PRICE TRANSMISSION & DYNAMIC CONNECTEDNESS:

CONSEQUENCES OF US-CHINA TRADE WAR AND THE UKRAINIAN-RUSSIAN WAR IN THE INTERNATIONAL AGRICULTURAL COMMODITY MARKETS

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Abstract

Global agricultural markets face unprecedented challenges from geopolitical tensions, raising concerns about food security and market efficiency. This dissertation examines how the international soybean market's resilience and dynamics respond to major disruptions—specifically the US-China trade war and the Russian-Ukrainian conflict. The research investigates changes in market efficiency, price transmission, and global market integration within the soybean industry during these periods of stress.

The study employs multiple econometric approaches to capture both linear and non-linear market relationships. Methods include Vector Error Correction Models (VECM), Time-Varying Parameter Vector Autoregressive (TVP-VAR) models, Quantile Vector Autoregression (QVAR), Threshold Autoregressive (TAR) and Momentum TAR models, alongside the Diebold and Yilmaz connectedness approach. Monthly time-series data (September 2009–May 2019 (ECI,ECII,ECII) and January 2011–January 2023(ECIII)) from key soybean markets were analysed: Chicago Futures, Rotterdam Port, Paranaguá Port, Rosario markets, and Chinese domestic and futures markets. Moreover, a range of agricultural and energy commodities were studied.

Results reveal a highly efficient and integrated global soybean market with rapid adjustments to long-term equilibrium despite geopolitical disruptions. Chicago Futures emerges as the primary price leader, though traditional methods struggled to detect structural breaks during market shocks. Overall price transmission is symmetric in these studied markets. The TVP-VAR analysis uncovered evolving market hierarchies, with Paranaguá and Rosario Futures emerging as new price leaders alongside Chicago. The multi-commodity QVAR analysis demonstrated that soybeans consistently drive price spillovers across agricultural, energy, and input markets.

This research offers crucial insights for policymakers and market participants navigating an increasingly volatile global commodity landscape. The findings indicate that, although established market mechanisms remain resilient even in the face of trade disputes or armed conflict, the geographic centres of price discovery are shifting. Consequently, it is necessary to adopt adaptive risk management strategies to maintain market stability amid ongoing geopolitical uncertainties.

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Abbreviation List

- ADC: Average Dynamic Connectedness
- ADF: Augmented Dickey-Fuller (test)

- APT: Asymmetric Price Transmission
- AR: Autoregressive (model)
- BDS: Brock, Dechert, Scheinkman, and LeBaron test for non-linearity
- Bar: Barley
- CBOT: Chicago Board of Trade
- CEPEA: Brazilian Center for Advanced Studies in Applied Economics
- CIF: Cost, Insurance, and Freight
- Coil: Crude Oil
- CONAB: Brazilian National Company for Food Supply
- DAP: Diammonium Phosphate
- DF-GLS: Dickey-Fuller Generalized Least Square
- EC: Empirical Chapter
- ECI: Empirical Chapter I
- ECII: Empirical Chapter II
- ECIII: Empirical Chapter III
- ECIV: Empirical Chapter IV
- ECM: Error Correction Model
- ERS: Elliot, Rothenberg, and Stock test
- EU: European Union
- FEVD: Forecast Error Variance Decomposition
- FOB: Free on Board
- FROM: Total aggregate of shocks received by all the markets
- GFC: Global Financial Crisis
- GFEVD: Generalized Forecast Error Variance Decomposition
- GIRF: Generalized Impulse Response Function
- GMO: Genetically Modified Organisms
- IRF: Impulse Response Function
- INASE: Argentina's National Seed Institute
- JB: Jarque-Bera test for normality
- LM: Lagrange Multiplier
- LOOP: Law of One Price
- LWZ: Likelihood Weighted Zone
- MTAR: Momentum Threshold Autoregressive (model)

- NC: Network Connectedness
- NET: Net Total Directional Connectedness
- NPDC: Net Pairwise Directional Connectedness
- NPT: Net Pairwise Transmitter
- Nga: Natural Gas
- OLS: Ordinary Least Squares
- PC: Potassium Chloride (fertilizer)
- PT: Price Transmission
- Q: Quantile
- QR: Quantile Regression
- QVAR: Quantile Vector Autoregression (model)
- SA: Ammonium Sulphate (fertilizer)
- SD: Standard Deviation
- SM: Soybean Meal
- SP: Simple Superphosphate (fertilizer)
- Soil: Soybean Oil
- Sunfl: Sunflower
- TCI: Total Connectedness Index
- T-max: T-maximum
- TAR: Threshold Autoregressive (model)
- TO: Shock distribution from each time series to the entire system
- TVP-VAR: Time-Varying Parameter Vector Autoregression (model)
- US: United States
- USN: DAP (Diammonium Phosphate fertilizer)
- USU: Urea (fertilizer)
- VAR: Vector Autoregressions
- VECM: Vector Error Correction Model
- Wh: Wheat
- λ (lambda): Adjustment speed of the error correction terms
- g-causality: Granger causality
- p: Positive residual
- p1: Positive series residual above the threshold
- p2: Negative series residual below the threshold

Chapter 1: Introduction

This research analyses two major geopolitical conflicts: the US-China Trade War and the Ukrainian-Russian conflict. The aim of this research is to understand how these significant political disruptions have affected the agricultural and energy commodity markets, with a specific focus on the international soybean market.

The geopolitical landscape has always played a crucial role in shaping global markets. The US-China Trade War, which began in 2018, has had profound implications for global trade dynamics (Bown and Kolb, 2021). This conflict, characterized by tit-for-tat tariffs and trade barriers, has disrupted traditional supply chains and forced markets to adapt to new realities. The soybean market has been significantly impacted due to China's position as a major importer of US soybeans. As tariffs were imposed, the flow of soybeans was redirected, causing shifts in prices and trade volumes.

Simultaneously, the Ukrainian-Russian conflict, which escalated in 2014 with the annexation of Crimea by Russia and has continued with ongoing tensions in Eastern Ukraine, has also had significant repercussions for commodity markets (Benabed and Bulgaru, 2022; Jagtap *et al.*, 2022; Kyriazis, 2022; Nasir, Nugroho and Lakner, 2022; Al-Saadi, 2023; Chen, 2023; Zaid and Khan, 2023). Ukraine is a key player in the global agricultural market, particularly in the production and export of grains and oilseeds, including soybeans (da Silva *et al.*, 2023). The conflict has disrupted agricultural production and export logistics, leading to volatility in global markets.

The impact of the US-China Trade War on the soybean market has been profound. Before the trade war, China was the largest importer of US soybeans, accounting for a significant share of US agricultural exports. However, with the imposition of tariffs, China shifted its purchases to other countries, such as Brazil and Argentina. This shift not only affected US farmers but also led to changes in global trade flows and price structures (Choe *et al.*, 2019). The classical price transmission methodology can help trace these changes, analysing how US export prices reacted to the tariffs and how these changes were transmitted to other markets.

In parallel, the Ukrainian-Russian conflict has introduced additional layers of complexity. Ukraine's agricultural sector has faced numerous challenges (Patytska, 2023), including disrupted supply chains and reduced access to critical inputs due to the conflict (Nehrey and Trofimtseva, 2022). These disruptions have led to fluctuations in production and export volumes, affecting global supply and prices. By applying the connectedness approach, this research can explore how these disruptions in Ukraine have produced volatility and prices spillover through the global soybean market and among energy and agricultural commodities.

Furthermore, this research acknowledges that the impacts of geopolitical conflicts are not isolated. The interconnectedness of the global economy means that changes in one region can have far-reaching consequences. For instance, the redirection of soybean trade flows due to the US-China Trade War has implications for other agricultural commodities and markets (Adjemian, Smith and He, 2021). Similarly, disruptions in Ukraine can affect not just soybeans but also other grains and oilseeds, influencing global food security (Hassen and Bilali, 2022; Mottaleb and Govindan, 2023) and market stability.

A comprehensive understanding of how these geopolitical conflicts have influenced the soybean market is achieved by integrating classical price transmission methodologies with the connectedness approach, this study seeks to capture the multifaceted nature of market dynamics. The classical price transmission methodology traditionally focuses on the relationships between prices at different stages of the supply chain, analysing how changes in one market segment affect others. This methodology helps in understanding the speed and magnitude of price adjustments between different market levels. This approach provides insights into the direct impacts of trade disruptions on prices.

On the other hand, the connectedness approach, emphasises the interconnectedness of markets. It considers not just direct price transmissions but also the broader network of relationships that link different markets and commodities. The connectedness approach helps in understanding volatility spillovers and designing risk management strategies (Mezghani and Boujelbène-Abbes, 2023). This approach is particularly useful for understanding the spillover effects of geopolitical events, capturing how shocks in one market can propagate through the entire system.

By combining these methodologies, this research aims to offer a nuanced perspective on the soybean market. The integrated approach allows for a detailed analysis of both direct and indirect effects, providing a more comprehensive understanding of market dynamics. This is crucial for policymakers and market participants who need to navigate the complexities of a globalised market influenced by geopolitical events. With this foundation established, we now turn our attention to the first major geopolitical conflict under study: the US-China Trade War.

1.1. The US-China Trade war

The trade war, which initiated during the Donald J. Trump administration, is an ongoing geopolitical dispute. This conflict includes several confrontations between the United States and China, as well as with U.S. allies, leading to widespread instability in the global economy, the free trade system, and the interconnected and globalised world. Virtually every sector of both the Chinese and American economies has felt the impact of this conflict, experiencing varying levels of consequences. The scope of this situation has influenced global economies to different degrees, either directly or indirectly, contributing to increased volatility and uncertainty in international and domestic markets, thereby hindering trade and investment (Bown and Kolb, 2021).

China is emerging as an ascending superpower (Almotairi, 2021), while the United States is experiencing a decline as the leading world superpower (Valli, 2018). The US government sought to reverse this decline, with the campaign slogan "Make America Great Again." The U.S. government aimed to strengthen the American economy by specifically addressing the trade deficit (Daugirdas and Mortenson, 2018), employing a wide range of tools such as import tariffs, quotas, duties, and threats to achieve trade equilibrium. These measures were directed not only at China but also at U.S. allies. The Chinese government perceived these actions as a direct attempt by the U.S. to hinder China's rise as a leading superpower and becoming the dominant global economy. In response, China implemented various countermeasures to address U.S. policies (Liu and Woo, 2018).

The US-China trade war, a significant economic conflict between the world's two largest economies, began in earnest in 2018 but has roots that extend back several decades. Understanding its origins and development requires examining the historical context of economic relations between the United States and China.

After World War II, China, under the leadership of Mao Zedong, adopted a centrally planned economy, largely isolating itself from global trade. The United States, on the other hand, emerged as a dominant economic power, promoting free trade and capitalism. Diplomatic relations between the two countries were virtually non-existent, especially after the Chinese Communist Party took control of mainland China in 1949 (Rawski, 2000). In 1978, Deng Xiaoping initiated economic reforms in China, shifting from a planned economy to a more market-oriented one. This era marked the beginning of China's integration into the global economy (Harris, 2001). The normalization of diplomatic relations between the United States and China in 1979 cemented the way for increased trade and economic cooperation. China's entry into the World Trade Organisation (WTO) in 2001 was a landmark event, symbolizing its commitment to global trade norms and significantly boosting trade relations with the US (Saich, 2001; Dorn, 2016).

Following its WTO accession, China's economy grew rapidly, becoming the second largest in the world. However, this growth was accompanied by increasing trade imbalances and tensions. The US trade deficit with China peaked, leading to growing concerns in the United States over job losses and unfair trade practices. Accusations against China included intellectual property theft, forced technology transfers, and state subsidies to Chinese companies (Wang, 2003; Hashimov and Aliyev, 2013). In early 2018, the Trump administration began investigating Chinese trade practices under Section 301 of the Trade Act of 1974. As a result of the findings, the U.S. imposed tariffs on $50 billion worth of Chinese imports, accusing China of unfair trade practices and intellectual property theft. In retaliation, China placed tariffs on an equivalent amount of American products, focusing mainly on agricultural goods and automobiles (Yue *et al.*, 2019).

The trade conflict quickly escalated. The US imposed additional tariffs on $200 billion worth of Chinese imports in September 2018, with tariffs ranging from 10% to 25%. China responded with tariffs on $60 billion worth of US goods. Throughout 2019, both countries continued with retaliations and imposing additional tariffs, affecting hundreds of billions of dollars in trade. The conflict caused significant disruptions in global supply chains and increased economic uncertainty worldwide (Tullo, 2019).

Despite the ongoing tariffs, both nations engaged in multiple rounds of negotiations. In January 2020, they signed the "Phase One" trade deal. Under this agreement

China pledged to boost its purchases of American products and services by a minimum of $200 billion over a two-year period, enhancing intellectual property protections, and providing more market access for American companies in financial services. In return, the US agreed to reduce some tariffs but left many others in place (Muhammad and Smith, 2020).

The trade war has had significant economic impacts, including slowed global economic growth and disrupted supply chains (Chen, 2023). Both countries have faced economic challenges, for instance US farmers and manufacturers were hit by tariffs on exports (Sabala and Devadoss, 2019), while China's export-driven economy faced pressure from decreased access to the American market (Jiao *et al.*, 2020).

The trade war between the US and China has led to a slowdown in global economic growth. The escalation of tariffs has negatively impacted global GDP and disrupted supply chains, affecting various industries worldwide. The interconnectedness of global value chains means that the repercussions of the trade war extend beyond the two countries involved, affecting economic stability globally (Itakura, 2020). US farmers and manufacturers have been significantly affected by the tariffs on exports. The imposition of retaliatory tariffs by China has led to a decrease in exports, particularly in the agricultural sector, causing substantial economic distress to American farmers. Additionally, US manufacturers have faced increased costs and decreased demand for their products due to the tariffs and associated supply chain disruptions (Benguria, 2019; Chen *et al.*, 2023)

The trade war between the US and China has led to a slowdown in global economic growth and disrupted supply chains, affecting various industries worldwide. The interconnectedness of global value chains means that the repercussions of the trade war extend beyond the two countries involved, affecting economic stability globally. With an understanding of these impacts, we shift our focus to another critical geopolitical event, the Russian-Ukrainian conflict, which has further shaped the dynamics of global commodity markets.

1.1.1. *Major Agricultural Trade Disputes*

Agricultural trade wars represent critical episodes of economic contention that have repeatedly disrupted global commodity markets, revealing both the vulnerabilities and resilience of international food systems. This section provides a systematic analysis of major agricultural trade disputes throughout recent history, examining their structural causes, immediate market impacts, policy responses, and long-term consequences. By tracing these conflicts chronologically, we can identify evolving patterns of market behavior and policy intervention while drawing comparative insights across disparate episodes.

1.1.1.1. The 1980s Grain Embargo and American "Food Power"

The 1980s commenced with a dramatic assertion of agricultural trade as geopolitical leverage when President Carter implemented a grain embargo against the Soviet Union in January 1980, following the Soviet invasion of Afghanistan. This action represented a pivotal test of American "food power"—the strategic deployment of agricultural exports as a foreign policy instrument. The embargo prohibited new sales of U.S. grain to the USSR beyond the 8 million tons already committed under the U.S.-Soviet Agreement (Paarlberg, 1980).

Market consequences of this unilateral action manifested rapidly. U.S. domestic grain prices declined significantly, with corn prices falling approximately 8% immediately following the announcement (Mustard and Schmidt, 1983). Simultaneously, U.S. export volumes reconfigured dramatically, as the proportion of U.S. coarse grain exports destined for the Soviet market declined from 27.6% to just 5.5% in 1980 (Mustard and Schmidt, 1983). However, the embargo's impact on Soviet agricultural markets proved remarkably limited. The USSR successfully secured alternative grain supplies from Argentina, Canada, and Australia, with Argentine exports to the Soviet Union increasing by 5.9 million tons in 1980 alone (Paarlberg, 1980).

The embargo's ineffectiveness highlighted a fundamental economic reality: unilateral trade restrictions in globally integrated commodity markets often trigger trade diversion rather than target deprivation. The Soviet Union's food supply remained largely unaffected, while U.S. farmers absorbed substantial economic losses. Furthermore, the embargo generated lasting reputational damage to the United States as a reliable supplier, prompting the Soviet Union to diversify its agricultural import sources permanently—a pattern that would recur in subsequent trade conflicts (Paarlberg, 1980).

1.1.1.2. The U.S.-EEC Agricultural Subsidy War

Running parallel to the Soviet grain embargo, a protracted subsidy conflict between the United States and the European Economic Community (EEC) intensified during the early 1980s. Unlike the geopolitically motivated embargo, this dispute centered on competing agricultural support policies. The EEC's Common Agricultural Policy provided substantial export subsidies for European grain, while the U.S. responded with its Export Enhancement Program, creating a mutually destructive subsidy escalation (Anderson and Tyers, 1983).

This subsidy war generated significant market distortions. Anderson and Tyers (1983) estimated that EEC export subsidies depressed world wheat prices by approximately 10.8%, while U.S. retaliatory measures further exacerbated price volatility. The conflict created a paradoxical situation where taxpayers in both regions funded increasingly expensive support programs, yet farmers received diminishing returns as global prices declined under the weight of subsidized overproduction.

Anderson and Tyers (1983) revealed that the welfare losses from this conflict were distributed asymmetrically. U.S. farm revenue losses were estimated at approximately five times larger than those experienced by European producers, partly explaining why European policymakers proved more resistant to subsidy reductions. Furthermore, their analysis indicated that unilateral subsidy withdrawal by either party would have been economically disadvantageous, creating a classic prisoner's dilemma that perpetuated the conflict until multilateral negotiations through the Uruguay Round of GATT finally established disciplinary frameworks.

1.1.1.3. U.S.-Japan Agricultural Trade Frictions

While not classified as a full-scale trade war, persistent agricultural tensions between the United States and Japan throughout the 1980s illustrated how market access restrictions could generate trade-war-like conditions. Japan maintained stringent import quotas on rice, beef, and citrus products, protecting domestic producers but creating substantial trade frictions with the United States, its largest agricultural supplier (Peterson, 1988).

The 1984-1988 U.S.-Japan beef negotiations provide a case study in gradual market Liberalisation. Japanese import restrictions maintained domestic beef prices at levels approximately 3-4 times the world price, creating substantial welfare losses for Japanese consumers and market opportunities for American producers (Peterson, 1988). Unlike the confrontational approaches characterizing other trade disputes, these negotiations resulted in phased market opening, with Japan agreeing to gradually expand import quotas rather than facing retaliatory tariffs.

The Liberalisation generated significant market effects. As Japan expanded beef import quotas in the late 1980s, domestic beef prices declined by approximately 7% annually, demonstrating how even partial barrier removal could initiate price convergence. This negotiated approach, while slower than unilateral Liberalisation, ultimately proved more sustainable and avoided the market disruptions characteristic of retaliatory trade wars. (Gaesser *et al.,* 2020)

1.1.1.4. The EU-U.S. Banana Trade Conflict

The 1990s witnessed a protracted dispute between the European Union and the United States regarding the EU's preferential banana import regime. Though not primarily an agricultural nutrition staple for either region, bananas became the focus of a significant trade conflict with substantial implications for global agricultural governance. The EU's preferential system, designed to benefit former colonies in Africa, the Caribbean, and Pacific regions, effectively discriminated against Latin American producers and U.S. distribution companies (Borrell, 1999).

This dispute's distinctive feature was its progression through formal WTO dispute settlement mechanisms, representing an evolution from the unilateral actions of previous decades. Borrell's (1999) partial equilibrium modeling quantified substantial welfare effects, including tens of millions of dollars in losses for EU consumers paying above-market prices and significant efficiency losses for Latin American producers due to market access restrictions.

When the WTO authorized U.S. retaliation in 1999, the U.S. implemented selective tariffs targeting politically sensitive EU exports rather than imposing broad agricultural barriers. This strategic targeting—focusing on products like French cheese and Italian handbags—demonstrated an increasingly sophisticated approach to trade retaliation, maximizing political pressure while minimizing domestic economic disruption. The dispute's eventual resolution in 2001 reinforced the WTO's role in disciplining preferential trade arrangements, though implementation delays highlighted the challenges of enforcing multilateral trade rules.

1.1.1.5. The EU-U.S. Beef Hormone Dispute

Concurrent with the banana conflict, the EU-U.S. beef hormone dispute centred on non-tariff barriers, specifically the EU's 1989 prohibition of hormone-treated beef imports. This case illustrates the tension between trade Liberalisation and regulatory sovereignty, particularly regarding food safety standards. The EU ban virtually eliminated American and Canadian beef from European markets, despite scientific risk assessments indicating negligible human health concerns.The North American beef industries lost approximately $250 million annually from the lost European market. Unlike price-based disputes, this regulatory conflict created a binary market access situation. Producers either met EU standards or faced complete exclusion. When the WTO ultimately authorized U.S. retaliation in 1999, the U.S. imposed 100% tariffs on approximately $116 million of European luxury food products, creating targeted pressure on politically influential EU constituencies(Johnson, 2015)

EU consumers paid 5-10% higher prices for beef, EU producers benefited from reduced competition, and North American producers experienced modest domestic price declines as exported product was redirected to home markets. Unlike other trade conflicts, this dispute persisted for decades, with only partial resolutions through negotiated tariff-rate quotas for hormone-free beef, demonstrating how regulatory disputes prove particularly resistant to conventional trade remedies.

1.1.1.6. Export Restrictions During the 2007-2008 Global Food Price Crisis

The 2007-2008 global food price crisis triggered a cascade of export restrictions that, while not constituting a bilateral trade war, created multilateral trade disruptions with profound market consequences. As international grain prices surged, more than 30 countries imposed export restrictions aiming to protect domestic consumers, including major exporters such as Russia, Ukraine, Vietnam, and India. These measures, though domestically motivated, collectively generated trade-war-like market conditions (Clapp, 2009)

Martin and Anderson (2012) revealed that these trade policy interventions significantly amplified price volatility. Their estimates indicate that approximately

45% of the rice price spike and 30% of the wheat price increase were attributable to export restrictions rather than underlying supply-demand fundamentals. For instance, when India banned non-basmati rice exports in October 2007, followed by Vietnam's restrictions in early 2008, global rice prices approximately doubled, with nearly half that increase attributable to policy responses (Martin & Anderson, 2012).

This episode demonstrated a collective action problem in agricultural trade governance. Each country's attempt to insulate domestic markets exacerbated global price volatility, ultimately undermining food security objectives.This crisis revealed critical gaps in multilateral disciplines on export restrictions, spurring subsequent G20 discussions on food security cooperation, though with limited binding commitments.

1.1.1.7. Russia's Agricultural Import Ban Following the Ukraine Crisis

The 2014 Ukraine crisis precipitated a significant agricultural trade conflict when Russia imposed import bans on food products from the European Union, United States, Canada, Australia, and Norway in response to Western sanctions. This politically motivated trade restriction created substantial market disruptions across multiple commodity sectors, with particularly severe impacts on European dairy, fruit, and meat exports to what had been their largest external market (Dragoi, 2018).

Market impacts manifested asymmetrically across commodities and regions. EU agri-food exports to Russia plummeted by approximately €5.3 billion between 2013 and 2016, representing a 43% decline (Dragoi, 2018). Price effects were similarly heterogeneous: Russian dairy prices increased sharply, rising by approximately 20% in 2014-2015 due to supply shortfalls, benefiting domestic producers but harming consumers (Yormirzoev & Teuber, 2017). Simultaneously, EU milk prices declined between 10-20% as processors scrambled to find alternative markets for previously Russia-bound production (Kapsdorferová & Sviridova, 2016).

Trade flows reconfigured significantly as market participants adapted. EU exporters redirected products to alternative markets, primarily in the Middle East, North Africa, and Asia, though often at lower prices. Russia increased imports from non-sanctioned countries, particularly Belarus, Brazil, and Turkey, while also expanding domestic production through import substitution policies. By 2018, analyses suggested that removing the ban would have had only limited effects on EU agriculture, indicating that a new market equilibrium had formed despite the continuing restrictions (Drăgoi, 2018).

This conflict demonstrated how geopolitically motivated trade restrictions can trigger structural market changes beyond short-term price effects. Russian self-sufficiency in previously imported products increased significantly; for example, cheese production rose sharply after 2014 as part of import substitution policies (Tleubayev et al., 2018). Neighbouring countries developed new specializations around sanctions evasion, with Belarus becoming a significant re-exporter of European products to Russia through processing and repackaging operations (Kašťáková et al., 2018).

1.1.1.8. Comparative Analysis and Emerging Patterns

This chronological examination of major agricultural trade conflicts reveals several consistent patterns with significant implications for market participants and policymakers. First, trade restriction impacts consistently manifest through both price and quantity adjustments, though their relative importance varies with market structure and product characteristics. For fungible commodities with global markets (e.g., soybeans, wheat), price effects often dominate as arbitrage opportunities emerge. Conversely, for specialized products with limited substitution possibilities (e.g., certain fruits, specific cuts of meat), quantity adjustments predominate as markets segment.

Second, trade diversion represents a universal response across all observed conflicts. When established trade flows are disrupted by policy interventions, market participants invariably seek alternative suppliers or buyers, though with varying efficiency. This reconfiguration frequently benefits third parties not directly involved in the dispute—Argentina during the Soviet grain embargo, Brazil during the U.S.-China conflict, and Belarus during the Russia-EU sanctions. However, these diverted trade flows typically involve higher transaction costs and reduced efficiency compared to pre-disruption patterns.

Price transmission mechanisms potentially exhibit asymmetric characteristics in global agricultural markets, especially during trade conflicts and trade policy disruptions. Empirical analyses show that tariff shocks often trigger faster price increases compared to the slower transmission of price decreases when market conditions improve (Meyer & von Cramon-Taubadel, 2004). This asymmetry is also evident across different stages of supply chains, where price shocks originating from international trade events are transmitted more strongly to wholesale and retail prices than back to producers (Verreth *et al.,* 2015). Together, this evidence underscores that asymmetric price transmission is not just a theoretical possibility, but an observed and persistent feature of agricultural markets exposed to trade conflicts.

When markets are artificially segmented through tariffs or bans, price signals propagate unevenly across regions and supply chain segments. This asymmetry typically manifests in three dimensions: magnitude (price changes differ between regions), speed (adjustment rates vary), and direction (increases and decreases transmit differently). These asymmetries reveal underlying power dynamics and market structures that may remain obscured during normal trading conditions.

Finally, government interventions frequently amplify or moderate market adjustments through compensatory policies. These include direct producer payments, stockpile releases, alternative market development programs, and domestic subsidies. Such interventions have grown increasingly sophisticated and substantial over time, from modest support during the 1980 grain embargo to the unprecedented scale of payments during the 2018 U.S.-China conflict.

The evolution of trade conflict patterns also reveals significant shifts in resolution mechanisms. Early disputes (1980s-1990s) increasingly moved toward multilateral frameworks, culminating in WTO dispute settlement for the banana and beef hormone cases. However, more recent conflicts have reverted to bilateral negotiations (U.S.-China Phase One) or remained unresolved for extended periods (Russia's import ban), suggesting a partial retreat from multilateral solutions.

This historical progression demonstrates that while agricultural markets display remarkable adaptability to trade disruptions, policy-induced market segmentation generates substantial efficiency losses and redistributes welfare in often unpredictable ways. The recurring nature of these patterns across diverse temporal and geographic contexts suggests fundamental dynamics in how agricultural trade systems respond to policy interventions—insights that can inform both theoretical modelling and practical risk management strategies for future disruptions.

1.2. Russian-Ukrainian Conflict

The Russian-Ukrainian conflict, which began in 2014 and escalated dramatically in 2022, is one of the most significant geopolitical events of the 21st century. This conflict has not only reshaped the political landscape of Eastern Europe but has also had far-reaching implications for the global economy (Limonova, 2022), particularly in the agricultural commodity markets (Nasi*, et al.,* 2022) and energy (Alwan and Hammadi, 2023; Nikulina and Sotnyk, 2023). Comprehending the nuances of this conflict and its economic repercussions is essential for understanding the intricate interconnections within international markets.

The origins of the Russian-Ukrainian conflict lie in a long and complex history of both shared and disputed events spanning several centuries (Sasse, 2001). Ukraine, often referred to as the "borderland" or “Kresy” (the semi-official name) between Europe and Russia, has been a focal point of geopolitical struggles for dominance. Following the collapse of the Soviet Union in 1991, Ukraine emerged as an independent nation, but its journey towards sovereignty has been fraught with challenges (Luke, 2022).

In November 2013, widespread protests, known as the Euromaidan movement, erupted after President Viktor Yanukovych chose to abandon an association agreement with the European Union in favor of strengthening relations with Russia (Metzger and Tucker, 2017). These protests culminated in Yanukovych's ousting in February 2014. Seizing this opportunity, Russia annexed Crimea in March 2014, a move that was met with international condemnation and sanctions (McDougal, 2015).

The situation further deteriorated as pro-Russian separatists in Eastern Ukraine, with support from Moscow, declared independence in the Donetsk and Luhansk regions, leading to a protracted and bloody conflict (Mdzinarshvili and Sa’atun, 2022). Despite numerous attempts at ceasefires and peace agreements, including the Minsk agreements, the conflict remained unresolved. The conflict took a dramatic turn on February 24, 2022, when Russia launched a full-scale invasion of Ukraine. This aggressive move was justified by the Kremlin as a "special military operation" aimed at "demilitarizing and denazifying" Ukraine (Lutskyi and Push, 2022). The invasion was widely condemned as an unprovoked act of aggression, leading to unprecedented sanctions against Russia by the international community (Nur and Soesilo, 2022; Hutsaliuk, 2023).

The invasion marked a significant escalation in hostilities, with widespread destruction and a massive humanitarian crisis. Cities such as Mariupol, Kharkiv, and Kyiv faced intense bombardment, resulting in thousands of civilian casualties and displacing millions of Ukrainians (Awuah *et al.*, 2022; Dzhus and Golovach, 2022; Haque *et al.*, 2022). The conflict has heightened geopolitical tensions globally, leading to increased energy supply shocks and commodity price volatility. Sanctions imposed on Russia by Western countries have caused ripple effects throughout the global economy, contributing to rising global inflation (Balbaa, Eshov and Ismailova, 2022; Al-Saadi, 2023).

The imposition of extensive sanctions on Russia (Appendix III.) by western countries including the United States, the European Union, the United Kingdom has had a ripple effect across the global economy. These sanctions targeted key sectors, including finance, energy, and technology, aiming to cripple Russia's economic capabilities. As a result, Russia's GDP contracted significantly, inflation soared, and the Ruble experienced extreme volatility (Gordievich and Ruzanov, 2023). The conflict also led to a sharp rise in global commodity prices. Energy prices, particularly oil and natural gas, surged due to disruptions in supply. The sanctions and subsequent countermeasures disrupted trade routes, leading to increased costs and logistical challenges for businesses worldwide (Chen, 2023).

Ukraine, often referred to as the "breadbasket of Europe," is a major exporter of wheat, maize barley, and sunflower oil. The conflict severely disrupted agricultural production and export activities. Key agricultural regions in Eastern Ukraine became battlegrounds, causing significant damage to infrastructure and farmlands. Blockades of Ukrainian ports and damage to transportation networks hindered the export of agricultural products, leading to logistical challenges and price hikes. Countries heavily dependent on Ukrainian grain, particularly in Africa and the Middle East, faced acute food security challenges (Ostashko, 2022) Furthermore, the MENA region has already been impacted by climate change, significantly affecting its agricultural production (Waha, 2017).

The war has impacted various sectors beyond agriculture and energy. For instance, it has contributed to significant price increases in strategic commodities and has affected global financial markets. The resulting inflationary pressures have had widespread economic consequences, affecting both developed and developing nations (Omerani and Oummou, 2023; Zaid and Khan, 2023).

Rising food prices and shortages have raised alarms about global food security (Chart 1). Countries dependent on Ukrainian exports are experiencing severe food inflation, affecting millions. Countries heavily dependent on Ukrainian exports, such as those in the Middle East and North Africa (MENA), have experienced severe food inflation. This inflation has exacerbated existing vulnerabilities and has posed a significant challenge to maintaining food security (Travnikar and Bele, 2022; Kapelista *et al.*, 2023). Humanitarian responses have been crucial in addressing these shortages, but long-term solutions are needed to stabilize the market (Ostashko, 2022)

Chart 1 Global Food Prices Surge Amid Russia-Ukraine War

The Russian-Ukrainian conflict has significantly disrupted food production in Ukraine, a major global supplier of wheat, soybeans, and maize (Appendix II). This disruption has led to a dramatic increase in global food prices and posed a serious threat to food security, particularly for low-income countries reliant on these imports. Having analysed the shifts in U.S. trade and the far-reaching impacts of the Russian-

Ukrainian conflict, it becomes imperative to understand how these developments affect crucial agricultural commodities such as soybeans.

1.3. Global Importance of the Soybean Market

Soybeans are one of the world's most strategically important agricultural commodities, underpinning food security and multiple industrial sectors. They serve as a critical source of protein for both direct human consumption (in products such as tofu, soy milk, and various soy-based foods) and, more importantly, for indirect consumption via animal feed. The vast majority of soybeans are processed to extract soybean meal and oil. The high-protein soybean meal, which typically contains 44–50% protein, is an essential ingredient in the feed formulations for poultry, swine, cattle, and aquaculture, thereby underpinning intensive livestock and poultry industries globally (FAO, 2023). Soybean oil, in addition to its predominant role as an edible oil, is increasingly used as a feedstock for biofuels, particularly biodiesel. This versatility (in food, feed, oil, and fuel)renders the soybean market strategically vital to global food systems and energy policies (USDA-FAS, 2024).

In terms of scale, the soybean market is enormous and continues to expand. Global soybean production has seen remarkable growth over the past few decades, driven by rising demand. For instance, world output increased from approximately 231 million tonnes in 2008 to 353 million tonnes in 2020, and production rebounded to record levels of around 388 million tonnes in 2021 (FAO, 2023). Projections for the 2024/25 marketing year even approach 420 million tonnes. This exponential increase from mid-20th century levels demonstrates the growing global importance of soybeans. Expansion has been driven both by an increase in the area cultivated (for example, the conversion of pasture and savannah lands in South America into soybean farms) and by yield improvements brought about by technological advancements and improved agronomic practices (USDA-FAS, 2024).

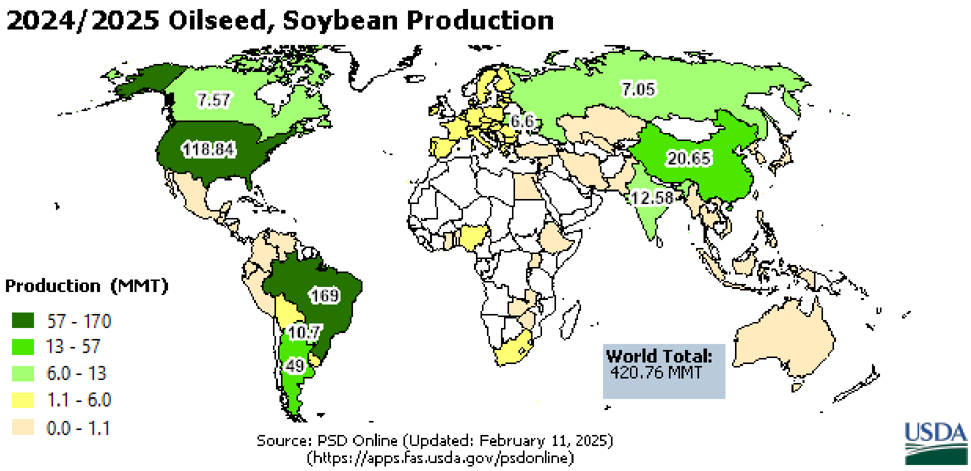
The significance of soybeans is also underscored by their role in international trade. When combined with their derivative products (soybean meal and oil), soybeans represent the most traded agricultural commodity in the world by value, accounting for nearly 9% of global agricultural trade. In 2023, global soybean exports were valued at over US$92 billion, reflecting the immense economic scale of the market. Approximately half of all soybeans produced are exported to meet the demand in countries that lack sufficient domestic production, making foreign exchange earnings from soybean exports a major income source for producing nations, while importing countries rely on these exports for their food and feed industries (Valdes *et al.,* 2023).

Soybeans are deeply embedded in the global food supply chain. Soybean meal has become the dominant protein meal in animal nutrition, far surpassing other oilseed meals, while soybean oil is the second most produced edible oil globally after palm oil. As of 2021, soybean oil contributed about 29% to global vegetable oil production, underlining its critical contribution not only to the edible oil market but also as a key input for biodiesel production (United Soybean Board, 2022). Overall, the multifaceted applications and expansive scale of the soybean market emphasize its strategic importance across both food security and energy policy frameworks.

1.3.1. *Main Producers and Exporters*

Soybean production is highly concentrated in a few key geographic regions. The Americas dominate global soybean output, with the United States, Brazil, and Argentina collectively accounting for over 80% of the world's production. Table 1 provides an overview of the top soybean-producing countries, where Brazil and the United States lead with each harvesting well over 100 million tonnes in recent years, while Argentina ranks third. These countries benefit from vast tracts of arable land, favorable climates, and advanced agricultural industries that enable massive production scales (FAO, 2023).

Figure 1. Global Soybean Production by Country (2024/25 Projections).



Note: The figure illustrates that Brazil, the United States, and Argentina collectively account for the majority of global soybean output.

Historically, the United States was the dominant producer and exporter of soybeans. However, over the past 20–30 years, Brazil has emerged as the world's single largest soybean producer. In 2022, Brazil contributed approximately 35% of global soybean output, while the United States produced roughly 33% (USDA-FAS, 2024). This shift reflects Brazil's rapid expansion, driven by the development of new agricultural frontiers in the Cerrado, the adoption of improved tropical soybean varieties, and robust global demand. Brazilian soybean output increased more than fourfold from 2004 to 2023, and by 2013 Brazil overtook the United States as the leading exporter of soybeans. In contrast, U.S. production has grown more modestly (roughly doubling from the early 2000s to the early 2020s),before plateauing in recent years. Argentina, although a significant producer, typically contributes around 8–12% of world production and experiences more pronounced fluctuations due to weather variations associated with phenomena such as El Niño and La Niña (Colussi *et al.,* 2024).

On the export side, the dominance of the United States and Brazil is even more pronounced. Countries like China and India, which are major soybean consumers, use most of their domestically produced soybeans and thus do not contribute significantly to exports. Consequently, the surplus production in Brazil and the United States drives international trade. In the 2021/22 marketing year, the United States and Brazil together accounted for nearly 90% of global soybean export volume. In 2023, Brazil's soybean exports reached an all-time record of approximately 102 million tonnes, marking a 29% increase from the previous year, while U.S. exports amounted to around 49 million tonnes (USDA-FAS, 2024). These figures underscore that Brazil and the United States are the principal engines of global soybean export supply.

It is noteworthy that Argentina, despite being the third-largest producer, processes most of its soybeans domestically and is a leading exporter of soybean meal and oil rather than raw soybeans. This is largely due to domestic policies that incentivize value-added processing through export tax structures. In contrast, Brazil and the United States primarily export whole soybeans, which then enter global value chains for further processing and distribution.

Table 1. Top Soybean Producers (2021) (Million Tonnes)

Country	Production (Mt)
Brazil	134.8
United States	121.5
Argentina	46.2
China	16.4
India	12.6
World Total	372.9

Source: FAO (2023).

1.3.2. *Main Importers and Consumers*

On the demand side, the global soybean market is driven predominantly by a few key importers, with China by far the largest. China's transformation into the world's largest soybean consumer and importer has been one of the most dramatic shifts in global agriculture over the past two decades. Rapid economic growth, rising incomes, and a shift in dietary patterns toward increased meat and poultry consumption have created an immense need for high-protein animal feed. As domestic soybean production in China is limited and primarily focused on food-grade soy products, the country has increasingly relied on imports to meet the demand for soybean meal. Chinese soybean imports have surged from approximately 15 million tonnes in 2000 to over 95 million tonnes in 2020, and China currently accounts for roughly 60–65% of total global soybean imports (USDA-FAS, 2021; IISD, 2024).

The European Union (EU) is the second-largest soybean importer, though its volumes are much smaller in comparison to China. The EU imports approximately 14–15 million tonnes annually, primarily to meet the high-protein feed requirements of its pork and poultry sectors, as well as for direct food processing and biodiesel production. Major EU importers include the Netherlands, Spain, Germany, and Italy. While the EU also imports soybean meal directly, whole soybean imports continue to be significant, accounting for about 8% of global trade (USDA-FAS, 2021).

After China and the EU, a number of smaller markets collectively contribute to global soybean imports. For example, Mexico is typically the third-largest importer, bringing in around 4–6 million tonnes annually to support its livestock feed and food processing sectors. Japan, Thailand, Egypt, Turkey, Indonesia, and Taiwan also represent significant markets, each importing between 1–3 million tonnes per year, depending on the scale of their domestic livestock industries and processing capacities.

Table 2. Major Soybean Importers (Annual Imports 2020–2021)

Country	Production (Mt)
Brazil	134.8
United States	121.5
Argentina	46.2
China	16.4
India	12.6
World Total	372.9

Source: USDA-FAS (2021).

China’s outsized role in the soybean market is driven primarily by its need to feed nearly one-fifth of the world’s population, as well as approximately half of the global pig population. The country’s heavy investment in soybean crushing infrastructure has allowed it to become one of the largest processors of soybeans into meal and oil. Policy shifts, such as the removal of soybean import quotas after China joined the World Trade Organisation in 2001, further fueled the surge in imports. Consequently, Chinese demand is now the primary engine of the global soybean market, with any shifts in China’s purchasing patterns having immediate effects on global prices and trade flows (USDA-FAS, 2021).

In contrast, while the EU's demand is significant, it is less volatile and is primarily driven by its robust meat and dairy sectors. The EU also emphasises biofuel production, thereby creating a dual demand for both soybean meal and oil. Other regions such as Southeast Asia, the Middle East, and North Africa have seen growing soybean imports as their livestock and poultry sectors expand in tandem with economic growth. In some instances, even traditionally producing countries like Argentina become importers to ensure continuous operation of domestic processing facilities, especially during periods of crop shortfalls.

1.3.3. *Global Trade Flows and Economic Significance*

The dynamics described above result in massive international trade flows of soybeans, both in terms of volume and monetary value. Annually, approximately 175–180 million tonnes of soybeans are traded internationally—roughly half of global production. South American producers, particularly those in Brazil and Argentina, contribute over 100 million tonnes in exports annually, while North America adds more than 50 million tonnes. The primary trade routes lead from the Atlantic and Gulf Coast ports of the Americas to the major consuming regions in East Asia and Europe (ITC, 2024).

In 2022, global soybean exports were valued at about US$93 billion, nearly doubling the value observed just five years earlier. By 2023, despite some price fluctuations, the export value remained historically high at approximately US$92 billion. Brazil and the United States are responsible for the majority of this trade value; in 2023, Brazil earned around US$53 billion from soybean exports while U.S. exports were valued at approximately US$28 billion (ITC, 2024). On the import side, China's dominance is underscored by the fact that its soybean imports were valued at about US$59 billion in 2023, constituting roughly 66% of global import value.

The flow of soybeans (from the Americas to East Asia and Europe) can be visualized as a network of thick trade streams. For instance, in 2023, approximately 70% of China's nearly 100 million tonnes of imports originated from Brazil, with around 24% sourced from the United States. This means that nearly 70 million tonnes of soybeans were shipped from Brazilian ports to China in a single year. European imports, while much smaller in volume, come from a diverse set of suppliers including Brazil, the United States, and occasionally Canada or Ukraine. Such trade patterns underscore the significant economic stakes involved for both exporting and importing nations, as well as the strategic interdependencies that exist within the global soybean market (TrendEconomy, 2024).

1.3.4. *Role of Emerging Markets*

The rise of emerging markets has fundamentally reshaped global soybean trade dynamics over the past two to three decades. Economic growth in developing countries has led to rapid urbanization, higher incomes, and significant shifts in dietary patterns, often referred to as a "nutrition transition." A critical aspect of this transition is an increased consumption of animal protein, which in turn drives up demand for animal feed ingredients such as soybean meal. China's transformation from a self-sufficient oilseed producer in the 1990s to the world's largest soybean importer in the 2000s is a prime example of this phenomenon (IISD, 2024).

However, China is not the sole emerging market influencing soybean trade. Across Asia, several countries, including Thailand, Vietnam, Indonesia, and Malaysia, have experienced economic booms that have driven increases in soybean imports. Although each country's import volume is relatively modest compared to China's, their collective demand contributes significantly to global trade growth. Additionally, regions in the Middle East and North Africa are expanding their soybean imports to support growing poultry industries and overall feed requirements. Even Mexico has steadily increased its imports as its food processing and livestock industries have expanded (USDA-FAS, 2021).

These shifting dynamics have prompted exporters to diversify their markets. For instance, U.S. soybean exporters have increasingly targeted markets in Southeast Asia, the EU, and the Middle East to reduce over-reliance on China. Conversely, Brazil has further entrenched its role as the primary supplier to Asia, with nearly three-quarters of its soybean exports destined for China. This realignment is not only a response to changing demand patterns but also a strategic adaptation to geopolitical risks and market diversification needs (Colussi *et al.,* 2024).

Moreover, emerging economies are beginning to contribute as producers and exporters as well. Ukraine, for example, expanded its soybean production and exports significantly in the 2010s, supplying both the EU and China until disruptions from conflict in 2022. Some African and Asian countries have also initiated soybean cultivation with the support of international donors or strategic investments from major consuming countries. These changes are likely to further alter the traditional dynamics of global soybean trade in the coming decades.

Brazil's export surge has reshaped global soybean trade. Brazil's exports quadrupled between 2004 and 2023, reducing the U.S. share of world trade (Ash and Dohlman, 2007; Colussi *et al.,* 2024). Today, Brazil's crop outcomes significantly affect world prices. A bumper crop in Brazil can pressure global prices downward, while a drought can send them spiking (OECD/FAO, 2021).

Argentina's crushing sector dominates the meal market. When Argentine output falters, global meal supplies tighten unless Brazil (or the U.S.) compensates by shipping more beans or meal (Zulauf, 2023). These multiple export sources can stabilize availability, though they also mean any local shock quickly reverberates internationally (Avileis and Mallory, 2021).

The rise of multiple major exporters introduces both supply diversification and new uncertainties. Integration means that a shock in one region (e.g., Brazilian trucking strikes or Argentine policy shifts) can quickly spill over into global prices (Xue et al., 2023). Studies show that volatility spillovers between U.S. and Brazilian markets have intensified; Brazil is now large enough that turmoil there can drive U.S. price fluctuations (Avileis and Mallory, 2021).

Overall, having more key suppliers can dampen volatility if one region compensates for shortfalls in another, but it also expands the set of risk factors (weather in two hemispheres, multiple currencies, varied policies) that can unsettle the market (OECD/FAO, 2021).

1.3.5. *Trends and Structural Changes in the Soybean Market*

The global soybean market is subject to continuous evolution driven by multiple structural factors and trends. Key drivers include population and income growth, dietary shifts, biofuel policies, environmental concerns, and geopolitical developments. Understanding these trends is essential for contextualizing the market and guiding future research.

1.3.5.1. Population Growth and Dietary Shifts

The world's population is projected to reach 9.7 billion by 2050, and increasing incomes in developing countries have led to a rising demand for protein-rich foods. This demand is reflected in the growing consumption of meat, eggs, and dairy products, which in turn boosts the need for soybean-based animal feed. Although some developed countries are experiencing trends towards vegetarian and plant-based diets, the overall global impact remains minor compared to the surging demand driven by expanding middle classes in emerging economies (USDA-FAS, 2021).

1.3.5.2. Biofuels and Renewable Energy Policies

Environmental and energy policies have also had a significant impact on the soybean market. Soybean oil is a key ingredient in biodiesel production, and policies promoting renewable energy such as the U.S. Renewable Fuel Standard and biodiesel mandates in the European Union, have increased the demand for soybean oil. These policies have, in some instances, led to a surge in domestic crushing and processing activities, further reinforcing the economic importance of soybeans as both a food and energy commodity (United Soybean Board, 2022).

1.3.5.3. Trade Policies and Geopolitical Tensions

International trade policies and geopolitical events exert substantial influence over soybean flows and prices. The U.S.–China trade war of 2018–2019, for example, led to a dramatic shift in soybean trade as China imposed tariffs on U.S. soybeans, prompting a rapid pivot to Brazilian supplies. Similarly, geopolitical events such as Russia’s invasion of Ukraine in 2022 have disrupted global commodity markets, indirectly affecting soybean prices by increasing energy and fertilizer costs. Such events highlight the vulnerability of the soybean market to political and economic shocks and underline the importance of diversified trade relations (ITC, 2024).

1.3.5.4. Environmental and Sustainability Regulations

Environmental concerns, particularly deforestation in key soybean-producing regions such as the Amazon and Cerrado, have spurred the adoption of sustainability measures. The European Union’s 2023 regulation on deforestation-free products, for example, requires proof that imported soybeans are not sourced from recently deforested land. These measures compel exporters to adopt more transparent and sustainable practices, which may reshape trade flows and production practices over time. In parallel, certification schemes such as those promoted by the Round Table for Responsible Soy are gaining traction, even if their market share remains limited (European Commission, 2023).

1.4. Price transmission key concepts

Price transmission is a fundamental concept in economics, reflecting how price changes at one level of the supply chain affect prices at another. It is essential for understanding the dynamics of market efficiency, competition, and economic welfare. Price transmission can occur vertically within the same supply chain or horizontally across different markets (Meyer and von Cramon-Taubadel, 2004). For example, horizontal or spatial price transmission occurs among different international markets for soybeans, while vertical price transmission takes place within the supply chain.

This process is crucial in the context of agricultural and food markets, where it influences both producers' and consumers' decisions. The concept of price transmission encompasses the mechanisms through which price changes at the production level are reflected in retail prices. The degree and speed of this transmission can be influenced by various factors, including market structure, the presence of intermediaries, and the nature of the goods involved (Meyer and von Cramon-Taubadel, 2005).

For instance Lloyd (2017), emphasises the significant role of the food industry in mediating price signals between agricultural producers and consumers, revealing complex interactions in the food chain where retail data provide nuanced insights into price transmission dynamics. Understanding the fundamental concepts of price transmission is crucial for comprehending how price changes at one level of the supply chain affect prices at another. Building on this foundation, we now delve into the specifics of asymmetric price transmission, which explores the variations in price adjustments in different segments of the supply chain.

1.4.1. *Asymmetric price transmission (APT)*

If a shock occurs which effects the international price of soybean, and the farmer's price remains the same, then there is no price transmission. However, if there is an increase in international prices but the increase in farmers’ prices is not proportional, then there is asymmetrical price transmission. This asymmetrical price transmission can be different in each part of the supply chain, depending on the speed of the transmission. The asymmetrical price transmission can be either temporary or permanent (Meyer and von Cramon-Taubadel, 2004)**.** The direction of the asymmetry can result in positive or negative asymmetrical price transmissions. A positive price asymmetry is when shocks occur, and farmer prices react faster to increases in the international prices than to decreases in those prices. On the other hand, when farmers' prices react faster to a decrease rather than an increase in the international prices, then this is a case of negative asymmetry (Vavra and Goodwin, 2005). Peltzman (2000), affirmed that asymmetrical price transmission is structural and behaves as a rule rather than the exception in most cases.

Having examined the nuances of asymmetric price transmission and its implications for market dynamics, we now turn to a foundational theory that underpins competitive pricing behaviours in interconnected markets: the Law of One Price. This theory explains how price equilibrium is achieved across markets linked by trade.

1.4.2. *The Law of One Price*

Transmissions of price signals are based on concepts related to competitive pricing behaviour. The underpinning theory is the *Law of One Price* (LOOP) (Fackler and Goodwin, 2001). This law explains that in a free-market regime, in markets linked by trade, the price of a commodity in market A should be the same as the commodity price of Market B. The only difference in prices should be the cost of a transaction such as transport costs or taxes. If there is a difference in prices between both markets, excluding the transaction cost, this will generate opportunities for arbitrage. Market agents will exploit the arbitrage opportunities between both markets, and the price gaps between both markets will be closed, reaching a new price equilibrium between both market A and B prices in the long term. The standard price determination models (Enke, 1951; Samuelson, 1952; Takayama and Judge, 1972) define a complete price transmission when the equilibrium price of a commodity is reached, expressed in the same currency for a domestic and foreign market (competitive markets), and only differing by transfer cost. According to this model's predictions, any changes in demand or supply conditions in one market will affect the price, and consequently affecting the second market price until the new equilibrium is reached through spatial arbitrage.

