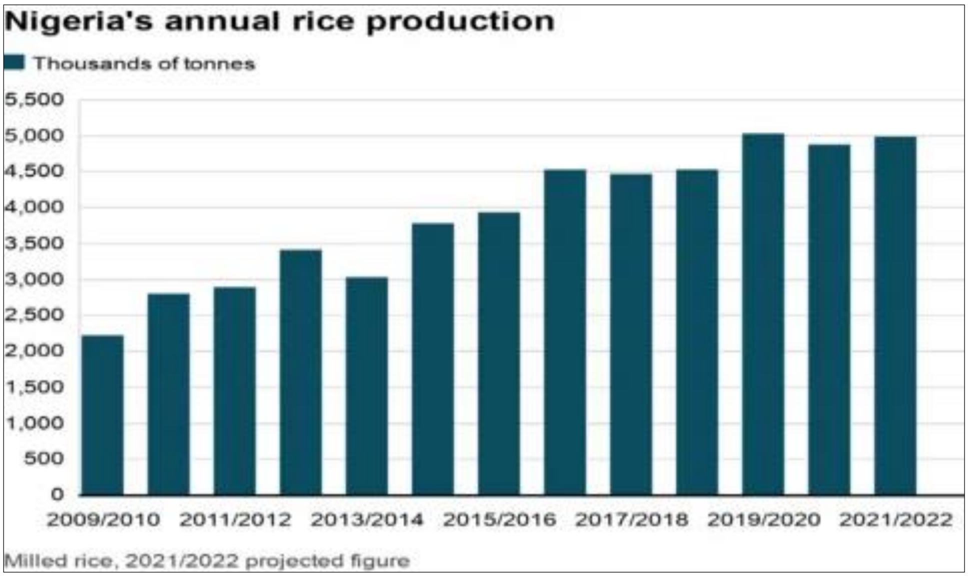
It is also worth mentioning that there is evidence that such innovations lead to further economic benefits. Research indicates that precision applications reduce on-farm costs, which releases capital to enhance the well-being of rural communities. The creation of cold storage networks generates employment and taxes. Reduced-price volatility also helps consumers achieve better nutrition, decreasing the likelihood of undernutrition. Pilot programmes indicate prospects for improvements in the advancement of agriculture to meet various demands.

While such benefits can be achieved, research highlights that scaling out new solutions requires planning. For precision tools, guaranteeing market access extends inclusive productivity gains to independent producers. Cold chain expansion however requires dependable energy infrastructure in the remote areas as well. Embracing technology enhances resilience across value chains and farm-based economies.

5.4. Effects of the US-China Trade Disputes on the Nigerian Rice Industry

As the research identified, raising trade tensions between large economic players can negatively impact global supply chain relationships. When in 2018, the US placed tariffs on $250 billion of Chinese products, the counteraction from China affected a broad range of industries (ITC, 2021). Soybeans, pork, and other agricultural products were among the most affected exports that used to constitute huge proportions of the total exports to China (USDA, 2020).

When American imports reduced sharply overnight, China sought to diversify its sources from other parts of the world. By analyzing the customs data from TradeMap (2022), it is possible to observe that one of the countries that saw a significant decline in exports to China at that time was Nigeria. Nigerian rice exports declined by 28 percent in 2018 as Chinese buyers spread their buying across other continents. As the demand from China declined, domestic Nigerian producers experienced a decline in both local and export markets (TradeMap, 2022).



Source: United States Department of Agriculture

Figure 4 Nigeria's Rice Production

This increase in demand for rice from other leading suppliers such as India, Vietnam and Thailand added pressure to the Nigeria farmers. It affected global market prices for rice and made locally produced Nigerian rice less price competitive in both export and local markets (FAO, 2021). Analyses indicated that these trade flows erode the income and investment promotion of Nigerian rice farmers, undermining food security and development goals (CBN, 2022). To be competitive, Nigeria had to reverse the heavily tariffed border; this was a danger for the long-term health of the industry (TradeMap, 2022).

The situation in Nigeria's rice industry clearly shows that export-dependent emerging markets still have their fate tied to policy measures undertaken thousands of miles away in other trade disputes. It is also noteworthy that even localized trade tensions may have nonlinear economic butterfly effects spreading far and wide (World Bank, 2021). This adds credence to the assertion that balanced, stability oriented cooperation is critical to a just globalization of food system.

5.5. Climate Change and Weather Extremes

New weather risks resulting from climate change threaten food supply chains if not addressed. Heavy rains and floods in the US Midwest in 2019 disrupted grain exports for over 12 weeks as determined by NOAA (2021). Modeling informs that the climate change exacerbates natural disasters affecting crops. The IPCC (2022) predicts 6-8% declines in wheat due to global temperature change in South Asia.

These impacts are quantified through quantitative analyses. According to the OECD (2022), the average cost increase due to unabated shocks maybe range from 5% up to 8%. Given dependence on vulnerable commodities, developing countries find themselves burdened with large adjustment costs. Hence, when production declines, terms of trade worsen under increased dependence on imports.

To promote economic security, international cooperation should shift its attention to mitigation and adaptation. Irrigation, reinforced infrastructure, and resistant varieties could be financed by investments. Insurance and early warning systems enhance coping capacity against increasing disruption risks. Since climate threats increases non-linearly, a precautionary approach means avoiding more costs later on. Coordinated risk reduction effectively manages those risks and protects livelihoods that depend on predictable agricultural supply chains.