With an understanding of how prices in different markets converge under the Law of One Price, it is essential to consider the broader implications of market interconnectedness. The Connectedness Index or Risk of Spillover framework provides valuable insights into how volatility in one market can propagate through various markets, highlighting the importance of monitoring these spillovers to maintain financial stability.

1.4.3. *Connectedness Index or Risk of Spillover*

Financial crises are notably recurrent and exhibit striking resemblances, during such crises, the volatility in financial markets typically surges and proliferates through various markets (Reinhart and Rogoff, 2008). There is a natural inclination to quantify and oversee these spillovers to establish ‘‘Early Warning Systems’’ (EWS) for impending crises and to monitor ongoing ones. For instance, Manzoor (2016), discusses the importance of EWS in maintaining financial stability by forecasting potential crises and taking pre-emptive measures. These systems are particularly vital for developing countries where robust prediction instruments are needed to avert financial disruptions.

In this context, Diebold and Yilmaz (2009) presented a measure for volatility spillover, relying on forecast error variance decompositions from vector autoregressions (VARs). This measure can be applied to assess spillovers in returns or return volatilities, among other return characteristics, spanning individual assets, asset portfolios, and asset markets, both intra and internationally, unveiling trends, cycles, and bursts in spillovers. Importantly, while it provides insightful data, it avoids contentious debates surrounding the definition and occurrence of ‘‘contagion’’ or ‘‘herd behaviour’’.

However, the framework by Diebold and Yilmaz (2009) poses several limitations, both in methodology and substance. On the methodological front, this methodology depends on the Cholesky-factor identification of VARs, making the resulting variance decompositions potentially sensitive to variable sequencing (Diebold and Yilmaz, 2012a). A more desirable spillover measure would be one indifferent to such ordering. Moreover, this methodology addresses only aggregate spillovers, leaving a need to explore directional spillovers towards a specific market.

On the substantive side, this methodology focuses solely on spillover measurements across homogenous assets (equities) in diverse countries. However, exploring spillovers across different individual assets also holds significant relevance. Diebold and Yilmaz (2012), generalized vector autoregressive framework, wherein the decompositions of forecast-error variance are unaffected by the sequencing of variables, suggesting metrics for both total and directional volatility spillovers.

Diebold and Yilmaz (2009), introduced a spillover index based on the concept of variance decomposition within an N-variable vector autoregression (VAR) model. This index provides a straightforward measure of overall spillovers but can produce order-dependent results due to the use of Cholesky factor orthogonalization. To address this limitation, Diebold and Yilmaz (2012) extended their approach by quantifying directional spillovers within a generalized VAR model, which eliminates the potential dependency of results on the ordering of variables.

The exploration of connectedness and spillover risks underscores the complexity of global market dynamics, especially during financial crises. This leads us to the core research problem and purpose of this study, which aims to bridge the gaps in existing literature and provide a more comprehensive analysis of price transmission in the context of recent global disruptions and geopolitical conflicts.

1.5. Research Problem and Purpose.

The international agricultural commodity markets have faced unprecedented challenges in recent years, with two major geopolitical disruptions. The US-China trade war beginning in 2018 and the Russian-Ukrainian conflict escalating dramatically in 2022, significantly reshaping global trade patterns and market dynamics. These sequential disruptive events provide a unique analytical opportunity to examine how global agricultural markets, particularly the soybean market, respond to different types of geopolitical shocks.

1.5.1. *Summary of prior empirical work*

The international soybean market presents a solid foundation regarding market dynamics, with numerous researchers contributing to build a robust understanding of this market. Price transmission analysis has been one of the most extensively applied economic tools in this field. There is vast empirical evidence regarding price transmission, elasticity of price transmission, asymmetric price transmission, market cointegration, and market efficiency for each regional market (Aguiar and Barros, 1991; Correia das Neves, 1993; Pino and Rocha, 1994; Mafioletti, 2001; Margarido, Turolla and Fernandes, 2001; Giembinsky and Holland, 2003; Silva and Machado, 2009).

Furthermore, researchers have studied the market power dynamic, identifying key players, price makers, price takers, and market power (Lima and Burnquist, 1997; Margarido and Souza, 1998; Margarido et al., 1999; Moraes, 2002; Margarido, Turolla and Bueno, 2007; Silva and Machado, 2009; Margarido, 2012). Studies have extended beyond traditional intra-market and supply chain price transmission analysis to cross-price transmission analysis, mapping the dynamic market integration, causality, and cross-price transmission among soybeans and different agricultural commodities, fertilisers, energy markets, and exchange rates (Yu, Bessler and Fuller, 2006; Campiche et al., 2007; Zhang and Reed, 2008; Nazlioglu and Soytas, 2011; Margarido, Araujo Turolla and Ferreira Bueno, 2014; Bini, Canever et al., 2016; Bini, Olivera et al., 2016).

Despite this extensive body of research, several significant gaps remain in our understanding of how geopolitical disruptions affect the international soybean market and related agricultural commodities, energy commodities, and agricultural inputs (fertilisers):

Many studies have relied on historical data and traditional econometric models, which may not fully capture the dynamic nature of modern global markets. With rapid technological advancements and evolving trade policies, market conditions have changed significantly, necessitating updated analyses using contemporary data and advanced methodologies. Traditional models often assume static relationships between markets, failing to account for the time-varying nature of market interactions during periods of geopolitical stress.

While numerous studies have examined price transmission between major markets like Brazil, the USA, and Argentina, there is limited research on the interactions with both emerging and mature markets and their integration into the global soybean supply chain. Understanding how these established and developing players influence and are influenced by traditional market leaders could provide valuable insights into global price dynamics, especially during times of geopolitical conflict.

The impact of recent global disruptions on soybean price transmission has not been extensively studied. These disruptions include two fundamentally different types of geopolitical events.

1.5.1.1. Policy-Induced Disruption: The US-China Trade War

The US-China trade war represents what might be termed a "policy-induced disruption" characterized by deliberate trade policy interventions. This conflict was systematically implemented through tariffs and counter-tariffs, non-tariff barriers, and negotiated agreements. The US initially imposed Section 301 tariffs on Chinese imports, which led to retaliatory tariffs by China specifically targeting US agricultural exports, particularly soybeans. As Bown and Kolb (2021) documented, the trade war created managed trade diversion rather than absolute supply constraints.

The trade war unfolded as a relatively gradual escalation with signal periods before full implementation, allowing market participants some adaptation time. The investigation of Chinese trade practices under Section 301 began in early 2018, providing an initial market signal. Tariffs were then implemented in phases, with advance announcements that allowed for some preemptive market adjustments. This phased implementation created "adjustment windows"; periods during which market participants could restructure supply chains, seek alternative markets, and develop risk management strategies.

The US-China trade war had a highly targeted impact, with soybeans bearing the brunt of retaliatory tariffs imposed by China, reflecting the crop's centrality to US agricultural exports and its strategic importance in China's food security planning (Fernández-Díaz and Morley, 2019). This commodity-specific shock disrupted US soybean exports and shifted global trade flows, as China sought alternative suppliers, particularly Brazil and Argentina, reinforcing South America's role as a key supplier in global soy markets (Zafeiriou *et al.,* 2018).

1.5.1.2. Supply Chain Disruption: The Russian-Ukrainian Conflict

In contrast, the Russian-Ukrainian conflict represents a "supply chain disruption" characterized by physical impediments to production, transportation, and export capabilities. Unlike the trade war's policy-induced changes to trade flows, the conflict directly disrupted agricultural production and logistics infrastructure. The conflict severely damaged Ukrainian port facilities, transportation networks, and created hazardous conditions for agricultural operations, particularly in eastern regions of Ukraine. These physical disruptions led to actual supply shortages rather than merely redirected trade flows. As noted by Nehrey and Trofimtseva (2022), the conflict disrupted supply chains and reduced access to critical agricultural inputs, creating genuine constraints on global supply rather than just adjustments to trade patterns.

The conflict, particularly its dramatic escalation on February 24, 2022, represented a sudden, high-intensity shock with minimal warning signals. The invasion immediately disrupted Black Sea shipping routes crucial for global grain exports and created instantaneous market volatility. This sudden disruption provided minimal adjustment windows, requiring immediate market reactions rather than strategic adaptations. The abrupt nature of this disruption is evidenced by the dramatic price spikes observed across agricultural commodities in late February and early March 2022.

The Russian-Ukrainian conflict generated broader cross-commodity impacts due to Ukraine and Russia's roles as major exporters of multiple agricultural commodities. The conflict simultaneously affected wheat, maize, barley, sunflower oil, and fertilisers, creating a multi-commodity shock that reverberated through interconnected agricultural markets. This broader disruption activated more complex cross-commodity substitution effects and intensified the connectedness between different agricultural market segments.

While some research has been conducted on the cross-price transmission between agricultural and energy commodities, there is a need for more comprehensive studies that integrate other critical factors, such as geopolitical tensions and market volatility. These factors are increasingly relevant in shaping market dynamics and should be incorporated into future research to provide a holistic understanding of price transmission mechanisms during periods of significant market stress.

The pandemic (COVID-19) has caused unprecedented shifts in supply chains and demand patterns, highlighting the need for research that considers these extraordinary events and their long-term implications on market behavior. Following this, the Ukrainian-Russian war has caused significant disruptions in global supply chains and commodity markets, including the soybean market. The conflict has led to increased volatility and uncertainty in the agricultural sector, as both Ukraine and Russia are major players in global grain markets. This has resulted in shifts in trade routes, increased transportation costs, and fluctuating prices, which have distorted the soybean market.

1.5.2. *Research Objectives and Hypotheses*

1.5.2.1. Research question

The aim of this research is to address a specific research question that has arisen as a consequence of this uncommon political situation: How and to what extent have the trade war and the Ukrainian-Russian conflict affected the international market of agricultural and energy commodities, agricultural inputs (fertilisers), and particularly the soybean complex? The wide nature of this research question draws several lines of investigations, and consequently several null hypotheses and many methodological approaches.

The central research question is: "Is there a relationship between the trade war, the Ukrainian-Russian conflict, and the international agricultural commodities markets, particularly soybeans? If so, how have these events affected these markets?" This overarching question forms the foundation for various lines of inquiry and specific research questions explored throughout the study.

Having defined the overarching research question, we proceed to formulate specific hypotheses related to the US-China trade war and the Ukrainian-Russian conflict. These hypotheses will help in systematically examining these geopolitical events' effects on market cointegration, market efficiency, market power, asymmetric price transmission, spillover effects, the connectedness index, and the validity of the Law of One Price for international soybean markets.

Given these gaps, there is a pressing need for research that considers these extraordinary events and their long-term implications on market behavior. Such studies would help in understanding how geopolitical conflicts affect price transmission, market efficiency, and the overall stability of the international soybean market. Specific research needs include:

1. The application of advanced time-varying methodologies to capture the dynamic nature of market relationships during periods of geopolitical stress.
2. Analysis of how different types of geopolitical disruptions (policy-induced versus supply chain) affect market integration, price leadership, and connectedness.
3. Examination of cross-commodity spillover effects during crises, particularly between agricultural commodities, energy markets, and fertilizer sectors.

4. Investigation of market resilience mechanisms and adaptation strategies in response to different types of geopolitical shocks.

These sequential disruptions provide a unique analytical opportunity to examine how global agricultural markets respond to different types of geopolitical shocks. While both events created substantial market perturbations, they differed fundamentally in their nature, progression, and impacts on trade flows, price transmissions, and market connectedness. The comprehensive analysis of these two events enables a more nuanced understanding of market resilience, adaptation mechanisms, and the evolution of price leadership in response to varying types of geopolitical stresses.

Future research should aim to address these gaps by employing advanced econometric techniques, utilizing real-time data, expanding the scope to include emerging markets, and considering the effects of recent global disruptions and other critical factors. By doing so, researchers can provide more accurate and relevant insights into the complex dynamics of the international agricultural commodity market and the soybean market.

The distinctly different nature of these disruptions provides a uniquely valuable context for examining price transmission dynamics, market integration, and connectedness under varying conditions of geopolitical stress. Advanced methodological approaches—combining classical price transmission techniques with dynamic connectedness approaches—are particularly well-suited for capturing the multifaceted impacts of these sequential disruptions and addressing the central research questions regarding the resilience and adaptability of global agricultural markets in an increasingly unstable geopolitical environment.

Having defined the overarching research question, we proceed to formulate specific hypotheses related to the US-China trade war. These hypotheses will help in systematically examining the trade war's effects on market cointegration, market efficiency, market power, asymmetric price transmission, spillover effects, the connectedness index, and the validity of the Law of One Price for international soybean markets.

1.5.2.2. US-China Trade War Hypotheses

- Market Cointegration and Structural Breaks

Should the trade war have substantially impacted market prices, one might infer that this event has precipitated a structural break within the time series data. The research question addresses whether the onset of the trade war has triggered such a structural break and disrupted the long-term relationship between the markets. The null hypothesis asserts that (This hypothesis is tested in the first and second empirical chapters):

1. **Null Hypothesis (H0):** The markets have not been dislocated, there is cointegration between the markets.
2. **Alternative Hypothesis (H1):** The markets have been dislocated, there is not cointegration between the markets.
   This hypothesis are tasted in the first and second empirical chapter

- The Market Efficiency Affectation

A fast speed of adjustment to the long run equilibrium and a complete price transmission are clear indicators of market efficiency. Moreover, the adherence to the Law of One Price consistently signals an efficient market. The research question in this context is whether market efficiency has been compromised. This inquiry gives rise to the following null hypotheses (This hypothesis is tested in the first empirical chapter):

1. **Null Hypothesis (H0):** The price transmission among the market has not been affected.
2. **Alternative Hypothesis (H1):** The price transmission among the market has been affected.

- Market Power

The global soybean market is significantly influenced by China, the largest consumer, and the United States, the leading producer and second-largest market. China’s domestic agriculture is increasingly challenged by climate change, which brings more frequent and severe extreme weather droughts, floods, and heatwaves that reduce yields of staple crops such as rice and soybeans. As a result, China must import a significant portion of its food and feed grains through both the official (main) channels and less-regulated (grey) markets to ensure its supply (Shi *et al.*, 2020). China has implemented strategic trade policies to reduce the United States' dominance, positioning itself as a key influencer. Furthermore, Brazil's rise as the top producer has altered the distribution of market power among these major players. It is essential to evaluate whether these developments have led to a notable shift in market power dynamics. This hypothesis is tested in the first and third empirical chapters, following:

1. **Null Hypothesis (H0):** Chicago and Rotterdam do not longer hold the causality of the prices
2. **Alternative Hypothesis (H1):** Chicago and Rotterdam still hold the causality of the prices.

- Asymmetric Price Transmission

It is essential to determine whether the soybean market exhibits symmetrical or asymmetrical price transmission, and to evaluate the extent to which the US-China trade war may have exacerbated any existing asymmetries. Market power and government intervention can lead to asymmetric price transmission, resulting in a loss of economic welfare and market efficiency. This hypothesis is tested in the second and third empirical chapters, following:

1. **Null Hypothesis (H0):** The international soybean market exhibits symmetrical price transmission.
2. **Alternative Hypothesis (H1):** The international soybean market exhibits asymmetrical price transmission.

- Spillover Effects of Trade War on Agricultural Commodities

In a globalised world, international agricultural markets are deeply interconnected. Therefore, it is possible to assume that shocks in one market will have spillover effects or contagion to other markets. Empirical evidence and economic theory have demonstrated that shocks in the prices of certain products will be transferred to other goods. Several researchers have shown a strong causal relationship between soybeans and different agricultural commodities such as maize, poultry, soybean meal, and soybean oil. Others have demonstrated the link between energy commodities and agricultural commodities. Therefore, it is reasonable to hypothesize that the spillover effects of the trade war have been transmitted from the main commodities market to other regional markets and from agricultural markets to energy markets. These hypotheses are tested in the third and fourth empirical chapters, following:

The following Null hypotheses can be drawn

1. **Null Hypothesis (H0):** The US-China trade war has not caused spillover effects from the main soybean commodities market to other regional markets.
2. **Alternative Hypothesis (H1):** The US-China trade war has caused spillover effects from the main soybean commodities market to other regional markets.

And secondly:

1. **Null Hypothesis (H0):** The US-China trade war has not caused spillover effects from agricultural to energy commodities markets.
2. **Alternative Hypothesis (H1):** The US-China trade war has not caused spillover effects from agricultural to energy commodities markets.

- Connectedness Index during the US-China Trade War.

The interconnectedness of agricultural markets has become increasingly significant. The US-China trade war has introduced various disruptions and uncertainties in international trade. These disruptions have particularly affected the soybean market, given its critical role in global agricultural trade. It is essential to investigate whether the trade war has led to an increase in the connectedness index of the soybean market, indicating stronger interdependencies between soybean and other related markets. This hypothesis is tested in the third and fourth empirical chapters, following:

1. **Null Hypothesis (H0):** The US-China trade war has not increased the connectedness index of the soybean market.
2. **Alternative Hypothesis (H1):** The US-China trade war has increased the connectedness index of the soybean market.

- Validity of the Law of One Price for International Soybean Markets due to the US-China Trade War

The central hypothesis of this research establishes the validity of the Law of One Price for international soybean markets. The law states that the price of the same commodity in two different markets is the same when transaction and transport costs are not considered in the determination of prices. This hypothesis explores whether the US-China trade war has affected this principle, this is tested in the first empirical chapters, following:

1. **Null Hypothesis (H0)**: The Law of One Price is still valid for international soybean markets despite the US-China trade war.
2. **Alternative Hypothesis (H1):** The US-China trade war invalidates the Law of One Price for international soybean markets.

Building on the analysis of the US-China trade war's impact on the international soybean market, it is equally important to consider the effects of the Ukrainian-Russian conflict. This conflict has introduced additional volatility and uncertainty into global agricultural markets. Therefore, we will now formulate hypotheses to investigate how this geopolitical event has influenced market volatility, commodity spillovers, and market stability, further enriching our understanding of the interconnectedness and dynamic behaviour of the international agricultural commodity market and in particular in the international soybean market/complex under varying geopolitical pressures.

1.5.2.3. Effects of the Ukrainian-Russian Conflict Hypotheses

- Impact of the Ukrainian-Russian Conflict on Global Soybean Market Volatility

The Ukrainian-Russian conflict has created substantial uncertainty and disruptions in global markets, particularly affecting the international soybean market. Understanding whether this geopolitical event has influenced price volatility is crucial for market participants and policymakers. This hypothesis is tested in the fourth empirical chapters, following:

1. **Null Hypothesis (H0):** The Ukrainian-Russian conflict has no effect on price volatility in the international soybean market.
2. **Alternative Hypothesis (H1):** The Ukrainian-Russian conflict significantly influenced the price volatility in the international soybean market.

- Market Disruptions and broader Agricultural Commodity and Energy Commodity Market ramifications.

The conflict between Ukraine and Russia has potential ramifications beyond the immediate region, possibly affecting various commodity's markets. This hypothesis pair explores the extent to which the conflict's impact on soybeans has caused spillovers to other markets. This hypothesis is tested fourth empirical chapters, following:

1. **Null Hypothesis (H0):** The Ukrainian-Russian conflict does not cause spillover effects to other commodities and fertilizer markets.

2. **Alternative Hypothesis (H1):** The Ukrainian-Russian conflict causes significant spillover effects to other commodities and fertilizer markets.

- Connectedness and Market Stability

The degree of interconnectedness between different markets can affect their stability and response to external shocks. This hypothesis investigates whether the Ukrainian-Russian conflict has increased the connectedness between soybean markets and other agricultural commodity market. This hypothesis is tested in the fourth empirical chapters, following:

1. **Null Hypothesis (H0):** There is no significant increase in the connectedness between soybean markets and other commodity markets due to the Ukrainian-Russian conflict.
2. **Alternative Hypothesis (H1):** There is a significant increase in the connectedness between soybean markets and other commodity markets due to the Ukrainian-Russian conflict.

Having established hypotheses to explore the impact of the Ukrainian-Russian conflict on global soybean market volatility, commodity spillovers, and market stability, we now shift our focus to the broader significance of this study. This section will discuss the contributions of our research to the existing body of literature, the practical implications for policymakers and market participants, and the unique insights provided by examining the soybean market within the context of these significant geopolitical events. Understanding these contributions is crucial for appreciating the study's relevance and the value it adds to the field of agricultural economics and beyond.

1.5.3. *Empirical Foundations: Data Methodological Approach*

1.5.3.1. First, Second and Third Chapter; Data source

This study employs an extensive array of secondary data sources to construct a robust and replicable analysis of the international soybean market. Data were gathered from reputable institutions, including the International Monetary Fund (IMF), the Chicago Board of Trade (CBOT), CEPEA Brazil (Centro de Estudos Avançados em Economia Aplicada), the Dalian Commodity Exchange (DCE) in China, the Wind Economic Database, the Bolsa de Rosario in Argentina, and the World Bank. The raw time series data were systematically standardized by converting them into monthly observations, expressing all values uniformly in United States dollars per tonne, deflating the figures to account for inflation, and then applying a natural logarithm transformation. These methodological adjustments were undertaken to remove excessive variations, simplify complex patterns, and enhance the accuracy of subsequent econometric models, ensuring that other researchers can replicate and validate the findings.These empirical chapters dataset covers September 2009 to May 2019 (Empirical Chapter I,II, II)

The analysis incorporates several key time price series, including LNCHIGF representing Chicago Futures, LNCHINASP for China Spot, LNDALIF from Dalian Futures, LNPARANAGUASP for the Paranaguá market, LNROSFT and LNROSSP corresponding to Rosario Futures and Rosario Spot, and LNROTTERDAM representing the Rotterdam market. These series were essential in investigating the dynamics of international soybean trade, particularly in the context of the US–China trade war and the horizontal price transmission among major market players such as China, the United States, the European Union, Brazil, and Argentina.

1.5.3.2. Studied Markets

1.5.3.2.1. The Chicago Board of Trade

The Chicago Board of Trade, established in 1848 and now a division of the CME Group, is instrumental in the global soybean market. It offers futures contracts for U.S. soybeans specifically, the No. 2 yellow variety, where each standardized contract represents 5,000 bushels traded on the CME Group's nearly continuous electronic platform, CME Globex. This market not only serves as a global benchmark for soybean pricing through daily price discovery but also plays a crucial role in risk management. The liquidity and transparency of the CBOT futures market enable producers, processors, exporters, and investors to hedge against price volatility and secure future pricing, thereby influencing both domestic and international market decisions.

1.5.3.2.2. China Domestic Market

Chinese Soybean spot prices are primarily obtained from the Wind Economic Database, which aggregates detailed macroeconomic and sector-specific data. The collected data correspond to the Heihe Grain Bureau in Heilongjiang Province, a pivotal agricultural hub that contributes roughly one-seventh of China's soybean production and facilitates cross-border trade with Russia.

The Dalian Commodity Exchange accounts "Dalain Soybean Futures" . This institution founded in 1993 and now the world's second-largest soybean futures market, lists contracts for genetically modified (No. 2) soybeans that are typically imported for oil extraction and animal feed. Additionally. The integrated role of these platforms and institutions underscores China's significance as the largest soybean importer globally and its influence on price formation through both domestic and international channels.

1.5.3.2.3. Brazilian Domestic Market

Brazil's referent price for the domestic soybean market is represented by the Port of Paranaguá, the country's largest agricultural export hub. Handling over 14.2 million tonnes of soybeans annually along with substantial volumes of soybean meal and oil, Paranaguá serves as a vital gateway that connects key production regions in Brazil to international markets in China, the European Union, and the United States.

The INDICADOR DA SOJA ESALQ/BM&FBOVESPA – PARANAGUÁ SPOT USS/tt, developed jointly by CEPEA/ESALQ and B3, functions as Brazil's primary soybean price benchmark by tracking the spot price of export-grade soybeans delivered to the port. This indicator, calculated by converting Brazilian reais to U.S. dollars using the daily commercial exchange rate and filtering out outliers through standard deviation techniques, is critical for price discovery, risk management via futures contracts on B3 (BM&FBOVESPA).

1.5.3.2.4. Argentina Domestic Market

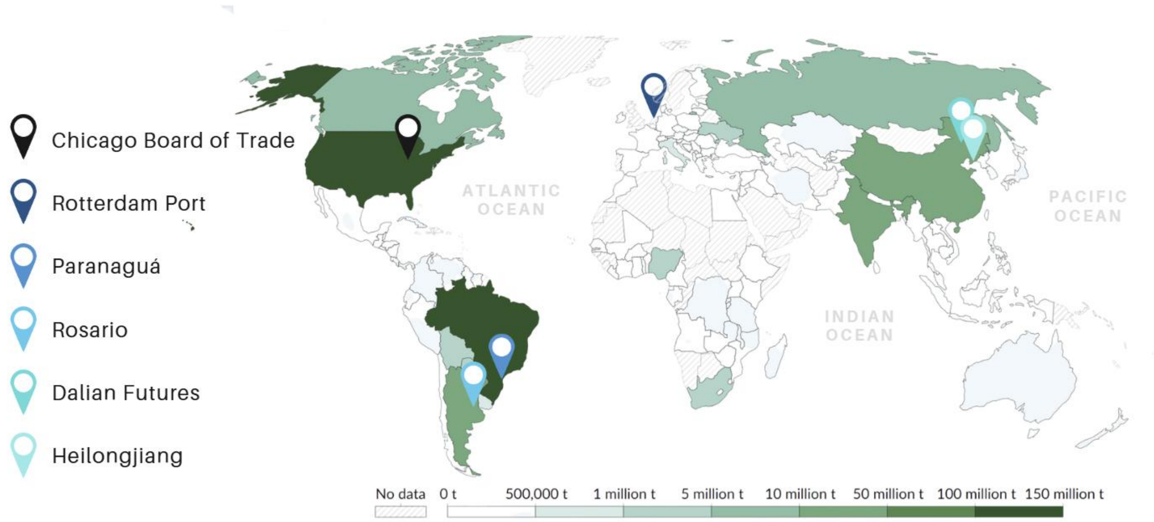
The Bolsa de Comercio de Rosario (BCR), which has been a key player in global grain trade since its establishment in 1884. The BCR offers a range of trading platforms, including spot markets and futures soybean contracts (facilitated through the Rosario Futures Exchange, ROFEX). In Argentina, futures contracts for soybeans, soybean meal, and soybean oil are denominated in Argentine pesos and later linked to international benchmarks, particularly those from the CBOT. This linkage not only facilitates hedging against price fluctuations but also ensures that local market dynamics shaped by government policies, export tariffs, and currency fluctuations are harmonized with global trading patterns.

1.5.3.2.5. European Union

The Port of Rotterdam further exemplifies the interconnectedness of the global soybean market. As Europe's primary gateway, Rotterdam benefits from a strategic location at the mouth of major rivers, state-of-the-art infrastructure, and advanced technological innovations such as digital twins and blockchain-based tracking. In 2021, Rotterdam handled 6.7 million metric tonnes of soybeans and related products, making it a critical node in the European supply chain.

The c.i.f. Rotterdam price, which includes cost, insurance, and freight, is widely used as a benchmark for European soybean pricing and influences global trade flows. The port's role in re-exporting and processing soybeans underscores its economic importance, despite environmental challenges like deforestation and sustainability issues. Figure 2 depicts global soybean production (2022) by country and market locations.

Figure 2. Soybean Production (2022) and Main markets localization.



(Source: FAO, 2023 ;Google Maps, 2025)

1.5.3.3. Fourth Chapter; Data Source

the fourth chapter a new dataset that includes energy commodities such as crude oil and natural gas and fertiliser markets to account for broader cross-sector dependencies in the new context of the Ukranian-Russian conflict.

The fourth empirical chapter draws upon the World Bank dataset covering the period from January 2011 to January 2023. The data, presented as monthly log returns, provide a comprehensive basis for analysing the intricate interdependencies across various segments of the international commodities market. In the agricultural sector, the study incorporates futures contracts for soybeans, soybean meal, and soybean oil each with its own specific contract specifications and pricing benchmarks as well as spot price data for:

1.5.3.3.1. Canadian No.1 Western Barley:

This time series tracks spot prices for Canadian No.1 Western barley. Prices, typically quoted in Canadian dollars per metric ton, reflect market conditions in major barley-producing regions such as Alberta and Saskatchewan. The series provides valuable insights into domestic and international barley market dynamics, influenced by production volumes, weather events, and global demand for feed and malting barley. Historical price volatility in this market is often driven by shifts in production yields, trade flows, and competing grain markets, including corn and wheat.

1.5.3.3.2. Kansas City Board of Trade (KCBT) futures for No.1 Hard Red Winter Wheat.

The KCBT futures series tracks the futures contract prices for No.1 Hard Red Winter wheat, primarily used for bread-making due to its high protein content. Prices are typically expressed in U.S. cents per bushel and reflect delivery at specified locations near Kansas City. This market serves as a global benchmark for wheat, directly influenced by production levels in key U.S. states (Kansas, Oklahoma, Texas), export conditions, international competition, and policy-driven events, such as changes in trade tariffs or subsidies. Monitoring KCBT wheat futures provides essential information on anticipated wheat market trends, price expectations, and supply-demand balances globally.

1.5.3.4. Sunflower Oil Spot Price

Spot prices for U.S. export-quality sunflower oil from the Gulf of Mexico represent actual transaction prices in the physical market for sunflower oil, a major edible oil used worldwide. Expressed in U.S. dollars per metric ton, this series is a useful gauge of global vegetable oil demand, supply disruptions, and the impacts of weather events on crop yields. Prices in this market can exhibit significant fluctuations driven by global factors such as demand shifts, production in major sunflower-growing countries (e.g., Ukraine, Russia, Argentina), changes in energy markets (due to biodiesel demand), and broader oilseed market conditions influenced by soybean, palm oil, and rapeseed market trends.

1.5.3.4.1. Soybean Futures U.S. No.2 yellow

Soybean futures contracts offered by the Chicago Board of Trade, for instance, standardize U.S. No.2 yellow soybeans in units of 5,000 bushels. Similarly, soybean meal futures contracts which represent 100 short tons minimum protein content of 48% and soybean oil futures, based on a standard contract size of 60,000 pounds.

1.5.3.4.2. Crude Oil Price

The Crude Oil Price Index, constructed as a simple average of spot prices for Dated Brent, West Texas Intermediate (WTI), and Dubai Fateh, serves as a key global benchmark for oil price movements. This index is crucial for tracking cost pressures in the agricultural sector, as fluctuations impact fuel, fertilizer, and transportation costs, directly influencing global food prices. Higher oil prices increase fuel and fertilizer expenses, raising production costs for farmers, while elevated transportation costs affect supply chain efficiency and food affordability.

1.5.3.4.3. Natural Gas

Natural gas is also analyzed through a Laspeyres-based index, which aggregates prices from key regions in Europe, the United States, and Japan. This index serves as a crucial indicator of cost fluctuations in one of the primary inputs for nitrogen-based fertilizer production. By tracking regional price movements, the index helps identify trends in input cost pressures, assess the global competitiveness of fertilizer producers, and anticipate potential shifts in agricultural production costs. Given the strong correlation between natural gas prices and fertilizer costs, this index offers valuable insights for policy makers, agricultural economists, and market analysts seeking to understand and forecast the impact of energy markets on food production and supply chains.

1.5.3.5. Diammonium Phosphate (DAP)

DAP is a key phosphorus-based fertilizer essential for promoting root development and overall plant growth. Its price, sourced from Bloomberg's Green Markets, serves as a critical indicator of phosphorus input costs for global agriculture. Since phosphorus is a finite resource with limited sources of extraction, fluctuations in DAP prices can significantly affect fertilizer affordability and availability, influencing crop yield potential and long-term soil fertility management. Soybean production, in particular, relies heavily on phosphorus fertilisers like DAP, as phosphorus plays a crucial role in root establishment, nitrogen fixation, and overall crop resilience. Given its role in balanced fertilization strategies, DAP pricing directly impacts farmers' planting decisions, procurement strategies, and regional agricultural competitiveness.

1.5.3.5.1. Urea

Prilled urea, a high-nitrogen fertilizer, is a crucial input for boosting crop productivity, particularly in nitrogen-intensive crops such as corn, wheat, and rice. Traded free on board in the Middle East, urea's spot price reflects supply-demand balances in global markets, often influenced by natural gas prices, which serve as a primary production input. Data for urea pricing is sourced from Bloomberg L.P. Green

Markets and S&P Global, providing comprehensive market intelligence on fertilizer trends. Because nitrogen fertilisers play a pivotal role in maximizing yields, price volatility in urea can affect farmers' cost structures, supply chain logistics, and fertilizer affordability in developing and developed markets alike.

The interconnected nature of these commodities underscores the importance of cross-dependency in both agronomic and economic terms, where the pricing of energy inputs such as crude oil and natural gas can indirectly influence agricultural output, while the cost of fertilisers such as urea and DAP further ties into the broader dynamics of crop production.

1.5.3.6. Disclaimer

The information cited under Wei (2023) is sourced from China Daily and has been used to provide context. However, as China Daily is a state-owned media outlet, its reporting may reflect certain biases. Where possible, additional sources have been consulted to ensure a balanced perspective

1.6. Significance of the Study

The significance of this study lies in its comprehensive analysis of the international soybean market, particularly in the context of significant geopolitical events such as the US-China trade war and the Ukrainian-Russian conflict. By examining price transmission, cointegration, and market efficiency, the research addresses critical gaps in the existing literature and provides valuable insights into the dynamics of agricultural commodity markets under stress.

1.6.1. *Study contribution and focus*

One of the primary contributions of this study is its focus on the geopolitical influence on agricultural markets. The US-China trade war, initiated in 2018, marked a period of heightened economic tension between two of the world's largest economies. This conflict, characterized by tariffs and retaliatory measures, had profound implications for global trade patterns. By specifically analysing the soybean market, the study sheds light on how such geopolitical events can disrupt traditional trade flows, influence price dynamics, and affect the overall stability of agricultural markets.

The secondary contribution of this study is its focus on the geopolitical, specifically the impact of the Ukrainian-Russian conflict. This conflict, which escalated in 2014 and further intensified in 2022, has significantly affected global agricultural trade. The Ukrainian-Russian conflict, characterized by military actions and economic sanctions, has disrupted traditional trade flows, particularly in key agricultural commodities. This study provides insights into how such geopolitical events can alter trade patterns, influence price dynamics, and affect the overall stability of agricultural markets.

Focusing on the soybean market, the study addresses a critical sector within global agriculture. Soybeans are a vital commodity, serving as a primary source of protein and oil and playing a crucial role in animal feed and biodiesel production. Given the importance of soybeans in global food security and economic stability, understanding the factors that influence their market dynamics is essential. The study provides a detailed examination of how trade policies and international conflicts impact the soybean market, offering insights that are relevant to both policymakers and industry stakeholders.

By focusing on the geopolitical influences on agricultural markets, particularly the soybean market, this study offers critical insights into how trade policies and international conflicts impact market dynamics. The contributions of this research extend beyond practical implications, enriching the academic discourse on price transmission and market integration. Transitioning from the specific contributions and focus of the study, this research will add to the existing body of literature, providing a deeper understanding of external shocks on market behaviour and setting a benchmark for future studies in similar contexts.

1.6.2. *Contribution to Literature*

The study contributes to the existing body of literature on price transmission and market integration. While previous research has extensively examined these phenomena, the unique context of the US-China trade war and the Russian-Ukrainian conflict provides a new lens through which to explore these issues. The research will contribute to a deeper understanding of how external shocks influence market behaviour and provide a benchmark for future research in similar contexts.

1.6.2.1. Gap 1: Classical Econometric Methodology

Many studies have relied on historical data and traditional econometric models, which may not fully capture the dynamic nature of modern global markets. With rapid technological advancements and evolving trade policies, market conditions have changed significantly, necessitating updated analyses using contemporary data and advanced methodologies.

This study contributes to the literature addressing this gap by utilizing real-time data and advanced econometric techniques, such as Time-Varying Parameter Vector Autoregression (TVP-VAR) and Quantile Vector Autoregression (QVAR). These methodologies allow for a more nuanced analysis of market dynamics, capturing both the immediate and long-term impacts of geopolitical events like the US-China trade war and the Ukrainian-Russian conflict on the soybean market. This approach provides a more accurate and relevant understanding of current market behaviours and trends, contributing to a more robust and timely body of literature.

1.6.2.2. Gap 2: Interactions with Emerging Markets

While numerous studies have examined price transmission between major markets like Brazil, the USA, and Argentina, there is limited research on the interactions with emerging markets and their integration into the global soybean supply chain. Understanding how these new players influence and are influenced by established markets could provide valuable insights into global price dynamics.

This research expands the scope of analysis to include emerging markets, examining their role and impact within the global soybean supply chain. By integrating data from these markets, the study provides a comprehensive view of global price dynamics, highlighting the interconnectedness and influence of emerging markets on established ones. This contributes to the literature by filling the gap in understanding the integration and significance of emerging markets in the global agricultural economy.

1.6.2.3. Gap 3: Impact of Recent Global Disruptions

The impact of recent global disruptions, such as the US-China trade war and the Ukrainian-Russia war, on soybean price transmission has not been extensively studied. These events have caused unprecedented shifts in supply chains and demand patterns, highlighting the need for research that considers these extraordinary events and their long-term implications on market behaviours.

This studies specifically examines the effects of the US-China trade war and the Ukrainian-Russian conflict on soybean price transmission, market efficiency, and stability. By incorporating data from these recent global disruptions, the research provides insights into how such events impact market dynamics, price volatility, and supply chain resilience. This helps fill a significant gap in the literature, offering a timely and relevant analysis of the soybean market under stress conditions.

1.6.2.4. Gap 4: Cross-Price Transmission Between Agricultural and Energy Commodities

While some research has been conducted on the cross-price transmission between agricultural and energy commodities, there is a need for more comprehensive studies that integrate other critical factors such as geopolitical tensions and market volatility.

This research employs an integrated approach to analyse the interconnectedness and spillover effects between agricultural commodities like soybeans and energy commodities such as crude oil and natural gas. By using advanced econometric models (Connectedness Approach based in a QVAR (Diebold and Yilmaz, 2012)), the studies explores how geopolitical tensions and market volatility influence cross-price transmission, providing a holistic understanding of the interplay between these markets. This addresses the gap in the literature by offering a detailed examination of the cross-market dynamics under geopolitical stress.

1.6.2.5. Gap 5: Market Efficiency and Asymmetric Price Transmission

Existing studies have extensively examined market efficiency and asymmetric price transmission within the soybean market, but there is a need for updated analyses that reflect the current market conditions and geopolitical influences.

These studies investigates the efficiency and asymmetric price transmission in the soybean market, focusing on the impacts of recent geopolitical events. By applying models such as the Error Correction Model, the Threshold Autoregressive (TAR) and the Momentum Threshold AutoRegressive (MTAR) models, the research provides updated insights into market behaviours and price adjustments. This contributes to the literature by offering a current perspective on market efficiency and asymmetric price transmission in the context of modern geopolitical events.

1.6.2.6. Gap 6: Comprehensive Understanding of Geopolitical Influences

There is a need for a comprehensive understanding of how various geopolitical factors collectively influence the soybean market, beyond isolated studies on individual events.

These studies offer a holistic analysis of the soybean market by examining multiple geopolitical factors, including the US-China trade war and the Ukrainian-Russian conflict, and their collective impact on market dynamics. By integrating various geopolitical events into a single framework, the research provides a comprehensive understanding of how these factors interact and influence the soybean market. This fills a critical gap in the literature, offering a broader perspective on the complex interplay of geopolitical influences on global agricultural markets.

With a clear understanding of how this study contributes to the existing literature on price transmission and market dynamics, integration and efficiency, we now turn our attention to the driving forces behind this research. The motivation for this research is rooted in the significant impacts of recent geopolitical events on global agricultural markets, particularly the soybean market. By exploring these motivations, we can better appreciate the relevance and urgency of the research, setting the stage for an in-depth analysis of how these geopolitical tensions affect market dynamics and price stability

1.7. Motivation

The motivation behind this research stems from the profound and far-reaching impact of recent geopolitical events on global agricultural markets, particularly the soybean market (Appendix 3; Table 1 & 2). Soybeans represent one of the world's most important commodities, crucial for securing food security globally. The US-China trade war, and the ongoing Russian-Ukrainian conflict have disrupted traditional trade flows, introduced significant market volatility, and challenged the existing understanding of market dynamics. These conflicts have not only affected the economies directly involved but also had a cascading effect on global markets, making it imperative to study their specific impacts on critical commodities like soybeans.

The US-China trade war, initiated by the Trump administration (July 6, 2018) , marked a significant departure from the era of increasing globalization and free trade. The imposition of tariffs and retaliatory measures disrupted long-established trade relationships, particularly between the world's largest economies. China, as the largest importer of soybeans, and the United States, as one of the top producers, found their agricultural trade severely impacted. This trade war presented a unique opportunity to study how such geopolitical tensions affect price transmission, market integration, and the exercise of market power in a highly efficient and integrated market like that of soybeans.

Similarly, the Russian-Ukrainian conflict has further complicated the global trade landscape. Both countries play crucial roles in the global supply of agricultural commodities particulary soybean market, and the conflict has led to increased volatility and uncertainty in these markets. Understanding the spillover effects of this conflict on the soybean market and other interconnected commodities is vital for developing strategies to mitigate the negative impacts on global food security and market stability. This research aims to fill the gap in the literature by providing an in-depth analysis of how these geopolitical events affect the interconnectedness and dynamic behaviour of international commodity markets. Moreover, the study aims to contribute to the theoretical understanding of price transmission and market efficiency under stress conditions. The soybean market, known for its high degree of integration and efficiency, provides an ideal case for examining the validity of the Law of One Price (LOOP) under extreme conditions.

Finally, this research holds significant practical implications for policymakers and market participants. By highlighting the impact of trade policies and geopolitical conflicts on agricultural markets, the study provides valuable insights for designing more resilient and effective trade policies. It underscores the need for robust market mechanisms that can absorb shocks and maintain stability, ensuring the smooth functioning of global trade. For market participants, understanding the dynamics of price transmission and market power can aid in better decision-making and risk management in a volatile and interconnected global market.

1.7.1. *Novelty*

This study represents one of the first comprehensive analyses of how the Russian-Ukrainian conflict has impacted global commodity markets, particularly the soybean complex and related agricultural and energy sectors. While previous research has examined commodity market dynamics during various geopolitical tensions, the Ukrainian-Russian conflict presents a unique case study due to its sudden onset, the physical destruction of agricultural infrastructure, and its direct disruption of traditional Black Sea export corridors. By applying advanced econometric methodologies such as Quantile Vector Autoregression (QVAR) models to capture extreme market behaviors and Time-Varying Parameter Vector Autoregression (TVP-VAR) to track dynamic market relationships, this research pioneers the quantitative assessment of direct physical supply chain disruptions on global commodity connectedness and price transmission.

The research is further distinguished by its comparative analysis of two distinct types of geopolitical disruptions within a single analytical framework: the policy-induced disruptions of the US-China trade war versus the physical supply chain disruptions of the Russian-Ukrainian conflict. This dual-focus approach allows for unprecedented insights into how commodity markets respond to different categories of geopolitical stress, providing a more nuanced understanding of market resilience mechanisms and adaptive behaviours. By examining these sequential but fundamentally different shocks within the same methodological framework, the study reveals pattern variations in price transmission, market leadership shifts, and cross-commodity spillovers that would not be observable in isolated analyses of either conflict alone, establishing a new empirical baseline for understanding commodity market dynamics during geopolitical crises.

1.8. Scope and Limitations

The first empirical chapter, scope of this study encompassed a comprehensive analysis of the international soybean market, focusing on the effects of significant geopolitical events such as the US-China trade. The research aimed to understand price transmission dynamics, market integration, and the impact of these geopolitical events on market efficiency. The study analysed key international soybean markets, including spot and futures markets, over a ten-year period from

September 2009 to May 2019, and extended to cover the impacts of more recent events up to 2020. The main contribution of this chapter is the identification of significant market cointegration and causality relationships within the international soybean market, demonstrating the robustness of the Law of One Price (LOOP) even during geopolitical conflicts such as the US-China trade war. The study employs advanced econometric models to reveal that market mechanisms effectively neutralize the impacts of tariffs, underscoring the resilience and efficiency of global soybean trade networks

The second empirical chapter focused on analysing the asymmetric price transmission (APT) in the international soybean market. It encompassed major soybean markets including the United States (Chicago Futures), Europe (Rotterdam), Brazil (Paranaguá), Argentina (Rosario Futures and Rosario Spot), and China (Spot and Futures). The study examined the price transmission dynamics between these markets over a period of nearly ten years, from September 2009 to May 2019. The main contribution of this chapter is the identification and analysis of asymmetric price transmission (APT) in the international soybean market. The study uses advanced econometric models such as TAR and MTAR to investigate the effects of government interventions in various markets, particularly in China and Argentina. It concludes that while government interventions can cause market inefficiencies and structural breaks, the international soybean market largely exhibits symmetric price transmission, highlighting its resilience and efficiency.

The third empirical chapter scope cantered on analysing the dynamic integration and price leadership in the international soybean market, focusing on key markets including the United States (Chicago Futures), Europe (Rotterdam), Brazil (Paranaguá), Argentina (Rosario Futures and Spot), and China (Dalian Futures and Spot). The research spanned approximately ten years from September 2009 to May 2019, aiming to capture the time-varying behaviours and spillover mechanisms within these markets. The main contribution of the chapter is its application of a dynamic connectedness methodology based on a Time-Varying Parameter Vector Autoregressive (TVP-VAR) model to capture the time-varying nature of price transmission and market connectedness in the international soybean market. The study reveals the ascension of Paranaguá and Rosario Futures markets as price leaders alongside Chicago, marking a shift from the traditional dominance of

Rotterdam and highlighting the bidirectional and dynamic nature of market causality over time.

The fourth empirical chapter this study analyses the interconnectedness and spillover risks among agricultural commodities, energy commodities, and fertilisers, particularly under the impact of geopolitical tensions such as the Russian-Ukrainian war. The study utilizes a Quantile Vector Autoregressive (QVAR) model to track connectedness over time by examining extreme quantiles, providing insights into how these commodities interact under stress. The main contribution of this Chapter is its comprehensive analysis of the interconnectedness between agricultural and energy commodities, focusing on the significant impact of geopolitical events such as the Russian-Ukrainian conflict. The study reveals how extreme quantiles can identify shocks and their transmission across commodities, highlighting soybeans as a primary shock transmitter. This approach provides critical insights for policymakers to design resilient strategies for market stability amidst global uncertainties.

Having outlined the scope and main contributions of each empirical chapter, it is crucial to acknowledge the limitations inherent in this study to provide a comprehensive understanding of the research context. While the analysis offers significant insights into the dynamics of the international soybean market and the interconnectedness of agricultural and energy commodities under geopolitical tensions, certain constraints and potential areas for further research should be considered.

1.8.1. *Research Limitations*

The study relied primarily on secondary data sources, which may inherently contain biases or errors stemming from the initial data collection processes. This reliance on existing data can compromise the quality and accuracy of the study's conclusions. Moreover, the focus on specific markets and price centres might have inadvertently overlooked dynamics in smaller or emerging markets, thereby limiting the scope and generalizability of the results. The temporal constraints of the study, confined to a ten-year period, while extensive, may not adequately capture long-term trends and structural changes that are critical for a comprehensive analysis of market behaviours.

The econometric models employed in the study assumed linearity, which might not fully encapsulate the complexity of market dynamics, especially in the presence of significant external shocks. While models like Augmented Dickey-Fuller (ADF) and Johansen cointegration are robust, they have inherent limitations in addressing non-linear relationships and structural breaks comprehensively. The assumption that parameters change smoothly over time may not hold true in scenarios where changes are abrupt or when there are sudden regime shifts, leading to potential misspecification of the time-varying process and incorrect inferences.

While VECM is useful for understanding the short and long-term dynamics between integrated variables, it assumes linear relationships and constant parameters over time. This can be problematic in the presence of non-linear relationships and structural breaks. VECM also relies on the assumption of cointegration, which may not always hold true in real-world data, potentially leading to misspecified models and biased results.

The MTAR and TAR models are designed to capture non-linear adjustments to equilibrium, making them useful for identifying asymmetric behaviours in data. However, these models are limited by their reliance on pre-specified threshold values, which may not accurately represent the underlying data dynamics. Moreover, they can be sensitive to outliers and may not perform well in the presence of multiple regimes or complex non-linearities.

TVP-VAR models address the issue of parameter instability by allowing parameters to change over time. Despite this flexibility, they assume smooth transitions in parameter changes, which may not capture abrupt shifts or sudden regime changes effectively. The computational complexity and the need for large datasets to estimate time-varying parameters accurately can also be limiting factors.

QVAR models analyse relationships at different quantiles of the distribution, offering insights into the behaviour of variables across the entire distribution. However, the assumption that these quantiles can be independently modeled might not hold true in practice. Dependence between quantiles can complicate the interpretation and reliability of the results, and the complexity of modeling quantile dependencies can be challenging.

The connectedness approach is valuable for understanding the spillovers and interdependencies between variables in a system. However, it typically relies on linear models and may not fully capture non-linear dynamics and structural breaks. Additionally, this approach assumes that shocks are contemporaneously uncorrelated, which might not always be the case. The interpretation of connectedness measures can also be complex, particularly when dealing with high-dimensional data.

Beyond the constraints, several other limitations warrant consideration. The adequacy and representativeness of the sample size used in the study are crucial for ensuring that the findings are generalizable to broader populations or contexts. Any assumptions made during data interpretation could introduce biases or limitations in the study's findings, potentially skewing the results.

Moreover, the external validity of the study, or the extent to which the findings can be applied to real-world settings beyond the specific contexts studied, is a critical consideration. The availability of alternative explanations or variables that were not included in the study could also impact the observed outcomes, highlighting the need for a comprehensive approach that considers multiple perspectives and factors.

Understanding the scope and limitations of this study provides a clear framework for analyzing the international soybean market and its reaction to significant geopolitical events. This groundwork is essential for interpreting the results and contextualizing the conclusions drawn from the empirical analyses. The next section, "Organisation of the Thesis," will detail how the research is structured, outlining the methodological approaches, literature review, empirical chapters, and conclusions, offering a roadmap for the comprehensive examination of price transmission and market dynamics in the context of geopolitical tensions.

1.9. Organisation of the Thesis

The organisation begins with an introduction that sets the stage for the study, followed by a comprehensive literature review. The core of the thesis consists of four empirical chapters. Finally, the discussion and conclusion chapters synthesise the findings.

1.9.1. *Introduction Chapter*

The introduction chapter provides a comprehensive analysis of how two major geopolitical conflicts—the US-China Trade War and the Ukrainian-Russian conflict—have affected agricultural and energy commodity markets, with specific focus on the international soybean market. It establishes the historical context of both conflicts, tracing the US-China trade tensions from post-World War II through China's economic reforms and WTO accession to the 2018 tariff escalations, while examining the Ukrainian-Russian conflict from its 2014 origins through the 2022 full-scale invasion.

The chapter thoroughly explores the global significance of the soybean market, detailing production patterns, trade flows, and market concentration among major players (Brazil, United States, Argentina) and China's dominant role as an importer. It examines structural market changes driven by population growth, dietary shifts, biofuel policies, and sustainability concerns, while highlighting the strategic economic importance of soybeans in global food security and energy markets.

Key theoretical frameworks are introduced, including price transmission mechanisms (both horizontal and vertical), the Law of One Price, asymmetric price transmission, and the connectedness approach for understanding market interdependencies and volatility spillovers. The chapter articulates specific research questions examining how these geopolitical disruptions affect market integration, efficiency, price leadership, and cross-commodity spillovers.

The research methodology is outlined with attention to data sources, processing techniques, and econometric approaches, while clear hypotheses are formulated to guide the empirical investigations. The significance of this research is emphasized through its contribution to understanding market resilience during geopolitical tensions, its practical implications for policymakers and market participants, and its academic value in advancing price transmission literature.

1.9.2. *Literature Review Chapter*

This chapter establishes the foundation for the empirical investigation by situating the study within the existing body of knowledge.

1.9.3. *Empirical Chapters*

The empirical chapters present the findings from the application of the integrated methodologies.. To maintain consistency throughout the dissertation, the numbering for the empirical chapters will not follow the overall sequence of the dissertation. Instead, each empirical chapter will be labeled with the acronym 'EC' (for Empirical

Chapter) followed by a Roman numeral (ECI, ECII, ECIII, and ECIV) to align with the numbering of the published empirical chapters.. These chapters are organised as follows:

1.9.3.1. Price Transmission Analysis of the International Soybean Market in a Trade War Context (Barboza Martignone *et al.,* 2022)

This empirical chapter investigates the impact of the US-China trade war on the international soybean market using a variety of econometric techniques. The study analyses monthly time-series data from September 2009 to May 2019 for the major soybean markets including the USA, the EU, China, Argentina, and Brazil. The research employs several econometric tests, such as the augmented Dickey-Fuller (ADF) unit root test for stationarity, the Bai-Perron multiple break test for structural breaks, and the Johansen cointegration test for long-term relationships. The Granger causality test is used to determine the direction of causality, while the vector autoregression (VAR) and vector error correction model (VECM) are applied to understand short-term and long-term causal relationships.

1.9.3.2. Asymmetric Price Transmission Analysis of the International Soybean Market (Barboza Martignone *et al.,* 2023)

This second empirical chapter investigates the dynamics of price transmission across various international soybean markets over a decade-long period from September 2009 to May 2019. It focuses on key markets, including the US (Chicago Futures), Europe (Rotterdam), Brazil (Paranaguá), Argentina (Rosario Futures and Rosario Spot), and China (Spot and Futures). The Phillips-Perron unit root test is utilized to assess the stationarity of the time series, while the Engle-Granger cointegration and Enders and Silko cointegration under asymmetry test (Enders and Siklos, 2001) to examines long-term equilibrium relationships. To determine the presence and nature of asymmetric price transmission (APT) the research further employs Threshold Autoregressive (TAR) and Momentum Threshold Autoregressive (MTAR).

1.9.3.3. A Shift in leadership on the international soybean market; The Rise of the triumvirate and The Fall of Rotterdam. A time-varying investigation (Barboza Martignone *et al.*, 2024b)

This chapter investigates the dynamic connectedness and price leadership within the international soybean market using a Time-Varying Parameter Vector Autoregressive (TVP-VAR) model and the connectedness index methodology. By examining major markets such as Chicago Futures, Rotterdam, Paranaguá, Rosario Futures and Spot, and Chinese domestic spot and Dalian futures, the research spans a decade from September 2009 to May 2019. The chapter focus on analyzing shifts in leadership within the international market, particularly in terms of price spillovers during the Trade war conflict.

1.9.3.4. The Rise of Soybean in International Commodity Markets: A Quantile Investigation (Barboza Martignone *et al.*, 2024a)

This chapter examines the interconnectedness and risk spillover among various agricultural and energy commodities using a Quantile Vector Autoregression (QVAR) model. This study focuses on the dynamic interplay between commodities such as wheat, barley, soybean, soybean oil, soybean meal, sunflower oil, crude oil, and natural gas, within the context of geopolitical events like the Ukraine-Russia conflict. The methodology leverages QVAR to track connectedness over time, particularly within extreme quantiles, enabling the identification of shocks from events like the Russian-Ukrainian war.

1.9.4. *Discussion Chapter*

The chapter provides a comprehensive synthesis of the findings from the previous empirical analyses, centring on the dynamics of the soybean market and related agricultural commodities in the context of significant geopolitical events like the US-China trade war and the Ukrainian-Russian conflict. It evaluates aspects such as market efficiency, price transmission, and the impact of government interventions, setting the groundwork for practical implications and policy recommendations.

The chapter is systematically organised to guide the reader through a logical progression of ideas. It starts by establishing the foundational concepts of market efficiency and integration, using comparative analyses to illustrate key points. It then moves on to assess the impacts of significant geopolitical events on the soybean market, examining both country-specific and global perspectives.

Subsequent sections delve deeper into the roles of individual countries within the international market, exploring shifts in leadership and influence. The discussion expands to consider the cross-price transmission in commodity markets.

- Market Efficiency and Integration in Soybean Markets: A Comparative Analysis

This section begins by highlighting the crucial role of market Liberalisation in achieving efficient and symmetrical price transmission, enabling rapid responses to international demand changes. It offers a comparative analysis of soybean production in Brazil and Argentina, illustrating how different government policies affect market efficiency and international competitiveness.

- Impact of the US-China Trade War on the Soybean Market

This section focusses in examining how the US-China trade war influenced the soybean market. The section discusses the methodologies used to identify structural disruptions in the market and analyses the extent to which the trade war affected market equilibrium dynamics and price dislocation.

- Influence of the Ukrainian-Russian Conflict on Commodity Markets

This part explores the significant disruptions in global agricultural commodity markets resulting from the Ukrainian-Russian conflict. It assesses the heightened volatility and uncertainty in markets for commodities that are primary exports of the involved nations, analyzing the surge in market interconnectedness and the transmission of shocks across commodities.

- Argentina's Future Role in the International Soybean Market

The section then delves into Argentina's position in the global soybean market, discussing how government interventions have shaped its role. It evaluates the implications of policy measures on market efficiency, price transmission, and the potential future trajectory of Argentina's soybean industry.

- Brazil’s Ascendance as a Global Soybean Leader

This section focuses on Brazil's rise in the international soybean market. It examines the factors contributing to Brazil's growing dominance, such as infrastructural developments, market Liberalisation, and technological advancements, highlighting how these elements have enhanced Brazil's competitive edge.

- The Complex Dynamics of China’s Soybean Market

This section analyses China's soybean market, exploring the interplay between government intervention, market integration, and international price dynamics. It assesses how policies affect China's market insulation from global influences and the implications for international price setting and market efficiency.

- The Decline of U.S. Leadership and Rotterdam's Influence in the Soybean Market

This section continues by examining the factors contributing to the diminishing dominance of the United States in the soybean market and the reduced influence of Rotterdam as a price setter. It discusses infrastructural improvements in competing countries and changes in global demand patterns that have reshaped market structures.

- A Shift in Leadership in the International Soybean Market

Building on the previous discussions, this section addresses the broader shift in global soybean market leadership. It analyses the declining influence of traditional market leaders and the emergence of new key players, considering the impact of geopolitical events and market strategies on these dynamics.

- Resilience in Agricultural Markets

Discusses the impact of the Ukrainian-Russian conflict on global agricultural commodity markets. It highlights the disruptions in supply chains, particularly for wheat, maize, barley, and sunflower oil, due to the conflict. The discussion ilustrates how these disruptions have led to increased volatility and uncertainty in the markets, affecting global prices and trade flows. The conflict has also caused logistical challenges and price hikes, impacting countries heavily dependent on these commodities

- The Role of Soybean in the International Commodities Market

Discusses the role of soybean in the international commodities market. It highlights the strategic importance of soybeans as a critical source of protein for both direct human consumption and animal feed. The analysis emphasises the versatility of soybeans, which are processed into soybean meal and oil, essential for livestock feed and biodiesel production. The chapter also explores the global scale of soybean production, with major producers like the United States, Brazil, and Argentina dominating the market. Additionally, it examines the significant trade flows and economic impact of soybeans, noting that they are the most traded agricultural commodity by value

- Policy Implications

This section synthesises the insights from the preceding empirical analyses to draw policy implications for the international soybean market and related commodities.

- Hypothesis Evaluation

This section methodically revisits the core research questions posed earlier in the study. This subsection effectively bridges the empirical analyses with the theoretical foundations laid out at the beginning of the study.

1.9.5. *Conclusion Chapter*

In the concluding chapter of the research, the study brings together the key themes and discussions explored throughout the work, focusing on the international soybean market and its response to major geopolitical events like the US-China Trade War and the Ukrainian-Russian conflict.

The chapter outlines the main research questions and objectives, emphasizing the multifaceted relationship between geopolitical conflicts and agricultural commodity markets.

Following this, the chapter provides a thematic summary of the key findings from the empirical chapters. The chapter then discusses the significance and contribution of the research to the field.

Acknowledging the limitations of the study, the chapter points out areas where further research is necessary.

1.10. Chapter Summary

This introductory chapter examines how the US-China trade war and Russian-Ukrainian conflict have disrupted the global soybean market, creating unprecedented instability in international trade and investment. Focusing specifically on price transmission, market integration, and dynamic connectedness, the research establishes the context for analyzing how these geopolitical events have transformed traditional market relationships.

The study employs advanced econometric methodologies including Vector Error Correction Model (VECM), Threshold Autoregressive (TAR), and Momentum Threshold Autoregressive (MTAR) models to analyze market efficiency and asymmetric price transmission. These techniques help identify structural breaks, cointegration relationships, and the persistence of the Law of One Price despite trade disruptions.

Additionally, the research utilizes Time-Varying Parameter Vector Autoregression (TVP-VAR) and Quantile Vector Autoregression (QVAR) models in conjunction with the Connectedness Approach to investigate dynamic relationships and spillover effects between soybean markets and other agricultural and energy commodities. These sophisticated models enable the research to capture price leadership shifts and market interdependencies under varying market conditions, providing a comprehensive framework for analyzing how geopolitical conflicts reshape global commodity markets.

Chapter 2: Literature Review

This chapter reviews the most significant empirical contributions to understanding price transmission in the soybean market, focusing on the methodologies employed and the key findings that have shaped current knowledge. The review also highlights gaps in the literature, particularly the limited focus on emerging markets and the under-explored impact of recent global disruptions, such as the US-China trade war and the Russian-Ukrainian conflict, on price transmission dynamics. By critically examining these studies, this section provides a foundation for identifying the current research gaps and setting the stage for the empirical investigations in the subsequent chapters.

2.1. Empirical work in price transmission in the international market of Soybean

The pioneering researchers in the domain of soybean price transmission were Aguiar and Barros (1991), who examined the causality and asymmetry of soybean prices in Brazil during the 1980s, specifically in the São Paulo State. They employed Granger-Sims causality tests and Houck's asymmetry test (Houck, 1977). Their findings indicated a directional causality of horizontal price transmission (PT) from international to Brazilian wholesale prices. This transmission was characterized by a more-than-proportional intensity (asymmetric price transmission - APT) with a time lag ranging from 1 to 4 months. Contrarily, Mafioletti (2001) reported different findings concerning the causality direction, suggesting that international prices influenced Brazilian domestic prices in the 1980s. Mafioletti's utilization of a distinct econometric method (Granger Causality test) could account for this divergence in results.

Aguiar and Barros (1991) also identified asymmetric price transmission within the Brazilian supply chain (vertical price transmission). They attributed this asymmetry to inflationary price expectations, positing that market agents might perceive price decreases as temporary and hence, resist passing on these decreases, or alternatively, preemptively increase prices due to anticipated inflation. The observed intensity of horizontal PT was attributed to the Liberalisation of the Brazilian economy, which enhanced market efficiency and subsequently, PT. These conclusions were later substantiated by Mafioletti (2001), who confirmed the presence of APT in Brazil’s domestic soybean industry throughout the 1980s and 1990s.

The findings of Correia das Neves (1993) on the elasticity of PT of soybeans from the international market to the Brazilian domestic soybean market and crushing industry for the period 1982 to 1990 contradict those of Aguiar and Barros (1991) and Mafioletti (2001). Correia das Neves (1993), did not find evidence that shocks in international prices were transmitted more than proportionally from the industry to the producer’s price, indicating non-asymmetric price transmission (SPT). Pino and Rocha (1994) analysed price transmission between the Chicago Board of Trade (CBOT) and the Brazilian market (producers and industry) for soybean grain and by-products, finding a high degree of dependency of Brazilian markets on Chicago. They utilized the transfer function model to reach this conclusion. Similarly, Giembinsky and Holland (2003) corroborated these findings, demonstrating that both markets exhibit long-term relationships (cointegrated markets) using the Engle and Granger cointegration test, VAR, and VECM models for the period 1990-2000. This integral relationship between the Brazilian and international markets was formally validated by the Law of One Price. Lima and Burnquist (1997) confirmed the applicability of this law in the previously mentioned market from January to December 1998 using Johansen's cointegration methodology. Moraes (2002) further analysed price formation in the Brazilian soybean market and established that the influence of CBOT’s first three soybean futures contracts on the domestic market is independent of the offseason period. Margarido and Souza (1998), employing the time series methodology developed by Box et al. (1976) for the period 1987 to 1997, found that price transmission from CBOT to Brazilian and Paraná prices was inelastic or asymmetric. They attributed this asymmetry to the national industry’s forward market positions and the substantial size of the domestic market for soybean derivatives, which was sufficient to buffer price changes.

Following the same line, Margarido *et al.* (1999) extended the research scope and investigated the price transmission among Brazil, Argentina, Rotterdam (EU), and Chicago (The United State), making the first approach to global soybean market research. The authors found that the price variations are transmitted faster and intensively transmitted from Rotterdam to Brazil and Argentina than from CBOT to Brazil and Argentina, concluding that price formation is the demand side

(Rotterdam-EU). Rotterdam is a spot market that represents the demand side exclusively. On the other hand, CBOT is a future market that represents the supply side. Future prices consider estimations of future production of the major soybean producer countries. This finding is entirely in harmony with Menger's Imputation Law explained by Bil'o (2004), which affirms that the prices are determined backward from the consumer value of judgment to all the structures of the production. In other words, the prices are determined from demand to supply. Besides, Margarido *et al.* (1999) found that Argentina has a higher sensitivity from international price fluctuations, while the Brazilian domestic market buffers those fluctuations (High domestic demand). In contrast, Machado and Margarido (2000) explain that Argentina used to export the entire production of soybean during the January 1991 – September 1999 period, creating a strong dependency on International prices. Machado and Margarido (2000) analysed if the seasonal behaviour of prices in Argentina and Brazil were more related to the seasonal behaviour of Rotterdam than CBOT for the period January -1991 to September 1999, using ARIMA models and generating a season index. The results confirmed the stronger relation of prices between Argentina, Brazil, and Rotterdam. However, the season standard index showed Rotterdam less accentuated, probably as the supply is constant all year. In contrast, Silva *et al.* (2005**)** show that the amplitude of seasonal standard is more accentuated in the US- off-season period than those of Brazil and Argentina. This phenomenon was more than expected since both Argentina and Brazil have different harvest season periods than the USA.

Margarido *et al.* (2001), shifted the approach and investigated the elasticity of price transmission in the market of soybean between Brazil and Rotterdam port (EU) for a period of 6 years (June 1994 - September 2000) using a VAR and VECM models, the impulse response function (IRF), variance decomposition of the forecast errors (FEVD). The underpinning theory was the "Law of one price" (LOOP), which authors validated and found a long-term relationship between the Rotterdam price and Brazilian price and concluded that the Brazilian market behaves efficiently based on the fast speed adjustment and the lack of APT. Da Silva *et al.* (2005) reached different results by investigating the PT of soybean grain from the Chicago Board of Trade to the Brazilian domestic market (spot prices; grain and oil) using the Johansen cointegration methodology. The researchers could not find cointegration between CBOT futures prices and Brazilian, soybean grain spot price, and soybean oil price for the period January 1999 to February 2005.

However, Da Silva *et al.* (2005) found that Chicago futures are cointegrated with Brazilian soybean meal. Moreover, using the impulse response function (IRF), the researchers found Chicago soybean price can explain 32.9% of Brazilian soybean price, 9.1% soybean oil, and 35.2% for soybean meal in the tenth month of convergence. The ARMAX model found transmission of the price variations within the domestic prices, from the domestic price of soybean to domestic soybean oil and soybean meal prices. Margarido *et al.* (2007), quantified the elasticity of price transmission between Brazil and the international market represented by Argentina, USA (central Illinois) and Rotterdam (CIF), for the period October 1995 to October 2003, based on the theoretical model of Mundlack and Larson (1992) and the Law of One Price (LOOP). Under this law, the elasticity of price transmission has to be near or equal to 1. The authors claimed that if there is a full price transmission from the international markets to the domestic market, then the LOOP is valid. Besides, if the market were fully integrated and the PT flows without restrictions, the arbitrage system will equalize the prices of the market in the long run. The econometric models used were ADF, Granger causality, Johansen cointegration, ECM, FEVD, and IRF. The Granger causality showed that group Rotterdam Argentina and USA Granger-cause Brazil but not the opposite way. The Johannsen cointegration approach showed at least two cointegration vectors. The ECM model was estimated again with the restrictions on β, assuming that there is full price transmission. The ECM showed that the disequilibrium in price represented by α is corrected by Brazil at 26.16% and Argentina at 31.27% (per monthly period).

According to the authors, that can be explained by the side of the domestic market. Whereas Brazil has a developed domestic market with a high level of demand, Argentina relies more on the international market, hence is more sensitive to the global market changes. This finding is consistent with Margarido *et al.* (1999). Rotterdam showed a slower response around 21% (monthly) explained by the status of “price maker”. The EU presented a constant supply of soybean across the year as a result of the alternation of harvest season between the two hemispheres. This continuous supply, consequently small seasonal variations, has been proven by Machado and Margarido (2000). The United States exhibited the slowest speed of adjustment to long-term equilibrium. This was largely due to its status as the largest soybean producer and exporter during that period. Additionally, the substantial domestic market in the U.S. made it less sensitive to short-term price fluctuations. The coefficients were statistically significant, indicating that long-term price variations are fully transmitted, with the price transmission elasticity tending towards 1. Consequently, the arbitrage process functions effectively in the selected markets, validating the Law of One Price.

Margarido (2012) resumed the previous work of Margarido *et al.* (2007) with a different approach based on the market integration model of Ravallion (1986) for the period October 1998 to December 2009. This model incorporates dynamic aspects that are not regarded in traditional PT models. The previously mentioned model assumes that there is a central market that determines the prices of local markets. Brazilian and Argentinian models were taken as local markets and Rotterdam, with the assumption that Rotterdam was the central market. According to Ravallion (1986), this model is useful when the markets are displayed in a radial configuration, and the local markets are linked to a central market. The implementation of this model is justified by the observation that soybeans entering the Rotterdam market predominantly originated from Brazil due to the European Union's restrictions on genetically modified organisms (GMOs) in soybeans, which were in place until 2016 (Reuters, 2016). Consequently, Brazil supplied Rotterdam with soybeans during the southern hemisphere's harvest season. Following this period, the EU's supply relied entirely on existing stocks. Thus, as Margarido (2012) posits, seasonal prices are influenced by the stock levels in both the EU and Brazil. While Argentina's soybean harvest overlaps with Brazil's (April to October), Argentinian soybeans are predominantly genetically modified and are primarily processed into soymeal for the international market. Therefore, price fluctuations in Argentina are unlikely to transmit to the Brazilian market or impact Brazilian soybean stocks.

Margarido (2012) employed the Johansen cointegration methodology and the Vector Error Correction Model (VECM) with a restriction on the parameter β (β=1). The findings revealed that Brazil exhibits a speed of adjustment parameter (α) of 32% per period, while Argentina shows an adjustment speed of 18% per period in response to a price shock in Rotterdam. In contrast, Rotterdam's adjustment parameter (α) is 0.00386, indicating that Brazil and Argentina act as price takers, whereas Rotterdam functions as a price maker within the model. The significance of the restriction on parameter β validates the long-term integration of the Brazilian and Rotterdam markets, confirming the Law of One Price. Additionally, despite the geographical proximity of the Argentine market to Brazil, price shocks in Argentina do not transmit to Brazilian prices. Ultimately, the author concluded that Brazilian and Argentine prices are not exogenous to Rotterdam prices, with the latter exerting influence over both.

To conclude, the domain of soybean PT, Aguiar and Barros (1991) were pioneering researchers, analyzing causality and asymmetry in Brazilian soybean prices using Granger-Sims causality tests and Houck's asymmetry test. Their findings indicated asymmetric horizontal price transmission (APT) from international to Brazilian wholesale prices with a lag of 1 to 4 months. Mafioletti (2001) similarly found international prices influencing Brazilian domestic prices using Granger causality tests. Aguiar and Barros (1991) also identified asymmetric vertical price transmission within the Brazilian supply chain due to inflationary price expectations. The Liberalisation of the Brazilian economy enhanced market efficiency and price transmission, as confirmed by Mafioletti (2001). Correia das Neves (1993), however, found no evidence of asymmetric price transmission from international prices to Brazilian producers. Pino and Rocha (1994) and Giembinsky and Holland (2003) demonstrated a high degree of dependency of Brazilian markets on Chicago, validating the Law of One Price using transfer function models and cointegration tests. Lima and Burnquist (1997) and Moraes (2002) further confirmed this relationship using Johansen cointegration methodology and time series analysis. Margarido and Souza (1998) found inelastic or asymmetric price transmission from CBOT to Brazilian prices due to the national industry's forward market positions

Extending this research, Margarido *et al.* (1999) found faster and more intensive price transmission from Rotterdam to Brazil and Argentina than from CBOT. Machado and Margarido (2000) confirmed stronger price relations between Argentina, Brazil, and Rotterdam using ARIMA models. Margarido et al. (2001) validated the Law of One Price using VAR and VECM models, finding long-term integration between Rotterdam and Brazilian prices. Da Silva *et al.* (2005) found cointegration between Chicago futures and Brazilian soybean meal prices, but not soybean grain or oil prices. Margarido *et al*. (2007) quantified price transmission elasticity between Brazil and international markets, confirming long-term price transmission. Finally, Margarido (2012) employed Johansen cointegration and VECM models, validating the Law of One Price and highlighting the influence of

Rotterdam on Brazilian and Argentine prices, while noting that price shocks in Argentina do not transmit to Brazil.

The extensive body of empirical research on soybean price transmission underscores the complex dynamics and varying influences of international markets on domestic prices, highlighting both horizontal and vertical transmission mechanisms. Building on this foundation, the following section delves into the cross-price transmission between agricultural and energy commodities, examining how fluctuations in energy markets, such as crude oil, ethanol, and biodiesel, impact agricultural commodity prices.

2.2. Cross price transmission between agricultural and energy commodities

Studies have explored the impact of energy commodities on the pricing dynamics of agricultural products. The role of agricultural policies and energy prices has also been explored, revealing that higher energy prices can influence the costs associated with agricultural production, such as fuel and fertilisers, leading to increased prices of agricultural commodities. This dynamic was especially evident in the context of the 1970s energy crises, which had a profound impact on agricultural sectors worldwide (Havlicek and Capps, 1977). Short *et al.* (1984) used a national interregional linear programming model to examine the effect of energy prices on commodity prices and farm income. Their findings indicated that an increase in energy prices leads to higher commodity prices, with feed grains, wheat, and soybeans experiencing price increases of 24.1%, 18.7%, and 9.9%, respectively.

In their seminal work Yu, Bessler, and Fuller (2006) delved into the extended interdependencies between various vegetable oils (such as rapeseed, sunflower, soybean, and palm oil) and crude oil prices over the period from January 1999 to March 2006. Applying a classic price transmission analysis; Johansen cointegration test, Vector Error Correction Model (VECM), complemented by Forecast Error Variance Decomposition (FEVD) and Impulse Response Function (IRF), the researchers elucidated notable endogenous price volatilities within the soybean oil market, which constituted 73% of the variations, with a relatively minor impact from palm oil prices, which accounted for 27%. In a six months period, the fluctuations in soybean oil prices were found to be largely self-contained, explaining approximately 87% of the variations, whereas crude oil prices contributed insignificantly, explaining only 0.34% of these fluctuations. The findings further recognised a consistent behaviour across edible oils, which are typically influenced by inherent price movements in the short term; however, over the long term, soybean oil prices emerge as the predominant factor engendering uncertainty in the edible oil market, impacting between 32% and 75% of the price shocks.

Conversely, the impact of crude oil prices on edible oil prices is minimal, with crude oil functioning primarily as an external variable within the edible oil market. In stark contrast Hasanov *et al.* (2016), using a more advanced methodology a four-variate version of non-diagonal GARCH-in-mean model , Generalize impulse respond function and the granger causality test found that Crude oil price volatility has a significant impact on the prices of major edible oils, such as rapeseed, soybean, and sunflower oils. This is particularly evident because these oils are used as feedstock for biodiesel production in the European Union, and there is strong evidence of causality from crude oil price volatility to edible oil prices.

Campiche *et al.* (2007) explored the covariability between crude oil and agricultural commodities (soybean, palm oil, maize, sorghum, sugar, and other edible oils such as soybean oil.) over the period 2003-2007 and using a price transmission methodology including the PT methodology (VECM, and Johansen cointegration approach). The research period was segmented into two phases, 2003-2005 and 2006-2007, with an anticipation of increased covariability linked to the interaction between agricultural feedstocks and crude oil prices in the latter phase due to developments within that timeframe. In the initial phase (2003-2005), the cointegration analysis revealed no cointegration among the agricultural commodities and crude oil prices. However, during the second phase, it was discovered that soybean and corn exhibited cointegration relationships with crude oil prices. The exogeneity tests indicated that crude oil prices were weakly exogenous in these cointegration relationships. The researcher highlighted that in 2007, a structural shift potentially enhanced the correlation between soybean and crude oil, a change attributed to the burgeoning ethanol and biodiesel markets.In other studies, Zhang and Reed (2008) investigated whether the prices international prices of crude oil were the main reason for rising food prices in China. In other words, the authors studied if there were cross price transmission between crude oil and agricultural commodities prices (China’s corn, soy meal pork prices) for the period between January 2000 and October 2007. Using a multivariate time series approach to infer the dynamic relationship among the variables; the ARIMA model, FEVD, IRF, Johansen-Juselius (1990) rank cointegration test, and Granger causality test (group technique). The results showed that world crude oil prices do not affect China's soymeal, pork, and corn prices concluding that the influence of crude oil prices in China's agricultural commodities is not significant and there is lack of cointegration. The crude oil prices are not driving the increase in prices of Chinese Agricultural commodities, even though the rise in crude oil prices might present a long-term increase in production cost. However, this is not reflected in agricultural prices in the short-term.

These findings are partially consistent with the model described in Nerlove (1958). Moreover, Nazlioglu *et al*. (2011) with a similar approach, included another variable the exchange rate, to study the effect of oil prices and exchange rates for certain agricultural commodities (soybean, sunflower, cotton, wheat, and maize) for Turkey. The results indicated that the prices of agricultural products did not exhibit a significant reaction to the changes in the prices of oil products.

A study by Margarido *et al.* (2014)**,** investigated the relationship between the international prices of crude oil (Dated Brent, light blend 38 API), and soybean (U.S. soybeans; Chicago Soybean), and a further regression for the future implications of the commercial supply of soybean No.2 Yellow (graded soybean)(Appendix IV). The analysis also established whether the prices converge in a long-term equilibrium, for the period from January 1989 to October 2010. The econometric techniques performed were, the Granger causality test, Johansen cointegration, exogeneity test, FEVD, IRF, multivariable GARCH-BEKK model. The result showed that both prices did not have any significant effect on each other, meaning that in the short term the price variations of each price did not affect the other price. Bini *et al.* (2016) arrived at the same conclusion using the same methodology. This is counter-intuitive finding can be expected that soybean prices do not affect crude oil prices because soybean is relatively not a relevant input in the economy as compared to crude oil. However, it is expected that crude oil can cause an increase in soybean prices, since, crude oil is an important input in the soybean production. This crop utilizes a considerable amount of herbicides that require fossil fuel to be produced. In addition, there is significant fuel consumption during the production process of soybean (sowing, spraying, the application of fertilisers, harvesting, etc). However, this can be explained by the model described by Nerlove (1958) model that indicated the impossibility of short term prices adjustment of agricultural product in changes in the prices of the inputs. This adjustment can occur only in the long term; therefore, there are no short-term causality relationship form crude prices to soybean prices.

The Johansen cointegration test conducted by Margarido *et al.* (2014), showed that there is one cointegration vector between both prices (Soybean, and Crude Oil) meaning that the markets are cointegrated. Therefore, presenting a long-term relationship converging to long-run equilibrium. The VECM model shown that the β (long term parameters) is roughly 0.36, meaning that there is an inelastic relationship in the long term. The prices are transmitted less than proportional (from crude oil to soybean). The short-term parameter α for soybean prices showed a very slow speed of adjustment around 4.6% per period (monthly) if shock in prices in the crude oil market occurs. This phenomenon is further explained in Nerlove (1958) model. The error correction coefficient for oil prices exhibited a positive sign, indicating that crude oil prices function as an exogenous variable, thereby confirming that crude oil prices are decoupled from international soybean prices. Furthermore, the analysis revealed the absence of a causal relationship from soybean prices to crude oil prices, a finding corroborated by an exogeneity test which assessed the variables' responses to long-term equilibrium conditions. The Forecast Error Variance Decomposition (FEVD) indicated that a non-anticipated shock in crude oil prices after 24 months (the maximum period considered) attributed 89.59% of the variance decomposition errors to crude oil prices and 10.40% to international soybean prices. Conversely, under identical conditions, soybean prices produced an 86.48% variance error, with 13.51% attributable to international crude oil prices. Bini et al. (2016), employing a similar methodology, found that after ten months, 95.7% of the variance decomposition for soybean prices could be attributed to the prices themselves, and only 2% to crude oil prices. This suggests that in the event of a price shock, the crude oil market is predominantly influenced by its own dynamics, with minimal impact from soybean prices. The authors concluded that there is a higher degree of interlacement of the market as a consequence of biofuel production has two significant affections in the agricultural commodity market. There is a noticeable increase in production cost in the supply chain and an increase in the volatility of agricultural commodities prices. Besides, a substitution effect occurs when agricultural producers substitute food production with the production of raw material for the generation of energy.

Shahzad *et al.* (2018) employed a combination of static and dynamic bivariate elliptical and Archimedean copula functions to estimate nonlinear dependence between oil and agricultural commodities, including soybeans. Using standard Value-at-Risk (VaR), conditional Value-at-Risk (CoVaR), and delta CoVaR (ΔCoVaR) allowed the researchers to measure bilateral spillover effects between these markets. The analysis utilized ARIMA-GARCH models with skewed t-distribution to obtain marginal distributions and various bivariate copulas, such as Clayton and Gumbel, to capture tail dependencies. The study used daily price data for crude oil and agricultural commodities from January 2000 to December 2016, sourced from the International Grains Council (IGC) and the Energy Information Administration (EIA). This 16-year period included significant economic cycles and financial turmoil, such as the Global Financial Crisis.

The study found that the dependence between oil and most agricultural commodities, including soybeans, was characterized by symmetry in tail dependence, but spillover effects were asymmetric and intensified during financial downturns. For instance, the downside CoVaR for soybeans from oil returns was -3.09 compared to an upside CoVaR of 2.91, indicating significant risk spillovers during market declines. Additionally, soybeans exhibited a high degree of bidirectional spillover effects with oil, evidenced by a ΔCoVaR of 0.3352 for downside spillovers from oil to soybeans, statistically significant at the 1% level. These findings highlighted the significant impact of oil price changes on soybean prices, particularly during periods of economic instability. However, the study had limitations, including the relatively short sample period for wavelet analysis, focus on specific commodities, potential model misspecification due to non-normality of residuals, and the reliance on specific copula functions. Despite these limitations, the research provided valuable insights into the interconnectedness and volatility in the oil and agricultural markets, especially for soybeans.

Building on these findings, Dejan *et al.* (2019) employed a combination of quantile regression (QR) and wavelet decomposition analysis to further investigate the interdependence between spot oil returns and five spot agricultural commodity returns, including soybeans. This approach allowed them to explore conditional dependence at different quantiles and understand how oil price changes impacted agricultural commodities under various market conditions. Wavelet decomposition provided insights into the dependence structure over different time horizons, covering six wavelet scales ranging from 2 to 128 days. Using daily data from January 2003 to September 2018, the study found that the oil-soybean combination exhibited highly statistically significant quantile parameters, indicating a strong spillover effect. For example, oil impacts on soybean prices in extreme market conditions showed quantile parameters as high as 21% in the midterm and 20% in the long-term horizons. The QR parameters for soybeans were the highest among all agricultural commodities analysed, reflecting the substantial economic significance of the oil-soybean relationship, particularly in the upper quantiles. Wavelet cross-correlation results revealed significant interlinkages between oil and soybeans across various time scales, with stronger effects in longer-term horizons. However, the study had limitations, such as the relatively short sample period for wavelet analysis and the focus on specific commodities, which might not capture the full complexity of global market interactions. These findings underscored the interconnectedness and volatility in the oil and agricultural markets, particularly soybeans, highlighting the importance of dynamic, multi-method approaches to understanding market behaviour under various conditions.

Bini *et al.* (2016) move forward the empirical research, assessing the cross price transmission among the oil prices, agricultural prices (poultry, soybean, and maize), fertilizer prices (simple superphosphate (SP), potassium chloride (PC) and ammonium sulphate (SA)). The methods used were the DF-GLS (Dickey-Fuller Generalized Least Square), VEC model, Johansen cointegration test, FEVD and the IRF. The cointegration test showed that there were at least two cointegrations vectors among the series. The Granger causality showed that there is not a short causal relationship among the agricultural and energy commodities at least the in the Brazilian market. Only the crude oil price was significant to influence the poultry price. However, there was no significant relationship between crude oil prices and the costs of fertilisers. The FEVD in ten months period showed that 86% of a shock in poultry prices in can be explained by itself 3.276% by maize prices being primary feed input crude oil can be explained 4.6% being the main input. In contrast, soybean can explain only 0.44% that counter-intuitive finding, since soybean is the primary source of protein in poultry feed (Zhang and Reed, 2008). However, a shock in the price of soybean can explain 23% of the FEVD of maize, while maize can explain only 0.16% of the FEVD. This finding shows the dependency of maize prices on the soybean prices. This effect occurs because both crops are summer crops and compete for the same areas of cultivation. Hence, any changes in prices in soybean will affect the prices of maize and the related food items. However, the results by Bini *et al.* (2016) indicate that soy has the price lead the costs of soybean are the central agriculture explicative variable in the FEVD explaining about 3.515% of SP, 6.2% of PC and 3.46% SA. The IRF showed that a 1% increase in soybean prices generate a positive shock of a 0.7% increase on maize prices (first month), 0.5% along all period in SP prices. In contrast, PC and SA have an adverse reaction in prices around -0.5% (12 month period).

In general, shocks in prices agricultural commodities are transmitted in a higher degree to the fertilizer prices, than the opposite situation. However, an increase of 1% in SA prices provoke a rise of 0.7% in maize prices, this can be explained by the high nitrogen dependency of this crop. The authors have found a high elasticity ratio (1:0.25) between crude oil prices and other commodities prices, which means that there is no expressive relationship. These results are consistent with previous findings of Zhang and Reed (2008) in China and Nazlioglu and Soytas (2011) in Turkey, but in contrast with Reboredo (2012) in The United State where a degree of transmission was observed. Bini *et al.* (2016) could not find cross-price transmission between crude oil and fertilizer, and between fertilizer and grain, the price transmission is bidirectional, though more robust from grains to fertilisers.

More recently, Simanjuntak *et al.* (2020) examined the price transmission between soybean, soybean meal, and soybean oil using monthly international price data from January 1996 to May 2019. It employed various econometric techniques, including Augmented Dickey-Fuller (ADF) and Phillips-Perron (PP) tests to check for stationarity, the Johansen cointegration technique to identify long-term relationships, and the Vector Error Correction Model (VECM) to estimate short-term dynamics. The results revealed a long-run equilibrium relationship among the prices, with soybean prices adjusting to correct disequilibrium (Soybean price adjustment coefficient: -0.31***). The IRF showed that a 1% increase in meal price led to a 0.03% increase in soybean price, while a 1% shock to oil price permanently increased soybean price by about 0.027%. The FEVD indicated that soybean oil prices contributed more to the variation in soybean prices (Oil price contribution to soybean price variance: 18% in the tenth period) compared to soybean meal prices (12%).

However, the study had several limitations. The Jarque-Bera test indicated non-normality of residuals, suggesting potential model misspecification (JB test for soybean price equation: p-value < 0.01). Additionally, the focus on international prices may not have fully captured the dynamics at the domestic or farm level, which could have led to misinterpretation of the joint products theory. Furthermore, the exclusion of other significant exogenous variables affecting price transmission may have influenced the speed of adjustment and overall results. These findings highlighted the interconnectedness of the soybean markets and the importance of considering joint product relationships in price transmission analysis, while also suggesting areas for further research to address the identified limitations.

The empirical analysis of cross-price transmission between agricultural and energy commodities reveals the intricate dynamics and varying degrees of influence that energy markets, such as crude oil, exert on agricultural prices. Building on these findings, the next section delves into the connectedness approach in previous empirical research, with a specific focus on the relationship between soybeans, other agricultural commodities, and energy commodities.

2.3. Connectedness Approach previous empirical research

The connectedness approach has become increasingly significant in analysing the complex interdependencies between agricultural and energy commodity markets, particularly for commodities like soybeans. This methodology quantifies how shocks and volatility in one market transmit to others, capturing the dynamic spillover effects that traditional models may overlook. By utilizing advanced econometric tools such as the spillover index, wavelet coherence, and Quantile Vector Autoregression (QVAR), researchers can assess both the direction and intensity of these interconnections across different time horizons and under varying market conditions, including extreme events like the COVID-19 pandemic.

Understanding these interconnected dynamics is crucial for several reasons. Firstly, it provides deeper insights into the price transmission mechanisms between commodities, highlighting how disruptions in energy markets can influence agricultural prices and vice versa. Secondly, it informs policymakers and market participants about the potential risks and volatility inherent in these markets, aiding in the development of strategies to mitigate adverse effects. Lastly, the connectedness approach enhances the robustness of empirical analyses by accounting for time-varying relationships and asymmetries in market responses, thereby offering a more comprehensive understanding of global commodity market behaviour essential for this research.

2.3.1. Soybean, agricultural commodities and energy commodities

Hung (2021) investigated the relationship between crude oil prices and agricultural commodity markets, including soybeans, before and during the COVID-19 pandemic using the spillover index of Diebold and Yilmaz (2012) and wavelet coherence approaches. It also employed a Quantile Vector Autoregression (QVAR) model to capture market dynamics under extreme conditions. The spillover index measured the direction and intensity of return spillovers, while wavelet coherence analysed time-varying co-movements between variables. The study used daily data on crude oil and agricultural commodity prices, including soybeans, from February 2018 to May 2020, divided into pre-COVID-19 (February 2018 to January 2020) and during COVID-19 (February 2020 to May 2020). This comprehensive approach allowed the researchers to track how market connectedness evolved over time and across different frequencies.

The study found significant changes in market behaviour due to global disruptions. During the COVID-19 period, the total spillover index increased to an average of 52.8% from 16.1% in the pre-COVID-19 period, highlighting intensified interdependencies between crude oil and agricultural markets. Specifically, soybeans emerged as a net transmitter of return spillovers, with its net contribution to market return reaching approximately 10% in the pre-COVID-19 period and peaking at 18% during the pandemic. Wavelet coherence analysis showed strong co-movement between WTI crude oil prices and agricultural commodities, particularly during the COVID-19 outbreak, with significant intercorrelations in the 4-to-16 day frequency bands. However, the study had several limitations, including the relatively short sample period, focus on specific commodities, and the use of daily data, which limited the ability to observe longer-term trends and structural changes. The non-normality of residuals, as indicated by the Jarque-Bera test, suggested potential model misspecification, which could affect the robustness of the findings. These results emphasized the need for policymakers to consider these dynamic spillovers when devising strategies to stabilize commodity markets, providing valuable insights into the increased interconnectedness and volatility in the crude oil and agricultural markets, particularly soybeans, during the COVID-19 pandemic.

Using the same connectedness approach however based on time-varying parameter vector autoregression (TVP-VAR) Umar *et al.* (2021), estimated the dynamic return and volatility connectedness between oil price shocks and agricultural commodity markets, including soybeans. Oil price shocks were categorized into risk, demand, and supply shocks. Using daily data from February 7, 2000, to September 17, 2020, the analysis covered significant economic events such as the dotcom bubble, the Global Financial Crisis (GFC), and the COVID-19 pandemic. This methodology allowed for a detailed examination of how connectedness measures evolved over time and during different crises, offering a comprehensive view of the spillover effects from oil to agricultural commodities.

Umar *et al.* (2021), found substantial dynamic return and volatility connectedness between oil prices and agricultural commodities, with soybeans showing significant spillover effects from oil price changes. The mean return connectedness was approximately 31.2%, while mean volatility connectedness was about 17.7%. During economic crises, such as the COVID-19 pandemic, the return connectedness for soybeans notably increased, indicating their role as net transmitters of return spillovers. However, the study had limitations, including the relatively short sample period for wavelet analysis and the focus on specific commodities, which might not capture the full complexity of global market interactions. Additionally, the non-normality of residuals suggested potential model misspecification. Despite these limitations, the findings provided valuable insights into the interconnectedness and volatility in the oil and agricultural markets, particularly soybeans, emphasizing the importance of dynamic, multi-method approaches to understanding market behaviour under various conditions.

Yang and Berna (2021) utilized the Vector Autoregressive Quantile (QVAR) model to analyse the asymmetric price transmission and connectedness among soybean and its products (soybean oil and meal). The analysis covered a period from January 1, 1992, to June 30, 2020, using daily futures prices from the CME Group (CBOT), converted to U.S. dollars per bushel. The methodology focused on three quantile indexes (0.05, 0.50, 0.95) to capture the relationship between economic variables across the entire distribution, particularly under extreme market conditions. The

QVAR model was chosen for its robustness in handling extreme market movements and its ability to provide a comprehensive view of price transmission dynamics.

The empirical results indicated the presence of asymmetric price transmission within the soybean complex. Both the own and cross-effects of lagged variables were statistically significant and differed across various points (quantiles) of the distributions. Specifically, the cross-lagged effects on soybean returns were positive at the lower quantile but turned negative at the higher quantile. Additionally, soybean products exhibited negative responses to input price shocks when the other two commodities were at the 0.05 quantile, and positive responses when at the 0.95 quantile.

Ghosh and Paparas (2023) utilized Quantile Vector Autoregression (QVAR) to analyse the interconnectedness of 14 agricultural commodities, including soybeans, over a 62-year period from January 1, 1960, to June 1, 2022.The researchers analysed extreme the lower (0.1), median (0.5), and extreme upper (0.9) quantiles to measure risk spillovers.This approach allowed the researchers to capture the dynamics of extreme market movements and understand the risk transmission among the commodities. The findings revealed significant, time-varying connectedness among the commodities, with soybeans identified as a consistent net emitter of shocks across extreme quantiles. The connectedness index remained high (83-85%) during stressed events like wars and supply chain disruptions. Soybeans contributed 10-14% to returns in maize, rice, beef, wheat, oils, and coffee during extreme high quantiles. The study also observed reduced complexity in the network of shock emitters and receivers at higher quantiles, establishing a new stylized fact in agri-commodity markets. Despite the robustness of the QVAR method, the study acknowledged limitations, including the novelty of the methodology and the potential overlook of middle quantile dynamics.

2.4. Previous Empirical work summary on Soybeans

Extensive research on soybean price transmission especially in Brazil over the past 40 years has employed various econometric and time series models to uncover the dynamics between domestic and international prices. Early studies by Aguiar and Barros (1991) and Mafioletti (2001) produced conflicting results: while Aguiar and Barros identified that international prices led Brazilian wholesale prices with a lag and exhibited marked asymmetry (possibly due to inflation expectations), Mafioletti observed causality in the reverse direction. Other research, such as Correia das Neves (1993), found no evidence of asymmetric transmission, whereas studies by Pino and Rocha (1994), Giembinsky and Holland (2003), Lima and Burnquist (1997), and Moraes (2002) confirmed a strong long-term link between Brazilian markets and the Chicago Board of Trade, in line with the Law of One Price. Margarido and Souza (1998) and Margarido et al. (1999) further highlighted inelastic or asymmetric transmission, noting that price adjustments from Rotterdam occurred more rapidly than those from CBOT, with later works by Da Silva et al. (2005), Margarido et al. (2007), and Margarido (2012) reinforcing these findings and emphasizing Brazil's market resilience compared to Argentina, along with the impact of exchange rate pass-through as detailed by Fraga et al. (2009).

Parallel research has focused on the influence of energy commodities on agricultural prices. Studies by Yu et al. (2006) and Campiche et al. (2007) revealed that soybean oil prices primarily drive edible oil market trends, while Zhang and Reed (2008) and Nazlioglu et al. (2011) found minimal short-term effects of crude oil on agricultural commodities. Further analyses by Margarido et al. (2014) and Bini et al. (2016) confirmed that while long-term relationships exist, crude oil's short-term impact on soybean prices remains inelastic and less-than-proportional. Advanced econometric investigations by Shahzad et al. (2018), Dejan et al. (2019), Hung (2021), Umar et al. (2021), Yang and Berna (2021), and Ghosh and Paparas (2023) have documented significant spillover effects and dynamic connectedness especially during economic downturns and global disruptions like COVID-19 underscoring the complex interdependencies among oil, agricultural, and fertilizer markets.

2.5. Previous Empirical Work in Trade Conflicts

The empirical analysis of trade conflicts has evolved significantly over time, with methodological innovations paralleling major historical episodes of trade tensions. This section reviews the development of empirical approaches chronologically, highlighting how researchers have progressively refined techniques to understand the economic consequences of trade wars.

2.5.1. Early Empirical Studies: The Interwar Period

Kitson and Solomou (1990) conduct a two-tiered empirical analysis to assess the macroeconomic and sectoral impacts of the 1932 General Tariff on Britain's economic recovery during the interwar period. Their sectoral-level analysis employs disaggregated trade and output data across key manufacturing industries newly shielded by the tariff. By applying time-series methods to track output growth, price behavior, and import penetration rates before and after tariff introduction, they isolate protection-induced import substitution effects within these sectors. This allows for a direct comparison between protected and non-protected industries, helping to measure the differential performance attributable to the tariff regime. The results show that the General Tariff triggered significant import substitution, particularly in manufacturing sectors with pre-existing underutilized capacity, leading to an accelerated rate of output growth in protected industries. These foundational studies faced significant methodological limitations, including rudimentary econometric techniques and data constraints.

Madsen (2001) advanced this literature by examining how trade barriers contributed to the collapse of world trade during the Great Depression. Madsen estimated bilateral trade equations (both exports and imports) for 17 countries over the 1929-1932 period, constructing a panel dataset that combined time-series data across countries.Madsen's analysis quantified how rising protectionism directly contributed to the collapse of world trade during the Great Depression, and found that many of the tariff increases and non-tariff barriers were selectively applied to protect trade within imperial and preferential blocs, reinforcing existing trade relationships at the expense of outsiders (Madsen, 2001). This research established an important empirical baseline but lacked the sophisticated identification strategies that would later emerge.

The empirical understanding of interwar protectionism was further enhanced by Jacks and Novy (2008), who applied modern gravity model techniques to historical trade data spanning the late 19th and 20th centuries. Their analysis revealed heterogeneous effects across trading partners, with some bilateral relationships showing relatively small impacts while others demonstrated highly significant trade destruction, depending on political alignment, currency regimes, and existing trade relationships. This highlighted an important nuance in trade war impacts: effects are rarely uniform across all trading relationships.

2.5.2. *Methodological Advancements: Post-WWII to 1990s*

The post-war period saw significant advancements in econometric techniques applied to trade policy analysis, culminating in the seminal contribution of Anderson and van Wincoop (2003). Their work fundamentally transformed the gravity model by introducing multilateral resistance terms, which account for the fact that bilateral trade flows depend not only on direct trade costs between two countries, but also on each country's trade costs with all other trading partners. This general equilibrium correction resolved a critical flaw in earlier gravity estimates, which systematically over- or underestimated the effects of bilateral barriers by ignoring broader global trade relationships. By embedding trade flows within a nonlinear system of equations, Anderson and van Wincoop (2002) enabled researchers to simulate counterfactual policy changes (like tariff increases or removals) while correctly accounting for the indirect trade diversion and suppression effects across the entire global trading system. This methodological innovation elevated the gravity model from a simple bilateral correlation tool to a fully structural, general equilibrium framework, making it one of the most important advances in empirical trade analysis.

As computational capabilities expanded, researchers began developing computable general equilibrium (CGE) models to simulate the economy-wide impacts of trade policies. These models, though primarily calibrated using Social Accounting Matrices (SAM) and existing parameter estimates, rather than directly estimated from data, provided a structured framework for quantifying welfare effects across sectors and countries (de Melo, 1988).

The 1990s saw increased methodological sophistication through panel data techniques, as researchers exploited cross-country and temporal variation in tariff rates to identify causal effects on economic outcomes. However, as Goldberg and Pavcnik (2016) emphasize, these studies faced a fundamental challenge of endogeneity: governments typically adjust tariffs in response to economic conditions, rather than randomly, complicating causal inference and limiting the reliability of simple panel data estimates.

2.5.3. Modern Empirical Approaches: 2000s-2010s

The early 2000s witnessed the emergence of more rigorous identification strategies in trade policy research. Topalova (2010) pioneered the use of regional variation in trade policy exposure to identify causal effects of trade Liberalisation on poverty in India, applying a difference-in-differences framework that leveraged variation in pre-Liberalisation industrial composition across districts and sectoral tariff cuts during India's 1991 reforms. This microeconomic approach; exploiting subnational variation in policy exposure—would later become instrumental in studying the distributional impacts of modern trade conflicts, including trade wars.

The development of Structural Vector Autoregression (SVAR) models can be traced back to the pioneering work of Christopher Sims (1980), who introduced vector autoregressions (VAR) as a flexible alternative to the structural simultaneous equations models prevalent at the time. Sims' framework allowed for the estimation of dynamic relationships among macroeconomic variables without the need for strong a priori restrictions. The SVAR extension, developed shortly after, introduced theoretically motivated identification restrictions, enabling researchers to recover structural shocks from reduced-form VAR residuals and to trace the dynamic propagation of policy shocks through the economy (Sims, 1980). Later refinements by Fernández-Villaverde and Rubio-Ramirez (2010) systematized the identification strategies used in modern SVAR applications, cementing the methodology's status as a core tool in empirical macroeconomic analysis (Fernández-Villaverde and Rubio-Ramirez, 2010).

A breakthrough in causal inference came with Abadie and Gardeazabal's (2003) development of the synthetic control method. Originally applied to conflict studies, this technique was later adapted to trade policy analysis, enabling researchers to construct data-driven counterfactuals for economies affected by trade shocks.

By the mid-2010s, Handley and Limão (2017) integrated trade policy uncertainty (TPU) into empirical trade models, demonstrating that uncertainty about future trade policy (not just realized tariff changes) can significantly affect firm entry, export decisions, and overall trade flows. Their analysis of China-U.S. trade relations showed that reducing uncertainty through China's WTO accession and the granting of PNTR status explained a substantial share of China's export boom to the U.S. This framework presciently laid the groundwork for analyzing the effects of trade wars through the lens of policy uncertainty.

2.5.4. Recent Empirical Literature: The 2018-2019 US-China Trade War

The 2018-2019 US-China trade conflict generated an unprecedented natural experiment for trade economists, spawning numerous empirical studies employing diverse methodological approaches. This episode has been particularly valuable for empirical work because, as noted by Fajgelbaum *et al.* (2020), the sector-level tariff increases appear uncorrelated with pre-trends once controlling for industry and time fixed effects, suggesting they can be treated as plausibly exogenous shocks.

Difference-in-differences (DiD) designs have featured prominently in this literature. Amiti *et al.* (2019) and Cavallo *et al.* (2021) compared price movements between tariffed and non-tariffed goods, documenting near-complete pass-through of import tariffs to domestic prices. These findings indicated that "U.S. consumers and importing firms bore almost the entire cost of tariffs in higher prices" rather than foreign exporters absorbing the costs.

More granular analyses examined distributional consequences across regions. Fajgelbaum *et al.* (2020) leveraged county-level industry composition data to show that U.S. counties more exposed to retaliatory tariffs experienced greater export losses and employment declines—the so-called "farm belt effect." This approach exemplifies how regional heterogeneity in trade exposure can identify causal effects even when policy changes occur at the national level.