5.6. Policy Influences on Resilience

Resilience within agricultural supply chains is significantly influenced by strategic policy settings. One technique that has been seen to be effective in reducing change in prices that result from shortage or surplus is to keep inventory and engage in stock pileage. According to Wossen et al. (2017) this approach assists in reducing undesirable price fluctuations which are unbearable to the poor consumers.

Trade policies that are finely tuned to enable fair access to the markets for agricultural inputs and export markets have also been found to improve the long term competitiveness as Lipinski et al. (2013) pointed out. The increase in trade liberalization is most effective in sourcing production inputs while enhancing export competitiveness in the farm sector.

Another important policy instrument is investments in rural infrastructure according to Poczai and Hynek (2020). Investment in irrigation, in improving transport connectivity of farms to ports, and rural electricity access are some examples which would be critical for raising productivity in the long-run. Thus, social protection programs that ensure minimum income levels for vulnerable populations help to recover rapidly from disruptive shocks since they are not pushed into poverty.

It is also important to have a comprehensive appraisal of the effects of policy on resilience through use of integrated modeling. For example, Schipper et al. (2021) used policy scenarios for modeling their effects on such factors as farm profits, prices, and trade. Such ex-ante policy impact assessments are useful in policy decision making.

Figure 5 Risk Management Tools for Active Investors

The policies also must be well balanced since overly prescriptive policies may lead to high costs to the farms as noted by Leisher et al. (2019). It is stability, transparency and consultation that drive the private investment that propels progress. Integrating resilience considerations ensures that policies have positive impacts on sustainability in the economic, social and even physical environment.

Table 3 Principal institutional and policy instruments to strengthen the resilience of agriculture

Category of Policy/Program	**Examples of Actions**
Market Interventions	- Strategic reserves - Price stabilization funds
Risk Management	- Subsidized crop insurance - Weather index-based insurance
Trade Policies	- Sanitary/phytosanitary standards - Preferential market access rules
Investments	- Rural roads/infrastructure - Irrigation expansion - R&D/extension services
Safety Nets	- Cash/food transfers - Employment guarantee schemes
Regulations	- Seed quality control - Fertilizer standards

As presented in Table 6, there exists a range of policy measures in each of the categories that can be used in a systematic way of developing resilience from the farm gate to the marketplace. The specific design works to promote the producers but safeguard the consumer.

6. Conclusion and Recommendation

Thus, the American agricultural supply chain is an essential link in the global economy despite its exposure to various risks because of the interconnected supply chain system. Even small problems that occur locally have been seen throughout this research to spread non-linearly to cause substantial economic consequences on the system. To counter such risks, a proper and concerted risk management plan should be employed by policymakers, industries, and farming societies. Strategic imperatives that include improvement of policies, technology, risk management, research, sustainability, and supply chain management require aggressive pursuit of full-spectrum recommendations. When used through public-private partnerships and evaluated, such strategies can secure the long-term stability and growth of agricultural markets under transition. It can be done alongside the environmental sustainability and social wellbeing hence the stability of food security across the globe due to the increasing world population and the effects of climatic change. It is therefore crucial to have a coherent approach to enhancing supply chain security from farm to fork through integrated methods.

Recommendations

- **Policy Development**: Governments have the responsibility of coming up with policies that enhance the development of supply chain resilience. This comprises of subsidies and tax credits for increased usage of efficiency improving technologies. Infrastructure investments in transport like roads and ports, storage like cold storage, and irrigation facilities add to capacity. Alternative, production and export diversification should also be encouraged through trade and market access provisions. While impact analyses can help reveal priorities, the later evaluation can help improve the efficiency of policies.
- **Technological Adoption:** Encouraging the use of better technologies on the farms increases resilience. Technologies used in precision agriculture reduce input usage thus reducing costs. Smart sensors control conditions, allowing for early intervention. Blockchain enhances the traceability and transparency within the supply chain. Benefits are demonstrated through pilot projects while training and financing availability ensures that these solutions reach resource poor farmers. Standardization helps to scale out innovations.
- **Risk Management:** Implementing sound risk management frameworks help to evade supply chain risks. Weather-indexed and other subsidies insurance plans protect livelihoods during such devastating events as droughts. Buffer stocks and buffer stocks balance markets during shortages. Enhanced emergency response plans ensure the organization of disaster relief operations. Risk mapping helps in determining which risks should be invested in for mitigation.
- **Research and Collaboration:** Continuous cooperation in the research process enhances the pro-resilience decision-making process. Determining what makes the butterfly effect worse at the systemic level helps in improving the weak-points. Partnerships of government, private sector and universities are transdisciplinary to focus relevant solution-oriented agendas. International information platform supports openly accessible data and information exchange.
- **Sustainable Practices**: Fostering climate resilient agricultural practices helps avoid risks from severe weather events that are escalating due to climate change. Conservation measures try to reclaim eroded soils. Resilience is supported by drought tolerant crops and stress resistant animals. Sustainable practices improve the productivity of the soil and water as protection against potential disruptions of production. Such steps are vital in order to ensure long-term sustainability and stability.
- **Supply Chain Integration**: Greater collaboration between supply chain members allows the utilisation of their competitive strengths. Contracting connects farmers to stable markets thus encouraging incentive investment. Public private logistics hubs enhance accessibility of infrastructure. Coordination in importers, exporters, and transporters enhance distribution streamlined to reduce supply fluctuations. Effective institution enhances cooperation among organizations

Compliance with ethical standards

Disclosure of conflict of interest

No conflict of interest to be disclosed.

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