Firm-level panel studies have illuminated microeconomic mechanisms. Benguria *et al.* (2022) employed Chinese firm data in a difference-in-differences framework to demonstrate how tariff hikes increased perceived uncertainty, subsequently depressing investment and R&D. Their innovative textual analysis approach quantified "firm-level increases in TPU (trade policy uncertainty) and linked these directly to real economic outcomes.

Complementing these microeconomic analyses, macroeconomic studies using SVAR techniques have traced economy-wide effects. Furceri *et al.* (2019) implemented a local-projection panel approach across 151 countries from 1963-2014, finding that tariff increases "significantly reduce domestic output and productivity in the medium term" while also raising unemployment and inequality.

The most recent methodological frontier involves synthetic control applications. Cai and Li (2024) employed a generalized synthetic control approach to construct counterfactual trade flows for the US and China, finding that "China's exports fell significantly below their synthetic counterfactual after 2018," confirming the substantial trade diversion effects of the conflict.

2.5.5. *Integration of Empirical Approaches*

The current empirical literature increasingly combines multiple methodological approaches to triangulate findings. For instance, evidence from the 2018-2019 US-China trade war shows convergence across methods: price regressions document consumer welfare losses; regional DiD studies demonstrate exporter suffering from retaliation; gravity simulations and synthetic controls quantify trade flow reallocations; and DSGE/SVAR analyses identify modest but non-trivial declines in investment and economic growth.

This methodological convergence builds confidence in several robust findings: consumers in importing countries typically bear most tariff costs; targeted exporters suffer significant losses; trade flows substantially reallocate to avoid tariffs; and the macroeconomic consequences include reduced investment and growth, though typically smaller than microeconomic disruptions might suggest.

The empirical literature has thus evolved from basic time-series analyses of historical trade wars to sophisticated multi-method approaches that can credibly identify causal effects across various economic dimensions. This progression has substantially deepened our understanding of how trade conflicts propagate through economies, providing policymakers with more reliable evidence on which to base decisions in an increasingly contentious global trade environment.

2.6. Literature Review; Research gaps

Many authors have contributed mapping the dynamics of the international market of soybean in terms of prices transmission, elasticity and asymmetry of prices transmission (Aguiar and Barros, 1991; Correia das Neves, 1993; Pino and Rocha, 1994; Mafioletti, 2001; Margarido, Turolla and Fernandes, 2001; Giembinsky and Holland, 2003; Silva and Machado, 2009). Previous researchers have identified the key players, prices maker, price takers, market efficiency for each regional market and market power (Lima and Burnquist, 1997; Margarido and Sousa, 1998; Margarido *et al.*, 1999; Moraes, 2002; Margarido, Turolla and Bueno, 2007; Silva and Machado, 2009; Margarido, 2012). Moreover, some has investigated the cross prices transmission among different agricultural commodities , fertilisers , energy commodities and soybean (Yu *et al.,* 2006; Campiche *et al.*, 2007; Zhang and Reed, 2008; Nazlioglu and Soytas, 2011; Margarido *et al.*, 2014). Some has studied the effects of the exchange rate in soybean prices transmission (Bini *et al.*, 2016). Despite of the fact that markets spontaneous order that cannot be forecasted or predicted (Hayek, 1989). Therefore, any attempt to replicate previous researchers work will generate new valued insights taking into account that the conditions of the market will be completely different.

Despite the extensive research on price transmission in the soybean market, several gaps remain. Firstly, the majority of studies have focused on historical data and traditional econometric models, which may not fully capture the dynamic nature of modern global markets. With rapid technological advancements and evolving trade policies, the market conditions have changed significantly, necessitating updated analyses using contemporary data and advanced methodologies.

Secondly, while numerous studies have examined price transmission between major markets like Brazil, the USA, and Argentina, there is limited research on the interactions with emerging markets and their integration into the global soybean supply chain. Understanding how these new players influence and are influenced by established markets could provide valuable insights into global price dynamics.

Thirdly, the impact of recent global disruptions, such as the COVID-19 pandemic and the Ukrainian-Russia war, on soybean price transmission has not been extensively studied. For instance, the pandemic has caused unprecedented shifts in supply chains and demand patterns, highlighting the need for research that considers these extraordinary events and their long-term implications on market behaviour. Following this the Ukrainian-Russian war has caused significant disruptions in global supply chains and commodity markets (Nasir *et al.,* 2022). The conflict has led to increased volatility and uncertainty in the agricultural sector, as both Ukraine and Russia are major players in global grain markets. This has resulted in shifts in trade routes, increased transportation costs, and fluctuating prices, which have distorted the soybean market. Consequently, there is a pressing need for research that considers these extraordinary events and their long-term implications on market behaviour. Such studies would help in understanding how geopolitical conflicts affect price transmission, market efficiency, and the overall stability of the international soybean market.

While some research has been conducted on the cross-price transmission between agricultural and energy commodities, there is a need for more comprehensive studies that integrate other critical factors such as climate change, geopolitical tensions, and sustainability practices. These factors are increasingly relevant in shaping market dynamics and should be incorporated into future research to provide a holistic understanding of price transmission mechanisms.

Therefore, future research should aim to address these gaps by employing advanced econometric techniques, utilizing real-time data, expanding the scope to include emerging markets, and considering the effects of recent global disruptions and other critical factors. By doing so, researchers can provide more accurate and relevant insights into the complex dynamics of the international soybean market.

Previous researchers based their investigation solely on prices transmission between two or more countries using a narrow set of econometric models. In some cases, introducing “atheoretical” concepts such as elasticity of prices transmission or failing to adopt a more integral approach when generating conclusions.

Due to this, most previous investigations generated slanted, mixed, and inconclusive results, and hence a partial understanding or incomplete knowledge of this market. It is evident that in a globalised world where the free trade is the fundamental foundation of a capitalist society, the market integration across the world market is far more complex that the boundaries of our capability. We cannot assume that markets are frankly exogenous or dislocated from other international markets. Therefore, new research should address the soybean market study considering the full dimension of it or at least the main market players. To achieve the full picture and overall international market dynamic, it is important to embrace the market from supply side, including the main exporters of soybean such as Brazil, the USA and Argentina. As well from the demand side including China and the European Union. In addition, it requires including future markets because they play an important role in future price expectations. It is necessary to adopt an integral approach taking into consideration, price transmission, asymmetric price transmission and market power.

The central research void has been pinpointed: the precise impact of the US-China trade war on the global soybean market remains unclear. This study seeks to elucidate whether the trade conflict has precipitated disruptions in the market, skewed the mechanisms of price signal transmission, and caused a misalignment of market integration (evidenced by a lack of cointegration). Furthermore, it interrogates the efficacy of tariffs and subsidies as instruments of Market Power within a market characterized by high efficiency and integration. It also aims to quantify the true economic burden of these trade interventions on the market and its participants. A critical aspect of this analysis is determining the victor of the Soybean Trade War.

Additionally, in the context of a bifurcated global political landscape, it is essential to assess whether China, or an emergent market such as Paranaguá, has gained a new proportion of market power, or if the Chicago market retains its status as the pivotal hub of price formation. Comprehending these dynamics is vital, particularly given the likelihood of the reoccurrence of such market anomalies under the current geopolitical climate.

Chapter 3: First Empirical Chapter

3.1. **Price Transmission Analysis of the International Soybean Market in a Trade War Context** (Barboza Martignone, Behrendt and Paparas, 2022)

3.1.1. Details Summary

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- Author Contributions

D.P. and K.B., supervision, project administration, methodology. G.B.M., conceptualization, formal analysis, investigation writing and review and editing. All authors have read and agreed to the published version of the manuscript.

- License

- Format

The format and general structure of the paper, including the numbering of headings and subheadings, have remained unchanged. Only the citations have been updated to Harvard style.

3.1.1.1. Presentation of Published Empirical Findings

This section presents the original empirical study, as published in MDPI Economies, titled “Price Transmission Analysis of the International Soybean Market in a Trade

War Context." The chapter is reproduced in full to maintain the accuracy of the findings and enable direct engagement with the original research. This study provides an essential foundation for the dissertation, offering valuable insights and data that are further analysed and expanded upon in the following chapters.

In accordance with academic standards, no changes have been made to the original content, except for citation formatting adjustments to match the dissertation’s style.

ECI 1. Introduction

The trade war is an ongoing geopolitical conflict that originated with the Trump administration. This conflict involved US-initiated battles between the USA, China and US allies, causing repercussions throughout the entire world economy, the free trade sys-tem and the globalised world as we know it (Bown and Kolb 2020). Most sectors of the Chinese and US economies have been impacted during this war, and all have suffered the consequences of it to differing extents. Further, the magnitude of this phenomenon has impacted all world economies in some way, whether directly or indirectly, and it has generated high levels of volatility and uncertainty in the international and domestic markets, hampering trade and investment (Bown and Kolb, 2021) On one hand, we have China, emerging as a rising economic power; whilst on the other hand, we have the USA, the first world economy in decline (Abdullahi and Phiri 2018). The Trump administration aimed to bend that decline and, as Trump’s campaign quoted, “Make America great again”. The US government intended to address this by boosting its economy by directly attacking the trade deficit, using extensive arsenals of importation tariffs, quotas, duties and threats to achieve a trade balance. The measures were imposed on China, as well as US allies. The Chinese government took these as direct attempts from the USA to eclipse the ascension of China as the first superpower and main world economy. They adopted different measures to respond to US policies.

The soybean market was in the spotlight during the first phase of the trade war since the Chinese government used this market and its market power as a leverage point to put pressure on the Trump administration. The international soybean market has been extensively studied for 50 years and empirical evidence suggests it is characterised as a highly efficient and cointegrated market, where the law of one price (LOOP) has been validated several times. The international soybean market has faced several market in-terventions from different players, such as “retentions” (export tariff) from Argentina (Margarido et al. 2007) or China’s domestic price intervention by price support policies and flashing import tariffs to protect the domestic market (Arnade et al. 2017). In all these situations, the international and domestic prices have remained cointegrated, at least in the long term. The LOOP has prevailed, holding the price equalisation; however, the soybean market has never faced an exogenous event of this magnitude and extent. There is no empirical research confirming that US prices have dislocated from the inter-national prices, away from the long-term equilibrium relationship, or that the LOOP was still valid or holding during the “soybean conflict”. This constitutes a research gap into how this phenomenon induced volatility in this market and how structural breaks may compromise the significance of the cointegration vectors. This provides an investigative route into price transmission and cointegration research. There is vast empirical research regarding this market in terms of price transmission and cointegration; however, the re-search mainly focused on diagnosing the extent of global market cointegration, the loss of market, and market power in terms of price leadership. To provide an understanding of the subject, it is critical to introduce some basic concepts and definitions to the reader.

ECI 1.1. Critical Concept and Definitions

To understand the spatial (horizontal) price transmission or the co-movement of soybean prices in different market locations, the spatial arbitrage condition is a fundamental theoretical concept to comprehend (Listorti and Esposti 2012). This concept states that price differences in the same product between different markets cannot surpass the transaction cost, otherwise the arbitrage opportunity would be rapidly exploited. Derived from the *spatial arbitrage condition*, the law of one price (LOOP) states that discounting the transaction cost and when expressed in the same currency, two homogenous goods will have the same price. This concept was raised by Cournot (1838) and later Marshall (1890). The concepts of market efficiency and market integration are complementary to the LOOP. The first concept, namely, *market efficiency*, can be explained by the capability of markets to minimise the cost when the supply and demand are matched. Under the assumption of a competitive market with perfect information, the arbitrage process will help to reflect all the transaction costs. The concept of *market integration* focuses on the tradability of goods among a spatially separated market (Barrett and Li 2002).

ECI 1.2. Previous Empirical Research

ECI 1.2.1. Law of One Price

There is vast empirical literature regarding the validity of the LOOP relating to the soybean market. Using the Johansen technique, Lima and Burnquist (1997) studied the validity of the previously mentioned law for the Brazilian, USA and German markets for the period 1985–1995 and the result showed the LOOP could not be rejected for those markets. Later, using a VECM, Margarido et al. (2001) studied the price transmission between the Brazilian market and the Rotterdam market, confirming the validity of the LOOP. Following this, Margarido et al. (2007) further extended the research by studying the price transmission of the soybean international market of Chicago, Rotterdam, Argentina and Brazil for the period between 1995 and 2003. Their research verified the validity of the LOOP for the soybean market by using cointegration and causality tests: the impulse response function (IRF), forecast error variance decomposition (FEVD) and the exogeneity test. de Sousa and Campos (2009) studied the price transmission of the Brazilian inter-regional market of soybean−specifically in the market involving Rio Grande do Sul, Parana and Matogroso, and according to the authors, the LOOP could not be perfectly validated amongst all markets.

ECI 1.2.2. Price Transmission

Several researchers studied the different effects of soybean price transmission for international markets (horizontal price transmission among different countries) and different countries' domestic market supplies (vertical price transmission). The vast majority of the research focused on the elasticity, price formation, incomplete price transmission and asymmetry of price transmission of the main players within the market**.** Aguiar and Barros (1991) set the precedent for price transmission studies for the international market of soybean and the domestic market of Brazil. Their study exposed the causality relationship between both markets, where the international soybean market, represented by the Chicago Board of Trade (CBOT), leads international prices at least within the main markets (e.g., Rotterdam, Argentina and Brazil markets). This relationship was corroborated later by almost all researchers (Pino and Rocha 1994; Margarido and Sousa 1998; Margarido et al.

2007; Margarido 2012), who found that the United States, as represented by the CBOT, and the European Union, as represented by Rotterdam, led the international prices of this commodity. The authors identified Brazil and Argentina as “price takers”. All the researchers found the international soybean market to be highly efficient and cointegrated (i.e., based on the market efficiency key performance indicators (KPIs), such as the speed of adjustment (error correction term) to shocks in the leading market.

ECI 1.3. Policy Implications in the International Market of Soybean: Price Transmission and Cointegration

To understand the real implications of the trade war on the international soybean market, it is necessary to understand the extent of this conflict and desegregate the main events that impacted or influenced the market from the secondary events that may have had minor importance. The soybean skirmish was composed of three main events. The first event occurred on 4 April 2018: the Chinese government imposed a 25% tariff on soybean. The second event occurred on 24 July 2018: the US government adopted subsi-dies for US farmers worth USD 27 billion. The third event occurred on 13 September 2019: the Chinese government lifted the tariff on imported US soybeans. Undeniably there were other minor factors in the soybean trade war, mostly in the form of threats, declarations and tweets from both sides, with the latter having the potential to increase the volatility of the future market and cause structural breaks. In order of magnitude, the aforementioned three main events were probably responsible for eventual price disloca-tion, loss of market efficiency and lack or partial temporal cointegration. The simplifica-tion of the “Soybean trade war” can go even further; it is possible to say that “essential-ly” this research is the study of a highly efficient market (soybean international market) in typically very volatile market conditions and under exogenous policy interventions of a tariff and a subsidy. Due to this, it is necessary to understand the theoretical effect of the policies in terms of price transmission and cointegration.

Empirical evidence showed that if two markets are linked by trade in a free market regime, the excess of demand or supply shocks will have an equal impact on prices for both markets (Mundlak and Larson 1992). The implementation of import tariffs on soy-bean into China would therefore be fully transmitted to the domestic prices of the com-modity. An increase in tariff will generate a proportional increase in domestic price, which will be further transmitted to international prices before reaching an equilibrium point. However, this did not occur in the Chinese domestic market in April 2018, which can be explained by the price intervention policies that characterised this market (Zhao et al. 2010). This raises the first question: is the Chinese domestic market cointegrated with the international soybean market, or at least with the Chinese futures market (Da-lian Futures)? There is empirical evidence to suggest that the degree of intervention in this market dislocated Chinese domestic prices from the international price, at least in the short term (Arnade et al. 2017); therefore, the Chinese price should not be affected in the short term. The rest of the international prices were highly cointegrated and the LOOP was validated; therefore, a rise in international prices from April 2018 would have been expected. However, this did not happen until July 2018 when the Chinese tariff was made effective. When the increase in tariff was prohibitively high, this could partially dislocate the domestic and international market prices and stimulate both to move inde-pendently of each other, preventing price convergence (Gardner 1975; Mundlak and Larson 1992; Quiróz and Soto 1995; Lima and Burnquist 1997; Baffes and Ajwad 2001; Abdulai 2007). This last scenario is what may have happened in July 2018 when domestic US prices were dislocated from international prices. It is well-known that policy inter-ventions can affect the price transmission dynamics and spatial arbitrage, especially in cross-country price transmission. Policies such as export subsidies, variable levies, tariff rates and quotas, non-tariff barriers and prohibitive tariffs may prevent price conver-gence. Fixed tariffs are expected to affect the price spread by acting as fixed or propor-tional transaction costs (Listorti and Esposti 2012).

The trade war scenario is more complex than a simple soybean imports tariff. A standard import tariff acts as a fixed transaction cost that allows price transmission to occur in the international soybean market (Rapsomanikis et al. 2013). However, taking the trade war scenario, the tariff was exclusively assigned to the USA, meaning only the USA export market faced a 25% tariff on their exported soybeans to China. Considering the volume of USA soybean production that is exported to China (two-thirds of the USA’s exported soybeans), this tariff acted as a fixed transaction cost, forcing Chinese importers to switch to alternative suppliers. When the tariff was announced on 4 April, all markets were falling, despite the fact that the US spot and US futures markets were the only ones affected by the tariff. The future market plays the role of future price expec-tations and is affected by future tariffs. It might seem sensible to think that other markets could not be affected by future pessimistic market expectations; however, the future market leads spot prices, which was demonstrated by previous empirical research; the Chicago future prices lead the Brazilian and Argentinian prices (Margarido et al. 2007).

Chicago is the main international market leading the prices. Since the tariff exclu-sively affected the USA, other countries have not been targeted, hence their own market has not suffered directly from a transaction cost. Although Chicago leads the interna-tional prices, and almost all markets are integrated (follow a long-term relationship), by the end of June 2018, the market showed the first sign of lack of convergence. By mid-July, the international prices were seen to be dislocated from the USA soybean price (Figure 1). The United States was undergoing a sustained fall, whereas the other interna-tional prices were actively recovering. The USA's soybean exports diverged from China's market (the largest importer market in the world) due to the high transaction cost. The USA's impossibility of selling its surplus production to the main market drove its soy-bean prices to drastically fall in US markets. Simultaneously, this generated a shortage in supply in the Chinese feed industry, where the Chinese domestic market had no capabil-ity to fill the gap left by US soybeans. This made Chinese importers switch to the Brazili-an market, which is a major soybean producer in the world and the only market capable of filling the void left by the United States (as their main supplier). When the Chinese importers redirected demand to Brazil, this generated a price increase in the Paranaguá market (Brazil). In turn, this generated a price displacement in the international market; whilst the US price was actively falling, the Brazilian price was peaking, generating a price dislocation at the end of June 2018. Interestingly, Argentina's price increased too, suggesting that it was following the Brazilian price. As previously mentioned, according to Margarido et al. (2007), Argentina's prices follow the Chicago price; therefore, theoret-ically, the Argentinian price should have followed the US fall. However, the price dislo-cation altered the price leadership, and it seems, at least for a short period, that Brazil led the international price.

Figure 1.

The price dislocation obeyed the mathematical principle of lack of cointegration vectors; this dislocation process means that the prices do not follow a long-term equilibrium. The US prices were dislocated from the international prices, at least in the short term. If the divergence is only in the short term, this means that the price may still be cointegrated. By mid-December 2018, the gap between different international prices closed. This showed that for 4.5 months, the international prices may not have been cointegrated with the USA prices. Over time, this gap was closed by the ability of the market to arbitrage around the tariff. The fall in US prices increased the competitiveness of US soybeans, allowing the production to be allocated to other destinations (Argentina, Iran and Europe); however, this was not enough to cover the loss of the Chinese market (two-thirds of USA soybean exports and two-thirds of the global demand). Europe has historically been supplied by Brazilian soybeans, but following the Brazilian price increase, Europe started to substitute Brazilian soybean and rapeseed for the low-cost US soybean (Setser 2019). In addition, the market arbitrage opportunity was taken advantage of by Argentina, using the high crushing capacity. Argentina imported the US low-cost soybean, crushing it to be re-exported as soymeal. All the evidence supports the idea that the markets exploited the arbitrage opportunities. The famous “invisible hand” regulated the market (Smith 1723), in other words, an example of the applicability of the LOOP and a highly efficient market.

By 24 July 2018, the second main event occurred. The Trump administration announced a compensation subsidy for farmers affected by the US soybean import tariffs. In other words, Trump implemented an export subsidy because the majority of US soybean was exported and, as a result, the US price increased in the following days, going against the economic theory and empirical evidence. Previous researchers demonstrated that when an export subsidy is implemented, the price tends to decrease (Kerkelä et al. 2005); however, this economic phenomenon did not occur in the short term, as there was a lag period where the economic agents adapted to the subsidy. Due to this, it is possible to infer that this notorious increase in price can be associated with the US futures market speculation process, or most probably the arbitrage process was already equalising international prices. This second theory is more likely: the swift demand from other countries was already leveraging prices in a display of market cointegration, cross-country price transmission and efficiency. The third event of the trade war was the tariff lift, which is believed to have had an almost null effect because, in that period, the international prices had already converged, the world supply and demand were already reorganised and the import tariff was acting as a transaction cost for the Chinese importers (although, Chinese importers were importing soybeans from other markets to avoid these). Despite this, it is believed that the tariff lift increased the market efficiency and economic welfare: Brazilian and US soybeans have different harvesting seasons, allowing importers to have a constant flow of soybean throughout the year with less price volatility and price seasonality.

In summary, this price convergence is a historical example of market efficiency and efficient price transmission that was reviewed in this investigation. By February 2019, all prices appeared to return to a long-term equilibrium, obeying the “Law of One price”. The market reorganised around the tariff. The complexity of this event opened the research question: to what extent was the international market affected by the trade war? The evidence seems to highlight that in a fully integrated market, market power can be easily overcome by avoiding asymmetrical price transmission or price dislocation. What happened during this historical event was the perfect example. The tariff counterpart, namely, the subsidy, which seemed to be useless, probably contributed in the long term to generating a US soybean surplus to flood the international market and drop the international prices, benefiting only US farmers and international soybean final consumers to the detriment of all international soybean producers and US taxpayers.

Since this geopolitical conflict is relatively new, there is no empirical research that verifies that the trade war induced breaks in the markets, or that the market was partly dislocated in the short term and “The Law of One Price” prevailed in the end.

Looking at the time price series, we can draw those conclusions without any complex mathematical and economical models; however, in science, things cannot be taken for granted and this is how our research began, perhaps attempting to verify the obvious, but the obvious cannot always be assumed.

This research attempted to analyse the impact of the trade war on the price system of the international market of soybean by using the latest econometric models and statistical analysis. To achieve this, it was first necessary to demonstrate market cointegration and understand the market causal relation and market efficiency so that we could later analyse how the exogenous shocks correlated with the trade war events affected the market price system.

ECI 2. Methodology

This research was fundamentally based on econometrics models based on time series. The secondary data came from several sources, such as the international monetary fund (IMF), Chicago Board of Trade (CBOT), CEPEA Brazil (Centro de Estudos Avançados em Economia Aplicada), Dalian Commodity exchange (China), Wind Economic Database (China) and Bolsa de Rosario (Argentina). All the time series were converted to monthly data expressed in the same currency and volume (USD/tonne), deflated and transformed into a natural logarithm. These adjustments were required to remove sources of variation, simplify patterns in the time series and increase the accuracy of the models. The evaluated period was from September 2009 to May 2019.

The econometric procedure followed a logical sequence. First, it was necessary to determine the order of integration of the time series; to do this, this research used the augmented Dickey and Fuller (1979) (ADF) stationarity test. Following this procedure, it was necessary to find structural breaks in the time series using the ADF-modified version of the test with breaks and Bai–Perron multiple breaks detection. After the breaks detection, it was necessary to infer cointegration between the time series using the Johnsen cointegration test, and if possible, to infer this mathematical property between the time series. However, cointegration and correlation do not imply causality; therefore, a Granger causality test was required to infer this property. The econometrics models selected helped to identify the effects the geopolitical situation caused, for instance, the cointegration test showed the cointegration amongst the markets. The lack of cointegration means that the markets were not integrated, i.e., they no longer followed a long-term equilibrium relationship. This can be implicitly associated with the trade war if the trade war spillover effect was significant in causing a partial or permanent dislocation of the markets. Previous researchers found and verified the cointegration amongst the soybean global markets. Margarido (2012) systematically investigated this mathematical property across different periods and geopolitical situations, reaching the same conclusion. Therefore, the cointegration test result can be a rigorous indicat yt;'l#4or of market integration. The absence of cointegration can be correlated with market dislocation or the absence of a free market regime, which can be caused by external shocks, such as the trade war. The unit root test (with breaks) is a stationarity test, and although it has low statistical power, it can be a useful indicator of exogenous shocks in the market. These exogenous shocks can introduce unit roots in the time series transforming the series into a non-stationary one. The process that then follows is the finding of the breaks (unit root with breaks test), which are then input as dummy variables into the cointegration test. When the structural breaks are integrated into the cointegration test as dummy variables, and if those breaks are statistically significant, the cointegration vector can stand out, highlighting cointegration between the series. The time series break may be later associated with the trade war events or other exogenous events. This process validates the importance of detecting structural breaks in time series, as this may disrupt the market by introducing unit roots and dislocating the time series (i.e., non-cointegration). According to Engle and Granger (1987), the cointegration concept has relevant implications, which are proposed in the Granger representation theorem. This states that if two trending variables integrated with order I(1) are cointegrated, the relationship between the variables can describe an error correction model (VECM) (Listorti and Esposti 2012). An error correction model (ECM) can be critical to assessing the market efficiency loss, and this phenomenon can later be associated with the trade war spillover. Using the speed of adjustment coefficient of the error correction term represented by the Greek letter λ (lambda), which is commonly known as the error correction term, it is possible to infer the market efficiency. This coefficient indicates the speed at which a market returns to the long-term equilibrium and will solely depend on the proximity of this coefficient to one. This proximity to one can be used to assess the extent to which distortions, transaction costs and policies delay the price adjustment to the long-term equilibrium. The study undertaken by Sharma (2002) is an example of assessing market policy implications through market integration, as estimated using error correction models. According to the author, in countries where the government intervenes through several policies, the error correction coefficients clearly indicated a slow speed of adjustment to the long-run equilibrium (lambda: (−0.01)–(−0.07) or 1−7% per period). From the construction of a vector error correction model, it is possible to extract short- and long-term regression coefficients. Using short-term equation regressor coefficients, it is possible to diagnose the short-term causality (in the Granger sense) and the short-run effects. The long-term causality can be inferred by the statistical significance of the long-term equation regressors. The Granger causality test is a useful methodology to map the causality of interconnected markets. It is possible to test the markets in pairs to infer the direction of the causality and recreate the market power dynamic. Previous researchers already mapped this causality for the period before and after the trade war, from which we can denote the change in causality. These might be correlated with the change in market power caused by the trade war. The VECM can provide a stylised image of the relationships between and within the markets. In addition, the error correction representation can be used as a framework for testing nonlinear adjustment to the long-term equilibrium (asymmetric price transmission) (Rapsomanikis et al. 2013).

This research was designed to use several econometrics models and tests at different stages of the study. In the first stage of the investigation, the author only used some of the econometric techniques mainly for price transmission research. Only the methodology used in this study will be explained. The mathematical theory behind the models is extensive and could easily drive the attention of the reader to technicalities and formalities; thus, the author assumes that readers have a technical understanding of econometrics and market dynamics. Therefore, the author has chosen to omit the underpinning mathematical–statistical theory and the explanation of the econometric models while, however, keeping the essential information. In contrast, it can be suggested that the main weakness of this study is the methodology since the econometric procedure might lack statistical power or the regression model might not prove causation.

ECI 2.1. Hypothesis

The following sections introduce the hypotheses used within this research.

ECI 2.1.1. Market Cointegration and Structural Breaks Paradigm

If the occurrence of the trade war has drastically affected the market prices, it should be possible to assume that this phenomenon has induced a structural break in the time series. As such, the research question is as follows: did the outbreak of the trade war induce a structural break and affect the long-term relations between the markets? The null hypotheses were as follows:

N0.1. The markets were not dislocated, i.e., there was cointegration between the markets.

N0.2. The trade war did not introduce a break in the soybean market time series; therefore, the time series were stationary at first difference.

ECI 2.1.2. The Market Efficiency Affectation

Complete price transmission and a high speed of adjustment clearly reflect the market efficiency. Furthermore, the validity of the law of one price is a consistent indicator of an efficient market. The research question concerns whether the efficiency of the market was affected. This research question generated several null hypotheses:

N0.1. The price transmission within the market was not affected.

N0.2. The law of one price held in the USA–China trade war.

ECI 3. Results

This chapter introduces the results of the econometric tests in the same logical order they were performed. They are summarised in table format to improve readability and to aid comprehension.

ECI 3.1.1. Unit Root Test

The first test performed was the unit root test. This test is critical for understanding the suitability of the data for different econometric procedures and econometric pathways. The ADF (unit root test) results for the seven time–price series (at level) showed that it was not stationary (Table 1). For all the series, the null hypotheses could not be rejected because the probability levels were higher than the critical level in all cases, meaning a high probability of committing a type I error (rejecting the null hypothesis when it is true). Therefore, it was necessary to transform the series to the first difference and rerun the test. After the time series were differentiated in the first difference, the ADF showed that they were stationary (Table 2). In conclusion, the t-stat was less than the test critical value in all cases at the 5% significance level. Furthermore, in all cases, the probability was less than 0.05 (5%); therefore, the null hypotheses were rejected and the alternative hypotheses were accepted. The test showed that all series were integrated with order 1-I(1).

ECI - Table 1. Unit root test level.

Price Series	**Test Critical Value 5%**		**ADF Test Statistic**	**Prob.**	**Null Hypothesis**
LNCHIGF	−2.88	<	−2.09	0.25	Accepted
LNCHINASP	−2.88	<	−1.47	0.55	Accepted
LNDALIF	−2.88	<	−1.83	0.36	Accepted
LNPARANAGUASP	−2.88	<	−2.25	0.19	Accepted
LNROSFT	−2.88	<	−2.55	0.11	Accepted
LNROSSP	−2.88	<	−2.37	0.15	Accepted
LNROTTERDAM	−2.88	<	−1.41	0.57	Accepted

ECI - Table 2. Unit root test first difference.

Price Series	**Test Critical Value 5%**		**ADF Test Statistic**	**Prob.**	**Null Hypothesis**
LNCHIGF	−2.88	>	−8.13	0.00	Rejected
LNCHINASP	−2.88	>	−8.06	0.00	Rejected
LNDALIF	−2.88	>	−10.26	0.00	Rejected
LNPARANAGUASP	−2.88	>	−7.42	0.00	Rejected
LNROSFT	−2.88	>	−7.44	0.00	Rejected
LNROSSP	−2.88	>	−7.99	0.00	Rejected
LNROTTERDAM	−2.88	>	−9.17	0.00	Rejected

ECI 3.3.1. Structural Breaks Test

Structural breaks in a time series can introduce a false unit root, leading to a lack of cointegration vectors; due to this, it is necessary to examine the occurrence of structural breaks. Moreover, the importance of finding structural breaks for later correlation with the events of the trade war is crucial for assessing the importance of the trade war on the international markets. The technique that was used to infer the structural breaks in the series was the Bai–Perron multiple break test (Table 3) (using the Schwarz and LWZ criteria) and the ADF test (unit root test with breaks) (Table 4). The test results for all the time series for the entire period showed a total of 49 breaks, with several being repeated, depending on the test, test criteria and time series. Only 17 were unique breaks in the collection of time series, of which all the breaks could be correlated with different exogenous shocks in the international soybean market. Different periods showed a higher frequency of market breaks; the higher frequencies were found around the last quarter of 2010, across 2012 and during 2014. The breaks were associated with climatic disasters, such as drought, and stock deficits or speculation processes. Only a single structural break was correlated with the trade war event in the Dalian Futures market in February 2018. Despite the fact that the trade war effectively started in March 2018 with Trump's tariff announcements, traders may have reacted to market rumours and/or inside information acting in anticipation and provoking a structural break in the market. However, the affectation in terms of external shocks that generated breaks in the market can be considered minimal for the studied period; this decreased the importance of the trade war in relative terms when considering other events of the studied period.

ECI Table 3. Bai–Perron test multiple breakpoint test.

Price Series	Breaks	of Coefs.	Sum of Sq. Resids	Log-L	Schwarz Criterion	LWZ Criterion	Schwarz Breaks	LWZ Breaks
LNCHIGF	2	5	0.728	140.92	−4.93	−4.75	2010M10	2010M11
	3	7	0.630	149.84	−5.00	−4.75	2012M04	2014M09
							2014M09	
LNCHINASP	3	7	0.251	206.19	−5.91	−5.67	2010M11	2010M11
	4	9	0.219	214.56	−5.97	−5.65	2012M08	2012M07
	5	11	0.198	221.00	−6.00	−5.61	2014M04	2015M10
							2015M10	
							2017M10	
LNDALIF	3	7	0.429	173.41	−5.38	−5.13	2010M09	2010M09
	4	9	0.385	180.11	−5.41	−5.09	2012M03	2012M03
							2015M09	2015M10
							2017M10	
LNPARANAGUA SP	3	7	0.806	134.63	−4.75	−4.50	2010M09	2010M09
							2012M04	2012M04
							2014M09	2014M09
LNROSFT	3	7	0.579	154.96	−5.08	−4.83	2010M10	2010M10
							2014M09	2014M09
							2016M05	2016M05
LNROSSP	2	5	1.00	120.91	−4.60	−4.37	2010M10	2010M10
	3	7	0.916	126.75	−4.62	−4.28	2012M04	2014M08
							2014M07	
LNROTTERDAM	2	5	0.639	148.94	−5.064	−4.88	2010M10	2010M10
							2014M08	2014M08

Minimum information criterion values are highlighted in yellow.

ECI Table 4. Unit root test with breaks

Price Series	Test Critical Value 5%		ADF Test Statistic	Prob.	Break Date
LNPARANAGUASP	−4.44	>	−8.15	<0.01	2012M07
LNROTTERDAM	−4.44	>	−9.74	<0.01	2012M07
LNCHIGF	−4.44	>	−8.64	<0.01	2014M09
LNROSFT	−4.44	>	−8.050	<0.01	2016M05
LNROSSP	−4.44	>	−8.41	<0.01	2016M05
LNCHINASP	−4.44	>	−8.83	<0.01	2016M09
LNDALIF	−4.44	>	−11.50	<0.01	2018M02

ECI 3.3.1. Cointegration Test

The cointegration determination is critical to assess the impact of the trade war; however, it is necessary to first check the assumption that all prices were cointegrated, thereby moving together and following a long-term relationship. This last mathematical property is fundamental to understanding whether the different events of the trade war provoked market dislocation and non-cointegration in the process. Using the Johansen cointegration test, which was performed in pairs for all the time series, the cointegration was checked, forming the cointegration matrix in Table 5. The primary conclusion was that not all the time series were cointegrated. This lack of cointegration could be explained by government intervention, such as in the cases of China and Argentina. These market interventions may cause price dislocation and loss of market efficiency. Market interventions could have caused structural breaks in the time series, and by using these breaks as dummy variables in the Johansen cointegration model, it was possible to find cointegration. The next step of the research was to re-run the cointegration analysis using the previous breaks as dummy variables. Using this technique, it was possible to find full cointegration between all the time series .

ECI Table 5. Johansen cointegration test: unrestricted cointegration rank test.

Unrestricted Cointegration Rank Test (Trace)							
	LNCHIGF	**LNCHINASP**	**LNDALIF**	**PARANAGUA SP**	**LNROSFT**	**LNROSSP**	**ROTTERD AM**
LNCHIGF	X	1	1	1	0	1	1
LNCHINASP	1	X	1	0	0	1	2
LNDALIF	1	1	X	1	0	1	1
LNPARANAGUASP	1	0	1	X	0	1	1
LNROSFT	0	0	0	0	X	1	0
LNROSSP	1	1	1	1	1	X	1
LNROTTERDAM	1	1	1	1	0	1	X

The numbers in the table represent the number of cointegration equations at the 0.05 level.

After re-running the Johansen cointegration test with the previously inferred structural breaks, we were able to find full cointegration between all the series (Table 6.). However, the break associated with the trade war was not able to act as a dummy variable that would help to infer cointegration vectors from the Dalian

Futures. This fact relativised the impact of the trade war as a disruptive factor that dislocated the international market of soybean. In other words, there were other exogenous events that had a stronger impact and dislocated the market in the studied period.

ECI Table 6. Johansen cointegration test: unrestricted cointegration rank test adjusted using breaks.

Unrestricted Cointegration Rank Test (Trace)

	LNCHIGF	**LNCHINASP**	**LNDALIF**	**LNPARANAGUASP**	**LNROSFT**	**LNROSSP**	**LNROTTERDAM**
LNCHIGF	X	1	1	1	1	1	1
LNCHINASP	1	X	1	1	1	1	2
LNDALIF	1	1	X	1	1	2	1
LNPARANAGUASP	1	1	1	X	1	1	1
LNROSFT	1	1	1	1	X	1	1
LNROSSP	1	1	2	1	1	X	1
LNROTTERDAM	1	2	1	1	1	1	X

The numbers in the table represent the number of cointegration equations at the 0.05 level.

ECI 3.3.2. Granger Causality Test

The Granger causality test was critical in this research to understand the dynamics of the market prices in terms of causality; this test allowed us to create a causal map of the market. The optimal lag selection was inferred using the Swartz information criterion and, according to this criterion, the optimal lag selection was one lag. The Granger causality matrix (Table 7) summarises the causality interactions for the optimal lag selection (one lag). The causality dynamic seemed to agree with the previous research. It can be clearly appreciated that the Chicago and Rotterdam prices led the markets without any trace of causality between them. It is noticeable that the Brazilian market of Paranaguá seemed to affect several international prices, such as the Rosario Spot, as well as the Chinese, Dalian Futures and China Spot markets. There is no previous empirical research suggesting the rise of the Brazilian market as a price leader. This creates an open question: when and how has the Brazilian market risen as a leading market? The sensible answer is that the increase in the Brazilian domestic market and crushing industry, on top of being the main soybean exporter of the world, progressively made Brazil a leading market. However, to what extent the trade war effect had leverage on the Brazilian market as an international leader is one undetermined factor.

ECI Table 7. Granger causality test (matrix).

Granger Causality Test with One Lag							
	LNCHIGF	**LNCHINASP**	**LNDALIF**	**LNPARANAGUASP**	**LNROSFT**	**LNROSSP**	**LNROTTERDAM**
LNCHIGF	X	↑	↑	↑	∂	↑	∂
LNCHINASP	←	X	←	←	←	←	←
LNDALIF	←	↑	X	←	∂	←	←
LNPARANAGUASP	←	↑	↑	X	∂	↑	←
LNROSFT	∂	↑	∂	∂	X	↑	∂
LNROSSP	←	↑	↑	←	∂	X	←
LNROTTERDAM	∂	↑	↑	↑	∂	↑	X

The direction of the arrows (←, ↑) represents the direction of the causality. ∂ represents no causality affectation.

Knowing that almost all series were cointegrated, and after the empirical results demonstrated the causal relationship between the different market time series, it was possible to develop a vector error correction model to capture the cointegration, the causal relation and price transmission.

ECI 3.5. Vector Error Correction Model

Another perspective to consider is the influence the trade war had on market efficiency. The vector error correction model is an important tool to assess the market efficiency through the price transmission and market power through implied causality on the short- and long-term equations. The result of the VEC model is an equation system, where the model incorporates the short-term and long-term relationships of the series. This methodology was applied in pairs to map individual and paired interactions. Following the same logic, global models were created to understand the compound dynamics of each time series. Several diagnostic tests were applied to avoid spurious regressions and assure the reliability of the results. Residual serial correlations were checked using the LM autocorrelation test and normality using the Cholesky (Lutkepohl) orthogonalisation test. The least squares regression in conjunction with the Wald test was applied to find the significance of the regressors.

ECI 3.5.1. VECM China Spot Market Pair Model

Several VEC models were built that embedded the Granger causality (g-causality) relationship and the cointegration between the time series (Table 8). As previously mentioned, in terms of the Granger causality, the China Spot market did not affect any of the studied markets. In contrast, the China Spot market was affected by almost all the investigated markets. This finding was coherent with the level of government intervention in this market. Despite the Chinese soybean importation tariffs being relatively low, the Chinese government used several other mechanisms to intervene to influence the prices., The Chinese policymakers probably used international prices to fix the domestic prices to some degree. This may be the reason behind the China Spot market showing itself as a weak market that tended to follow the others. The degree of intervention can clearly reflect the loss of market efficiency, which can be captured by the speed of adjustment of the error correction term (VECM). For all the different models created, the speed of adjustment was extremely low, varying between 1.27–5.46% per period, indicating poor market efficiency. The China Spot price seemed to adjust faster to the Chicago prices (5.46%), meaning that a shock in prices in Chicago resulted in China's domestic soybean price returning to the long-term equilibrium in 18 months, denoting a poor market efficiency and incomplete price transmission. For all the different model combinations, the short-term regressors were not significant; only the Chicago price at an alpha of 10% was significant. This suggested that in the short-term, China tended to dislocate from the international prices, but to some degree, the Chicago price influenced the Chinese policymaker in the short term. In the long-term, however, the Chinese price tended to follow and adjust based on international prices led by Chicago. The minimum price program was created by the Chinese government and was designed to adapt to market liberalisation. Other measures, such as "target price" and "deficit payment", were measures created to compensate Chinese farmers for international price fluctuation (Jamet and Chaumet 2016). All these measures shielded the market from international price fluctuations and interrupted efficient price transmission. The VEC models showed that Chicago prices could only explain 7.51% of the China Spot prices and Rotterdam and Rosario could explain 6.48% and 5.54% of the price increases, respectively. Dalian Futures could be associated with decreases in price in the China Spot market, explaining 1.73% of the price decreases.

Equation (1): VECM corrected using coefficient significance

$$CHINASP = -0.055(LNCHINASP_{t-1} - 0.95LNCHIGF_{t-1} - 0.73) + 0.185\Delta LNCHINASP_{t-1} + 0.075\Delta LNCHIGF_{t-1} \qquad (1)$$

$\lambda = -0.0546$

Equation (2): VECM corrected using coefficient significance

$LNCHINASP = -0.103(LNCHINASP_{t-1} - 0.97LNDALIF_{t-1} - 0.21) + 0.29\Delta LNCHINASP_{t-1}$ ← *No short-term regressors from Dalian Futures* (2)

$\lambda = -0.103251$

Equation (3): VECM corrected using coefficient significance

$LNCHINASP = -0.047(LNCHINASP_{t-1} - 1.033LNPARANAGUASP_{t-1} - 0.173) + 0.21\Delta LNCHINASP_{t-1}$ ← *No short-term regressors from Paranguas* (3)

$\lambda = -0.047338$

Equation (4): VECM corrected using coefficient significance

$LNCHINASP = -0.013(LNCHINASP_{t-1} - 2.43LNROSFT_{t-1} + 7.26) + 0.24\Delta LNCHINASP_{t-1}$ ← *No short-term regressors from Rosario Futures* (4)

$\lambda = -0.012727$

Equation (5): VECM corrected using coefficient significance

$LNCHINASP = -0.032(LNCHINASP_{t-1} - 1.266LNROSSP_{t-1} + 0.715) + 0.256\Delta LNCHINASP_{t-1}$

←*No short-term regressors from Rosario Spot* (5)

$\lambda = -0.031843$

The creation of a global model for the China Spot market resulted in a spurious regression (Table 9). All the coefficients failed to be significant, and the residuals were not normally distributed. These can be considered expected and intuitive results, as the slow speed of adjustment and the low determination coefficient from the model pairs were in concordance with a high degree of government intervention. This market seemed to be dislocated from the international prices in the short term and, to some degree, was affected by the Chicago prices.

ECI Table 8. Vector error correction pairs model for China Spot.

Heteroskedasticity Tests									
	Lag	**D(LNCHINASP)**	**<**	**D(LNCHIGF)**	**Elasticity**	**Correlation LM Tests**	**Normality Test**	**Without Cross Term**	**With Cross Term**
CointEq1	1	−5.46%		7.51%	1:0.95	0.9724	0.00000	0.9270	0.9662
		D(LNCHINASP)	<	D(DALIF)					
CointEq1	1	−10.33%		−1.73%	1:0.97	0.5821	0.00000	0.2897	0.2932
		D(LNCHINASP)	<	D(PARANAGUASP)					
CointEq1	1	−4.73%		5.04%	1:1.03	0.9341	0.00000	0.6773	0.6915
		D(LNCHINASP)	<	D(ROSFT)					
CointEq1	1	−1.27%		6.48%	1:2.43	0.9864	0.00000	0.4850	0.2489
		D(LNCHINASP)	<	D(ROSSP)					
CointEq1	1	−3.18%		1.45%	1:1.26	0.9048	0.00000	0.3379	0.6308
		D(LNCHINASP)	<	D(ROTTERDAM)					
CointEq1	1	−5.02%		5.54%	1:1.12	0.8665	0.00000	0.8224	0.8361

ECI Table 9. Vector error correction global model for China Spot.

CointEq1	**Lag**	**ΔLNCHINASP**	**<**	**ΔLNCHIGF**	**ΔDALIF**	**ΔPARANAGUASP**	**ΔROSFT**	**ΔROSSP**	**ΔROTTERDAM**
λ	1	−1.40%		15.64%	0.10%	0.50%	−4.81%	−3.74%	3.56%
						Correlation LM	**Normality Test**	**Without Cross Term**	**With Cross Term**
						0.32740	0.00000	0.13050	0.05870

ECI 3.5.2. VECM Dalian Futures

The error correction model for Dalian Futures for the different pair combinations showed an overall higher speed of adjustment and market efficiency than the China Spot market (Table 10). The lambda coefficient from the error correction term fluctuated between 13.8% and 7.5%. The Chicago and Rotterdam models showed higher adjustment speeds, with 13.7% and 13.5%, respectively. Chicago could be associated with an increase in the price of 4.58% and Rotterdam with an increase of 6.45%. This higher market efficiency could be associated with a lower degree of market intervention; however, in contrast with previous empirical evidence, this speed of adjustment was relatively slow. The short-term equation for all VEC pair models did not show any short-run regressors, implying a meaningless, short-term, causal relationship with the entire market. The creation of a global model incorporating all the cointegrated series resulted in a spurious regression, even at an alpha of 10%; therefore, it was not included in this investigation.

Equation (6): VECM corrected using coefficient significance

$\Delta LNDALIF = -0.138(LNDALIF_{t-1} - 0.793LNCHIGF_{t-1} - 1.672)$ (6)

← *No short-term regressors*

$\lambda = -0.138$

Equation (7): VECM corrected using coefficient significance

$\Delta LNDALIF = -0.106(LNDALIF_{t-1} - 0.888LNPARANAGUASP_{t-1} - 1.051)$ ← *No short-term regressors* (7)

$\lambda = -0.106$

Equation (8): VECM corrected using coefficient significance

$\Delta LNDALIF = -0.135(LNDALIF_{t-1} - 0.868LNUSROTTERDAMCIF_{t-1} - 1.122)$ ← *No short-term regressors* (8)

$\lambda = -0.135$

Equation (9): VECM corrected using coefficient significance

$\Delta LNDALIF = -0.075(LNDALIF_{t-1} - 1.065LNROSSP_{t-1} - 0.421)$ (9)

← *No short-term regressors*

$\lambda = -0.075$

ECI Table 10. Vector error correction pairs model for Dalian Futures.

Heteroskedasticity Tests									
	Lag	**ΔLNDALIF**	**<**	**ΔLNCHIGF**	**Elasticity**	**Correlation LM Tests**	**Normality Test**	**Without Cross Term**	**With Cross Term**
CointEq1	1	−13.76%		−4.58%	1: 0.79	0.3891	0.00000	0.4118	0.3303
	lag	ΔLNDALIF	<	ΔPARANAGUAS					
CointEq1	1	−10.60%		−3.36%	1: 0.89	0.2002	0.00000	0.2837	0.4106
	lag	ΔLNDALIF	<	ΔROSSP					

CointEq1	1	−7.53%		−3.07%	1: 1.06	0.3251	0.00000	0.3923	0.5137
	lag	ΔLNDALIF	<	ΔROTTERDAM					
CointEq1	1	−13.52%		−6.45%	1: 0.89	0.2351	0.00000	0.5950	0.8554

ECI 3.5.3. VECM Paranaguá

The Paranaguá overall VEC model showed a high adjustment speed in the error correction term, with 27.32% for Rotterdam and 26.80% for Chicago (Table 11). Rotterdam appeared to lead the prices for this market, and this was in concordance with previous empirical research. (Margarido et al. 2007) explained that the Rotterdam price led the Brazilian market since the price formation was on the demand side. In other words, if a shock in the Chicago or Rotterdam market occurred, Paranaguá would return to the long-term relationship in around 3 months and two weeks. However, all model pairs failed to present short-term significant regressors; thus, there was no evidence of short-term causality between Rotterdam and Paranaguá. This can be explained by the size of the Brazilian domestic market, its crushing capacity and high domestic consumption. This suggested that this gave the market a buffer zone that smoothed the international price fluctuations in the short term. The global VEC model that included Rotterdam and Chicago as independent variables was found to be statistically significant, with an adjustment speed of the error correction term of 27.35% (3.5 months). This global model associated Chicago with an increase in prices, explaining 15.11% of the increase, and Rotterdam with price decreases, explaining 12.14% of the decrease (Table 12).

Equation (10): VECM corrected using coefficient significance

$$\Delta LNPARANAGUASP = -0.260(LNPARANAGUASP_{t-1} - 0.942LNCHIGF_{t-1} - 0.403) + 0.41\Delta LNPARANAGUASP_{t-1} \quad (10)$$

← *No short-term regressors from Chicago*

$\lambda = -0.260$

Equation (11): VECM corrected using coefficient significance

$$\Delta LNPARANAGUASP = -0.273(LNPARANAGUASP_{t-1} - 1.056LNUSROTTERDAMCIF_{t-1} + 0.40) + 0.4\Delta LNPARANAGUASP_{t-1} \quad (11)$$

← *No short-term regressors from Rotterdam* λ = −0.273

ECI Table 11. Vector error correction pairs model for Paranaguá.

	Lag	ΔPARANAGUA)	<	ΔCHIGF)	Elasticity	Correlation LM Tests	Normality Test	Without Cross Term	With Cross Term
CointEq1	1	−26.08%		−7.35%	1: 0.94	0.1305	0.00020	0.0015	0.0023
	lag	ΔPARANAGUA)	<	ΔROTTERDAM)					
CointEq1	1	−27.32%		−7.49%	1: 1.056	0.9821	0.00020	0.0002	0.0001

ECI Table 12. Vector error correction global model for Paranaguá.

Lag	ΔPARANAGUAS)	<	ΔCHIGF)	ΔROTTERDAM)	Correlation LM	Normality Test	Without Cross Term	With Cross Term
1	−27.35%		−15.11%	12.14%	0.79050	0.00000	0.0132	0.0010

Equation (12): VECM corrected using coefficient significance

$$\Delta LNPARANAGUASP = -0.273(LNPARANAGUASP_{t-1} - 0.915LNCHIGF_{t-1} - 0.0366NUSROTTERDAMCIF_{t-1} - 0.341) + 0.393\Delta LNPARANAGUASP_{t-1} \quad (12)$$

← *No short-term regressors from Chicago Futures and Paranaguá Futures*

λ = 0.273

ECI 3.5.4. VECM Rosario Spot

The VEC model for the Rosario Spot market showed a moderate market efficiency, as represented by the adjustment speeds of the error correction terms: −0.214 (λ) and −0.253 (λ) for Chicago and Rotterdam, respectively; any shocks in those markets and Rosario returned to the long-term equilibrium in around four and five months, respectively (Table 13). However, the fastest speed of adjustment occurred between Paranaguá and Rosario (λ = −0.3186) and had a lag period of 3 months before returning to the long-term equilibrium, where the first market was associated with 4.49% of the price increases in Rosario (Table 13). The results became counterintuitive when the VEC model for Rosario Spot explained by Rosario Futures showed a lower adjustment speed (20% per period) than other leading markets (Paranaguá, Chicago and Rotterdam). However, the model indicated that Rosario Futures could explain and was associated with almost half of the price decreases (47%) in Rosario Futures, while Rotterdam and Paranaguá could be associated with 16.91% and 5.63% of the price decreases in Rosario Futures due to Chicago and with associated price increases explaining 4.95% (Table 13). The construction of a global model was only significant at an alpha of 10%, where this model showed the fastest price transmission (λ = −0.40) and significant short-term and long-term regressors on both sides of the equations (Equation (17). In this overall model, Rosario Futures was the most important market associated with explaining the price decreases at the first lag (t − 1), followed by Rotterdam (t − 1). Despite the interesting result of the overall model, the last one was not statistically significant at an alpha of 5% and the residuals were not normally distributed (Table 14.).

Equation (13): VECM corrected using coefficient significance

$$\Delta LNROSSP = -0.253(LNROSSP_{t-1} - 0.798LNCHIGF_{t-1} - 0.852) + 0.424\Delta LNROSSP_{t-1} + 0.273\Delta LNROSSP_{t-3} - 0.293\Delta LNCHIGF_{t-3} \quad (13)$$

λ = −0.253019

Equation (14): VECM corrected using coefficient significance

$$\Delta LNROSSP) = -0.213(LNROSSP_{t-1} - 0.848LNUSROTTERDAMCIF_{t-1} - 0.456) + 0.217\Delta LNROSSP_{t-1} \quad (14)$$

← *No short-term regressors from Rotterdam (alpha 10%*)

λ = −0.213640

Equation (15): VECM corrected using coefficient significance

ΔLNROSSP) = −0.318(LNROSSP$_{t-1}$ − 0.858*LNPARANAGUASP$_{t-1}$ − 0.443) + 0.388ΔLNROSSP$_{t-1}$ (15)

← *No short-term regressors from Paranaguá Spot*

$\lambda = -0.318580$

Equation (16): VECM corrected using coefficient significance

ΔLNROSSP) = −0.203(LNROSSP $_{t-1}$ − 1.149*LNROSFT$_{t-1}$ + 0.823) + 0.470ΔLNROSFT$_{t-1}$

← *No short-term regressors from Rosario Futures* (16)

$\lambda = -0.203718$

ECI Table 13. Vector error correction pairs model for Rosario Spot.

	Lag	ΔROSSP)	<	ΔCHIGF)	Elasticity	Correlation LM Tests	Normality Test	Without Cross Term	With Cross Term
CointEq1	3	−25.30%		−4.95%	1: 0.798	0.4155	0.4298	0.0300	0.0591
	lag	ΔROSSP)	<	ΔROTTERDAM)					
CointEq1	1	−21.36%		16.91%	1: 0.848	0.3810	0.00220	0.1708	0.2306
	lag	ΔROSSP)	<	ΔPARANAGUAS)					
CointEq1	3	−31.86%		5.63%	1: 0.858	0.3605	0.01930	0.4502	0.4405
	lag	ΔROSSP)	<	ΔROSFT)					
CointEq1	1	−20.37%		46.99%	1: 1.149	0.5674	0.0720	0.0005	0.0007

Equation (17): VECM corrected using coefficient significance

ΔLNROSSP= −0.405(LNROSSP$_{t-1}$ + 0.373*LNCHIGF$_{t-1}$ + 0.096LNUSROTTERDAMCIF$_{t-1}$ − 1.015LNPARANAGUASP$_{t-1}$ − 0.466*LNROSFT$_{t-1}$ + 0.295) − 0.28ΔLNCHIGF$_{t-1}$ − 0.283ΔLNCHIGF$_{t-3}$ + 0.372ΔLNUSROTTERDAMCIF$_{t-1}$ − 0.452ΔLNPARANAGUASP$_{t-2}$ + 0.536ΔLNROSFT$_{t-1}$ (alpha 10%) (17)

$\lambda = -0.405295$

ECI Table 14. Vector error correction global model for Rosario Spot.

Lag	ΔROSSP <	ΔCHIGF	ΔROTTERDAM	ΔPARANAGUAS	ΔROSFT	
3	−40.53%	−27.81%	37.29%	−4.64%	53.63%	
				Correlation LM	**Normality Test**	**Without Cross Term**
				0.1255	0.00000	0.2217

ECI 4. Discussion

This study was comprehended within the framework of a comprehensive study of the efficiency and dynamicity of the soybean market and how the international market confronted the geopolitical situation (US–China trade war). The unit root test and the Bai–Perron test with multiple breaks were useful to scale and downsize the trade war in comparison with other historical events that had affected the soybean market. The conflict showed that only a single structural break found could be partially associated with the US–China trade war. This suggested that the international market has arbitraged around the Chinese tariff, neutralising the price dislocation effect. This might be associated with a highly efficient and fully cointegrated market. The first attempt of this research showed that the international markets were highly cointegrated, except for Rosario Futures, which was only cointegrated with the Rosario Spot market. Against expectations, the China Spot market presented a high number of cointegration equations with the other markets; this finding is in contrast with what is normal for government-intervened markets. The Chinese government has systematically intervened to shield the market from the price volatility of the international market, such as the “price minimum” initiative, “target price” and “deficiency payment policies” (Jamet and Chaumet 2016). This intervention provoked partial price dislocation within the international market, at least in the short term. Vavra and Goodwin (2005) pointed out that import tariffs will allow, in relative terms, full price transmission; hence a proportional price increase in international prices will generate a proportional increase in the domestic market price, except for prohibitively high tariffs. Consequently, prices in relative terms are fully transmitted. It is possible to assume that this was not the case for China, as the different combinations of price interventions shielded the market from international price volatility. The last empirical fact can be supported by the lack of short-term significant regressors in the short-term equation. In Argentina's case, it is well known for having an intervened domestic market; the Argentinian government designed different intervention policies, such as export tariffs and currency interventions (Margarido *et al.,* 2011; Vassallo *et al*., 2011). All these policies distort price transmission and can generate asymmetrical price transmission and price dislocation. However, for the Argentinian case, the tariff may act as a fixed cost, enabling price transmission. The Brazilian market, represented by the Paranaguá market, presented cointegration with Chicago and Rotterdam. This falls in line with previous research by Margarido and Souza (1998) and Mafioletti (2001).

The lack of cointegration vectors for many of the results in the first attempt of finding cointegration can be explained by a long period of market instability where several breaks occurred. All the breaks were associated with different exogenous shocks that were generated by shortages or surpluses, a difference in stocks and market speculation. These shocks had different origins, such as climatic problems and government interventions that affected the market, introducing breaks in the time series. The second attempt to find cointegration between the time series using the previously identified structural breaks as dummy variables was found to be effective by finding cointegration between all the main international markets. In other words, all series followed a long-term equilibrium, and this finding can be considered unique as many authors had shown that the soybean markets were integrated to some degree: USA (Correia das Neves 1993; Pino and Rocha 1994; Lima and Burnquist 1997; Margarido and Souza 1998; Mafioletti 2001; de Moraes 2002; Giembinsky and Holland 2003; Da Silva *et al*., 2005); Brazil and Rotterdam (Europe) (Margarido *et al*., 2001); for Brazil, Rotterdam and Argentina (Margarido 2012); Argentina, Brazil, Chicago (USA) and Rotterdam (Europe) (Margarido *et al.* 1999; Machado and Margarido 2000; Da Silva *et al.* 2005; Margarido *et al*., 2007). Furthermore, cointegration was found between the Chicago Prices.

The vector error correction models using pairs and the global approach resulted in a suitable methodology to understand the dynamics of the international market. The first results showed a lack of short-term regressors in several models, indicating the strengthening of the domestic market and industry, such as in the case of the Brazilian market of Paranaguá. The other explanation involving statistically insignificant short-term regressors was government intervention, such as in the case of the China Spot market. Despite the structural government intervention in the domestic market, the China Spot market presented significant long-term regressors (at an alpha of 5%), meaning that Chinese authorities considered the Chicago prices as a reference for fixing the domestic price (Jamet and Chaumet 2016). China presented only a long-run causal relationship with other markets and a very slow speed of adjustment with all the different markets. These facts showed an incomplete price transmission and probably asymmetrical price transmission. In the short term, all international prices were frankly exogenous from China's domestic price system, and in the long term, almost all markets presented a long-term causal relationship with all the studied markets. Dalian Futures showed a consistently higher market efficiency, as represented by the speed of adjustment and higher market cointegration (Rapsomanikis *et al*., *2*013).

The Paranaguá market showed a very high speed of adjustment from shocks in Chicago and Rotterdam. Rotterdam seemed to lead this market in the long term. In the short term, the VEC model using pairs did not present statistically significant coefficients, showing that the selected market did not have a short-term causal relationship with Paranaguá. This finding was in contrast to Margarido et al. (2001), where the difference in findings can be explained by the period that both studies covered and the current development of the Brazilian domestic market and significant crushing industry. This industry has a high demand for soybean oil from the Brazilian domestic market. This heavy demand for national soybean can buffer short-term price fluctuations. The Rosario Spot market showed relatively efficient behaviour in the pair model with Paranaguá, adjusting at rates of 31.86% per period from Paranaguá shocks. Along the same line, Rosario adjusted at 26.80%, 27.27% and 20.37% per period for Chicago, Rotterdam and Rosario Futures, respectively. The Argentinian market was systematically intervened in by the government to discourage soybean exportation and encourage the development of the crushing industry (Margarido *et al.*, 2007; Vassallo *et al*., 2011). Despite this market intervention, the market efficiency marginally increased from the last empirical research performed by Margarido *et al.* (2001), when the speed of adjustment was found to be 26.16%. Margarido (2012) studied the relationship between the Brazilian and Argentinian markets, finding that prices in Argentina were not transmitted to Brazilian prices, which was consistent with this research's findings. In other words, Argentina (Rosario Spot) did not present short-term and long-term causalities with Brazil (Paranaguá). However, the results of this research showed that there was long-term and short-term causal relations between Brazilian prices and those of Argentina (Brazilian prices affected Argentinian prices). Rosario Futures affected the Rosario Spot market via Granger causality. However, Rosario Futures market did not present a short-term statically significant regressor (VECM) for Rosario Spot. The effect of Rosario Futures could explain almost half of the price decreases in Rosario Spot. To some degree, the Argentinian government intervention failed to dislocate the market; the tariffs acted as fixed costs and the increase in international price provoked a proportional increase in domestic market.

In summary, this research failed to reject the null hypothesis that the trade war dislocated the market; there was not enough empirical evidence to support the claim that the trade war provoked breaks in Chicago, Brazil, Rotterdam and Argentina. Therefore, it was not possible to use the structural break correlated with the trade war as a dummy variable to find cointegration. This finding reduced the significance of the trade war and it is necessary to reformulate the question and understand why the US–China trade war did not affect the international market, as well as other events over the past 10 years have. How the international market overcame the tariff and arbitrage around it can be partially explained by the results of the vector error model that showed a highly efficient market that was capable of efficiently arbitraging around the tariffs with the fast speed of transmission and a highly cointegrated market.

ECI 5. Conclusions

In general, the international market showed itself as highly efficient and cointegrated with a fast speed of adjustment from exogenous shocks in the leading markets. Chicago remained the most important market, leading the international prices. In other words, Chicago affected all prices, except for the Rotterdam price. However, both Chicago and Rotterdam failed to present short-term, causal relationships with most of the markets. This can be explained by the development of the domestic market and crushing industry, as well as the domestic and international demand for soybean derivates (soybean oil, soymeal, etc.) in those markets. The development of domestic demand acted as a buffer zone for international price fluctuation, at least in the short-term (Brazilian case). The next scenario of lack of short-term causal relationship was explained by government interventions, such as in the case of

China, where the market was price dislocated, at least in the short term. Rotterdam continued to be the second-most important centre of price formation, presenting a long-term causal relation with all markets, excluding Chicago. The Brazilian market rose to a significant level, presenting a long-term causal relationship with markets such as Rosario Spot, China Spot and Dalian Futures. Paranaguá rose as a leading market, creating the following question: to what extent did the trade war speed up this process? For a market with high market efficiency and market cointegration, the consequences of the trade war seemed to be relatively less significant. First, the tariff imposed by China did not cause a structural break in the main markets (Chicago, Rotterdam, Paranaguá and Rosario); therefore, price dislocation did not happen, at least in the short term. The tariff acted as a fixed cost for the Chinese importation of US soybean. The four markets managed to arbitrage around the tariff and return to the long-term price equilibrium. This is an excellent example of how free markets that are highly efficient regulate themselves, managing to overcome government interventions.

ECI 5.1. Policy Implications

The empirical evidence suggested the extraordinary capability of free markets to reorganise and arbitrage around tariffs, where the LOOP redirected the commercial flow around the tariff, equalising the international prices. The market agents acted fast to exploding arbitrage opportunity and the market converge under the same price. In terms of policy implication, China underestimated the market capability of the soybean market to rearrange and miscalculated the real impact of a tariff on US soybean. On the other hand, the Trump administration acted demagogically by giving farmers subsidies and distorting the price. The implementation of subsidies was unnecessary because the prices had converged fast due to the already explained arbitrage process. The trade war showed how well and efficient free markets work, making this event irrelevant and statistically not significant. The soybean trade war was one of several battles fought by the largest two economies of the world. According to Bown and Kolb (2020), this war generated a loss of economic welfare for the final consumer.

ECI 5.2. Recommendation for Further Study

This research quantified and described the market relation of the different international markets of soybean. Future research should focus on the individual contribution of each variable in the VECM by utilising the forecast error variance decomposition (FEVD). This will quantify the degree of explanation or contribution of each independent variable to a dependent in the autoregression model. Moreover, utilising the IRF will determine how the model variables respond to external shocks in one or more variables and give the model reaction as a function of time. This will help to identify the market power and build an overall understanding of the dynamic behaviour market by contrasting the magnitudes of different shocks (financial crisis, droughts, etc.) with the shocks introduced by the trade war.

The determination of the asymmetric price transmission on government-intervened market can generate insights regarding policy implications and market power. Through the threshold autoregressive model (TAR), momentum threshold autoregressive model (M-TAR) and asymmetric error correction model (AECM), these techniques will help to evaluate the loss of market efficiency due to trade war government interventions. Furthermore, Phillis and Perron (1998) stated that the unit root test could be applied to improve the unit root detection, and the Engle and Granger (1987) cointegration test can be used to contrast with the Johansen cointegration test. This will result in a complete quantification of market efficiency and the impacts of government interventions and policies on the selected markets.

Despite the fact that there is enough empirical evidence of the international market condition before the trade war, the methodology and the econometric tools applied might differ from the methodology used in this research. Therefore, to evaluate and compare results to assess the consequences of the trade war, it is necessary to investigate the market in the three different periods: before the trade war, during the trade war and after the trade war using the same methodology.

Finally, the rise of the Brazilian market is evident; therefore, it is important to evaluate the main component of this upsurge. As aforementioned, the trade war might have had some direct implications on this phenomenon.

Chapter 4: Second Empirical Chapter.

4.1. Asymmetric Price Transmission Analysis of the International Soybean Market

4.1.1. Details Summary

Authors.

1. Gustavo Maria Barboza Martignone (PhD Student)
2. Dimitrios Papadas (First Supervisor)
3. Karl Behrendt (Second Supervisor)

- Author Contributions

D.P. and K.B., supervision, project administration, methodology. G.B.M., conceptualization, formal analysis, investigation writing and review and editing. All authors have read and agreed to the published version of the manuscript.

- License

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- Format

The format and general structure of the paper, including the numbering of headings and subheadings, have remained unchanged. Only the citations have been updated to Harvard style.

4.1.1.1. Presentation of Published Empirical Findings

This section includes the original empirical study, as published in Agricultural Science, titled “Asymmetric Price Transmission Analysis of the International Soybean Market." The chapter is presented in its entirety to preserve the integrity of the findings and facilitate direct engagement with the original research. This study serves as a critical component of the dissertation, providing key insights and data that are further explored and expanded upon in the subsequent chapters.

Apart from citation formatting adjustments to align with the dissertation’s style, no changes have been made to the original content, in accordance with academic standards.

ECII 1. Introduction

The international soybean market is one of the most important in the world, as it represents a key source of protein for animal consumption (Voora, Larrea and Bermudez, 2020) and the fourth largest agriculture market in terms of volume. There are many actors in this commodity market, but few have relative importance in terms of production, consumption, and price leadership. Brazil is the main producer of soybean, accounting for 121.8 million tonnes (2020), closely followed by the United States with 112.55 million tonnes (2020). Thirdly, Argentina produced 48.80 million tonnes (2020) (*Our World in Data*, 2021). Together, they represent the main supply of raw and crushed soybean. On the other hand, on the demand side, China clearly consumes the most soybean (14.07 billion U$S by 2020), followed by the European Union (1.91 billion U$S) (USDA, 2020).

In terms of price leadership, several authors have identified the US-Chicago Market and the European Port of Rotterdam as the price leaders of the market (Margarido, Turolla and Bueno, 2007). This market is characterized as cointegrated and highly efficient, where the Law of One Price (LOOP) has already been validated. The free market status of the international soybean market has not always been the rule, with different market actors having intervened within the market several times. For example, in the case of Argentina with its export tariff known as “retentions” (Margarido, Turolla and Bueno, 2007), or its fixing of exchange rates limiting production and trade, and promoting stockpiling of production in anticipation of a better political scenario. Similarly, China has intervened within the domestic market via the introduction of price support policies, such as imposing a “floor price” or increasing import tariffs to protect the domestic market (Arnade, Cooke and Gale, 2017), or applying a selective tariff on US soybean exports. Kinnucan and Forker (1987), argue that these types of policies and market interventions can generate asymmetric price transmission (APT). It is widely agreed that intervention generates a loss of market efficiency and asymmetry of price (Meyer and von Cramon-Taubadel, 2004). Given the structure of the global soybean market and the interventions imposed some players, the question remains as to what degree have the interventions generated APT across the international market. This research focuses on and addresses this gap, trying to understand the implications in terms of APT in a highly efficient and cointegrated market.

APT can be caused by various factors, the main literature suggests that non-competitive markets and adjustment costs can play a role (Meyer and von Cramon-Taubadel, 2004). However, since the soybean market is highly efficient and competitive, this may not be a problem. There are several other factors that might generate APT such as inventory management, asymmetric information, asymmetric costs, market power, and political intervention (Bailey and Brorsen, 1989). The latter two factors were suggested by (Barboza Martignone, Behrendt and Paparas, 2022), for the previously mentioned case of government-intervened markets such as in the case of Argentina (Margarido, Turolla and Bueno, 2007) and China (Arnade, Cooke and Gale, 2017). Goodwin and Piggott (2001), suggest that APT in the spatial dimension can also be generated by differences in transportation costs. Some trade channels might be more developed in terms of infrastructure, storage facilities, capabilities, and transportation.

The Threshold Autoregressive (TAR) and Momentum Threshold autoregressive models (MTAR), alongside Engle and Granger's (1987) methodology, have been widely used for studies of APT. Nakajima (2012), was the first researcher to study APT in the international soybean market. He examined US domestic and export prices using the sub-sampling methodology of Bermejo, Peña and Sánchez (2011), repeated the TAR model to avoid sample selection problems. Nakajima (2012) conclusion was that from 1967 to 1977, the PT was positively asymmetric and then became symmetrical and asymmetrically negative after 1977 until 1988. During the next period until halfway through the 1990s, APT shifted to negative. This result can be attributed to the rise of Brazil and Argentina as world leaders in soybean export. Later on, Yang and Berna (2021) successfully found evidence of APT in the soybean complex of the Chicago Board of Trade, between soybean futures prices and the prices of soymeal and soybean oil. The authors used an innovative methodology, a multi-variate quartile approach by a Vector Autoregressive Quantile Model (VARQ). The authors demonstrated the superiority of quantile regression over OLS regression, as the VARQ model provides a more detailed view for identifying the sources and patterns of APT between downstream and upstream markets. The authors found evidence of APT in the soybean complex, with a negative response from soybean products to shocks in input prices. Yang and Berna (2021), have studied the APT in the vertical dimension from futures prices or across different linked commodities, such as raw soybeans, soybean oil, and soymeal. This research opens up a gap in the study of horizontal APT across the same commodity in different spatial markets. It remains unclear if APT is the rule rather than the exception in the international market. Previous authors who have studied APT in soybeans have solely focused on the US market, which is already considered to be the most efficient market in terms of PT. Therefore, if the US market has presented structural APT during different periods, it is likely that other markets, such as the Argentinian and Chinese markets, which have structural market intervention and lower degrees of market efficiency, also present APT. The aim of this research is to address this gap and understand the dynamics of the international soybean market in terms of PT. This question remains whether the intervened markets with decreased market efficiency present APT, which can be associated with intervention policies, market power, asymmetric information, or other factors.

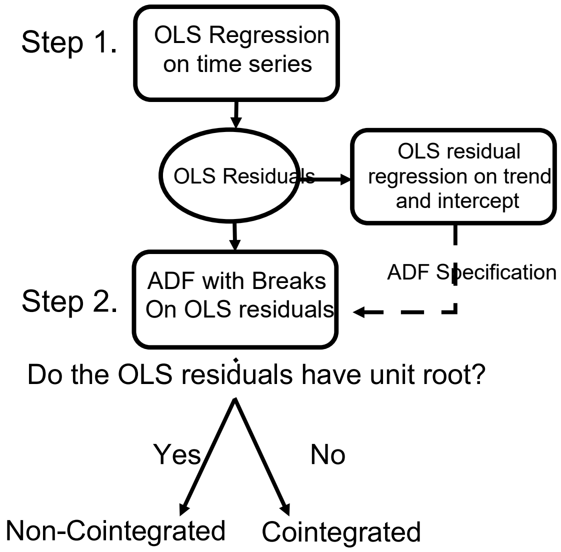
ECII 2. Methodology

This research is based on econometric and statistical procedures and models that use time series analysis of prices (secondary data). The secondary data comes from a variety of sources, such as: Wind Economic, which provided time series data for the China Spot market; The Dalian Commodity Exchange, which provided data for the Dalian Future market; the International Monetary Fund’s website, which was the source of data for the Chicago Board of Trade (CBOT) and Rotterdam; the Brazilian Centre for Advanced Studies for Applied Economics (CEPEA), which provided data from the Brazilian market of Paranaguá port; and finally, the Rosario Stock Exchange (Bolsa de Rosario), which provided data for the Argentina Spot and Futures market of Rosario. For this type of research, the data has been conditioned and transformed into natural logarithms to decrease variation in the data, simplifying patterns and increasing the robustness of the models, following a standard econometric procedure.

This investigation builds upon previous research from Barboza Martignone, Behrendt and Paparas (2022). The same dataset and structural breaks were used, with the starting point being a continuation of the previous results. Using the Augmented Dickey-Fuller test (1979), the previous research found that all the time series are stationary at the first difference, indicating that the integration order is I(1). In this research, the Phillips-Perron unit root test was implemented to complement and confirm the robustness of the framework. The structural breaks were already identified (using Bai-Perron’s multiple breakpoint test and ADF with breaks) in the aforementioned research and were used as dummy variables for cointegration under asymmetry test (Enders and Pierre L. Siklos, 2001). Barboza Martignone, Behrendt and Paparas (2022) also found full cointegration among the studied time series using the Johansen Cointegration test. To ensure the validity of the previous results, this investigation performed the Engle-Granger cointegration test using a two-step estimation (Figure 1).

ECII Figure 1. Engle-Granger cointegration test, two-step estimation.

Engle-Granger cointegration test two-step estimation



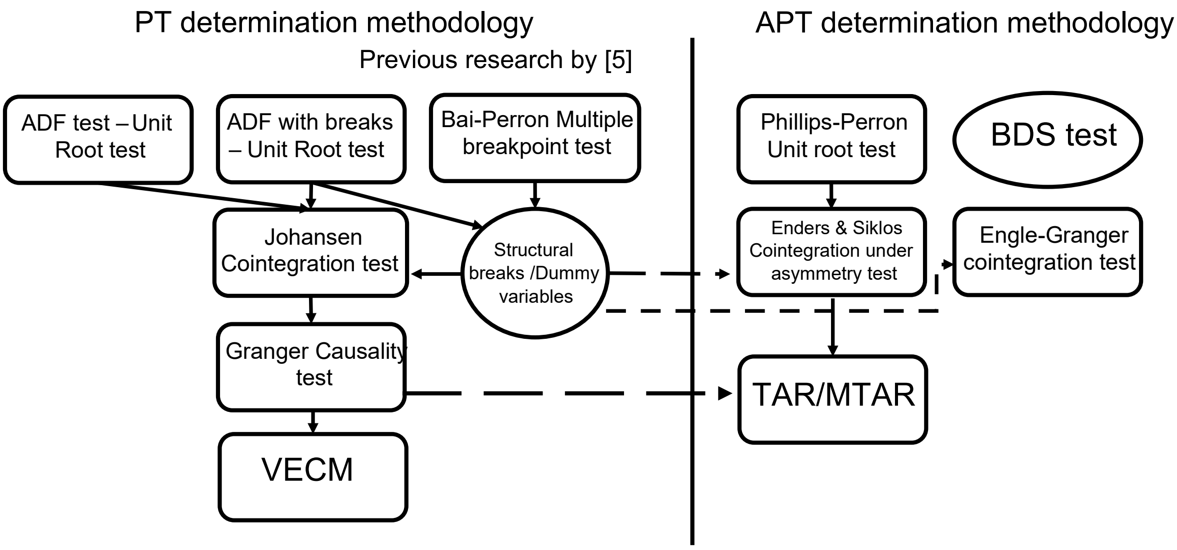
First, an ordinary least squares (OLS) regression was created for an overall model that encompasses all time series. Then, the procedure was repeated in paired models for all combinations of time series. For each individual model, the residuals were regressed on intercepts (constant) and a trend to understand their significance, which were later useful for the Augmented Dickey-Fuller (ADF) test specification. The second step was to perform the ADF test on the residuals of each OLS model. The modified version of the test, "ADF with breaks," was used in some scenarios where the time series have structural breaks that mislead the results into a false unit root. Cointegration is found if the ADF rejects the Null Hypothesis of Unit root on the residuals of the previously estimated model (Bilgili, 1998).

Barboza Martignone, Behrendt, and Paparas (2022) previously established the causality of the price series using the Granger Causality test. Based on the same integration order, cointegration, and causality among all variables, the relationship among the time series can be represented by an Error Correction Model (VECM) (Listorti and Esposti, 2012). Following Barboza Martignone, Behrendt, and Paparas (2022) built several VECM models to describe the relationship among variables and the market dynamics. Based on the models previously created by the aforementioned authors, this investigation evaluated if the model that accounted for linear and symmetric relationships in PT are valid for non-linear behaviour or asymmetric price transmission. Therefore, to switch from linear to nonlinear modeling, it is necessary to check the nature of the time series. To achieve this, the research used the nonparametric BDS test for nonlinearity (Broock *et al.*, 1996). The BDS test was originally developed by Broock *et al.* (1996) for detecting serial linear dependence in time series. It is useful for diagnosing nonlinear dependencies in the time series. To correctly perform the test, it is necessary first to increase the statistical power of the test, that's why the series should be transformed into first differences and natural logarithms. The main advantage of the BDS test is that it doesn't require any distribution assumptions. The Null Hypothesis is that the time series are independently and identically distributed, the alternative hypothesis is the opposite of the Null Hypothesis implying nonlinear dependency.

The simplicity and intuitive qualities of linear models have dominated theoretical and applied economics and econometrics for most of the 20th century (Skare, Tomic and Porada-Rochoń, 2019). However, due to the possibility of nonlinear relationships in time series data, nonlinear models are starting to gain attention. The assumption of linearity in linear models can result in stationary solutions that converge to a point with a tendency towards infinity, and they may fail to explain nonlinear phenomena in natural sciences (Skare, Tomic and Porada-Rochoń, 2019). The applicability of the Vector Error Correction Model (VECM) assumes linear behaviour in time series data. Asymmetrical price transmission suggests a nonlinear relationship among variables.

To account for asymmetrical price transmission (APT), TAR and MTAR models are often used. Both models are classified as bilinear models, and they are popular in econometric literature and have been used in studies of APT in various agricultural markets, such as Wheat in India by Paul and Karak (2022), Skim Milk Powder International Trade by Xue, Li and Wang (2021) and Chinese pork and pig market by Dong *et al.* (2018). The TAR model is a piecewise-linear approximation to a general nonlinear model, an Autoregressive (AR) model with abrupt changes between equations. This type of model can capture deep asymmetry in data. Similarly, the MTAR can capture deep asymmetry in data (Tayyab, Tarar and Riaz, 2012). To improve the comprehension, the economic procedure and the bounder between this research and Barboza Martignone, Behrendt and Paparas 2022) study the Figure 2 illustrates the econometric pathway.

ECII Figure 2. Econometric pathway



ECII 2.1. MTAR & TAR Models Specification

As previously mentioned, the series were already detrended (converted into first differences) and the threshold value is set to 0. To filter the series residuals from the long-term equation, a heaside indicator is defined and the series residuals are decomposed into positive (p1) above the threshold, and negative (p2) below the threshold, and the models are estimated. The trimming factor is set at 15%, removing higher values from both ends and using the 75% remaining values to estimate the threshold parameters. A Monte Carlo simulation was used for estimating the critical values. Both the MTAR and TAR models were estimated using the econometric software Eviews.

ECII 2.2. Data Summary

As previously mentioned, the secondary data was obtained from a previous investigation Barboza Martignone, Behrendt and Paparas (2022). Table 1 presents the data summary and demonstrates the impact of government intervention on the soybean market. The free markets in Chicago, Paranaguá, and Rotterdam have similar average soybean costs per ton, with any variations in price being attributed to transaction costs. However, the average prices in the markets of China and Argentina deviate significantly from the international market prices. This discrepancy can be attributed to government intervention; China's price support policies have artificially inflated domestic market prices, while Argentina's tariffs and export retention measures have resulted in lower export prices.

ECII Table 1. Soybean data summary.

	Paranagua Spot U$S/tt	Rotterdam U$S/tt	Chicago futures U$S/tt	Dalian Futures U$S/tt	China Spot U$S/tt	Rosario Futures U$S/tt	Rosario Spot U$S/tt
Mean	438	461	415	630	630	282	288
SD	82.6	78.2	80.6	88.2	82.6	40.6	47.6
Kurtosis	0.58	−0.41	−0.78	−1.23	−1.08	−0.77	0.14
Media	407	432	379	618	607	271	276
Max	714	684	623	786	785	390	429
Min	327	357	306	458	522	225	216
Q1	373	394	354	557	562	248	251
Q2	407	432	379	618	607	271	276
Q3	503	521	497	712	702	319	320

ECII 3. Results

In this section, the results are explained in the logical sequence in which they were produced. The results were summarized in tables to facilitate comprehension.

ECII 3.1. Phillips-Perron Unit Root Test

The Unit Root test is necessary to open the path to many econometric procedures and models under the assumption that the data is stationary. The results of the Phillips-Perron unit root test (Table 2) failed to reject the Null Hypothesis (unit root at level); the probability was higher than the test critical value for all time series. Therefore, there was a high probability of rejecting the Null hypothesis when it is true (Error type I). After transforming the series to the first difference and re-running the test, the Null Hypothesis was rejected. Therefore, the alternative hypothesis was accepted, meaning that all series are stationary at the first difference and with integration 1-I(1) (Table 2). These results are in line with (G. Barboza Martignone, Behrendt and Paparas, 2022) where the authors found the same order of integration using the Augmented Dickey Fuller test.

ECII Table 2. Phillis-Perron Unit root test for all-time series

Phillips-Perron Unit Root Test (level)		Adj. t-Stat	Prob.*
Rotterdam		-1.63	0.47
Rosario Spot		-1.61	0.47
Rosario Futures		-1.62	0.47
Paranagua Spot		-1.78	0.39
Dalian Futures		-1.70	0.43
China Spot		-1.12	0.71
Chicago Futures		-1.66	0.45
Phillips-Perron Unit Root Test (First Difference)		Adj. t-Stat	Prob.*
Rotterdam		-9.10	0.00
Rosario Spot		-7.79	0.00
Rosario Futures		-7.25	0.00
Paranagua Spot		-7.28	0.00
Dalian Futures		-10.58	0.00
China Spot		-7.87	0.00
Chicago Futures		-7.83	0.00
Test critical values:	1% level	-3.485	
	5% level	-2.886	
	10% level	-2.580	

ECII 3.2. Engle-Granger Cointegration Test

This cointegration methodology requires two steps. Firstly, it requires estimating an OLS model. In this case, the China Spot market is used as the dependent variable, as previous causality tests performed by Barboza Martignone, Behrendt and Paparas (2022) revealed that this market was the most Granger-caused by all the studied markets. The linear OLS model showed a high coefficient of determination and all independent variables were statistically significant (Table 3).

Secondly, it is necessary to perform the Augmented Dickey-Fuller Unit Root test on the OLS model residuals. If the residuals are stationary, this means that the series are cointegrated. However, it was necessary first to correct the ADF test specification for trend and intercept. Therefore, a regression of trend and constant on the OLS residuals was performed (Table 4). The regression showed that the intercept and trend are statically significant, therefore it is necessary to include them in the ADF unit test. The ADF test, including the exogenous constant and trend, rejected the Null Hypothesis of Unit Root, meaning that the residuals are stationary (Table 5). The stationarity of the residuals means that the series are cointegrated. These results are in line with the empirical evidence from previous research, such as that of Barboza Martignone, Behrendt and Paparas (2022)who arrived at the same conclusion using the Johansen cointegration methodology, as well as many other researchers who have proved cointegration among different soybean markets.

Despite the previous procedure having confirmed a long-term relationship among the markets (time-price series), to understand the price transmission dynamic between two markets, it is necessary to check for cointegration in pairs. The previous methodology was applied in pairs for all combinations of time series. However, the large number of results generated can compromise the readability of this research. Therefore, for all pairs of models, the results have been removed from the paper and summarized in Table 6 (the results are available upon request). Pairwise OLS models were created for all different combinations of time series. For each individual model, the residuals were regressed on an intercept and trend in order to correctly specify the ADF. The residuals were then tested with the ADF unit root test with correct specification (trend and constant). In some cases, the ADF test failed to reject the Null hypothesis of Unit Root. In this scenario, the modified test “ADF with breaks” was applied. This test finds structural breaks in the time series and uses them as exogenous variables, avoiding false unit roots.

In the scenario where the Null hypothesis cannot be rejected, the selected structural breaks from Barboza Martignone, Behrendt and Paparas (2022) found with the Bay-Perron methodology were introduced as exogenous variables. After following the previously mentioned procedure, the results showed that not all time-price series were cointegrated in pairs. This result is in contrast with the results of the previously mentioned researchers. Empirical evidence suggests that the Johansen cointegration test performs better than single equation and alternative multivariate methods and dominates cointegration analysis (Bilgili, 1998). Among the series that did not present cointegration among their pairs, China Spot stands out as the least cointegrated. China Spot presented cointegration only with Dalian Futures and Rosario Spot. Rosario Futures exhibit the second-place in lack of cointegration among pairs, being only cointegrated with Rosario Spot, Dalian and Paranaguá. However, the number of cointegrated pairs increases if the alpha is set at 10%, suggesting a fading effect of the Cointegration vectors or a lack of statistical power from Engle-Granger.

The evidence suggests that the lack of statistical power of the Engle-Granger test, in addition to a high number of structural breaks and government intervention in the previously mentioned markets (Argentina and China), can lead to Error Type II (failure to reject the Null hypothesis when it is true) and spurious results.

ECII Table 3. OLS regression all-time series.

Variable	Coefficient	Std. Error	t-Statistic	Prob.
LNCHIGF	0.42	0.11	3.93	0.00
LNDALIF	0.76	0.05	14.27	0.00
LNPARANAGUASP	0.25	0.10	2.37	0.02
LNROSFT	-0.53	0.13	-3.99	0.00
LNROSSP	0.38	0.14	2.75	0.01
LNUSROTTERDAMCIF	-0.67	0.12	-5.67	0.00
C	2.50	0.30	8.30	0.00

R-squared	0.85	Mean dependent var	6.44
Adjusted R-squared	0.84	S.D. dependent var	0.13
S.E. of regression	0.05	Akaike info criterion	-3.04
Sum squared resid	0.31	Schwarz criterion	-2.88
Log likelihood	193.91	Hannan-Quinn criter.	-2.97
F-statistic	106.97	Durbin-Watson stat	0.67
Prob(F-statistic)	0.00		

ECII Table 4. OLS regression on residuals.

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	-0.02	0.01	-2.65	0.01
@TREND	0.00	0.00	3.07	0.00

R-squared	0.07	Mean dependent var	0.00
Adjusted R-squared	0.06	S.D. dependent var	0.05
S.E. of regression	0.05	Akaike info criterion	-3.20
Sum squared resid	0.29	Schwarz criterion	-3.15
Log likelihood	198.52	Hannan-Quinn criter.	-3.18
F-statistic	9.41	Durbin-Watson stat	0.72
Prob(F-statistic)	0.00		

ECII Table 5. ADF on residuals.

Augmented Dickey-Fuller		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-5.12	0.00
Test critical values:	1% level	-4.03	
	5% level	-3.45	
	10% level	-3.15	

*MacKinnon (1996) one-sided p-values.
Null Hypothesis: Residual OLS model has a unit root
Exogenous: Constant, Linear Trend

ECII Table 6. Engle-Granger cointegration matrix.

	Chicago Futures	Dalian	China Spot	Rosario Futures	Rosario Spot	Rotterdam	Paranaguá
Chicago Futures	X	√	X	X	√	√	√
Dalian	√	X	√	√	√	√	√
China Spot	X	√	X	X	√	X	X
Rosario Futures	X	√	X	X	√	X	√
Rosario Spot	√	√	√	√	X	√	√
Rotterdam	√	√	X	X	√	X	√
Paranaguá	√	√	X	√	√	√	X

ECII 3.3. BDS

The investigation of the presence of non-linearity in the time series is considered a standard procedure before modeling MTAR and TAR asymmetry models, which are considered close approximations of non-linear models. Firstly, in order to perform the BDS test, the series must be detrended, and autocorrelation needs to be eliminated. Therefore, all series must be in natural logarithm and differentiated (first difference). The Null Hypothesis is that the series are identical and identically distributed. The alternative hypothesis is that the data is not linearly dependent. The results of the BDS test are reported in Table 7. The results show that most of the series were non-linearly dependent in nature, except for Rotterdam and Dalian.

ECII Table 7. BDS results.

	Dimension	BDS Statistic	Std. Error	z-Statistic	Normal Prob.	Bootstrap Prob.
Chicago Futures	2	0.021	0.008	2.736	0.006	0.017
	3	0.042	0.012	3.427	0.001	0.006
Paranagua	2	0.023	0.006	3.521	0.000	0.004
	3	0.028	0.010	2.728	0.006	0.022
China Spot	2	0.028	0.009	3.190	0.001	0.010
	3	0.039	0.014	2.792	0.005	0.018
Rosario Futures	2	0.016	0.007	2.441	0.015	0.040
	3	0.023	0.011	2.157	0.031	0.054
Dalian Futures	2	0.003	0.007	0.423	0.672	0.624
	3	0.000	0.011	-0.029	0.977	0.899
Rosario Spot	2	0.015	0.006	2.364	0.018	0.045
	3	0.017	0.010	1.741	0.082	0.117
Rotterdam	2	0.012	0.007	1.648	0.099	0.136
	3	0.012	0.012	1.013	0.311	0.312
	Dimension	**C(m,n)**	**c(m,n)**	**C(1,n-(m-1))**	**c(1,n-(m-1))**	**c(1,n-(m-1))^k**
Chicago Futures	2	3705	0.510	5079	0.700	0.489
	3	2715	0.380	4976	0.697	0.338
Paranagua	2	3729	0.514	5087	0.701	0.491
	3	2630	0.368	4985	0.698	0.340
China Spot	2	3767	0.519	5089	0.701	0.491
	3	2714	0.380	4991	0.699	0.342
Rosario Futures	2	3703	0.510	5102	0.703	0.494
	3	2615	0.366	5000	0.700	0.343
Dalian Futures	2	3575	0.492	5080	0.700	0.490
	3	2466	0.345	5011	0.702	0.346
Rosario Spot	2	3696	0.509	5105	0.703	0.494
	3	2591	0.363	5011	0.702	0.346
Rotterdam	2	3664	0.505	5095	0.702	0.493
	3	2530	0.354	4995	0.700	0.342

ECII 3.4. TAR

Several TAR models were estimated following the combination from VECM models previously proposed by Barboza Martignone, Behrendt and Paparas (2022). The previously mentioned authors used the model accounting for Granger causality of the prices, first in pairs, and then using all series that were independent and cointegrated with the dependent Granger-caused series “target series.” Table 8 shows different pair combinations of TAR models for the China Spot market, and in the last column, an overall model that uses all series that Granger-cause the China Spot market.

ECII Table 8. TAR model for China Spot.

China Spot	Chicago futures		Rotterdam		Paranagua		Dalian Futures		Overall model	
	Coeff.	Std. Error	Coeff.	Std. Error	Coeff.	Std. Error	Coeff.	Std. Error	Coeff.	Std. Error
Above Threshold P1	-0.05	0.04	-0.04	0.04	-0.04	0.04	-0.34	0.09	-0.35	0.08
Below Threshold P2	-0.08	0.05	-0.06	0.04	-0.09	0.05	-0.21	0.08	-0.41	0.08
Differenced Residuals(t-1)	0.17	0.09	0.13	0.09	0.24	0.09	0.15	0.09	0.39	0.08
Differenced Residuals(t-2)	-0.03	0.09	-0.02	0.09	-0.05	0.09			0.27	0.09
Threshold value (tau):	0.00		0.00		0.00		0.00		0.00	
F-equal:	0.27	2.81	0.08	2.68	0.67	2.88	1.30	2.09	0.36	1.76
T-max value:	-1.23	-2.13	-1.21	-2.12	-1.07	-2.10	-2.45	-2.43	-4.64	-3.01
F-joint (Phi):	2.05	5.93	1.57	5.92	2.32	5.76	10.07	7.36	20.94	10.15

From Table 8, it is possible to observe the lack of cointegration under asymmetry from the T-Max value and the F-joint (phil) were lower than the critical value. This is in contrast with previous findings of Barboza Martignone, Behrendt and Paparas (2022) in line with the Engle-Granger test. Even though all previous breaks found from the ADF with breaks and Bai-Perron multiple break test were used as dummy variables in the cointegration test, the results failed to find cointegration between the China-Spot and Chicago-Futures and China-Rotterdam. The different cointegration methodologies with differing statistical power can partially explain the mixed results. For the China Spot-Dalian and the overall model, both T-Max and F-joint t-static were higher than the critical value, finding cointegration among the time series. However, the test did not show asymmetry under cointegration. Therefore, it is possible to assure that there is a symmetric price transmission among the time series cointegrated series.

The TAR models for Paranaguá as the dependent variable paired with Chicago and Rotterdam as dependent variables and the combined model (Table 9) showed a clear cointegration under asymmetry. The T-statistic was higher than the critical value for all three models (T-max and F-Joint (Phi)). However, the model failed to find any trace of asymmetry (F-equal). Therefore, the null hypothesis of symmetric price transmission is accepted. This finding is in line with the empirical evidence that presents those markets as highly efficient in terms of price transmission and has a high degree of market freedom.

The Rosario Spot TAR models (Table 10) all presented cointegration among the time series. However, there is mixed results regarding cointegration between Rosario Spot and Rosario Futures, where the F-joint (Phi) t-statistics were higher than the critical value, therefore rejecting the null hypothesis of non-cointegration among the time series. However, for the T-max, the t-statistic was lower than the critical value, failing to reject the non-cointegration null hypothesis. Despite many attempts to incorporate structural breaks as dummy variables, full cointegration was not successful. Previous results have shown clear cointegration between the Rosario Futures and Rosario Spot time series.

ECII Table 9. TAR model for Paranaguá.

Paranagua Spot	**Chicago futures**		**Rotterdam**		**Overall model**	
Variable	Coeff.	Std. Error	Coeff.	Std. Error	Coeff.	Std. Error
Above Threshold	-0.35	0.07	-0.27	0.09	-0.30	0.07
Below Threshold	-0.33	0.09	-0.37	0.10	-0.38	0.08
Differenced Residuals(t-1)	0.43	0.08	0.14	0.09	0.41	0.08
Differenced Residuals(t-2)	0.16	0.09	0.03	0.09	0.24	0.09
Threshold value (tau):	0.00		0.00		0.00	
F-equal:	0.04	2.88	0.54	2.83	0.7	2.22
		-				
T-max value:	-3.57	2.11	-3.03	-2.12	-4.53	-2.43
F-joint (Phi):	17.21	5.83	9.68	5.99	19.29	7.24

ECII Table 10. TAR model for Rosario Spot.

Rosario Spot	Chicago Futures		Rotterdam		Paranagua		Rosario Futures		Overall model	
Variable	Coeff.	Std. Error	Coeff.	Std. Error	Coeff.	Std. Error	Coeff.	Std. Error	Coeff.	Std. Error
Above Threshold	-0.21	0.07	-0.31	0.10	-0.36	0.09	-0.25	0.07	-0.31	0.07
Below Threshold	-0.30	0.07	-0.27	0.10	-0.35	0.09	-0.14	0.09	-0.35	0.09
Differenced Residuals(t-1)	0.32	0.09	0.04	0.09	0.27	0.09	0.25	0.09	0.30	0.09
Differenced Residuals(t-2)	0.16	0.09	0.04	0.09	0.11	0.09	-0.08	0.09	0.23	0.09
Threshold value (tau):	0.00		0.00		0.00		0.00		0.00	
F-equal:	1.02	2.83	0.11	2.19	0.01	2.91	0.99	2.80	0.15	1.70
T-max value:	-3.10	- 2.11	-2.77	-2.44	-3.70	- 2.11	-1.53	- 2.13	-3.95	-2.99
F-joint (Phi):	11.91	5.79	7.96	7.26	13.04	5.85	6.81	5.92	15.15	10.00

ECII 3.5. MTAR

In contrast with TAR models, the MTAR models using the Enders and Siklos (2001) cointegration test under asymmetry and corrected by structural breaks as dummy variables all-time series presented cointegration, following the line of previous empirical evidence. The China Spot market has historically presented structural government intervention, protecting the market from exogenous shocks in prices and international price fluctuation. Therefore, the presence of APT was likely to happen according to Barboza Martignone, Behrendt and Paparas (2022). In contrast to the previous suggestion, all test results for all the time series and the overall model (Table 11) failed to reject the null hypothesis of symmetry of price transmission. These results seem counterintuitive given the market is intervened and non-efficient common source of APT. The TAR model showed the same result, failing to reject the null hypothesis. Therefore, it is possible to conclude that the price transmission from the international soybean market to the Chinese Spot domestic market is symmetrical. Following the TAR model, the results of the MTAR models for Paranaguá, when paired with Rotterdam, Chicago Futures, and overall combined, are presented in Table 12.

ECII Table 11. MTAR model for China.

China Spot	Chicago Futures		Rotterdam		Paranagua		Dalian Futures		Overall model	
	Coeff.	Std. Error	Coeff.	Std. Error	Coeff.	Std. Error	Coeff.	Std. Error	Coeff.	Std. Error
Above Threshold	-0.17	0.08	-0.15	0.07	-0.18	0.06	-0.35	0.12	-0.39	0.08
Below Threshold	-0.28	0.07	-0.27	0.07	-0.19	0.06	-0.40	0.10	-0.37	0.08
Differenced Residuals(t-1)	0.26	0.09	0.15	0.09	0.35	0.09	0.19	0.09	0.39	0.08
Differenced Residuals(t-2)	0.11	0.09	0.05	0.09	0.01	0.09	-0.11	0.10	0.27	0.09
Threshold value (tau):	0.00		0.00		0.00		0.00		0.00	
F-equal:	1.40	3.78	1.58	3.89	0.04	3.88	0.14	3.92	0.03	3.77
T-max value:	-2.11	-1.98	-2.00	-1.97	-2.90	-1.98	-2.92	-2.00	-4.65	-2.80
F-joint (Phi):	10.80	6.33	9.09	6.33	8.06	6.30	10.64	6.48	20.72	10.66

ECII Table 12. MTAR model for Paranaguá.

Paranaguá Spot	Chicago		Rotterdam		Overall model	
Variable	Coeff.	Std. Error	Coeffi.	Std. Error	Coeff.	Std. Error
Above Threshold	-0.37	0.08	-0.23	0.09	-0.36	0.07
Below Threshold	-0.32	0.08	-0.43	0.10	-0.31	0.07
Differenced Residuals(t-1)	0.40	0.09	0.13	0.09	0.41	0.08
Differenced Residuals(t-2)	0.16	0.09	0.07	0.09	0.25	0.09
Threshold value (tau):	0.00		0.00		0.00	
F-equal:	0.19	3.80	2.37	3.89	0.37	3.76
T-max value:	-4.28	-1.97	-2.50	-1.97	-4.14	2.30
F-joint (Phi):	16.70	6.31	10.74	6.35	19.06	7.80

All the models for the same market combination showed cointegration under asymmetry, again confirming the long-term relationship of the series. However, all the tests failed to reject the symmetry null hypothesis. In other words, the price transmission is symmetric among the different time series. This is in perfect agreement with the empirical evidence, especially for this market that presents highly efficient price transmission. Therefore, the result can be classified as expected according to economic theory.

The MTAR model for the Rosario Spot in pairs with Chicago futures, Paranaguá, Rosario Futures, and the overall model, presented a very similar pattern to the TAR model. Both failed to reject the null hypothesis, indicating that the price transmission is symmetric. The only observed difference between the TAR and MTAR model is in the cointegration test under asymmetry. The TAR model failed to reject the null hypothesis of non-cointegration between the Rosario Spot and Rosario Futures markets. However, the MTAR model with the cointegration test of Enders and Siklos (2001) rejected the null hypothesis and found cointegration between these markets, in line with the empirical results Barboza Martignone, Behrendt and Paparas (2022). This result is consistent with empirical evidence. In terms of asymmetric price transmission, against intuition and expectation due to government intervention, the Rosario spot market did not present any evidence of APT (Table 13).

ECII Table 13. MTAR model for Rosario Spot.

Rosario Spot	**Chicago**		**Rotterdam**		**Paranagua**		**Rosario Futures**		**Overall model**	
	Coeff.	Std. Error	Coeff.	Std. Error	Coeff.	Std. Error	Coeff.	Std. Error	Coeff.	Std. Error
Above Threshold	-0.23	0.07	-0.23	0.09	-0.34	0.09	-0.18	0.07	-0.40	0.08
Below Threshold	-0.22	0.07	-0.21	0.08	-0.32	0.09	-0.28	0.10	-0.25	0.08
Differenced Residuals(t-1)	0.30	0.09	0.03	0.09	0.26	0.09	0.24	0.09	0.31	0.09
Differenced Residuals(t-2)	0.15	0.09	0.03	0.09	0.10	0.09	-0.08	0.09	0.21	0.09
Threshold value (tau):	0.00		0.00		0.00		0.00		0.00	
F-equal:	0.03	3.89	0.03	2.78	0.04	3.73	0.70	3.85	2.22	3.90
T-max value:	-3.28	-1.98	-2.54	-2.10	-3.67	-2.00	-2.56	-1.97	-3.11	-2.83
F-joint (Phi):	9.92	6.34	6.04	5.85	11.87	6.39	6.65	6.34	16.45	10.58

ECII 4. Discussion

This study was conducted as an extension of previous research on market integration, efficiency, and price transmission in the soybean market by the same authors. The aim of the study was to investigate the possible asymmetry of price transmission in soybean markets that are subject to government intervention. The methodology was designed to complement the previous results and provide a more comprehensive understanding of the topic.

The BDS test results suggested a non-linear nature of the majority of the time series, which calls into question the applicability of linear models such as the Vector Error Correction Model (VECM) and opens up the possibility of using non-linear approximation models such as TAR and MTAR. The Phillips-Perron unit root test indicated that the series were stationary at first difference and integrated at order I(1), which is consistent with the previous research by Barboza Martignone, Behrendt and Paparas (2022) using the same data set but a different methodology (the Augmented Dickey-Fuller unit root test).

The mixed results from the Engle-Granger cointegration test and both the cointegration and threshold test proposed by Enders and Siklos (2001) and the Johansen cointegration test raise questions about the statistical power of the first test. Empirical evidence supports that Johansen cointegration test is superior in terms of cointegration analysis. This test overcomes the limitations of the Engle-Granger methodology by estimating and testing for the presence of multiple cointegration vectors through canonical correlation. Monte Carlo simulation studies have provided evidence of better performance from the Johansen methodology (Bilgili, 1998).

The results of this study revealed a clear association between government intervention, structural breaks, and a lack of cointegration vectors.

The Johansen test performed better in correcting for structural breaks and finding cointegration equations, as was seen in the study by Barboza Martignone, Behrendt and Paparas (2022). The cointegration and threshold test proposed by Enders and Siklos (2001) for the MTAR model showed similar results to the Johansen methodology. However, the same test applied to the TAR model showed a lack of cointegration in intervened markets. This suggests that the Johansen cointegration test has greater statistical power to detect cointegration vectors. Furthermore, when market interventions generate exogenous shocks that affect the market, the cointegration gradually fades over time, and the Engle-Granger test starts to give mixed or inconclusive results.

In conclusion, despite some cointegration tests (Engle-Granger) failing to find cointegration in some cases, the Enders and Siklos (2001) test for the MTAR and the empirical evidence from the Johansen cointegration test indicate that the market is highly cointegrated, showing long-term relationships among and between the series.

The MTAR and TAR models failed to find any evidence of asymmetric price transmission among and between the time series. This contradicts the suggestion of asymmetric price transmission from the international market to Argentina and the Chinese spot market made by previous researchers. One limitation of using the TAR model is the arbitrary selection of sample periods. The choice of sample period can affect the TAR model's parameters, making it necessary to test different sample sizes (Bermejo, Peña and Sánchez, 2011).

Ignoring these limitations, the research results suggest that instead of asymmetric price transmission, the transmission is symmetric, and market intervention might be associated with a lack or fade of cointegration equations or temporary APT in intervened markets. Many of these interventions generated structural breaks in the market when converted as dummy variables and used as exogenous variables to correct the cointegration model. This raises questions about whether these interventions temporarily dislocate the market and if the arbitrage process efficiently returns to symmetrical long-term equilibrium. Barboza Martignone, Behrendt and Paparas (2022) failed to prove this in the case of market dislocation caused by the US-China trade war, but their methodology might have overestimated the impact of the trade war in terms of generating structural breaks in different international markets.

ECII 4.1. Further Research & Policy Implications

Despite the conclusive results regarding APT, further research is needed to address the limitations of the TAR/MTAR methodology (Bermejo, Peña and Sánchez, 2011) and explore alternative methods. One such approach could be to adopt a multivariate quantile approach, such as the Vector Autoregressive Quantile Model (VARQ), which is considered superior to conventional OLS regression as it is not influenced by extreme values (Yang and Berna, 2021).

The nature of the results, indicating symmetrical price transmission in all markets, despite consistent structural market intervention, may lead to the conclusion that there is no association between market intervention and APT in this case. However, the researchers believe that this is not the case, and therefore, caution is advised when drawing policy implications until further research clarifies the mixed results.

ECII 5. Conclusions

The non-linear nature of the time series raises doubts about the applicability of autoregressive models and opens the possibility of investigating non-linear models. The results of the Engle-Granger cointegration methodology for highly government-intervened markets showed a lack of cointegration vectors. However, the cointegration and threshold adjustment test proposed by Enders and Siklos (2001) for the MTAR model showed that the market is fully cointegrated after the series were corrected for structural breaks. In other words, this result reflects the presence of a long-run equilibrium that converges over time.

Contrary to previous researchers' suggestions of APT, the TAR and MTAR models did not show any signs of asymmetric price transmission. Instead, all models showed symmetric price transmission. This suggests that the international soybean market is highly cointegrated, efficient, and symmetrical, capable of circumventing market interventions through arbitrage and converging to long-term equilibrium. Government interventions in some markets (China and Argentina) have caused structural breaks, temporal loss of cointegration vectors, and a loss of market efficiency, instead of generating asymmetric price transmission.

Chapter 5: Third Empirical Chapter.

5.1. Leadership shift in the global soybean market: Dynamic connectedness approach (TVP-VAR)

5.1.1. Details Summary

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- **Author Contributions**

D.P. and K.B., supervision, project administration, methodology. G.B.M., conceptualization, formal analysis, investigation writing and review and editing. All authors have read and agreed to the published version of the manuscript. B.G., formal analysis, review , methodology.

- **License**

- Format

The format and general structure of the paper, including the numbering of headings and subheadings, have remained unchanged. Only the citations have been updated to Harvard style.

5.1.1.1. Presentation of Published Empirical Findings

“Leadership Shift in the Global Soybean Market: Dynamic Connectedness Approach (TVP-VAR)." The chapter is presented in full to preserve the accuracy of the findings and allow for a direct examination of the original research. This study provides a crucial foundation for the dissertation, offering valuable insights and data that are further analysed and expanded in the subsequent chapters.

Except for adjustments to citation formatting to match the dissertation's style, the content remains unchanged, in line with academic standards.

ECIII 1. Introduction

In the complex and interconnected world of soybeans markets, understanding the dynamics of market integration and price transmission becomes crucial for economists and policymakers alike. This research embarks on an innovative journey to unravel the intricacies of soybean markets integration by exploring beyond the traditional realm of Johansen and Engle-Granger cointegration approaches, which have been the foundation for previous studies in diagnosing the interlinkages among various markets. Despite the invaluable insights provided by these cointegration methodologies, which primarily focus on static relationships, there exists an increasing need to delve into the dynamic aspects of the different soybean markets connectedness in dynamics terms. This research aims to bridge this gap by concentrating on the dynamic connectedness (Diebold and Yilmaz, 2012b; Antonakakis and Gabauer, 2017) a concept that transcends the static nature of cointegration, thereby offering a more time dynamic understanding of price time-varying behaviours and spillover mechanisms. By conducting a comprehensive examination of a diverse array of markets within the horizontal or spatial dimension, this research encompasses pivotal trading hubs such as the U.S. Soybean Futures market (Chicago Board of Trade), the Rotterdam port spot market an essential nexus for the European soybean trade and the Paranaguá port spot market, which is representative of the Brazilian soybean sector. Additionally, it incorporates the Argentinian futures and spot markets of Rosario, the Chinese domestic spot market (Heihe Grain Bureau), and the Dalian Commodity Exchange (Dalian soybean futures). This study provides an extensive analysis spanning approximately a decade, from September 2009 to May 2019, thereby offering robust insights into the temporal dynamics and inter-market linkages of these critical global soybean markets.

The international soybean market, known for its efficiency and integration (Barboza Martignone, Behrendt and Paparas, 2022), serves as a fertile field for this study. With a rich history of research delving into various economic phenomena ranging from price transmission to market power, the soybean market exemplifies a well-studied yet continually evolving domain. This research, therefore, seeks to add a fresh perspective by employing a time-varying parameter methodology (Antonakakis and Gabauer, 2017) to capture the dynamic connectedness or spillover process and price leadership in a globalised context marked by incessant exogenous shocks and market condition changes.

The methodology section sets the stage for a comprehensive exploration of the Time-Varying Parameter Vector Autoregression (TVP-VAR) and the connectedness index (Diebold and Yilmaz, 2012b). This methodology (Antonakakis and Gabauer, 2017) allows us to improve the comprehension of the mechanism of price time-varying and price spillover. As the narrative unfolds, the results are systematically presented, juxtaposed with previous empirical findings, to shed light on the causal relationships and capturing exogenous shocks. This comparative analysis not only enriches our understanding of market dynamics but also highlights the limitations and strengths of the chosen methodological approach.

Building upon the discussion and policy implications, this research aims to synthesise key findings, historical contexts, and contemporary policy frameworks to provide a comprehensive and coherent analysis. By synthesizing insights from the study with prior research, it aims to offer cogent interpretations of the results and their broader implications. Furthermore, the discussion extends to future expectations and market trajectories, providing a forward-looking view of the international soybean market and its constituents.

ECIII 1.1. Key concepts

Price Transmission (PT) and Asymmetric Price Transmission (APT) explore the dynamics of price changes within market levels and their unequal propagation respectively. PT emphasises how market-level price alterations influence other market levels, essential for market efficiency by indicating supply and demand shifts (McCorriston, Morgan and Rayner, 2001). APT indicates market inefficiencies where price increases are transmitted differently compared to price decreases, often due to market power or cost structures(Meyer and von Cramon-Taubadel, 2004). The Connectedness Index or Risk of Spillover (Diebold and Yilmaz, 2012b) measures the impact of market disturbances on others, crucial in finance for understanding asset or market volatility propagation (Zhao, Fan and Ji, 2022). A higher index signifies greater market interdependence, suggesting that shocks in one area can significantly impact others (Lastrapes and Wiesen, 2021). Cointegration, a statistical concept in econometrics, assesses long-term relationships among time series variables. If variables are non-stationary but their combination is stationary, they are considered cointegrated, suggesting a stable long-term equilibrium between them despite short-term fluctuations. This is vital for analysing economic relationships, such as between prices of substitutes or interest rates and investment (Dewynne *et al.*, 1999).

ECIII 1.2. Previous research and empirical work

The international soybean market is known for being a highly efficient and integrated market, making it a fertile field for applied economics. Many researchers over the years have focused on this market, studying different economic phenomena such as price transmission (PT) (Margarido *et al.*, 1999; Barboza Martignone, Behrendt and Paparas, 2022), price formation (Margarido and Sousa, 1997), price volatility (Margarido, Araujo Turolla and Ferreira Bueno, 2014) , seasonal PT (Machado and Margarido, 2000), elasticity of PT (Margarido, Turolla and Fernandes, 2001), asymmetric PT (APT) (Yang and Berna, 2021; Barboza Martignone, Paparas and Behrendt, 2023), effects of timing of crop and trade (Margarido, Turolla and Bueno, 2007) , market integration and market power (Song, 2006). Most of these researchers have used classical cointegration, AR models, and price transmission methodologies, which are useful tools that test economic theory against observed reality.

However, this methodology has several limitations. For example, the availability and quality of data can lead to inaccurate or unreliable results. The choice of model specification can also affect the results of price transmission analysis, as different models may yield different results. Additionally, market structure, such as the degree of competition and market power, can also affect the results of price transmission analysis. Furthermore, many price transmission models assume that parameters are constant over time, but they may vary. This can lead to biased or unreliable results if not accounted for (Baffes, 2007) .

This research builds on previous research that has already analysed the same data set; therefore, it is necessary to understand the previous results to contrast the different methodology results. Previous researchers had transformed the data into natural logarithms and first differences in order to make the data stationary. The Augmented Dickey-Fuller (ADF) test and ADF test with breaks were performed by Barboza Martignone, Behrendt and Paparas (2022) concluding that the data was stationary in the first difference I(1). Later on,the before mentioned authors performed Phillips-Perron unit root test, confirming the order of integration I(1).

The previously mentioned authors concluded that all markets were cointegrated to different degrees, using the Johansen cointegration test and, after correction by structural breaks, all markets presented cointegration among and between them. Using the Engle-Granger cointegration test Barboza Martignone, Behrendt and Paparas (2022) struggled to find cointegration among all the time series, especially among and between series that presented structural breaks correlated with government intervention. The China spot market was the least cointegrated series, only presenting cointegration equations with Rosario Spot and Dalian Futures. The authors suggested the lack of statistical power of the Engle-Granger test, with the extenuating effect of structural government intervention that has generated several structural breaks, fading the cointegration vectors. The cointegration under asymmetry test by Enders and Siklos (2001) applied under TAR and MTAR models by Barboza Martignone, Paparas and Behrendt (2023) showed that the model results presented no trace of asymmetric price transmissions among the markets, but the cointegration test under asymmetry (Enders and Siklos, 2001) showed that it was always necessary to correct for dummy variables (structural breaks) in order to show full cointegration. The TAR model for China showed a lack of cointegration under asymmetry for Rotterdam, Paranaguá, and Rosario (China is only cointegrated with Dalian futures). The cointegration test under asymmetry (Enders and Siklos, 2001) for the MTAR model showed that all series are cointegrated after being corrected for structural breaks. This opens the question of how integrated the markets are. Since cointegration is a static concept, it cannot be totally extrapolated to dynamic markets. Therefore, it is necessary to adopt another approach.

Several researchers have utilized the dynamic connectedness methodology, based either on a Time-Varying Parameter in a Vector Autoregressive model (TVP-VAR) or on a Quartile Regression model (QVAR). (Antonakakis and Gabauer, 2017) studied the uncertainty transmission between developed economies using these methodologies. They examined the spillover effect among the EU, US, Japan, the UK, and Canada, and their findings suggested significant transmission of uncertainty from the EU to the US. Balcilar, Gabauer and Umar (2021) studied the connectedness among crude oil, grains, livestock, sugar, soybean oil, cocoa, corn, lean hogs, soybeans, wheat, and cattle using the connectedness methodology based on a TVP-VAR. The authors found high net connectedness among the studied sample 70% implying strong cointegration or co-movement among the selected commodities. The results suggested that crude oil most significantly affects other markets. However, it is also affected by changes in agricultural commodities markets, shifting from being a net transmitter to a net receiver over time. Only livestock and grain displayed consistent net transmitter behaviour over time.

Ghosh and Paparas (2023), used the dynamic connectedness methodology based on a Quartile Regression model (QVAR) to study the risk of spillover, or connectedness, for fourteen agricultural commodities: poultry, beef, soybean, coffee grains, cocoa, palm oil, corn, wheat, tea, groundnut oil, palm oil, sugar, orange juice, and rice. Their results indicated a high connectedness index over 55% for the entire period from 1965 to 2022. This suggests that the risk of spillover hasn't decreased in recent years, and the agricultural commodity markets are quite susceptible to external shocks. They also found that soybean, corn, wheat, and palm oil are net transmitters, leading in prices and transmitting the most to other commodities.

ECIII 2. Materials and Methods.

The descriptive results for the selected dataset showed low variance in the data and a Gaussian nature of the distribution. The majority of the data was grouped under the mean, meaning that a standard quantile regression could not express the nature of the time series. Therefore, a Time-varying parameter Vector Autoregressive (TVP-VAR) model was built. This type of model enables us to capture the time-varying nature of the time series. The TVP-VAR model assumes that the data is stationary. To achieve this, the data was mean-reverted, assuming that the data converges to the average price over time, transformed into natural logarithm twice in order to achieve homeostasis and approximate the data under normality. This will make the series stationary and facilitate the prediction mechanism to perform better. To check if the transformed data met the previously mentioned assumptions, the Jaque-Bera test for normality and the Elliot, Rothenberg, and Stock (ERS) test for stationarity were applied. After the data met the correct specification, the TVP-VAR model was built using the Antonakakis and Gabauer (2017) method. From the vector moving average, the time-varying coefficient was extracted, a key piece of the connectedness (Diebold and Yilmaz, 2012b) , used in the Generalized Forecast Error Variance Decomposition (GFEVD) (Koop, Pesaran and Potter, 1996; Pesaran and Shin, 1998) and the Generalized Impulse Response Function (GIRF).

The GFEVD and the GIRF are crucial tools in the connectedness approach, which is employed to analyse the interdependence and dynamic interactions among multiple time series variables. The GFEVD is utilized to understand the proportion of the forecast error variance of a particular variable that can be attributed to shocks in other variables within the system. Unlike the traditional variance decomposition, which requires orthogonal shocks and is sensitive to the ordering of variables, the GFEVD allows for the decomposition of forecast error variances using shocks that are not orthogonal. This makes the GFEVD a more flexible and robust tool, especially in systems where variables are contemporaneously correlated. By decomposing the forecast error variance, the GFEVD provides a detailed picture of how shocks propagate through the system over time, highlighting the relative importance of each variable in influencing others.

The GIRF measures the response of each variable in the system to a shock in any one variable, considering the generalized nature of the shocks. This function extends the traditional impulse response analysis by not requiring orthogonal shocks, thus making the analysis invariant to the ordering of variables in the vector autoregression (VAR) model. The GIRF traces out the effect of a one-time shock to one of the innovations on the current and future values of the endogenous variables, offering a more accurate depiction of the dynamic interrelationships among variables. In the connectedness approach, these tools are integral for quantifying and visualizing the interconnections among variables. The GFEVD constructs connectedness tables, summarizing the degree of connectedness among all pairs of variables, while the GIRF provides a temporal dimension to this analysis, examining how shocks to one variable affect the others over time. Together, these tools enhance the connectedness approach by offering a comprehensive framework for analyzing interdependencies and dynamic interactions in a multivariate time series context, thereby uncovering the underlying structure of market dynamics and informing risk management practices and policymaking.

ECIII 2.1. Methodological Limitations

Despite the robustness and flexibility of the Time-Varying Parameter Vector Autoregressive (TVP-VAR) model in capturing the dynamic nature of time series data, several limitations must be acknowledged. Firstly, the assumption of stationarity is critical for the TVP-VAR model. Achieving stationarity required transforming the data through mean-reversion and double natural logarithm transformations, which, while effective in this context, may not be universally applicable or appropriate for all datasets. This transformation process also assumes that the data will converge to an average price over time, which may not hold true in markets with structural breaks or non-stationary behaviours.

Additionally, the methodology relies heavily on the validity of the Jaque-Bera test for normality and the Elliot, Rothenberg, and Stock (ERS) test for stationarity. These tests, while standard, may not fully capture the complexities or subtle deviations from the assumptions in real-world data. Another limitation arises from the use of the Generalized Forecast Error Variance Decomposition (GFEVD) and Generalized Impulse Response Function (GIRF). Although these tools provide a detailed picture of shock propagation and dynamic interrelationships, their effectiveness can be compromised in systems with high dimensionality or where the relationships between variables are not linear. Furthermore, the results from the GFEVD and GIRF can be sensitive to the model specification and the quality of the data. Hence, the findings should be interpreted with caution, particularly in cases where the underlying data may exhibit significant noise or outliers that were not fully addressed during the preprocessing stages. These limitations highlight the need for careful application and interpretation of the TVP-VAR model and its associated tools in the connectedness approach.

ECIII 2.2. Averaging Data Pricing

This involves calculating the mean (average) price of the data over a specified period. Helps to smooth out short-term fluctuations and highlight longer-term trends in the data.

Mathematical Representation (equation 1):

$$\bar{X} = \frac{1}{N}\sum_{i=1}^{N} X_i \qquad (1)$$

where $\bar{X}$ is the average price, N is the number of observations, and X_i represents the individual data points.

ECIII 2.3. Mean Reversion.

Mean reversion is a statistical property of a time series where values tend to return to the mean (average) level over time. In finance, mean reversion suggests that high prices will tend to decrease and low prices will tend to increase over time, converging to the average price.

For instance (equation 2):

For a time series $X_{t+1} = \mu + \theta(X_t - \mu) + \epsilon_t$ (2)

Where:

μ is the long-term level

θ is the speed of reversion to the mean ($0 < \theta < 1$).

ϵ_t is a random error term.

ECIII 2.4. Transformation into Natural Logarithm

This transformation aims to achieve data homeostasis (stability) and normalizing the data distribution.

If X_t represents the original time series, then the transformed series Y_t can be represented as equation 3.

$$Y_t = \ln(X_t) \tag{3}$$

where $\ln$ is the natural logarithm function.

ECIII 2.5. TVP-VAR

As before mentioned, TVP-VAR method of Antonakakis and Gabauer (2017) to examine how transmission changes over time was applied. This approach builds on the original connectedness method of Diebold and Yilmaz (2009, 2012b) by incorporating a Kalman Filter estimation with forgetting factors to account for varying variances. The TVP-VAR model can be represented by the following equations (4)(5).

$$Yt = \beta_t z_{t-1} + \epsilon_t \qquad \epsilon_t \mid F_{t-1} \sim N(0, S_t) \tag{4}$$

$$vec(\beta_t) = vec(\beta_{t-1}) + \nu_t \qquad \nu_t \mid F_{t-1} \sim N(0, R_t) \tag{5}$$

The vectors y_{t-1} and z_{t-1} = [y_{t-1}, ..., y_{t-p}]′ represent N × 1 and N_p×1 dimensional vectors, respectively. The time-varying coefficient matrix is represented by β_t, which is an N × Np dimensional matrix. The error disturbance vector is represented by ϵ_t, which has an N × 1 dimensional with an N × N time-varying variance-covariance matrix, S_t. $vec(\beta_t)$, $vec(\beta_{t-1})$ and ν_t are N^2p × 1 dimensional vectors and R_t is an N^2p × N^2p dimensional matrix. In order to calculate the generalized impulse response functions (GIRF) and generalized forecast error variance decomposition (GFEVD) (Koop, Pesaran and Potter, 1996; Pesaran and Shin, 1998) **,** the VAR was transformed into its vector moving average (VMA) representation (equation 6 & 7).

$$Yt = \sum_{j=0}^{\infty} L' W_t^j L \epsilon_{t-j} \tag{6}$$

$$Yt = \sum_{j=0}^{\infty} A_{jt}\epsilon_{t-j} \tag{7}$$

L and W are dimensional matrix (Equation 9 & 8)

$$W = \left[\beta_t; I_{N(p-1)}, 0_{N(p-1)\times N}\right] \quad (N_p \ \times N_p) \tag{8}$$

$$L = \left[I_{N,..,}0_p\right]' \quad (N_p \ \times N) \tag{9}$$

And A_{jt} is an $N \times N$ dimensional matrix

The GIRFs, or Generalized Impulse Response Functions, show how all variables react when there is a shock in variable j. Since there is no structural model available, the team compares a forecast for J steps ahead where variable j is shocked to one where it is not shocked. The difference between the two is attributed to the shock in variable j and can be determined through the equation provided (10).

$$GIRF_t\left(J, \delta_{j,t}, F_{t-1}\right) = E\left(\epsilon_{j,t} = \delta_{j,t}, F_{t-1}\right) - E(\ Y_{t+1} \mid F_{t-1}\ ) \tag{10}$$

$$\psi_{j,t}^{g}(J) = \frac{A_{J,t}S_t\epsilon_{j,t}}{\sqrt{S_{jj,t}}} + \frac{\delta_{j,t}}{\sqrt{S_{jj,t}}} \qquad \delta_{j,t} = \sqrt{S_{jj,t}} \tag{11}$$

$$\psi_{j,t}^{g}(J) = S_{jj,t}^{-\frac{1}{2}} A_{J,t}S_t\epsilon_{j,t} \tag{12}$$

The GIRFs for the variable j is represented by $\psi_{j,t}^{g}(J)$ where J represents the forecast horizon (equation 11 & 12). The selection vector represented by $\delta_{j,t}$ with zero or one on the jth position. And F_{t-1} set until t -1. Subsequently, GFEVD is calculated interpreted as the variance portion one variable has in others (equation 13).

$$\tilde{\phi}_{ij,t}^{g}(J) = \frac{\sum_{t=1}^{J-1}\psi_{ij,t}^{2,g}}{\sum_{j=1}^{N}\sum_{t=1}^{J-1}\psi_{ij,t}^{2,g}} \tag{13}$$

.

Assuming the following (equation 14 & 15):

$$\sum_{j=1}^{N} \tilde{\phi}_{ij,t}^{g}(J) = 1 \tag{14}$$

$$\sum_{i,j=1\,,i\neq j}^{N} \tilde{\phi}_{ij,t}^{g}(J) = N \tag{15}$$

Afterwards is possible construct the total connectedness index (TCI) following (equation 16):

$$C_t^g(J) = \frac{\sum_{i,j=1\,,i\neq j}^{N} \tilde{\phi}_{ij,t}^{g}(J)}{\sum_{i,j=1}^{N} \tilde{\phi}_{ij,t}^{g}(J)} * 100 \quad = \frac{\sum_{i,j=1\,,i\neq j}^{N} \tilde{\phi}_{ij,t}^{g}(J)}{N} * 100 \tag{16}$$

This connectedness method demonstrates how a shock in one variable affects other variables. We first consider the scenario where a shock in variable i is transmitted to all other variables j, known as total directional connectedness to others, as defined in the following equation (17).

$$C_{i\rightarrow j,t}^{g}(J) = \frac{\sum_{j=1\,,i\neq j}^{N} \tilde{\phi}_{ji,t}^{g}(J)}{\sum_{j=1}^{N} \tilde{\phi}_{ji,t}^{g}(J)} * 100 \tag{17}$$

Next, we determine the directional connectedness that variable i receives from variables j, referred to as total directional connectedness from others, which is defined as equation 18.

$$C_{i\leftarrow j,t}^{g}(J) = \frac{\sum_{j=1\,,i\neq j}^{N} \tilde{\phi}_{ij,t}^{g}(J)}{\sum_{i=1}^{N} \tilde{\phi}_{ij,t}^{g}(J)} * 100 \tag{18}$$

Finally, the net total directional connectedness was calculated by subtracting the total directional connectedness to others from the total directional connectedness from others (equation 19).

$$C_{i,t}^{g} = C_{i\rightarrow j,t}^{g}(J) - C_{i\leftarrow j,t}^{g}(J) \tag{19}$$

The net total connectedness sign shows if variable i is driving the network or being driven by the network. Where if $C_{i,t}^{g} > 0$, i is driving the network or if $C_{i,t}^{g} < 0$, i is being driven by the network. Finally, we analyse the net total directional connectedness by computing the net pairwise directional connectedness (NPDC) to examine the bidirectional relationships (equation 20).

$$NPDC_{ij}(J) = \frac{\tilde{\phi}^{g}_{ji,t}(J) - \tilde{\phi}^{g}_{ij,t}(J)}{N} * 100 \quad (20)$$

ECIII 2.6. Connectedness Decomposition

Since we are studying the spillovers between two countries, we are interested in how much of the spillovers is transmitted within the country and how much is transmitted from one country to another. The decomposition of k countries can be represented as follows (equation 21):

$$\phi(J) = \left[\tilde{\phi}^{g}\right]_{ij,t}(J) = [C_{11}\ C_{12}\ \cdots\ C_{1k}\ C_{21}\ C_{22}\ \cdots\ C_{2k}\ \vdots\ \vdots\ \ddots\ \vdots\ C_{k1}\ C_{k2}\ \cdots\ C_{kk}\ ] \quad (21)$$

C_{ii} encompassed the internal spillover of country i.

C_{ij} represents the spillover of country j to country i

Next, to determine the internal and external spillovers, it requires to set $diag(C_{ii}) = 0$ and determine:

$$TO_{ij} = \sum_{n=1}^{k} C_{ij,nm} \quad (22)$$

TO_{ij} stands for the total country-specific connectedness to others (equation 22).

$$FROM_{ij} = \sum_{m=1}^{k} C_{ji,nm} \quad (23)$$

$FROM_{ij}$ refers to the total country-specific connectedness from others (equation 23).

$$NET_{ij} = TO_{ij} - FROM_{ij} \quad (24)$$

NET_{ij} represents the net total country-specific connectedness. (equation 24)

$$NI_{ij} = \sum_{n=1}^{k}\sum_{m=1}^{k} C_{ij,nm} - \sum_{n=1}^{k}\sum_{m=1}^{k} C_{ji,nm} \quad (25)$$

NI_{ij} represents the net international total market-specific connectedness (equation 25).

This equation 22 is arrived at by recognizing that TO_{ij} is a summation over *nm* subscript where *i* is the first subscript, while $FROM_{ij}$ is a summation over the *nm* subscript where *i* is the second subscript. The difference between these two sums (i.e., $TO_{ij} - FROM_{ij}$ *T*) gives you NI_{ij}, which represents the net balance of connectedness for market *i* in relation to country *j*, considering all sectors.

ECIII 3. Results

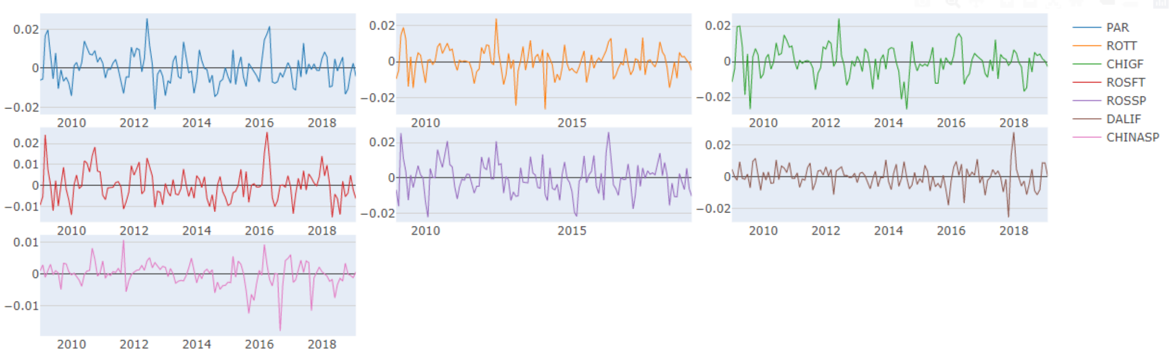
ECIII 3.1. Descriptive statistics and Diagnostic test.

In Chart 1, we can observe all the time series after they have been double-logged and mean-reverted. The descriptive statistics are presented in Table 1. As the data has been double logged, the mean and variance are zero, which improves the model's robustness and allows for modelling under the Gaussian assumption of zero mean and unit variance. The kurtosis levels for nearly all time series are relatively low (platykurtic), except for the China Spot market, which has a kurtosis of 4.2. This higher kurtosis makes it leptokurtic and exhibits a fat tail (distribution skewed towards the tail). The elevated kurtosis of the China Spot market can be partially attributed to structural market interventions. The Elliott, Rothenberg, and Stock (ERS) test indicated that all-time series are stationary following the aforementioned transformation.

ECIII Table 1. Descriptive Statistics.

	PAR	ROTT	CHIGF	ROSFT	ROSSP	DALIF	CHINASP
Mean	0	0	0	0	0	0	0
Variance	0	0	0	0	0	0	0
Skewness	0.442**	-0.186	-0.308	0.644***	0.226	-0.032	-1.020***
	-0.043	-0.379	-0.151	-0.005	-0.287	-0.877	0
Kurtosis	0.368	1.394**	0.948*	0.870*	0.239	2.466***	4.195***
	-0.287	-0.014	-0.051	-0.065	-0.413	-0.001	0
JB	4.663*	10.583***	6.492**	12.266***	1.33	30.935***	110.627***
	-0.097	-0.005	-0.039	-0.002	-0.514	0	0
ERS	-3.509***	-2.639***	-2.726***	-2.443**	-3.624***	-3.582***	-4.910***
	-0.001	-0.009	-0.007	-0.016	0	-0.001	0
Q (10)	20.879***	8.582	16.805***	19.673***	14.735***	7.959	17.445***
	0	-0.132	-0.002	0	-0.006	-0.173	-0.001
Q2(10)	7.444	2.354	10.147*	5.289	7.923	15.334***	2.759
	-0.213	-0.902	-0.065	-0.463	-0.175	-0.005	-0.853

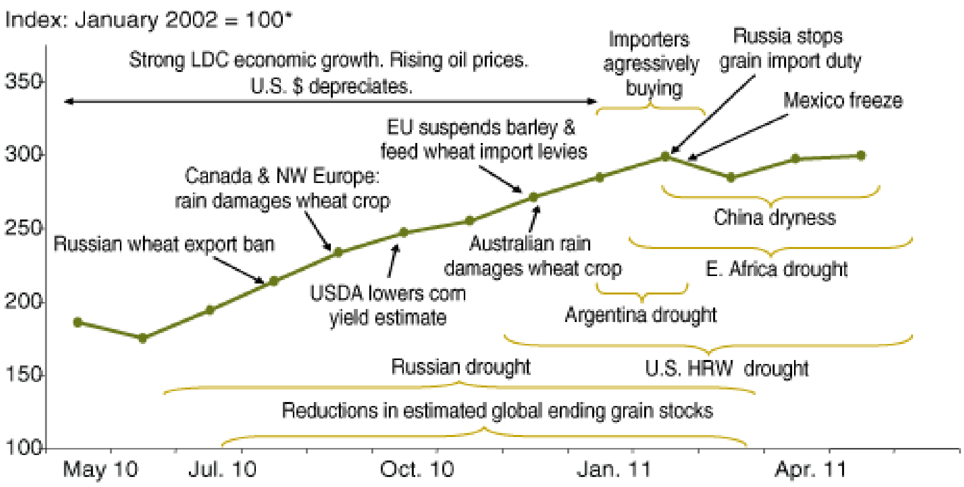
ECIII Chart 1. Data as a time series.



ECIII 3.2. Average and Dynamic Total Connectedness Measures

In Chart 2, the Total Connectedness Index (TCI) or the Total Spillover Index (TSI) can be observed over the years. Between mid-2010 and mid-2011, there was a noticeable increase from 65 to 90, indicating a crisis or disturbance in the market during that period. This can be attributed to large and rapid price increases followed by larger swings in prices that occurred during 2010 and 2011, which were caused by various exogenous factors (Trostle *et al.*, 2011). Some factors directly affected soybean supply. In November 2010, the "La Niña" meteorological phenomenon of high temperatures combined with a lack of rain generated a significant drought across Argentina, considerably reducing soybean prospects. Increased demand for meat, beef, and pork caused the price of feed, including soybean, to rise. Additionally, importers began adopting aggressive strategies to ensure supply by contracting grain quantities for the following 4-6 months (Trostle *et al.*, 2011). Many factors added uncertainty and affected other agricultural commodities. Due to the cross-commodity price transmission or volatility spillovers among different energy commodities (such as oil prices to agricultural prices), these changes might have influenced soybean prices. The strong economic growth experienced by less developed countries and the depreciation of the US dollar put inflationary pressure on food and grain prices. Alongside many other factors, this created uncertainty in market price swings and spillover effects across different agricultural commodities (Chart 3).

ECIII Chart 2. Crop index over the time

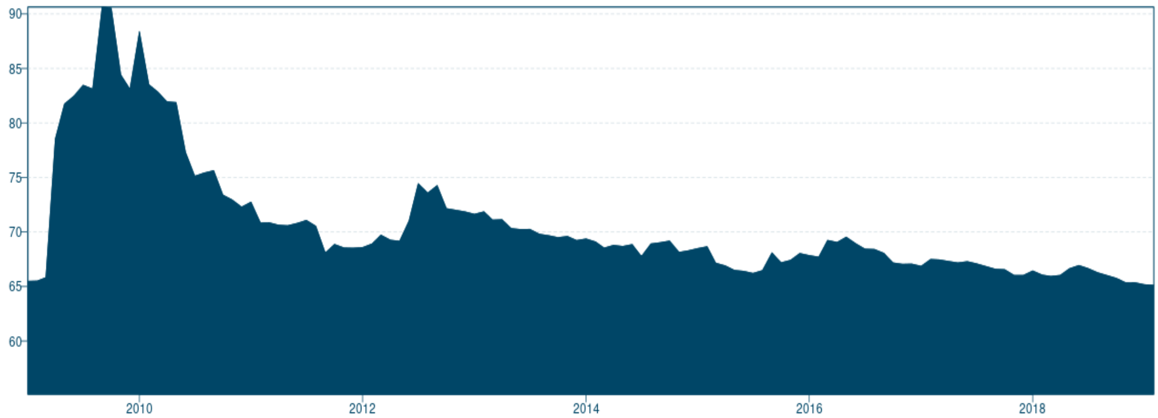


Notes: LDC=Least developed country. HRW=Hard red winter wheat. * = Four-crop price index: Monthly wheat, rice, corn, and soybean prices, weighted by global trade shares.
Source: USDA, Economic Research Service using International Monetary Fund, International Financial Statistics.

Source: (Trostle *et al.*, 2011)

By 2012, the incidence of the disturbance has disappeared, however, around March to May there was another turbulence in the market, peaking the index to 75. After 2014, the index stabilized around 67 until the last period recorded, this clearly indicates a mature and steady market capable of overcoming market shocks or distortions. This follows the case of the US/China Trade war, as mentioned by Barboza Martignone, Behrendt and Paparas (2022), where the authors suggested that the international market of soybeans was capable of arbitrage around tariffs and circumvent them , rearranging the trade flows in order to get around the trading barriers.

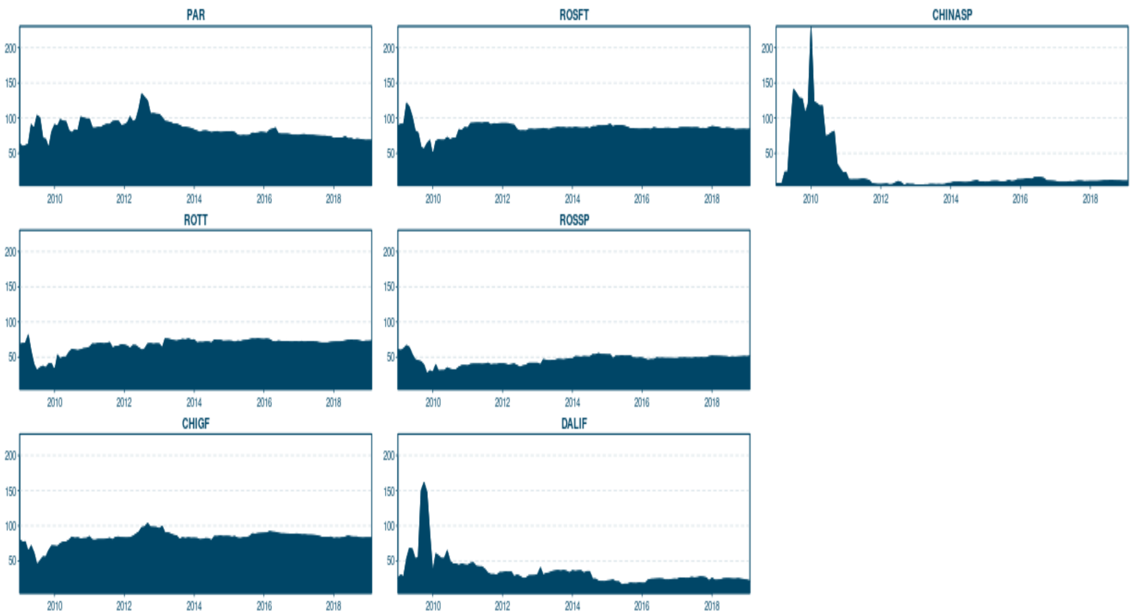
ECIII Chart 3. Total Connectedness Index over the years.



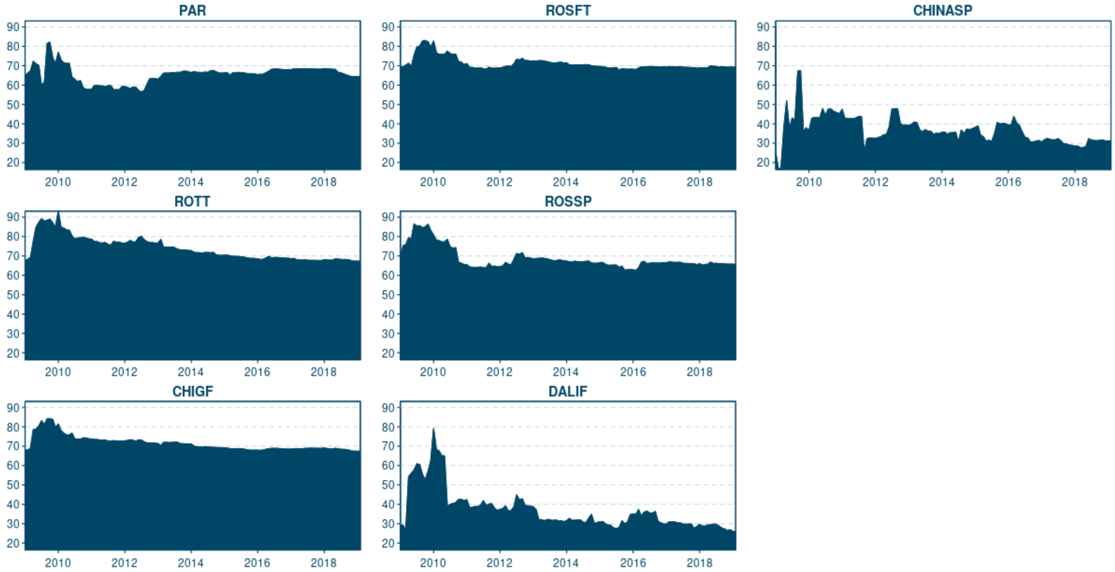
Moreover, this finding suggests a degree of market insulation from exogenous shocks, as the TCI index remains steady over time, at least since 2014. In other words, while agricultural commodity markets tend to be quite volatile, soybean prices exhibit less random fluctuation and appear relatively stagnant. This could mean that supply and demand are stable, or that the market is highly developed and capable of absorbing shocks. Both supply and demand have been growing steadily, driven by China's increasing soybean consumption and the consistent expansion of soybean farming areas in Brazil (Carneiro Filho and Costa, 2016) and Argentina (Phélinas and Choumert, 2017) which in turn boosts supply. As a result, it is plausible to propose that the market's level of development, efficiency, and integration are the primary factors explaining why the TCI index remains steady and relatively constant over time. The TCI hovers around 65%, indicating a moderate spillover risk for almost a decade. In Chart 4, the transmitted shocks or spillover effects from the studied markets to other markets can be observed. Paranaguá, Rosario Futures, Chicago, and Rotterdam are the markets that transmit shocks most significantly (after mid-2012), as indicated by their higher connected net index. The spillover for these markets remains relatively stagnant over time. China, from 2009 to 2011, exhibited a high connectedness index, transmitting shocks to others. However, after 2011, this ceased, and the connectedness index sharply decreased and remained low, almost marginal, and steady for the last period, suggesting a market insulation process caused by government interventions. Dalian Futures exhibited similar behaviour, with the TCI peaking in mid-2009 and sharply decreasing until 2010. Since then, the connectedness index to others has remained low and relatively steady (excluding a series of minor shocks), without significant spillover or influence on other markets.

Chart 5 also displays the shocks or spillover received from other markets. Rotterdam, Rosario Spot, and China Spot are net receivers, meaning they tend to be more affected by other market shocks than influencing other markets. Overall, all markets tend to be highly influenced by external markets, which is normal, following the Law of One Price (LOOP) and market arbitrage processes. As previously mentioned, the China Spot market has a very low or marginal impact on other markets (Chart 2); however, the connectedness index from other markets tends to be significantly higher than the connectedness index to other markets. This indicates that the China domestic Spot market has limited importance on an international scale, exerting marginal influence on other markets, yet being influenced by international markets. It is important to understand that the Chinese government has protected its domestic market from the international market to ensure national food security. However, this market plays a minor role in meeting domestic demand. The domestic supply produces only 16 million tonnes, while 102 million tonnes of soybean are provided by the international market (Wang and Siqi, 2022).

ECIII Chart 4. TO Others.



ECIII Chart 5. FROM Others.



In Table 2, it is possible to observe a bidirectional influence of different markets. The connectedness of the system is divided into two forms. First, the last column named "FROM" shows the total aggregate amount of shocks that all the considered markets are receiving from the entire system. The estimation of this column's value is the result of adding all the horizontal numbers, apart from the on-diagonal numbers. Second, the last row "TO" expresses the transmission of shocks for each soybean market to the entire system. The value of this row is calculated by summing all the vertical numbers, excluding the on-diagonal numbers.

The Paranaguá spot market appears to have two thresholds of influence. The first threshold shows a strong influence on Chicago futures (19.3%), Rotterdam (18.93%), Rosario Futures (16.18%), and is associated with a higher degree of market freedom, market integration, increased connectedness, and volatility spillover. This low-influence threshold follows a positive correlation with Liberalisation or a negative correlation with market intervention and market insulation.

The second threshold is a low-influence zone, where the Paranaguá market only influences Rosario Spot by around 11.83%, China Spot by about 9.19%, and Dalian Futures by 8.33%. This low-influence threshold is associated with a high degree of market intervention, market insulation, and lower overall connectedness. Despite the average connectedness, the table shows bidirectional causality. Barboza Martignone, Behrendt and Paparas (2022) empirically demonstrated, using the Granger causality test, that there is no influence of the Paranaguá Spot on Chicago and Rotterdam, in contrast with the results of the Connectedness table (Table 2). It is possible to agree with the authors that the influence of the Paranaguá spot on the rest of the studied markets was noticeable in both investigations. The total spillover from the Paranaguá market transmitted to ("TO") other markets is 83.75%, making it the second-highest market to transmit shocks, and including itself, it is the highest transmitter. The Paranaguá market is influenced mostly by itself (34.49%), followed by Chicago (19.11%), Rosario Futures (16.68%), Rotterdam (13.56%), and marginally influenced by Rosario Spot, Dalian Futures, and China Spot (7.6%, 4.48%, and 3.99% respectively). The influence of Rotterdam tends to be less than expected, and the influence of Rosario Futures is higher than Rotterdam on Paranaguá, which contrasts with (Margarido, Araujo Turolla and Ferreira Bueno, 2014) ,who proposed that Paranaguá and Rosario Futures were satellite markets of Rotterdam. Finally, we can affirm that Paranaguá is a net transmitter, transmitting shocks at 83.75% "TO" and receiving shocks "FROM" at 65.51%, giving Paranaguá a net transmission of spillovers of 18.24%.

ECIII Table 2. Average Dynamic Connectedness Table.

	PAR	ROTT	CHIGF	ROSFT	ROSSP	DALIF	CHINASP	FROM
PAR	34.49	13.56	19.11	16.68	7.68	4.48	3.99	65.51
ROTT	18.93	26.26	20.03	15.76	9.9	6.87	2.25	73.74
CHIGF	19.3	18.51	28.62	17.54	7.93	6	2.09	71.38
ROSFT	16.18	12.95	15.69	28.97	16.97	6.46	2.77	71.03
ROSSP	11.83	12.99	9.89	25.04	31.48	3.98	4.79	68.52
DALIF	8.33	4.96	7.55	5.52	2.09	63.29	8.25	36.71
CHINASP	9.19	4.39	10.59	4.41	1.15	6.98	63.28	36.72
TO	83.75	67.37	82.88	84.95	45.72	34.78	24.14	423.6
Inc.Own	118.25	93.63	111.5	113.92	77.21	98.08	87.42	TCI=67%

In Table 2, it appears that the Rotterdam market has a low influence on the Brazilian market of Paranaguá (13.56%). This finding contrasts with previous studies, such as Margarido, Turolla and Bueno (2007) and Barboza Martignone, Behrendt and Paparas (2022) which have empirically demonstrated a strong influence of Rotterdam on the Paranaguá spot, suggesting that price formation relies on the demand side (Rotterdam) rather than the supply (Brazilian). However, Margarido *et al.* (2004) research was based on a much earlier period, during which market conditions might have been different. Furthermore, Barboza Martignone, Behrendt and Paparas (2022) used a different methodology, which might explain the divergence in results.

However, Table 2 shows a high influence of Rotterdam on Chicago (18.5%), which contradicts the findings of previous studies Barboza Martignone, Behrendt and Paparas (2022) that have demonstrated a lack of bidirectional-causality between Rotterdam and Chicago Futures. The previously mentioned author results may seem counterintuitive, as they suggest a lack of causality between two of the most important markets in the international soybean market, which goes against the Law of One Price (LOOP). The influence of Chicago on Rotterdam is slightly higher (20%) than vice versa (18.5%). This can be easily explained by the fact that Chicago is a price leader and the largest market in the world (Margarido, Turolla and Bueno, 2007) However, the influence of Rotterdam on Chicago is still high and significant. This can be explained by Chicago being a futures market and taking into account market futures expectations, harvest futures, stocks, and future demand (e.g., consumption in developing countries and EU union futures demand), US monetary policy, financial speculation, and energy commodities, etc. (Gavilanez Hernandez, 2012) .

For other markets, the influence of Rotterdam is relatively low and limited (Paranaguá Spot 13.56%, Rosario Spot 12.99%, Rosario Futures 12.95%, Dalian Futures 4.96%, and China Spot 4.39%). This follows a pattern where the influence decreases with the degree of market intervention or increases with market freedom, which is consistent with economic theory and market integration. The received spillovers "FROM" other markets (73%) are higher than the spillover transmitted "TO" others (67.37%), making Rotterdam market a net receiver (5.63%). This means that Rotterdam is no longer a price leader and has lost its prominence in the international soybean market. This result goes against previous empirical research from Margarido, Turolla and Bueno (2007) and Barboza Martignone, Behrendt and Paparas (2022) that highlighted the importance of Rotterdam as a price maker.

The Chicago market has a high influence on the Paranaguá spot market (19.11%), and as previously mentioned, Paranaguá also has a similar influence on the Chicago market (19.3%). This demonstrates that the causality between both Chicago and Paranaguá is bidirectional and suggests that Paranaguá is moving toward price leadership. The Chicago market also has a high influence on Rotterdam (20%) due to its leadership status, which is an intuitive finding. The influence of Chicago significantly decreases for the Argentinian (Rosario futures 15.69% and Rosario Spot 9.89%) and Chinese markets (Dalian Futures 7.55% and China Spot 10.59%), following the previously mentioned pattern and likely associated with government intervention and market freedom.

The observation to consider is that Chicago seems to exert more influence on the China Spot market, known for structural intervention, as opposed to the Dalian futures market, which enjoys a higher degree of market freedom. The explanation relies on the fact that the Chinese government uses Chicago prices as a reference for fixing the domestic market (Jamet and Chaumet, 2016), while the Dalian market relies more on the market price discovery process and futures expectations, being less influenced by Chicago. Han, Liang and Tang (2013), using IRF and FEVD, stated that the information transferred from Chicago to Dalian was very similar in magnitude (CBOT attributed to DCE 0.1% to 5% and DCE attributed to CBOT 5% to 25%). This follows the results of this research, where the net transmitted from Chicago to Dalian was 7.5% and from Dalian to Chicago was around 6%. However Han *et al*. (2013) stated that the facts reveal the key role of Dalian in global soybean price discovery. However, the evidence supports that the influence of Dalian, despite being bidirectional and of the same magnitude, is quite low in comparison to other markets that tend to influence Chicago. For instance, Paranaguá (19.3%), Rosario futures (17.5%), and Rotterdam (18.51%) spillover is approximately three times higher than Dalian. In contrast to previous research, Chicago futures transmit slightly fewer shocks (15.69%) than shocks received from Rosario Futures (17.54%), indicating bidirectional causality in favour of Rosario Futures. These findings contradict previous empirical evidence suggesting a change in leadership. Finally, Chicago positions itself as a net transmitter of shocks, with a total spillover "TO" of 82.88% against received shocks "FROM" 71.38%, with a net transmission of 11.5%.

Rosario futures have the highest connectedness and influence on Rosario spot at 25.04%, confirming previous research from Barboza Martignone, Behrendt and Paparas (2022), which showed that Rosario futures can be associated with approximately half (47%) of Rosario spot price decreases and cause Rosario spot. The influence fades to 16.97% in the other direction. Rosario futures also show a higher degree of influence on Rotterdam than the other way around, which goes against what previous researchers have suggested. Margarido and Sousa (1997) had suggested that price formation relies on the demand side (Rotterdam) and expected this market to hold a higher level of influence. As previously mentioned, the influence of Rosario futures in Chicago is higher than vice versa (17.5% vs. 15.7%). This positions Rosario in a position of price leadership. However, Rosario Futures has marginal influence on Dalian futures (5.5%) and China spot (4.4%). Rosario Future is mostly influenced by itself (28.97%) followed by Rosario Spot (16.97%), and at the same time, it transmits shocks or spillover to Rosario Spot at a higher degree (25%). Rosario Futures and Spot have a complementary relationship, as previously explained by Barboza Martignone, Behrendt and Paparas (2022). Finally, Rosario Futures can be considered a net transmitter of shocks, transmitting 84.95% (TO) and receiving 71.03% (FROM), leaving a positive spillover of 14%. The question that arises is why Rosario Futures shows a high degree of influence on other markets while the Argentina Spot market is highly suffocated by government intervention.

The influence of Rosario Spot is considerably low for almost all-time series (9.9% for Rotterdam, 7.9% for Chicago futures, 7.68% for Paranaguá, 2% for Dalian Futures, and 1.2% for China Spot). However, the influence of Rosario Spot on Rosario Futures is considerably high at 16%, as expected from complementary markets. Rosario Spot is highly influenced by itself (31.48%) and as previously mentioned, influenced by Rosario Futures (25%), followed by Rotterdam (12.99%), Paranaguá (11.8%), Chicago (9.9%), China Spot (4.8%), and Dalian Futures (3.98%). Rosario Spot receives "FROM" the studied markets 68.52% and transmits "TO" other markets 45.72%. Therefore, it is possible to affirm that Rosario Spot is a net receiver (22.8%). This raises the question of why the influence of Rosario Spot is so low in comparison with Rosario Futures. The first thing to understand is that Rosario Spot is a market where Argentine farmers sell their production, and this market has a degree of market intervention. There is an export tariff called "retentions" of around 33% to 35%, which may prevent domestic and international price convergence, partially dislocating the price and insulating the market (Listorti and Esposti, 2012b). This might explain the low connectedness, relatively low "FROM" and "TO" other market influence found in this market. Moreover, currency control and restrictions might further disconnect the market from international markets.

Dalian Futures market tends to be marginally affected by international markets and seems to be affected primarily by itself (63%), and marginally affected by Paranaguá (8.33%), China (8.6%), Chicago (7.6%), and Rosario Futures (5.5%). This means that there is no clear evidence of a complementary relationship between the Chinese futures market and the spot market. This can happen due to a high degree of market intervention that disconnects both markets, as is the case with China Spot intervention (Jamet and Chaumet, 2016). Therefore, this might explain the marginal influence of Dalian Futures on China (6.98%), but still, the influence of China's domestic market on Dalian is low; however, in comparison to other markets, it is quite high in relative terms. China Spot is the second most important market that influences Dalian. However, it is challenging to explain the lack of influence of Dalian Futures on the international soybean market, as it is the second-largest market globally in terms of value (Wang and Houston, 2015). The influence is marginal, and Dalian is classified as a net receiver -1.93% (TO 34.78%, FROM 36.71%).

Finally, China seems to mainly influence itself (63.29%), presenting marginal influence on other markets, and only having relative influence on Dalian Futures (8.25%). In relative terms, it is modestly influenced by other markets, being affected by Chicago Futures (10.59%), Paranaguá (9.19%), Dalian Futures (6.98%), and Rosario Futures (4.41%). This lack of connectedness can be explained by the degree of market intervention presented in this market. Barboza Martignone, Behrendt and Paparas (2022) already pointed out the difficulty in finding cointegration within the market with international markets and the lack of significant regressors in the VECM, finding only a significant long-term regressor in Chicago Futures. This suggests that Chinese policymakers use Chicago prices as references to fix prices (Jamet and Chaumet, 2016). Potentially, Chinese policymakers are using Paranaguá prices as references as well. Finally, China's spot market behaves as net receivers -12.6% (TO 24%, FROM 36.7%)

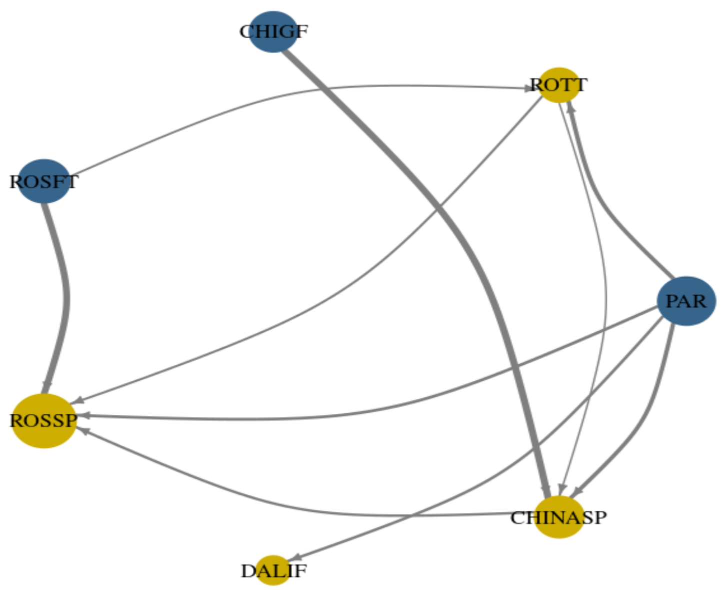
Chart 6 is a network plot that shows the net transmitters in blue and net receivers in yellow. The size of the circles represents the relative importance of the transmitter and receiver markets. This chart illustrates the dynamics of the international market, and even indirectly, causality. Previous researchers have demonstrated the price leadership of Chicago and Rotterdam. In contrast, the results show the ascension of Paranaguá and Rosario futures market as a price leader, affecting all transmitter markets to all receiver markets in conjunction with Chicago. The results clearly show that Chicago futures have lost international price leadership, in favour of a triumvirate with Rotterdam and Paranaguá, which goes against the results of previous empirical research from Barboza Martignone, Behrendt and Paparas, 2022).

The results suggest a gradual fading of price leadership or a shift in price leadership for the researched period. This decline in Chicago's leadership is an interesting interpretation. This decay seems to be paired with the ascension of Paranaguá and Rosario Futures, as previously mentioned. The decline interpretation can be seen as a strong statement, as different authors have arrived at different results using different methodologies. This raises questions about the suitability and robustness of these different methodologies. Chicago remains a net transmitter, but its influence is limited to China. The China spot market uses Chicago prices as a reference price for fixing their prices (Jamet and Chaumet, 2016). Therefore, as long as Chinese policymakers believe that Chicago represents the international price and use this price as a reference, Chicago's influence will remain. The results showed that the Rotterdam market should be classified as a net receiver, being affected by Paranaguá and Rosario futures. This finding contrasts with Margarido *et al.* (1999) who found that in terms of price transmission, causality works the other way around (from Rotterdam to Paranaguá and Rosario futures). Despite being classified as a net receiver, Rotterdam also transmits shocks to Rosario spot and China spot, which is consistent with previous research results by Barboza Martignone, Behrendt and Paparas (2022).

Rosario futures appear as a net transmitter. As previously mentioned, this market transmits to Rotterdam and Rosario spot. The relationship of futures affecting the spot market (from Rosario futures to Rosario spot) can be explained by futures expectations affecting actual prices, such as next harvesting yield expectations, expected demand increases or decreases, global recession, or global growth. All this information is compressed in the futures price and affects the spot market (Wang and Siqi, 2022) The Rosario spot market shows itself as a net receiver, affected by China spot, Paranaguá, Rotterdam, and as previously mentioned. The China spot market shows itself as a net receiver, being affected by Chicago, Rotterdam, and Paranaguá, with the most significant impact coming from Chicago.

This result aligns with Barboza Martignone, Paparas and Behrendt (2023) who demonstrated the Granger causality from Chicago, Rotterdam, and Paranaguá to China and developed a global VECM (using the same markets) that revealed the only statistically significant regressor remaining in the long-term equation was from Chicago, signifying its importance for the China spot market. Finally, Dalian futures appears as a highly insulated market, being affected only by Paranaguá. In contrast, Fung, Leung and Xu (2003) found that Dalian was a satellite market subordinate to Chicago. This research suggests that Dalian might be a subordinate market under the influence of Paranaguá. However, it is worth noting that Fung, Leung and Xu (2003) was conducted prior to the rise of Brazil and Argentina in the international market.

ECIII Chart 6. Network Plot.



In Chart 7, we can observe the pairwise connectedness. A higher level of cointegration and market efficiency is reflected in stable pairs, as prices move together, and shocks are uniformly transmitted. The highest connectedness and most stable pair are Rosario Futures and Rosario Spot, demonstrating clear cointegration and potentially efficient price transmission. This finding is expected since both markets are complementary. Paranaguá and Chicago also form a pair, excluding the period from 2009 to mid-2010, which distorts the results. This outcome is anticipated due to the strong cointegration among these markets and the efficiency represented by fast and symmetrical price transmission (Error correction term: 30% per month) (Barboza Martignone, Behrendt and Paparas, 2022; 2023) . Excluding the period with diverse exogenous shocks causing large price swings (Trostle *et al.*, 2011) (2009-mid 2010), pairwise connectedness tends to be relatively stable, at least for highly cointegrated markets (Rotterdam-Chicago, Chicago-Rosario Futures, Rosario Futures-Rosario Spot, Rosario Futures).

For the Chinese spot market, the pairwise connectedness tends to be variable and highly unstable, even for the pair China Spot-Dalian Futures. Dalian Futures has a higher connectedness index compared to China Spot, but not as high as the western markets. From mid-2009 to 2011, the dynamic pairwise connectedness for the Chinese domestic market peaks with almost all markets. This period suggests that the China spot market might have been affected by a combination of exogenous supply shocks that the world experienced during that time, or that Chinese droughts may have pushed prices up, affecting domestic demand and increasing soybean imports. Dalian's dynamic pairwise connectedness appears to fade over time with highly cointegrated markets such as Chicago, Rosario Futures, Paranaguá, and Rotterdam, indicating further future market isolation. As mentioned earlier, connectedness is an analogous concept to cointegration in a dynamic sense, and it seems that market cointegration is one of the main components affecting the pairwise connectedness index. The pairwise connectedness of Paranaguá-Rotterdam tends to be unstable and decrease over time. To a lesser extent, the same occurs with Rotterdam-Rosario Futures and Rotterdam-Rosario Spot. This can be interpreted as the stagnant demand for soybeans from the EU compared to other markets, causing Rotterdam to lose pairwise connectedness with the main markets, Paranaguá and Chicago. In other words, Rotterdam's leadership and importance in terms of prices and demand are diminishing.

ECIII Chart 7. Dynamic pairwise connectedness.

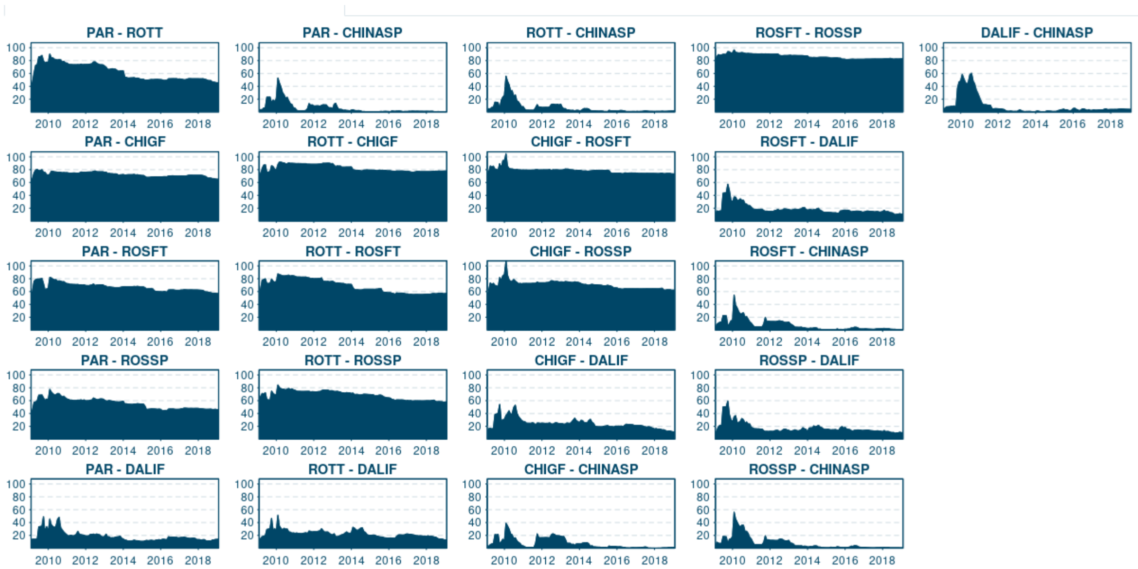


Chart 8 displays the net pairwise directional connectedness, allowing us to appreciate the spillover direction in pairwise markets. Trostle *et al.* (2011) correlated several events that may have caused price shocks from the beginning of 2010 to mid-2011 and illustrated how these events might have pushed up prices and generated long swings in the market (Chart 2). Interestingly, the diverse nature of these events made it difficult to pinpoint the exact nature of the shocks and the weighted causality. No empirical work has proven causation for the different events related to market instability. However, using pairwise connectedness, it is possible to understand the origin of the shocks. A common pattern in the different pairwise combinations consistently show the Asian markets as responsible for the spillover to other markets during the previously mentioned instability period. After that period, the Chinese market shifted from being net transmitters of shocks to being net receivers. The influence of the Chinese market on the international market could be attributed to a combination of Chinese importers aggressively purchasing soybeans to secure a six-month supply and imminent dryness in China, which could depress soybean production or generate future expectations of a shortage, or directly shift the supply curve to the left. This occurred in both futures and spot markets. It is possible to observe that during the disturbed period, the pairwise connected spillover between Dalian and China shifted a couple of times, but on average, the China spot market had the most significant influence. In addition, excluding the Asian market, it seems that for the disturbed period, Paranaguá reacted faster than other western markets, likely adjusting the price first and influencing Rotterdam.

Chicago Futures also responded faster, alternating between receiving and transmitting shocks with Paranaguá.

The net pairwise directional connectedness could be useful in understanding causality from one market to another over time. Incorporating additional analyses, such as Granger causality tests, could enhance our comprehension of the underlying dynamics. If we analyse the net pairwise directional connectedness for each case, excluding the previously mentioned disturbed period, we can draw the following conclusions:

The Paranaguá-Rotterdam pair shows a fading influence of Rotterdam over time, where previous work by Barboza Martignone, Behrendt and Paparas (2022) shows that Rotterdam Granger-causes Paranaguá. The Paranaguá-China Spot pair clearly positions Paranaguá as a net transmitter, influencing China Spot. The Rosario Futures-Rosario Spot pair demonstrates the consistent influence of Rosario Futures over Rosario Spot over time, in line with the Granger causality results from previously mentioned authors. Similarly, in line with the previously mentioned research, Dalian Futures have had a more significant influence on China over time.

The Paranaguá-Chicago Futures pair shows that over time, Chicago has had more influence on Paranaguá; however, that influence seems to be decreasing over time. Again, this is in line with the previous researchers' Granger causality tests. The Rotterdam-Chicago pair, according to the previous researchers, had no causality between them. The pairwise directional connectedness showed an abrupt change in causality at some point in mid-2013; from then on, the influence of Chicago over Rotterdam has been slowly and consistently growing over time. This suggests that by the end of the studied period, Chicago probably Granger-caused Paranaguá.

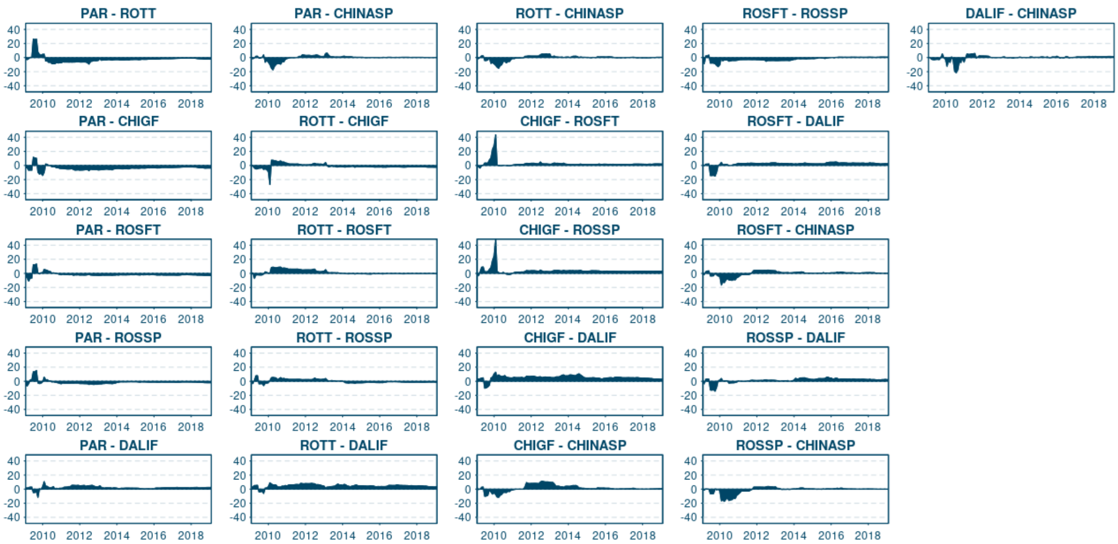
Regarding the Chicago Futures-Rosario Futures pair, the previous researchers stated that there was causality between both markets. The pairwise net connectedness shows that Chicago slightly influences Rosario Futures; however, it is not clear if that influence is decreasing over time. In the case of Rosario Futures and Dalian Futures, the empirical evidence from (Barboza Martignone, Behrendt and Paparas (2022) supports that there is no causal relationship between both markets. In contrast, the directional pairwise connectedness suggests Rosario Futures clearly influence Dalian Futures, transmitting shocks to the Asian market. This also occurs with Paranaguá and Rosario, where the previous researchers empirically demonstrated no causation between both markets; the pairwise directional connectedness shows that Rosario Futures might influence Paranaguá. The explanation for this relies on the nature of both markets: while futures markets depend on future expectations, future demand, yields from upcoming harvests, exogenous events, and pure speculation, spot markets rely on actual demand and supply, and future prices can prompt suppliers to adapt by increasing or decreasing production according to price expectations. Therefore, it is understandable that Rosario Futures and Chicago Futures affect Paranaguá. However, the opposite happens with Paranaguá and Dalian, and these results are in line with the previously mentioned researchers.

The Rotterdam-Rosario Futures net pairwise directional connectedness shows that, for the first part of the period, Rotterdam had a more significant influence on Rosario Futures. At some point in 2013, this influence ended, and there was a neutral balance between both markets, indicating no causality between them. This finding is in line with the previous researchers' conclusions.

The Chicago Futures-Rosario Spot net pairwise directional connectedness clearly demonstrates causality from Chicago Futures to Rosario Spot, which is consistent with the previous researchers' findings. Rosario Futures show a clear influence on China Spot after the turbulent period, again in line with Barboza Martignone, Behrendt and Paparas (2022). The Rosario Spot-Paranaguá pair showed that Rosario Spot caused Paranaguá until 2014. The reason behind this could be a left shift in Argentina's market supply in 2014, followed by changes in the export tariff regimen, which might have transmitted shocks to Paranaguá. The stability of Paranaguá does not make it a source of spillovers. After 2014, the balance between the pairs remains neutral, and no causality occurs between them. The previous researchers stated that Granger causality goes from Paranaguá to Rosario Futures.

The Rotterdam-Rosario Spot pair shows an effect going from Rotterdam to Rosario Spot. From 2014, there is a shift in causality from Rosario Spot to Rotterdam. However, the effect tends to be rather marginal, between 1 to 20%. The previous researchers empirically demonstrated that causality goes from Rotterdam to Rosario. The Chicago Futures-Dalian Futures net pairwise directional connectedness clearly shows a significant influence of Chicago on Dalian, which contradicts and aligns with Barboza Martignone, Behrendt and Paparas (2022). The pairs with Dalian or Rosario Spot - Paranaguá or Rotterdam all exhibit the same result as Chicago-Dalian: a clear effect from those markets on Dalian Futures, consistent with findings from the previously mentioned researchers. Chicago Futures-China Spot initially shows a significant effect going from Chicago to China that decreases over time and tends to be neutral in 2016. This can be explained by active market intervention to reduce international spillover into the domestic market. To a lesser degree, the same pattern can be observed in the Rosario Spot-China Spot pair. According to Barboza Martignone, Behrendt and Paparas (2022), causality goes from Chicago and Rosario Spot to China Spot. Granger Causality results for the same series and period can be appreciated in table 3.

ECIII Chart 8. Net pairwise directional connectedness.



ECIII Table 3. Granger Causality test Barboza Martignone, Behrendt and Paparas (2022).

Granger Causality Test with One Lag

	LNCHIGF	LNCHINASP	LNDALIF	LNPARANAGUA	LNROSFT	LNROSSP	LNROTTERDAM
LNCHIGF	X	↑	↑	↑	∂	↑	∂
LNCHINASP	←	X	←	←	←	←	←
LNDALIF	←	↑	X	←	∂	←	←
LNPARANAGUA	←	↑	↑	X	∂	↑	←
LNROSFT	∂	↑	∂	∂	X	↑	∂
LNROSSP	←	↑	↑	←	∂	X	←
LNROTTERDAM	∂	↑	↑	↑	∂	↑	X

The direction of the arrows (←, ↑) represents the direction of the causality. ∂ represents no causality affectation.

Source: Barboza Martignone, Behrendt and Paparas (2022)

ECIII 4. Discussion and Policy implications.

Empirical evidence suggests that the degree of market freedom plays a fundamental role in the efficient transmission of market signals and faster reactions to international demand. The expansion of soybean production in Brazil (Carneiro Filho and Costa, 2016) and Argentina (Phélinas and Choumert, 2017) serves as a perfect example. While the Argentinian government imposed several restrictions, including export tariffs and fixed exports, the Brazilian government did not interfere with soybean expansion in the country. As a result, Argentina struggled to sustain soybean expansion and missed out on the economic growth it could have generated. Moreover, this intervention led to a significant exodus of farmers and capital to neighbouring countries such as Paraguay and Uruguay (Vassallo, 2011), where the conditions for farming and exporting production were more favourable. In contrast, Brazil capitalized on the economic benefits of soybean expansion, strengthened its domestic market, and competed with the United States in soybean exports. The prolonged market freedom and economic stability in Brazil allowed for the development of the domestic market and the expansion of soybean crops across the fertile soils of the Brazilian states of Mato Grosso, Paraná, and Rio Grande do Sul, achieving 36.95 million hectares in the 2019/2020 season (CONAB, 2020). In the same season, Argentina's soybean area was estimated at 14.92 million hectares (INASE, 2022). This development eventually paved the way for Brazil to become the price leader and a worldwide reference in terms of soybean production.

Many empirical research studies have shown that the US has continued to hold price leadership in this market (Margarido, Turolla and Bueno, 2007; Barboza Martignone, Behrendt and Paparas, 2022) but this research diverges. However, the empirical evidence still indicates that the importance of the US remains crucial. The US has experienced a high degree of market freedom and a well-developed market for a long time, with the Chicago Board of Trade being one of the oldest futures markets in the world, inaugurated in 1848 and first started operating with soybean contracts in 1984. The question that arises is why the US leadership is declining and being overtaken by Brazil. While it may be too early to suggest that this is happening, there are three main factors that might have affected the price leadership. Firstly, the US-China trade war has actively redirected trade flows, making Brazil the primary supplier to China for a period. Secondly, soybean production in Brazil continues to grow, surpassing the US in 2019 and projected to produce almost 24% more than the US by 2023 (Statista, 2022).

Finally, the Chinese government's intervention in the domestic market with various price support policies has isolated the market from international market fluctuations. Previous research has faced difficulties in detecting cointegration or has only succeeded after correcting for structural breaks and employing different methodologies, as noted in studies by Barboza Martignone, Paparas, and Behrendt (2022, 2023). These results suggest that government intervention may be contributing to the diminishing strength of the cointegration vector. This is in line with previous research, despite differing methodologies, as the Chinese domestic market exhibited the lowest TCI of the time series for both the total connected index and dynamic pairwise connectedness. However, before 2012, both indicators showed noticeably higher spill-over, suggesting a period of less government intervention and higher market integration. After that, the TCI index decreased marginally, indicating a more isolated market.

Barboza Martignone, Behrendt and Paparas (2022) found that the most significant market for China's domestic market was Chicago Futures, which aligns with this research, showing that China's domestic market is affected by the main markets of Chicago, Rotterdam, and Paranaguá, but Chicago has the most significant impact on the Chinese domestic market. The previously mentioned research suggests that this might happen because Chinese policymakers use Chicago prices as references to fix domestic prices. Chinese policymakers may need to reevaluate their reference market and use Paranaguá as the new price reference. It is well known that any price-fixation policy will distort the market, but if your price-fixation equation incorporates a term with a price that is no longer an international reference, the market distortion will be higher.

The Chinese government, through the 14th five-year plan (Ministry of Agriculture and Rural Affairs), is seeking to boost soybean production from 16.4 million tonnes in 2021 to 23 million tonnes by 2025, an increase of 40% to ensure food security (Wang and Siqi, 2022). However, these attempts at self-sufficiency may fall short, as 23 million tons of soybeans represent only 22.5% of total imports. China's new policy aims to increase subsidies for soybean farmers, extend credit lines for farms, and offer insurance to cover costs and ensure incomes. These incentives aim to engage Chinese farmers from the North and Southeast and the lower and middle reaches of the Yangtze River to participate in a pilot program where soybeans and corn are grown alongside each other. In addition, the implementation of new technology, such as innovative cultivation methods, machinery, and seeds, provides a competitive edge to increase yields (Wei, 2023((China Daily)). These policies will increase domestic soybean production, aiming to substitute soybean imports with domestic production. This will lead to a drop in demand for international soybeans, causing a fall in prices in the international market, which will have a knock-on effect on Chinese domestic prices, decreasing the price. These attempts by the government to achieve food security might empower China's domestic and future markets if this policy follows a price Liberalisation policy, potentially integrating market cointegration and boosting the efficiency of price transmission.

The decline of Rotterdam as a price leader and price maker is evident, with the results showing Rotterdam as a net receiver, influenced by Chicago Futures, Paranaguá, and Rosario Futures. However, the net balance is slightly negative, meaning that Rotterdam still serves as a source of shocks and spillovers to other markets, particularly Chicago and Rosario Spot. The question that arises is how Rotterdam's influence has faded and how this important market has transitioned from being a price leader to a price taker, influenced by other markets. First, it is essential to understand that Rotterdam represents the European Union and the demand side; the role of the European Union as a major importer of soybeans has eroded over the last 20 years, as the demand for soybeans from China has consistently grown, while the European Union's demand has remained relatively stagnant. Over the years, China has overtaken the European Union in terms of demand, accounting for 65% of international soybean imports. This process has weakened Rotterdam's price leadership.

Argentina's current and future role in the international market is clouded by a high level of uncertainty. The current government has imposed strict trade restrictions, such as export tariffs and currency manipulation, followed by regional droughts that have severely impacted yield expectations. The future of Argentina's soybean farmers seems to be highly compromised, at least in the domestic market (Spot market). The presidential elections in October 2023 may bring economic Liberalisation, lifting currency restrictions and export tariffs, potentially increasing Argentina's market efficiency and integration, and unlocking its full potential in terms of soybean exports. Otherwise, Argentina's future role in the international soybean market may be further jeopardized. In the meantime, despite the high level of intervention in the domestic market, the Argentine Futures market has positioned itself as a price leader, price maker, and net transmitter of shocks and spillovers, influencing major markets such as Paranaguá, Chicago, and Rotterdam.

The reign of Chicago and Rotterdam as canters of price formation seems to have come to an end. Rotterdam has fallen to a secondary role in the international soybean market, while Paranaguá (Brazil) and Rosario Futures (Argentina) have risen to lead the international market alongside Chicago. This new triumvirate maintains price leadership and competes for market share. The Chinese government has adopted an active strategy to ensure food security by increasing domestic production, but this seems to be unattainable in the short to medium term. China has failed to capitalize on its position as the world's leading soybean importer and translate this into market power, thereby empowering the futures and domestic markets. Both markets remain relatively insulated and disconnected from the mainstream, unable to influence international prices and acting as net receivers.

Dalian Futures, the world's second most important agricultural futures market, is still far behind in price leadership and market efficiency.

This innovative methodology has allowed us to gain a deeper understanding of the international soybean market from a time-varying perspective. One of the key findings is that causality is not static over time and is generally bidirectional, with shifts in causality occurring over time. Shocks can be transmitted from satellite markets to mainstream markets, and the connectedness index clearly demonstrates that these shocks and spillovers can originate from any part of the international market and be transmitted horizontally. The efficiency of price transmission may play a fundamental role in conveying these spillovers. The connectedness approach methodology makes it easier to correlate exogenous shocks with spillovers in the market, allowing for a more accessible understanding of the origin of exogenous shocks and tracking them across the market's spatial dimensions.

ECIII 5. Conclusion

The dynamic connectedness methodology outlined in Antonakakis and Gabauer (2017), based on a Time-varying Parameter Vector Autoregressive (TVP-VAR) model and the connectedness index (Diebold and Yilmaz, 2012b), has proven to be a game-changer in understanding market integration and price transmission. It introduces the concept of dynamic cointegration and time-varying causality, which better aligns with market processes where shocks, price changes, and shifts in demand and supply occur across the international market in multiple directions. This research focuses on understanding the international soybean market by studying the US market (Chicago Futures), Rotterdam representing the European soybean market, Paranaguá market on behalf of Brazil, Argentina represented by Rosario Futures and Spot, and finally the Chinese domestic spot market and Dalian futures on behalf of China. The study period covers approximately ten years from September 2009 to May 2019. The results suggest that the soybean market is highly mature and capable of circumventing exogenous shocks, at least for the past seven years. The dynamic connectedness index revealed a highly connected and developed market (67% average connectedness). The research found a higher degree of connectedness in the western market (Chicago Futures, Rotterdam, Paranaguá, and Rosario Futures and Spot). However, the connectedness between the Western and Eastern markets (China Spot and Dalian) was quite low, indicating market isolation. Furthermore, the pairwise connectedness index between Dalian Futures and China Spot market appeared to be quite low, and the GFEVD demonstrated that both China and Dalian are net receivers, being influenced to varying degrees by most western markets and denoting market isolation. The pairwise net directional connectedness was able to trace the origin of market disturbances that occurred between 2009 and 2011, as explained by Trostle *et al.* (2011). The test indicated the origin of the disturbance in China, attributed to dryness and changes in import strategies that shocked the international market and were transmitted from the Eastern to Western markets, with China as the epicentre. The net pairwise connectedness also showed that causality between the markets is not static and is rather dynamic, changing over time. The results reveal the ascension of Paranaguá and Rotterdam as price leaders, affecting most markets to varying degrees. Rotterdam's leadership seems to be fading over time, likely due to stagnant demand and a lack of growth in this market over recent years. Chicago remains one of the most important markets, exerting a strong influence on most markets, but sharing price leadership with Paranaguá and Rosario in a dynamic triumvirate of net shock transmitters.

ECIII 5.1. Suggestion for further research

The TVP-VAR connectedness index methodology is an innovative technique that offers opportunities for additional investigation into price transmission and market integration. It would be insightful to examine the cross-price transmission occurring between the international soybean market, other agricultural commodities, and energy commodities such as crude oil, natural gas, and various fertilizer prices. Analysing the connectedness among these commodities and identifying the causality in terms of net transmitters and net receivers could prove valuable. Another suggestion is to refine the granularity of the data and employ the QVAR models and connectedness index methodology to study more recent geopolitical events, such as the Russian-Ukrainian conflict. By doing so, researchers can assess the impact of the conflict on agricultural commodities and trace the spillover effects transmitted across different energy and agricultural commodities.

Chapter 6: Fourth Empirical Chapter.

6.1. The rise of Soybean in international commodity markets: A quantile investigation

6.1.1. Details Summary

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- Author Contributions

D.P. and K.B., supervision, project administration, methodology. G.B.M., conceptualization, formal analysis, investigation writing and review and editing. All authors have read and agreed to the published version of the manuscript. B.G., formal analysis, review, methodology.

- License

- Format

The format and general structure of the paper, including the numbering of headings and subheadings, have remained unchanged. Only the citations have been updated to Harvard style.

6.1.1.1. Presentation of Published Empirical Findings

This section presents the original empirical study, as it was previously published in Helyion, under the title “The rise of Soybean in international commodity markets: A quantile investigation". The chapter is reproduced here in its entirety to maintain the integrity of the published findings and to allow for direct engagement with the original research. This empirical work forms a critical foundation for the dissertation, providing key insights and data that are subsequently synthesised and expanded upon in the following chapters.

In accordance with academic standards, no modifications have been made to the original content with only citation formatting corrections made to align with the dissertation’s style.

ECIV 1. Introduction

ECIV 1.1. The world of Soybeans

Often referred to as the "king of beans," soybeans contribute significantly to the global intake of protein, both directly and indirectly Voora *et al.* (2024). Soybeans stand out as one of the rare plant-based foods offering a complete set of nine essential amino acids (Sacks *et al.*, 2006). Because of this nutritional profile, soybeans have become a crucial protein source for both humans and animals (Lassaletta *et al.*, 2016). The high protein content, ranging from 36% to 40%, makes soybeans one of the most protein-dense legumes (Banaszkiewicz, 2011). Moreover, soybeans are rich in bioactive compounds like isoflavones, which are linked to various health benefits such as reducing the risk of heart disease and cancer (Messina *et al.*, 2022).

Additionally, their use as a key ingredient in biodiesel manufacturing, particularly in nations such as Brazil, has further heightened their worldwide demand (Silveira *et al.,* 2017)**.** In 2023, soybeans were not only the most traded commodity in the agricultural sector worldwide but also ranked as the fourth most traded commodity overall. None of the top three traded agricultural commodities (corn, wheat, and palm oil) possess the potential to effectively substitute soybeans as a primary source of protein. While corn and wheat do contain protein, their protein content and quality are significantly lower and less efficient compared to soybeans. Furthermore, palm oil does not serve as a protein source, rendering it unsuitable as a substitute for soybeans in terms of protein provision.

This distinction highlights the significant role of soybeans in global trade, reflecting their importance in various industries and economies (Lewis, 2023). After palm oil, soybean oil holds the second position as the most widely used cooking oil worldwide representing 34% of the value Palm oil market. Its significance extends to global trade, with approximately with a export value of approximately USD 19 billion (10^9) (FAOSTAT, 2022). The soybean industry is mainly concentrated in a few key countries , primarily the United States, Brazil, and Argentina, which collectively accounted for 90% of total exported quantity dominating global exports in 2022 (FAOSTAT, 2022)

Soybeans have become increasingly vital in meeting the demands of a growing global population. However, the sustainability challenges associated with soybean cultivation necessitate the search for more environmentally friendly food options. The rising production of soybeans contributes to nitrogen pollution due to the extensive use of fertilisers, adversely affecting soil and water ecosystems. The development and adoption of sustainable soybean (RTRS soybean) (Garrett *et al.*, 2016) farming practices could offer a solution to these environmental concerns (Lassaletta *et al.*, 2016). The increasing cultivation of soy to meet rising demand has led to the destruction of crucial ecosystems, particularly in the Brazilian Amazon and “Cerrado” regions (Silva *et al.*, 2017; Voora *et al.*, 2024). Currently, around 76% of soy production is allocated as an affordable, high-quality protein source for animal feed used in meat and dairy production. Approximately 20% is used in edible oils and food products for human consumption, such as tofu, soy milk, and tempeh. The remaining 4% is primarily used in industrial applications, mainly for biodiesel production (Ritchie, 2021).

The global soybean industry, currently valued at USD 155 billion, is expected to reach USD 278 billion by 2031, with an estimated compound annual growth rate (CAGR) of 6% (Persistence Market Research., 2023) cited by Voora *et al.* (2024) The Food and Agriculture Organisation of the United Nations (FAO) forecasted a significant increase in global soybean production for the 2022/2023 harvest season, reaching record levels due to rising demand from China, which is tied to the expansion of livestock production and the replenishment of domestic stockpiles (FAO, 2022).

This significant growth is mainly attributed to the expansion of soybean cultivation areas and improved yields. For instance, soybean production in South America has surged due to a threefold increase in yields and a 200-fold expansion in cultivated land since the 1960s (Fraanje and Garnett, 2020). The soybean sector employs a substantial workforce globally. In 2016, around 240,000 Brazilian farms were engaged in soybean cultivation, while soybean farming in the U.S. alone directly employs around 280,000 farmers (Voora, Larrea and Bermudez, 2020). The FAO recorded that the soybean production reached 353 million tonnes (Mt) in 2020, a significant increase from about 231 Mt in 2008. This growth was achieved by cultivating soybeans on 126 million hectares of land (FAO, 2022). Although soybean production consistently grew at a Compound Annual Growth Rate (CAGR) of 3.6% from 2008 to 2020, this rate declined to 2.42% from 2014 to 2020 (FAOSTAT, 2022). Despite the decline in the Compound Annual Growth Rate (CAGR) between 2014 and 2020, global soybean production exceeded projections in 2021, reaching 388,098 Mt.(FAOSTAT, 2023).

Finally, Soybeans are a vital global commodity, offering a complete set of essential amino acids and standing as a primary protein source for both humans and livestock. As the most traded agricultural commodity and a cornerstone of the global economy, soybeans hold immense significance, particularly in the economies of the United States, Brazil, and Argentina, which control 90% of global exports. Despite the significant nutritional benefits of soybeans, the rapid growth of the soybean industry has raised substantial environmental challenges. These include deforestation in Brazil's Amazon and Cerrado regions, and nitrogen pollution resulting from extensive fertilizer use. Addressing these issues requires robust solutions such as the Round Table on Responsible Soy (RTRS) certification and the exploration of alternative protein sources. With rising global demand pushing the industry's value to a projected USD 278 billion by 2031, it's crucial to balance this growth with sustainable practices to mitigate environmental impacts and safeguard vital ecosystems.

The intricate nexus between the soybean and other agricultural commodities (Jiang *et al.*, 2016), energy commodities (Tiwari *et al.*, 2021), and fertilisers stands at the crossroads of contemporary economic research, given their pronounced interdependencies and the escalating concerns about global food security, energy sustainability and commodities financialization (Ouyang and Zhang, 2020;

Zaremba, Umar and Mikutowski, 2021). As the world grapples with volatile economic conditions, heightened in recent times by geopolitical tensions like the Russo-Ukrainian conflict (Nasir, Nugroho and Lakner, 2022), the global pandemic and Climate Change (Mourtzinis *et al.*, 2015; Lesk *et al.*, 2021), understanding the interrelated dynamics of these critical sectors becomes even more paramount. The recent war has created a new dimension of uncertainty into the global commodities market increasing the connectedness, with agricultural commodities (Alam *et al.*, 2022).Given Ukraine's significant role as the "breadbasket of Europe", experiencing considerable fluctuations in both supply and price determinants. In such a global backdrop, the connectedness and risk spillover mechanisms between these commodities emerge as pivotal constructs. They elucidate how disturbances in one domain, be it due to geopolitical upheavals or other factors, potentially reverberate across others, influencing price determinants, supply chain mechanisms, and global trading systems.

Deploying risk spillover index or connectedness index of Diebold and Yilmaz (2012) based on generalized forecast error variance from a Quantile Vector Autoregressive (QVAR) model, an advanced econometric tool allowing us to track connectedness over time through the examination of extreme quantiles, this study embarks on an exploratory journey to dissect the intricate layers of connectedness or risk of spillover among these pivotal commodity groups in the shadow of geopolitical tensions. Typically, a heightened stress effect elevates the overall connectedness (TCI) within a network. Additionally, the TCI displays significant variations across quantiles (Bouri *et al.*, 2021; Bouri *et al.*, 2021). Recently, numerous research efforts have delved into the relationships between agricultural commodities and factors such as oil shocks, industrial and energy prices, and metal markets using the Connectedness approach (Umar, Jareño and Escribano, 2021; Umar, Riaz and Zaremba, 2021). Many of these investigations utilized methodologies closely aligned with or similar to the approach used in the study. Nonetheless, wavelet techniques and different Copula methods could be considered as potential alternatives.

The risk of spillover index or connectedness index from (Diebold and Yilmaz, 2012b) based in a QVAR model, with its rich structural underpinnings, allows for a nuanced understanding of the multifaceted interplays at various quantiles, thereby providing insights not just at an aggregate level, although also at specific, and critical junctures of connectedness. By casting a spotlight on these interdependencies, particularly under the specter of the Russian-Ukrainian war, this research aims to provide stakeholders, ranging from policymakers to industry practitioners, with a granular understanding of the systemic intricacies. Furthermore, in discerning the nature and extent of the connectedness among these sectors, the study aspires to inform strategies that mitigate potential vulnerabilities, ensuring a resilient and sustainable future for agriculture, energy, and the broader global economy. Additionally, the interconnectedness and risk propagation among different agricultural commodities fluctuate over time. These variations can be symmetric on some occasions and asymmetric on others, largely due to legislative adjustments in the agricultural sector (Shahzad *et al.*, 2018) . Thus, it is vital to comprehend potential asymmetries in price transmission, as well as their underlying causes.

<u>ECIV 1.2. Previous empirical Research.</u>

The foundation of this investigation is built upon a comprehensive study that previously mapped the international soybean market using a variety of methodologies and analysed various global historical events. The prior research, conducted by Barboza Martignone, Behrendt and Paparas (2022) focused on market cointegration, efficiency, and price transmission across the various international soybean markets. In their methodology, the researchers employed the classic price transmission approach, using the Augmented Dickey-Fuller test (ADF) to determine the order of integration. They utilized ADF with breaks, and the Bai-Perron multiple breakpoint test to pinpoint possible structural breaks within the time series. These breaks were later correlated with exogenous events that had disrupted the market and were thus employed as dummy variables in the cointegration analysis. The authors then performed the Johansen cointegration test, correcting for the previously mentioned dummy variables as a standard procedure. To determine the market's causality, the researchers applied the Granger Causality Test, paving the way for the development of several Vector Error Correction Models (VECM), both in pairs and as a global model. Their findings aligned with those of previous researchers, such as Margarido *et al.* (2014)(Margarido, Araujo Turolla and Ferreira Bueno, 2014). The research of Barboza Martignone, Behrendt and Paparas (2022) provided insights into market dynamics, price leadership, and overall market efficiency. The authors specifically focused on the events of the US-China trade war, striving to quantify its impact on the international market. The conclusion drawn was unambiguous: the soybean market's development and efficiency exhibit a strong capacity for arbitrage around tariffs, reorganizing trade flows and returning to natural long-term equilibrium. This suggests that the impact of the US-China trade war was insignificant. The investigation also revealed that the Chinese and Argentine markets demonstrated a diminished level of cointegration and, to a certain extent, less market efficiency.

The research by Barboza Martignone, Paparas and Behrendt (2023) extended their investigation, building upon previous findings, to search for evidence of asymmetric price transmission within the international soybean market. Their key conclusion was the absence of asymmetric transmission among the markets. However, they identified a methodological challenge related to the different cointegration tests they used. These tests, the Johansen cointegration test, Engle-Granger cointegration test, and the cointegration under asymmetry test by Enders and Siklos (2001) yielded different results, highlighting methodological limitations. The authors noted that cointegration appeared to be a static concept, highly dependent on selected time windows, and perhaps not entirely suitable to depict the complex dynamics of market situations across varying time periods. Additionally, the price transmission methodology presumed constant parameters, failing to consider potential variations. To address these methodological issues, Barboza Martignone *et al.* (2023), introduced a time-varying approach using the connectedness index based on TVP-VAR. This study corroborated earlier suggestions by Barboza Martignone, Behrendt and Paparas (2022) by affirming that a highly mature and developed market can indeed circumvent exogenous shocks. The results displayed a steady connectedness index of 67% for the last decade. Moreover, no significant evidence was found regarding the impact of the US-China trade war, further validating the conclusions drawn by Barboza Martignone, Behrendt and Paparas (2022). Contrary to prior investigations, the researchers suggested that market causality can be bidirectional, irrespective of price leadership. The authors proposed a shift in leadership, with the historic dominance of Chicago being replaced by shared leadership with Brazil and Argentina. Balcilar, Gabauer and Umar (2021) pioneered research on agricultural commodities using the Connectedness Index through the Time Varying Parameter Vector Autoregressive (TVP-VAR) model. They focused on major agricultural commodities such as grains, sugar, livestock, cocoa, corn, soybean oil, lean hogs, soybeans, wheat, and cattle, and energy commodities, specifically crude oil, due to their significant role in global trading. The authors emphasized the key influence of crude oil on agricultural commodities. However, they noted that causality could oscillate from crude oil to agricultural commodities markets, shifting agricultural commodities from the position of net receivers to net transmitters. The study suggested that only grain and livestock demonstrated consistent net transmitter behaviour over time. Inspired by the concept of studying connectedness across agricultural commodities. Despite the comprehensive methodologies employed most previous researchers (Balcilar, Gabauer and Umar, 2021; Barboza Martignone *et al.,* 2022; 2023) utilized a wide range of Vector Autoregression (VAR) models, cointegration, and Time-Varying Parameter Vector Autoregression (TVP-VAR), these models still fall short in capturing the network of spillovers under extreme scenarios. Exogenous shocks that disturb the market are not reflected at the median of the conditional distribution, although rather, they emerge at the extreme Quantiles of the previously mentioned distribution. To address the aforementioned methodological limitations, Ghosh and Paparas (2023) expanded upon the connectedness methodology. They introduced the use of a Quantile Vector Autoregression (QVAR), which measures connectedness based on quantile levels. This approach involves fitting VAR models at various quantiles, specifically at 0.1, 0.5, and 0.9. and applying it to a broader range of commodities such as soybean, maize, wheat, beef, poultry, coffee grains, cocoa, palm oil, tea, groundnut oil, sugar, rice, and orange juice. The commodities studied included highly interdependent ones like soybean and wheat, the main ingredients in poultry feeds, or split between maize and soybean in the US corn belt, which are primary ingredients in beef production. The authors also incorporated commodities that are unrelated or exhibit no cross-dependency, and hold less transactional significance, such as orange juice and tea. The research uncovered a high connectedness index of over 55% for the entire study period (1965-2022). This suggests that the interconnectedness among commodities does not solely rely on explicit relationships between them (e.g., Soybean/Feed/Poultry). There may be underlying layers of interconnectedness or complex relationships that are challenging to identify. Interestingly, the authors found that palm oil, corn, wheat, and soybeans are net transmitters, directing the price market of bulk commodities. This finding underscores the importance of soybeans as a price leader in the global agricultural commodity market.

ECIV 1.3. Research gap

Numerous authors have explored the dynamics of the soybean market using various methodologies. Despite the many contributions these authors have made, shedding light on, and deepening our understanding of this topic, a multitude of research questions remain unanswered. This investigation aims to further enhance the general knowledge in this field. Firstly, there is a recognised gap in understanding of the interconnectedness between primary agricultural commodities, energy commodities, and fertilisers.

Agricultural commodities are highly interconnected. This is because the demand for these commodities often treats them as near equivalents, they share comparable costs of production, compete for the same scarce natural resources, and utilize the same market data (Gardebroek, Hernandez and Robles, 2016). Additionally, fertilisers, which are critical for agricultural food commodities, represent one of the most significant input costs for arable crops. In a similar vein, crude oil, a crucial energy commodity, is strongly interconnected with agricultural commodities due to its role in production costs. Likewise, natural gas is deeply linked with urea fertilizer due to its significant role in fertilizer production, further demonstrating the intricate web of connections in these sectors. While Balcilar, Gabauer and Umar (2021) have already probed this area, there is still room for further research. Their results suggest a bidirectional causality, although their investigation solely included the price of crude oil. The void extends to the pricing of fertilisers, which exhibit cross-dependency with agricultural commodities, such as wheat, maize, barley, and urea, due to their role as crucial inputs in production. Additionally, the relationship between soybeans, soybean meal, and soybean oil has been studied in terms of asymmetric price transmission (Yang and Berna, 2021). However, it remains unclear which commodity holds the market leadership in terms of causality and net transmission. This research aims to address these identified gaps. Even though there might be overlap with the work of Balcilar, Gabauer and Umar (2021), this study apply use a Quantile Vector Autoregression (QVAR) methodology, which presents clear advantages over the Time Varying Parameter Vector Autoregressive (TVP-VAR) model. Lastly, the research will seek to understand the influence of the US-China trade war on the soybean market once again, albeit with a broader scope. This includes studying the impact of the Russian-Ukrainian conflict, which has caused shocks in the natural gas and wheat markets. The goal is to trace the origins of these shocks across all commodities studied. The QVAR methodology, adept at identifying hypothetical shocks in agricultural commodities, is highly suited for this purpose. As previously mentioned, implementing quantile regression and fitting VAR models at different quantiles (Q1: 0.1, Q2: 0.5, Q3: 0.9) enables us to identify spillover associated with extreme positive and negative shocks. Furthermore, utilizing the extreme quantiles allows us to ascertain the factors triggering these severe shocks across different agricultural and energy commodities, as well as fertilisers.

ECIV 2. Data & Research Methodology

The agricultural commodities selection for this study was influenced by an agronomic and an economic cross dependency as well as following the lead of previous studies. Primarily, we focused on arable crops grown on a large scale, choosing those with the highest trading volume and value, such as Soybean, Barley, and Wheat. Additionally, we included byproducts such as Soybean Meal, Soybean Oil, and Sunflower Oil due to their significance in domestic human consumption and animal production, especially in the case of Soybean Meal. The selection of energy commodities, namely Crude Oil and Natural Gas, was driven by their critical roles in agricultural processes. Crude Oil serves as a vital input in arable crop production, whereas Natural Gas plays a key role in the production of fertilisers such as Urea. Finally, we incorporated fertilisers (Urea and DAP) into the study given their crucial impact on crop production. The aim is to understand the relationship between energy commodities and fertilisers, considering the importance of the former in the production of the latter.

The secondary data was sourced from the World Bank and covered a twelve-year period from January 2011 to January 2023 monthly. The data for Soybeans was obtained from the Chicago futures contract (U.S. Soybeans, No. 2 yellow and par, priced in US$ per metric ton) (Soy), acknowledging the Chicago Board of Trade as a credible price reference for the international soybean market. Data for Soybean Meal and Soybean Oil were also derived from their respective Chicago futures contracts (Soybean Meal - Minimum 48 percent protein, and Soybean Oil, exchange approved grades, both priced in US$ per metric ton). For Barley, the study used the spot price of Canadian No.1 Western Barley (US$ per metric ton) as the international price reference. Wheat prices were represented by Kansas Wheat (No.1 Hard Red Winter, ordinary protein, Kansas City, US$ per metric ton), indicating the international prices of wheat. Sunflower oil prices were represented by the spot price of US export from the Gulf of Mexico (US$ per metric ton). Instead of utilizing a specific international price reference for crude oil, the research incorporated a Price Index for Crude Oil (Crude Oil (petroleum), simple average, equally weighed of three spot prices; Dated Brent, West Texas Intermediate, and the Dubai Fateh (Source: World Bank). Similarly, the Natural Gas Index (Laspeyres), average of Europe, US, and Japan (LNG), weights based on 5-year average consumption volumes was employed. The prices of the fertilisers Urea (Ukraine, prill spot f.o.b. Middle East), named USU, beginning March 2022; previously, f.o.b. Black Sea) and DAP (diammonium phosphate), spot, f.o.b. gathered from Bloomberg; Bloomberg L.P., Green Markets (formerly Kennedy Information LLC) named USN.

We adapted the connectedness context according to the methods suggested by Diebold and Yilmaz (2012). As per Ando, Greenwood-Nimmo and Shin (2022) approach, the research utilized a quantile vector autoregression to investigate the connectedness between agricultural commodities energy commodities and fertilizer' monthly log return series. These commodities include Soybean, Soybean meal, Soybean oil, Sunflower oil, Barley , Wheat, Crude oil, Natural gas, Urea and DAP. Our analysis focuses on the extreme quantiles lower and upper quantiles. This approach allows us to consider the significant market fluctuations throughout numerous extreme events over the previous 12 years. The formula for the estimation of quantile vector autoregression, QVAR(p) is as follows:

$$y_t(\tau) = \mu(\tau) + \sum_{j=1}^{p} \varphi_j(\tau)\ y_{t-j} + u_t(\tau) \tag{1}$$

Where t represents time and τ stands for the quantiles. The vector $y_t$is composed of n endogenous variables, which includes ten agricultural and energetical commodities denoted by $u(\tau)$. The matrices of coefficients are represented by $\varphi_j(\tau)$, while the error vector is indicated by $u_t(\tau)$. The upper limit for the lag length, also known as p , is 4, a specification that aligns with existing literature by Linnemann and Winkler (2016) and Ando, Greenwood-Nimmo and Shin (2022).

By leveraging Wold's theorem (Cramér and Wold, 1936) , we adjust the QVAR(p) in equation (1) into a quantile vector moving average form, or QVMA(∞):

$Q_t(y_t|F_{t-1}) = \mu(\tau) + \sum_{i=0}^{\infty} A_i(\tau)u_{t-1}(\tau)$with $A_i(\tau) = \Theta_1(\tau)A_{i-1}(\tau) + \Theta_2(\tau)A_{i-2}(\tau) + \cdots$ applicable for $i = 1,2,\ldots;$ $A_o(\tau) = I_n$ and $A_i(\tau) = 0$ applicable for $i < 0. I_n$ stands for $n \times n$ identity matrix . We applied the QVMA(∞) form and calculate the H-step ahead of generalized forecast error variance decomposition (GFEVD) following equation (2).

$$\psi_{ij,\tau}^{g}(H) = \frac{\sigma_{jj}^{-1}\sum_{h=0}^{H-1}\left(e_i^T A_h(\tau)\Sigma e_j\right)^2}{\sum_{h=0}^{H-1}\left(e_i^T A_h(\tau)\Sigma A_h(t)^T e_i\right)} \tag{2}$$

Σ represents the variance matrix of the vector for error terms, where σ_{jj} stands for the standard deviation associated with the error term of j. e_i is a vector with $n \times 1$ dimensions that assigns the value 1 to the i-th element and 0 to the rest. Following this, the computation of the normalized Generalized Forecast Error Variance Decomposition (GFEVD) (Pesaran and Shin, 1998) (Koop, Pesaran and Potter, 1996) was carried out. The utilization of GFEVD in this methodology serves as a gauge of robustness, as seen in equation (3).

$$\psi_{ij,\tau}^{\sim g}(H) = \frac{\psi_{ij,\tau}^{g}(H)}{\sum_{j=1}^{k}\varphi_{ij,\tau}^{g}} \tag{3}$$

$\psi_{ij,\tau}^{\sim g}(H)$ illustrates the proportion of forecast error variance in i that is attributed to j when i falls within the τ quantile. Following this, we perform calculations for the subsequent spillover indexes to encapsulate the total spillovers among the variables:

$$FROM_{i,\tau}(H) = \frac{\sum_{j=1,j\neq i}^{n}\tilde{\psi}_{ij,\tau}^{g}(H)}{n} \times 100 \tag{4}$$

$$TO_{i,\tau}(H) = \frac{\sum_{j=1,j\neq i}^{n}\tilde{\psi}_{ji,\tau}^{g}(H)}{n} \times 100 \tag{5}$$

$$NET_{i,\tau}(H) = TO_{i,\tau}(H) - FROM_{i,\tau}(H) \tag{6}$$

$$TCI_{\tau}(H) = \frac{\sum_{i,j=1,j\neq i}^{n} \psi_{ji,\tau}^{g}(H)}{n} \times 100 \tag{7}$$

The “TO connectedness index,” as denoted in equation (5), indicates the comprehensive influence of variable i on all other variables j. The FROM connectedness index, as outlined in equation (4), conveys the impact of shocks on all other variables j to variable j. The NET connectedness index, referred to in equation (6), measures the net spillovers from i to all other variables j, where a positive (negative) value implies that i acts as a source (recipient) of shocks within the system. Finally, we consider the total connectedness index (TCI). As depicted in equation (7), the total connectedness index (TCI) measures the complete interconnectedness among variables in the system and is employed as a representative indicator for the contagion of market risk.

Our empirical investigation focus on validating the quantile connectedness at the 0.1, 0.5, and 0.9 quantiles. These quantiles represent the interconnectedness among agricultural commodities, energy commodities and bulk fertilisers during extreme negative, median, and extreme positive shifts. Besides studying static interconnectedness, we explore dynamic interconnectedness by calculating the rolling spillover indexes utilizing a 200-day rolling window.

The approach employed in this study presents several distinct benefits over comparable models such as TVP-VAR and DCC-GARCH. Essentially, all these models expand upon the connectedness model (Diebold and Yilmaz, 2012b). In the QVAR model, the interaction and feedback effects among the variables are contingent on their quantile dynamics. As shocks (either positive or negative) visibly influence extreme quantiles, this methodology is fitting for this type of research. To further validate the results and gain a different perspective, the research also employed a more orthodox alternative methodology. Specifically, the Granger causality test was utilized to map pairwise causality among the various commodities. To achieve this, the following procedure was employed: A VAR (Vector Autoregression) model was created for each pairwise time series. The Lag order selection was studied, and using the Schwarz information criterion, the number of lags was determined for each pair. Subsequently, the Granger Causality Test was conducted, and the results were summarized in a causality matrix.

ECIV 2.1. Methodology limitation.

The connectedness approach, particularly when grounded in Quantile Vector Autoregression (QVAR), provides a nuanced framework for understanding market dynamics and the transmission of shocks across different economic sectors. However, it is essential to objectively consider its limitations alongside its strengths to foster a balanced view of its applicability across various market conditions. One notable aspect of the QVAR-based connectedness approach is its pronounced sensitivity to the extremes of market distributions. This characteristic implies a heightened efficacy in mapping out the connectedness and spillover effects under extreme market conditions, such as during bullish or bearish trends, compared to periods of market stability. These give the QVAR approach a substantial advantage to analyse the potential exogenous disruption on the market such as the case of US-China trade war, the outbreak of the pandemic (COVID-19) and the Ukrainian-Russian war. While this feature is invaluable for stress testing and scenario analysis, it suggests a potential limitation in the approach's ability to capture the subtleties of spillover effects during more tranquil market phases.

Acknowledging these limitations does not diminish the value of the QVAR-based connectedness approach in market analysis. Instead, it provides a more comprehensive understanding of when and how the method can be most effectively applied. For regulators, policymakers, and market participants, recognizing these nuances is crucial. It allows for a more informed application of the approach, ensuring that insights derived from QVAR analyses are leveraged appropriately, considering the context of market conditions and the specific objectives of the analysis.

ECIV 2.2. Network chart interpretation.

The Chart 3,7 and 10 represent the Network Plots for quantile 0.5, 0.1 and 0.9 respectively. The diagrams portray the complex interrelationships between various agricultural commodities across this quantile. Nodes in blue indicate net shock transmitters and nodes in yellow indicate net receivers. The node's size corresponds to the absolute value of the NET connectedness index. The arrows' direction signifies the path of spillover effects between pairs of variables, while the arrows' thickness indicates the strength of these spillovers.

ECIV 3. Results & Discussion.

ECIV 3.1. Results interpretation.

The principal findings can be summarized as follows. First, we will present the descriptive statistics (Table 1) and illustrate the time-series data (Chart 1). Secondly, the results will be divided by Quantiles and presented in the following order: the median Quantile (0.5), lower Quantile (0.1), and upper Quantile (0.9). For each Quantile, the corresponding results will be described and interpreted.

ECIV 3.1.1. For Each Quantile

- Total Connectedness Index (TCI): This index measures the total proportion of forecast error variance in a network that can be attributed to shocks from other parts of the network. It provides a sense of the overall interconnectedness within the system.
- Average Dynamic Connectedness (ADC): refers to an average measure of dynamic connectedness over time, an average of the TCI over a specified period, reflecting how connectedness evolves.
- Network Connectedness (NC): reflects the interconnectedness of the entire network or system under study. It quantifies the extent to which components within the network are influenced by each other.
- Net Pairwise Directional Connectedness (NPDC): this measure reflects the net connectedness between two specific commodities in the network. It considers the directional impact of one entity on another and vice versa, offering a net measure of this bidirectional interaction.
- Net Total Directional Connectedness (NTDC): this index measures the net contribution of each individual entity to the total connectedness in the system. It captures the difference between the shocks transmitted by an entity to others and the shocks it receives from the rest of the network.

ECIV 3.1.2. In Overall

- Descriptive statistics:

The Jarque-Bera tests were conducted to assess the normality of the data distribution, while skewness and kurtosis were examined to understand the shape of the distribution. Additionally, extreme quantile ratios were analysed to identify potential outliers or extreme observations in the dataset.

- Time-series illustration:

A time-series illustration was employed to visualize the trends and fluctuations in the data over a specific period, providing insights into the temporal dynamics of the variables under consideration.

- Chart TCI over various quantiles:

Total Connectedness Index (TCI) is analysed over various quantiles, it illustrates how the interconnectedness within a financial system or network changes across different states or conditions of that system. This approach is typically used to understand how relationships between different commodities of a network vary under different levels of market stress or volatility.

- Granger causality test:

The Granger causality test was utilized to determine whether past values of one variable can predict the current values of another variable, thus establishing a causal relationship between them.

ECIV 3.1.3. Variable Abbreviations

Each variable is represented by a specific abbreviation to streamline our discussion. "Coil" refers to Crude Oil, a major energy commodity. "Nga" stands for Natural Gas, another key energy source. Agricultural commodities are also included, with "Bar" representing Barley, "SM" for Soybean Meal, and "Soil" denoting Soybean Oil. Additionally, "Sunfl" corresponds to Sunflower, and "Wh" is the abbreviation for Wheat, both important in the agricultural sector. In the realm of fertilisers, we use "USU" to refer to Urea and "USN" for DAP, which stands for Diammonium

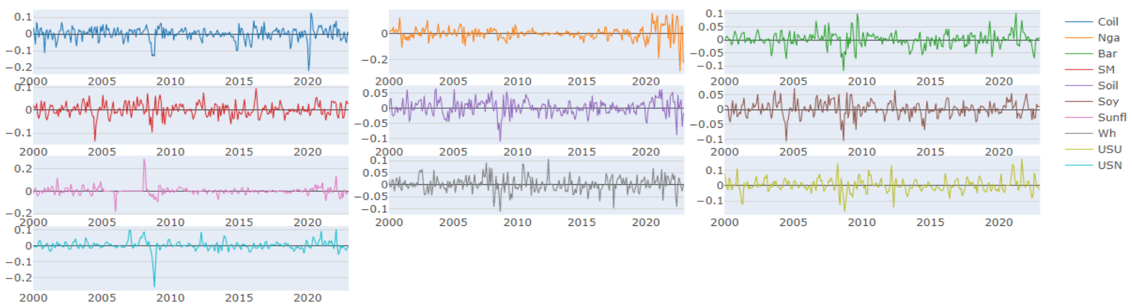
Phosphate. Finally, “Soy” refers to Soybean price. Each of these variables plays a crucial role in our analysis, representing diverse sectors from energy to agriculture.

ECIV 3.3. Descriptive statistic & Graphical Illustration

Table 1. Descriptive statistic of the time series.

	Coil	Nga	Bar	SM	Soil	Soy	Sunfl	Wh	USU	USN
Mean	0.002	0.001	0.001	0.002	0.002	0.002	0.002	0.002	0.002	0.002
Variance	0.002	0.003	0.001	0.001	0.001	0.001	0.001	0.001	0.002	0.001
Skewness	-1.216*	-0.881*	-0.136	-0.296*	-0.313*	-0.467*	2.198*	-0.06	0.178	-2.030*
Kurtosis	4.265*	6.328*	2.343*	1.859*	1.183*	2.073*	20.432*	1.449*	2.743*	20.753*
JB	278.188*	497.991*	64.233*	43.922*	20.661*	59.688*	5041.413*	24.398*	88.277*	5161.001*
ERS	-3.729*	-4.554*	-6.587*	-5.555*	-5.287*	-6.380*	-4.407*	-4.424*	-2.218*	-6.118*
Q(10)	30.222*	33.473*	33.380*	38.852*	34.575*	47.688*	41.278*	15.432*	55.628*	112.851*
Q2(10)	72.629*	115.092*	37.190*	5.873	34.075*	11.143*	35.354*	5.363	28.285*	39.378*

ECIV Chart 1. Time series graphical analysis



Given that your test result of Jarque-Bera (JB) (Table 1) is larger than any of these critical values (5.99 at alpha 5%), the null hypothesis at any of these significance levels is rejected. This implies that the sample data does not appear to have the skewness and kurtosis of a normal distribution. Crude oil, Natural Gas, Sunflower Oil, USN (DAP) presented an excess of Kurtosis (Leptokurtic): Distributions with positive excess kurtosis have heavier tails and a more peaked centre than the normal distribution. With an excess kurtosis in the data, it indicates the presence of outliers or extreme values. For Barley, Soymeal, Soybean oil, Soybean, Wheat, and

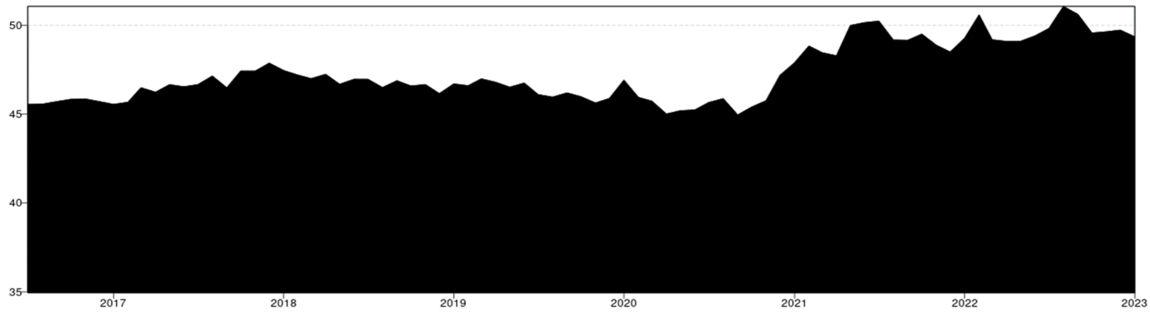
Urea they present a negative excess of kurtosis (Platykurtic): Distributions with negative excess kurtosis are flatter with lighter tails compared to the normal distribution. This suggests that the data is platykurtic. Meaning the distribution has fewer and less extreme outliers than the standard normal distribution. The skewness analysis indicates that the time series, in general, exhibits negative skewness, where the tail on the left side (representing smaller values) is longer or fatter than that on the right. However, Urea and Sunflower oil deviate from this trend, exhibiting positive skewness where the tail on the right side (representing larger values) is more pronounced than on the left. Wheat, on the other hand, demonstrated near-zero skewness, suggesting a symmetric distribution, though not necessarily a normal one. The results from the ERS test indicate that the series do not exhibit a unit root, suggesting that it is stationary (Table 1)

ECIV 3.4. Middle Quantile 0.5

ECIV 3.4.1. Total Connectedness index (TCI) (Q 0.5)

The middle quantile, represented as the 0.5 quantile or the 50th percentile, is the median of the distribution. In a quantile regression model, estimating the middle quantile means modeling the median of the dependent variable conditional on the independent variables. The median is less sensitive to outliers compared to the mean. Therefore, the TCI under the median quantile gives a more robust estimate of the central tendency when the data contains outliers or is skewed. In this study based on agricultural commodities, energy commodities, and fertilisers, the TCI under the median (0.5) quantile would help understand the typical (median) connectedness between these commodities under normal market conditions, as opposed to extreme conditions (represented by lower and upper quantiles).

ECIV Chart 2. Total Connectedness Index (TCI) (Q 0.5)



For the 0.5 Quantile the total connectedness averaged around 47% (Chart 2). From mid-2016 until the end of 2021 it remained stable at 45% to 46%. Peaking around the beginning of 2021, close to 49% starting a period of great volatility that remains actively high until the end of the studied period. The influence of US-Chinese trade war seems to be relatively not significant in terms of connectedness around agricultural and energy markets. As previously noted by Barboza Martignone, Behrendt and Paparas (2022), this phenomenon may arise due to the market efficiently circumventing the tariff, predominantly impacting the U.S. market (And only soybeans) (Li, 2023) while benefiting others.

The beginning of the Covid 19 pandemic cannot be correlated with any spike in connectedness or risk of spillover despite that has disturbed in the world trade has not significantly; however, by the end of 2020 the connectedness index started to peak indicating a disruption of the market which might have been a lag effect of the pandemic probably associated with the 200-day rolling window spillover index. The disruptions caused by the pandemic (Voora *et al.*, 2024) may have impacted the supply chain, leading to positive shocks in prices, particularly evident in the higher quantile Q 0.9. The disruption of the Ukrainian- Russian war (2021 – onwards) it might have a strong influence on increase of shocks spillover, and this is clearly appreciated in the chart showing a greater period of volatility and uncertainty during the before mentioned period. According to Just and Echaust (2022), the spillover index peaked during the Russia-Ukraine conflict, with the commodities most significantly impacted being those primarily produced by these nations, including wheat, maize, and barley. The pronounced peak in connectedness within this quantile warrants special attention, particularly since this quantile represents the median. Previous studies utilizing mean models have been inadequate in highlighting external shocks, primarily because such shocks tend to manifest predominantly within extreme quantiles (Ghosh and Paparas, 2023)

Timeline & Key events.

1. 2017-2019 (U.S.-China Trade War): The trade war between the U.S. and China began in early 2018. Despite significant market disruptions due to tariffs, the impact on the TCI was relatively insignificant. This indicates that global markets adapted efficiently, particularly as the tariffs primarily impacted U.S. soybean markets, with limited spillover effects on other commodities (Barboza Martignone *et al.*, 2022; 2023).
2. 2020 (COVID-19 Pandemic):The COVID-19 pandemic began in early 2020. The pandemic did not cause an immediate spike in connectedness. The lack of a significant increase in TCI could be attributed to the swift market adjustments and government interventions that stabilized commodity markets. However, the end of 2020 marked the beginning of an upward trend in connectedness, potentially indicating lag effects of the pandemic on supply chains and market disruptions (Voora, Larrea and Bermudez, 2020).
3. 2021-2022 (Russia-Ukraine Conflict): The Russia-Ukraine conflict began in 2022. The TCI spiked in early 2021 and maintained higher volatility throughout the period, reflecting significant market disruptions caused by the conflict. Russia and Ukraine are key producers of commodities like wheat, barley, and maize, and the conflict disrupted global supply chains, leading to positive shocks and increased connectedness in these markets. The TCI peaked, highlighting the pronounced spillover effects of the conflict on global commodity markets (Just and Echaust, 2022; Voora *et al.*, 2024).

ECIV 3.4.3. Average Dynamic Connectedness (ADC) (0.5 Q)

ECIV Table 2. Average Dynamic Connectedness (ADC) (0.5 Q)

	Coil	Nga	Bar	SM	Soil	Soy	Sunfl	Wh	USU	USN	FROM
Coil	66.4	2.01	6.95	2.38	8.92	5.13	2.29	0.96	1.48	3.47	33.6
Nga	3.91	83.76	2.21	2.21	1.98	1.9	1.31	0.67	0.82	1.22	16.24
Bar	4.81	0.69	41.04	12.66	9.94	16.37	2.2	11.4	0.63	0.25	58.96
SM	1.08	0.94	9.7	36.91	10.04	30.53	1.42	8.76	0.32	0.3	63.09
Soil	4.87	0.4	9.53	8.39	43.63	21.36	2.66	7.25	0.93	0.99	56.37
Soy	1.66	0.41	10.55	24.48	19.83	32.19	1.66	8.42	0.59	0.21	67.81
Sunfl	2.58	0.42	3.52	2.27	5.48	3.58	77.64	0.99	0.45	3.07	22.36
Wh	0.83	1.17	11.14	12.41	8.41	14.15	0.9	50.49	0.14	0.35	49.51
USU	3.27	4.1	2.1	1.37	2.38	1.92	2.93	2.02	73.67	6.23	26.33
USN	5.19	2.89	2.51	2.31	3.6	2.76	3.31	1.68	7.19	68.55	31.45
TO	28.21	13.02	58.2	68.49	70.58	97.71	18.7	42.16	12.55	16.1	425.71
Inc.Own	94.61	96.79	99.24	105.39	114.21	129.9	96.34	92.65	86.22	84.65	TCI=49%
NET	-5.39	-3.21	-0.76	5.39	14.21	29.9	-3.66	-7.35	-13.78	-15.35	
NPT	4	3	5	7	8	9	3	5	1	0	

Table 2. depicts a two-way interaction between different markets. The system's interconnectedness is broken down into two categories. Firstly, the final column, labeled "FROM," represents the total aggregate of shocks received by all the markets under consideration from the entire system. The calculation for this column's value is the sum of all the horizontal figures, excluding the diagonal figures. Secondly, the "TO" row at the end illustrates the shock distribution from each time series to the entire system. The total for this row is determined by adding all the vertical figures, excluding the diagonal ones. The numbers represented column-wise signify the contribution of one commodity to the forecast error variance in another one. The numbers provided row-wise depict the cumulative contribution of all other commodities to the forecast error variance in a specific commodity.

The first noteworthy observation when we rank commodities by the magnitude of their spillover transmission to other markets, is that Soybean stands out as having the most significant influence in terms of shock spillover within the entire market studied. With 97.71% of spillover transmission, Soybean emerges as the top net transmitter (29%) and price leader. This outcome aligns with the research conducted by Ghosh and Paparas (2023) which underscored the paramount role of soybean as a net transmitter. However, it contrasts with the findings of Balcilar, Gabauer and Umar (2021) which highlighted crude oil's key influence over soybean. This dominant position of soybeans in the international agricultural commodities market can be correlated to their vital role in global trade. As the most traded agricultural commodity and the fourth most traded commodity worldwide (Lewis, 2023), resulting in soybeans take position as net spillover transmitter in the market.

The second observation when ranking commodities by the extent of spillover transmission reveals that, following Soybean in first place, its byproducts Soybean Oil and Soybean Meal take the second and third positions, respectively. This can be seen as a further testament to the primary role and dominance of Soybean. Soybean Oil has been observed to transmit approximately 70.58% of spillover, with a net transmission of 14.21%. Subsequent to this, Soybean Meal demonstrates an overall transmission of 68.49%, and a net transmission of 5.39%. The triumvirate of Soybean, Soybean Oil, and Soybean Meal are the only three commodities with a positive transmission balance, in other words, they are net transmitters. This suggests that for the 0.5 Quantile, these commodities have dominated the market, acting as price leaders, and playing a key role in price formation under “normal” market circumstance (Q 0.5). The significant role of soybean oil and soymeal in the market can be attributed to their interdependent economic relationship, as both are by-products of soybeans. This interdependence means that the demand for soybean oil and meal directly influences the demand and price of soybeans, which in turn are the primary cost factors for soybean oil and meal production. The joint products theory suggests that the price of soybeans is determined by a combined average of the earnings from soybean meal and soybean oil, subtracting the costs involved in processing. Simanjuntak *et al.* (2020) revealed that these theories do not necessary apply for this case. According to the researchers the constant in the cointegration equation, which was expected to align with theoretical predictions, did not. This constant shows that the price of soybeans in Rotterdam is higher than the combined average prices of Dutch oil and Hamburg meal. This suggests that the price of Rotterdam soybeans does not have a direct correlation with the prices of the Hamburg meal and Dutch oil, indicating a lack of joint product relationship between them. Furthermore . Simanjuntak *et al.* (2020) findings from the Vector Error Correction Model (VECM) suggest that over the long term, only the price of soybeans adjusts to maintain equilibrium. This makes sense considering that oil and meal are products with significantly larger markets. Soybeans are among the most influential commodities, notably for the 0.5 Quantile (Normal market conditions). Intuitively, this commodity has the most significant impact on soybean meal, at 30.53%, and soybean oil, at 21.36%. However, the reverse influence (that is, from soybean meal and soybean oil to soybeans) is 24% and 19.83%, respectively. This indicates a strong bidirectional causality, with soybeans predominantly leading in price fluctuations. In contrast with Simanjuntak *et al.* (2020) findings our results suggest that the price of soybeans is a primary component influencing the price changes of both soybean oil and meal. This shifts the conversation's focus, suggesting that price formation is primarily driven by production costs. However, the strong bidirectional causality also implies that price formation could be influenced equally by both cost and demand factors.

Our research suggests there is a potential for multidirectional spillover effects among these commodities, arising from either the cost side or the demand side. Furthermore, this close relationship could accelerate the system's adjustment speed, mirroring the price fluctuations of the leading commodity (soybeans) rapidly. This rapid adjustment may lead to a perceived, yet misleading, causality in price movements (or price spillover) from secondary commodities (such as soybean meal and oil) to the broader market.

The second most noticeable spectrum of influence for soybean is the influence of this commodity on Barley (16.37%) and Wheat (14.15%) with the inverse influence being considerably lower for Barley at 10.55% and Wheat at 8.4 although still bidirectional. The third spectrum of influence of soybean is considerably lower Crude Oil (5.13% v 1.66%) , Sunflower oil (3.58% v 1.66%), Phosphate fertilizer (2.76% v 0.21%), Urea (1.92% v 0.59%), Natural Gas (1.9% v 0.41%) this means that the connectedness with this last group is considerably lower that from the beforementioned first and second, despite soybean still influence the price. Finally, soybean is mostly influenced by itself (32.19%).

Barley, ranking fourth (58%) and Wheat, in fifth place (42%), are respectively noted. However, with their negative net balances of -0.76% and -7.35% respectively being identified as net receivers, it becomes clear that Barley and Wheat are predominantly price followers in the agricultural commodities market. The relatively secondary position of Wheat and Barley in the agricultural commodity market could be attributed to their significantly lower total trading volumes (Lewis, 2023) compared to soybeans.

Following Crude Oil (28.21%), Sunflower Oil (18.72%), Natural Gas (13.02%), Urea (12.55%), and Di-ammonium Phosphate (DAP) (16.1%) demonstrate minor roles in price leadership. These commodities, classified as net receivers and price followers, are influenced to a larger extent than they influence others. For the case of Crude Oil the results are in line with Hung (2021) that using the connectedness approach show that the influence exerted by the crude oil market on the returns of agricultural commodities was less pronounced than the influence in the reverse direction, where agricultural commodity returns impacted the crude oil market. For the case of Sunflower Oil (Santeramo, Di Gioia and Lamonaca, 2021) (Santeramo, Di Gioia and Lamonaca, 2021) indicated a strong interconnectedness between various vegetable oils, particularly noting that sunflower oil prices are highly sensitive to changes. This implies that factors affecting the sunflower oil market are not solely internal but are also affected by fluctuations in other vegetable oil markets. These might explain the net receiver's behaviour of the sunflower market as well with the Russia-Ukraine conflict has had far-reaching effects on global trade dynamics. Specifically, it has resulted in a notable decrease in sunflower oil exports. This decline can be attributed to the closure of plants and ports in Ukraine, a major sunflower oil producer (CBI, 2022). Consequently, there has been a surge in demand for alternative oils, particularly soybean oil, as market participants seek to fill the gap left by the disruption in sunflower oil supply. This shift in demand has not only altered trade flows but has also underscored the interconnectedness of global commodity markets.

These results are highly intriguing, as they reposition energy commodities and fertilisers (Natural Gas, Crude Oil, and Fertilizer) to a secondary level, driven predominantly by certain agricultural products. The Natural Gas and Crude Oil net spillover receivers' behaviour at normal market conditions (Q 0.5) is difficult to explain. Firstly, despite the trading contract volumes for natural gas surpassing those of soybeans and all other commodities examined in this study (Lewis, 2023), this does not necessarily confer a leading position in the market or establish it as a net transmitter of price behaviour. However, these results align with the findings related to crude oil spillover, as previously mentioned by Hung (2021) , who assessed the behaviour of crude oil market spillovers and their impact on agricultural commodity markets.

ECIV 3.4.4. Network connectedness middle quantile (NC) (Q 0.5)

ECIV Chart 3 Network connectedness (NC) (Q 0.5).

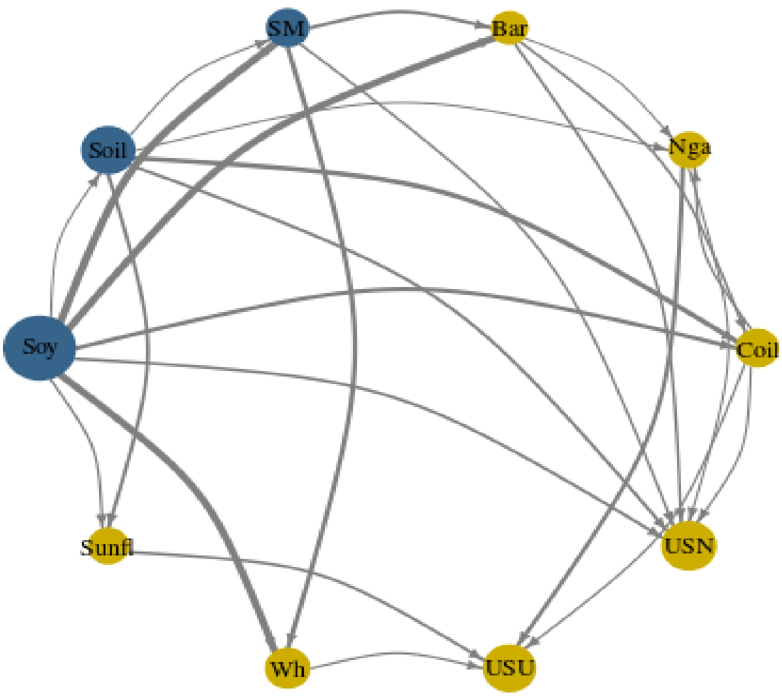


Chart 3 represents the Network Plot for quantile 0.5. As before mentioned, soybean plays the leading the studied market, being the main net transmitter followed by Soybean oil and Soybean meal. Together the three the only net transmitting leading the shocks spillover in the market Phosphate fertilizer and Urea the most susceptible commodities and net receivers.

ECIV 3.4.6. Net pairwise directional connectedness middle quantile (NPDC) (Q 0.5)

ECIV Chart 4 Net Pairwise Directional Connectedness (NPDC) (Q 0.5)

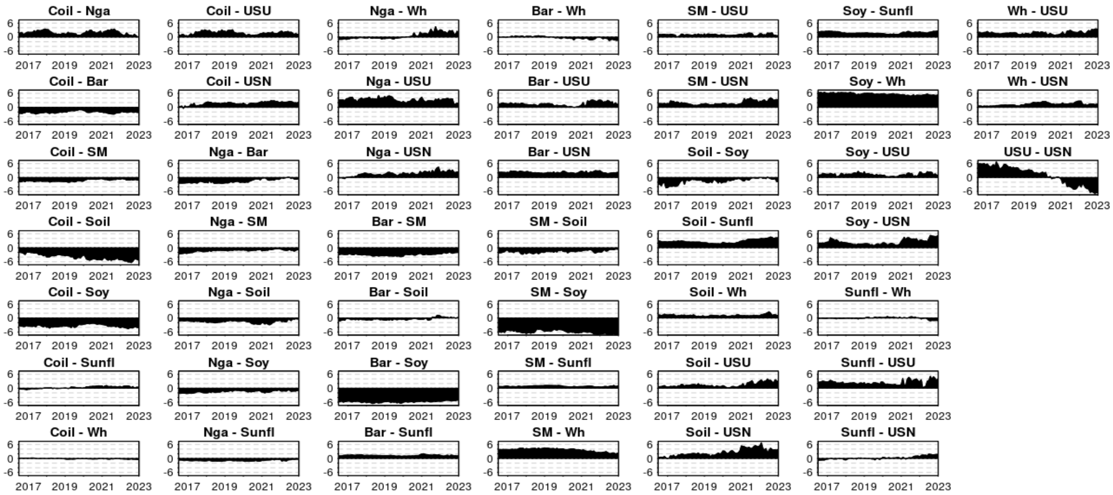


Chart 4 illustrates the Net Pairwise Directional Connectedness for the median Quantile, 0.5. This graphical representation allows us to interpret the direction of the spillover between pairs. A clear observation from the chart is the dynamic within the pair of crude oil and natural gas. Here, crude oil consistently shows a causal influence, transmitting shocks to natural gas throughout the entire period under consideration. This relationship was previously studied by Yorucu and Bahramian (2015) finding that the Crude oil prices and taxation have significant impacts on natural gas prices, suggesting a unidirectional relationship from crude oil to natural gas prices (Under normal market circumstances Q 0.5) In line Stavroyiannis (2020) research unraveled a unidirectional causality runs from the Dubai crude oil market to the US natural gas market, with the Dubai crude oil price positively affecting the US natural gas price.

A similar pattern can be seen between crude oil, urea, and phosphate, indicating that crude oil's price significantly influences the price of these fertilizer and energy commodities (Under typical market conditions, (UTMC) Q 0.5). This is in line with Batten, Ciner and Lucey (2017) research that investigated the time-varying price spillovers between natural gas and crude oil markets. While it focuses on natural gas and crude oil, the findings highlight the interconnectedness of energy markets, which could indirectly suggest similar dynamics might exist between crude oil and urea prices, given the energy-intensive nature of urea production (UTMC-Q 0.5).

The net pairwise directional connectedness amongst fertilisers, specifically urea and phosphate, presents an intriguing outcome. Until mid-2021, urea was the primary transmitter, while phosphate primarily received shocks. However, this dynamic experienced a reversal later on, with phosphate assuming the role of the main transmitter and urea becoming the primary receiver of shocks. The economic dynamics between urea and phosphate fertilisers are influenced by their production processes and global supply chains. Urea, a nitrogen fertilizer, is predominantly produced through the Haber-Bosch process, which heavily relies on natural gas, making its production dependent on natural gas price. Phosphate fertilisers, on the other hand, are derived from mined minerals, with major production concentrated in countries like China, the United States, India, Morocco, and Russia. This geographical concentration in production and the different base resources required for urea and phosphate fertilisers create a complex global trade dynamic, where disruptions in supply or geopolitical tensions can significantly impact global prices and availability. The Ukrainian-Russian conflict may limit Russia's ability to export phosphate, leading to reduced supply and increased prices for this commodity. Consequently, this could cause price rises in related commodities, such as urea, due to spillover effects. Prior to Russia's military action in Ukraine in February 2022, the world was already experiencing a surge in fertilizer costs. This increase was a consequence of the COVID-19 pandemic, which led to widespread disruptions in supply chains and transportation issues, affecting global fertilizer production and distribution (USDA, 2023). By August 2021, prices for most fertilisers had risen by 25 percent compared to March of the same year. The situation was further exacerbated by Russia's incursion into Ukraine early in 2022, which caused more disruptions in transportation, particularly in the Black Sea area, and led to the imposition of additional trade barriers. These developments further constrained the already limited supplies of fertilizer, resulting in a price spike of over 50 percent between February and April 2022 (USDA, 2023).

A study by Lakkakula (2018) specifically investigates the causal relationships among the prices of various fertilisers, including urea, diammonium phosphate (DAP), muriate of potash, rock phosphate, and triple super phosphate. The results indicate that urea prices exhibit a significant Granger-causal relationship with all other fertilizer prices, including diammonium phosphate (DAP). This suggests that fluctuations in urea prices serve as a strong predictor for subsequent changes in DAP prices, underscoring the interconnectedness of global fertilizer markets. Our findings align with Lakkakula (2018) up until 2021. However, utilizing the connectedness approach, we identified a shift in causality post-2021, likely driven by major geopolitical disruptions.

A key factor in this shift was the imposition of sanctions on Belarusian potash and phosphate fertilisers, which severely restricted global supply chains. In June 2021, the European Union (EU) banned imports of Belarusian potash, a critical input for phosphate fertilisers. The sanctions intensified in March 2022, when the EU prohibited the transit of Belarusian fertilisers through European ports, particularly affecting the Lithuanian port of Klaipėda, which previously handled a significant portion of Belarus' exports

Lahmiri and Bekiros (2018) study indicated that the recent global financial crisis had a significant impact on the cointegration and causal connections between fertilizer markets. Moreover, the crisis also influenced the asymmetry, leverage effects, and the enduring nature of shocks on fertilizer price volatility. The Ukrainian-Russian war might affect the casual connection between DAP and Urea inversing the relationship. Sanctions and trade constraints have reduced the export of fertilisers from Russia and Belarus, major players in the global production of nitrogen and potassium fertilisers. This has caused scarcities and a sharp rise in fertilizer costs. As a result, numerous farmers have transitioned from wheat to crops that require less fertilizer, such as soybeans, adding to the unpredictability in global food markets (Voora *et al.*, 2024).

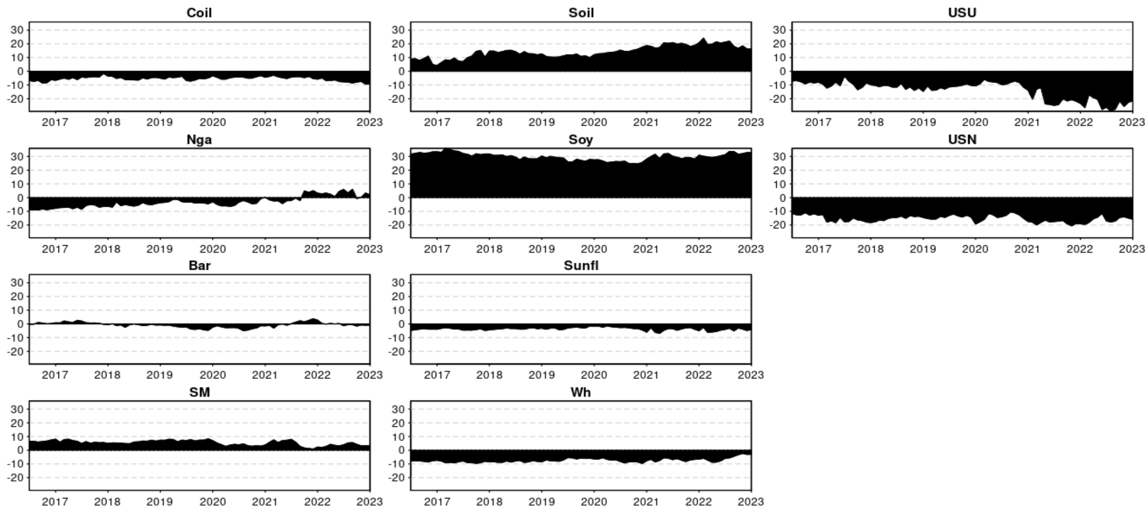
Another notable shift in causality was observed between Natural Gas and Wheat. Until 2020, Wheat was the dominant net transmitter, although Natural Gas assumed this role thereafter. This change may have been influenced by the occurrence of the Russian-Ukrainian war. This can be explained given that fertilisers are a significant input in wheat production, this relationship suggests that rising natural gas prices can indirectly impact wheat prices through increased production costs.

Similarity the Barley shift in Wheat's net directional causality could potentially be a consequence of Russian attacks on Ukrainian grain facilities, which hindered Ukraine's ability to export their wheat production. The Barley causality in Wheat was already reported (Dawson *et al.,* 2006) indicating that developments in the barley market can significantly influence wheat market prices. The Barley shift in importance have been previously reported by Just and Echaust (2022). As a result, the shift in causality led to the transmission of shocks from wheat prices to barley prices.

Soybean is unanimously the leading commodity across all studied pairs, always serving as the net transmitter for other commodities. The degree of directional connectedness is more pronounced among grains than energy commodities or fertilisers. This might imply that spillover primarily initiates from soybean to the grain market before reaching others such as energy commodities and fertilisers. Alternatively, it could indicate that shocks are more intensely transmitted between commodities with high cross-relatedness, such as grains. The data clearly underscores the significance of soybean in terms of causality and market leadership.

ECIV 3.4.7. Net Total Directional Connectedness (NTDC) Middle Quantile (Q 0.5)

ECIV Chart 5. Net Total Directional Connectedness (NTDC) (Q 0.5)

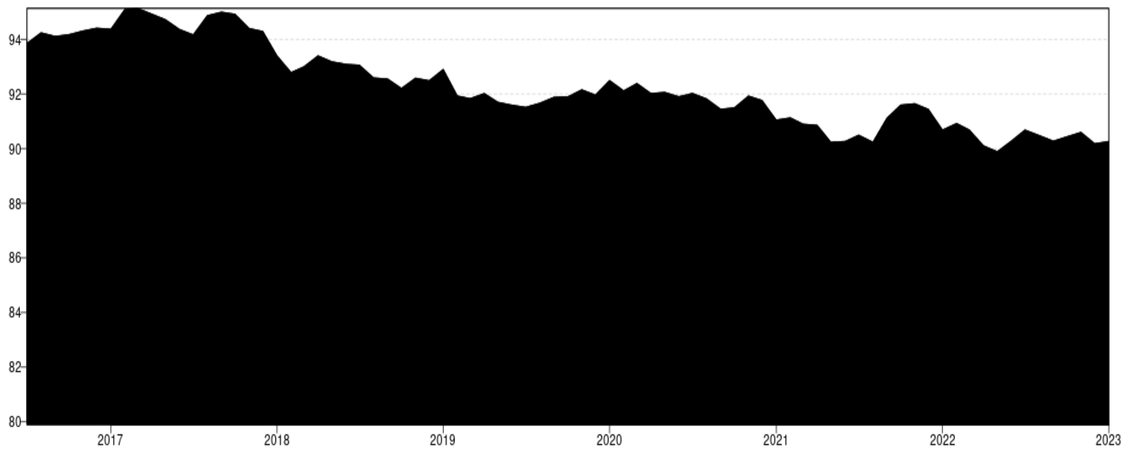


The Net Total Directional Connectedness provides an indication of the spillover direction for a specific commodity over the study period. If the sign is positive, this signifies that the commodity is a net transmitter of influence, whereas a negative sign indicates that the commodity is a net receiver. For the 0.5 Quantile (representing normal market condition) in line with Hung (2021) and in contrast with Balcilar, Gabauer and Umar (2021) for the studied market, crude oil has consistently been a net receiver throughout the entire period (Chart 5). Conversely, and in line with Ghosh and Paparas (2023) soybeans have persistently acted as a net transmitter. Soybean oil and soybean meal have displayed a similar pattern, albeit to a lesser extent. Natural gas was a net receiver up until the end of 2021, which may be correlated with the dispute between Russia and the European Union. Wheat has mostly behaved as a net receiver throughout the entire period, though a potential shift began in mid-2022. However, it is still too early to confirm this trend. Both urea and phosphate fertilizer have consistently acted as net receivers during the studied period. However, beginning in the first quarter of 2021, urea exhibited a heightened vulnerability to external shocks, likely stemming from the impact of the Ukrainian-Russian gas dispute on natural gas prices. Lastly, barley has fluctuated throughout the studied period, alternating between being a net receiver and transmitter of influence.

ECIV 3.6. Lower Quantile (Q 0.1)

ECIV 3.6.1. Total connectedness index (TCI) (Q 0.1)

ECIV Chart 6. Total Connectedness index (TCI) (Q 0.1)



In quantile regression, analyzing the TCI at the lower quantile, specifically the 0.1 quantile or the 10th percentile, offers unique insights, particularly in understanding the behaviour of a dependent variable under less typical conditions. This quantile focuses on the lower end of the distribution of the dependent variable. The 0.1 quantile TCI enables understanding how variables behave in terms of connectedness under less favorable or more extreme lower-end conditions, such as market downturns, low demand, or low prices. In the context of our research on agricultural and energy commodities, the TCI under 0.1 quantile allows you to understand the dynamics of these commodities during periods of significant market stress or downturns.

The total connectedness for the lower Quantile stands at 91%, indicating a substantial level of interconnectedness across the different commodities, the highest among the varying Quantiles. The overall trend exhibits a consistent decrease in connectedness over the studied period. Despite significant global events such as the US-China Trade War in January 2018, the outbreak of a global pandemic in 2019, or the Ukrainian-Russian conflict in February 2022, the lower quantile connectedness seems to have decreased and stabilized over time. (Chart 6). The diminished connectedness observed in the lower quantile correlates with negative price shocks. During events such as the pandemic and the Russo-Ukrainian conflict, it is plausible that the predominant external disturbances were positive shocks. These shocks primarily impacted the upper quantile, inducing inflationary pressures. These results align with those of Ghosh and Paparas (2023), who employed a similar methodology over a more extended period. Their study revealed that the connectedness within the agricultural commodities market consistently increased in the first quantile (Q1) from 1976, peaking during the subprime crisis of 2008-9. However, since 2018, there has been a steady decline in the system's connectedness.

Timeline & Key events.

1. 2017-2018: The TCI peaks in early 2017 and maintains a relatively high level throughout 2017 into early 2018. This period saw the beginnings of trade tensions between the U.S. and China, impacting commodity markets, including soybeans and other agricultural products. The peaks in TCI suggest heightened interconnectedness among commodities during this period, possibly due to market anticipation and reaction to trade policies.

2. 2018-2019: A dip in TCI occurs around mid-2018, coinciding with the escalation of the U.S.-China trade war. The trade conflict led to significant tariffs on various commodities, including soybeans, which were especially impacted due to China's role as a major buyer. This dip might reflect reduced interconnectedness as the soybean market and other commodities responded uniquely to trade measures.

3. 2020 (COVID-19 Pandemic): The TCI fluctuates and generally trends downward through 2020, which aligns with the onset of the COVID-19 pandemic. The global disruption caused by the pandemic affected supply chains, demand, and production across commodities, potentially leading to more isolated movements rather than synchronized trends.
4. 2021-2022 (Post-Pandemic Recovery and Russia-Ukraine Conflict): In 2022, following a period of fluctuation throughout 2021, the Total Connectedness Index (TCI) experienced a notable decline. This dip can be attributed in part to the repercussions of the Russia-Ukraine conflict on global commodity markets. The conflict led to significant disruptions in key sectors such as wheat, oil, and energy, likely diminishing overall interconnectedness, particularly among the lower quantiles. Conversely, there was an observed increase in connectedness among the higher quantiles, notably within the 0.9 Q (Positive Shocks) range. Additionally, the lingering inflationary effects of the pandemic contributed to price hikes, particularly evident in the upper quantile.

Overall, the TCI (Q 0.1) chart shows fluctuations that appear to align with major global economic events, reflecting changes in the interconnectedness of commodity markets, especially during periods of extreme market conditions like trade wars, pandemics, and geopolitical conflicts.

ECIV 3.6.3. Average dynamic connectedness (ADC) lower quantile (Q 0.1)

ECIV Table 3 Average Dynamic Connectedness (ADC) (0.1 Q)

	Coil	Nga	Bar	SM	Soil	Soy	Sunfl	Wh	USU	USN	FROM
Coil	17.56	7.95	10.18	9.1	11.44	10.24	5.73	9.4	8.84	9.57	82.44
Nga	9.5	21.92	8.88	9.4	9.38	10	6.57	8.8	7.84	7.71	78.08
Bar	9.63	7.91	14.08	10.34	11.38	11.88	6.23	11.23	9.18	8.13	85.92
SM	7.44	6.9	11.29	18.23	10.96	16.64	5.6	11.25	6.26	5.42	81.77
Soil	9.43	7.07	10.72	10.44	17.19	13.8	6.17	10.3	7.65	7.22	82.81
Soy	8.04	6.59	11.58	13.94	13.32	16.21	5.57	11.23	7.5	6.02	83.79
Sunfl	9.86	8.22	9.41	8.83	10.8	9.89	16.07	9.23	8.71	8.98	83.93
Wh	8.18	7.37	11.56	11.97	10.7	12.31	5	19.31	7.05	6.55	80.69
USU	11.77	8.58	9.26	8.39	11.02	9.6	6.23	9.7	16.01	9.43	83.99
USN	10.72	9.05	10.11	9.64	10.72	10.62	6.37	9.77	9.96	13.05	86.95
TO	84.55	69.66	93	92.06	99.72	104.97	53.47	90.91	73	69.02	830.36
Inc. Own	102.11	91.58	107.08	110.3	116.91	121.18	69.54	110.22	89	82.07	TCI=91%
NET	2.11	-8.42	7.08	10.3	16.91	21.18	-30.46	10.22	-11	-17.93	
NPT	4	3	7	6	8	9	0	5	2	1	

Table 3 presents a bi-directional interplay among various markets. The commodity that proves to be the most influential for the 0.1 Quantile is Soybean, displaying a spillover transmission of 105% and a net average dynamic connectedness (ADC) of 21%. It is closely followed by Soybean oil, which exhibits a spillover transmission of 99.72% and a net ADC of 16.91%. This results in in contrast with Ghosh and Paparas (2023) for the Q1 that showed on the first place and second place as in terms of net spillover on the system was held by Palm oil and wheat respectively. This discrepancy can be attributed to the significantly longer research period in Ghosh and Paparas (2023) study compared to ours. Considering that the prominence of soybean has only emerged in the last 20 years, and Ghosh and Paparas (2023) research spanned the past 63 years, the importance of soybean becomes apparent only in the most recent two decades. The increasing importance of soybeans over the last 20 years can be attributed to several factors, including its role as a substitute product, the socio-economic impacts of its trade, and the influence of agricultural policies and market demands Boerema *et al.* (2016).

While the specific influence of soybeans on the 0.1 quantile of agricultural commodities is not directly addressed in literature review, previously collectively suggest that soybeans, as a key agricultural commodity, have a significant impact on market dynamics, particularly in extreme market conditions (Jiang *et al.*, 2016)

For this Quantile, Barley, with an ADC of 93%, supersedes Soymeal, which has an ADC of 92% and a net ADC of 7.08%. Barley transitions from being a net receiver (Q 0.5) to a being net transmitter (Q 0.1).This finding is in line with Just and Echaust (2022) suggested that the peak of spillover effects during the Russia-Ukraine conflict significantly impacted commodities produced in those countries, as evidenced by the cases of barley and wheat.

Despite being displaced by Barley, Soybean Meal maintains its position at fourth place overall, although it ranks third in terms of net ADC 10.22%. Both Wheat (ADC 90, Net 10.22) and Crude Oil (ADC 84.6 %, Net 2.11) shift from their previous roles as net receivers to net transmitters, providing a stark contrast to the trends observed in the middle Quantile. These results uncover the potential of Barley, Wheat and Crude Oil to shift from net receivers to net transmitter within the lower and medium quantile. In simpler terms, our findings highlight the capacity of these three commodities to propagate spillover effects during economic downturns

In the lower Quantile, Soybean again claims the top spot as the most influential commodity. However, the magnitude of influence in terms of risk of spillover for this Quantile has reduced for Soybean Oil (13.8%) and Soybean Meal (16.64%), in comparison to the medium Quantile (21.36% and 30.53%), this finding is in line with Ghosh and Paparas (2023). This pattern is also mirrored in the second sphere of influence, which includes Barley (11.8%) and Wheat (12.31%). In contrast, the third spectrum, comprising Crude Oil, Natural Gas, and Fertilizer, exhibits an inverse pattern. Here, the influence of Soybean significantly escalates, leading to a substantial increase in the magnitude of the negative shocks transmitted to Crude Oil, Natural Gas, and Fertilizer. As previously mentioned, Crude oil has significantly increased its total spillover transmission to other commodities, resulting in the highest absolute spillover to fertilisers like Urea (increasing from 3.27% to 11.77%) and Phosphate (rising from 5.29% to 10.72%). The influence of Crude oil on different commodities has risen within the 0.1 Quantile. Crude oil has notably shifted from being a net receiver to a net transmitter of negative shocks. Demonstrating a similar pattern, Wheat and Barley have also experienced a shift from being net receivers to becoming net transmitters. Overall, within this Quantile, the interconnectedness is considerably higher. As a result, the transmission of shocks has also increased across all different commodities within the studied sample. However, only some have managed to turn the net difference into a positive balance, transitioning from being net receivers to net transmitters. (Table 3)

ECIV 3.6.5. Network connectedness (NC) lower quantile (Q 0.1)

ECIV Chart 7 Network Connectedness (NC) (Q 0.1)

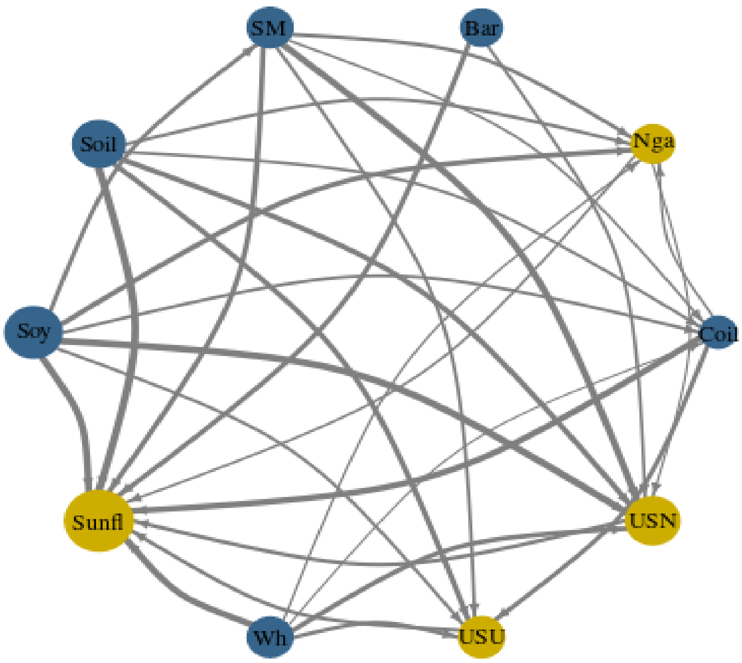
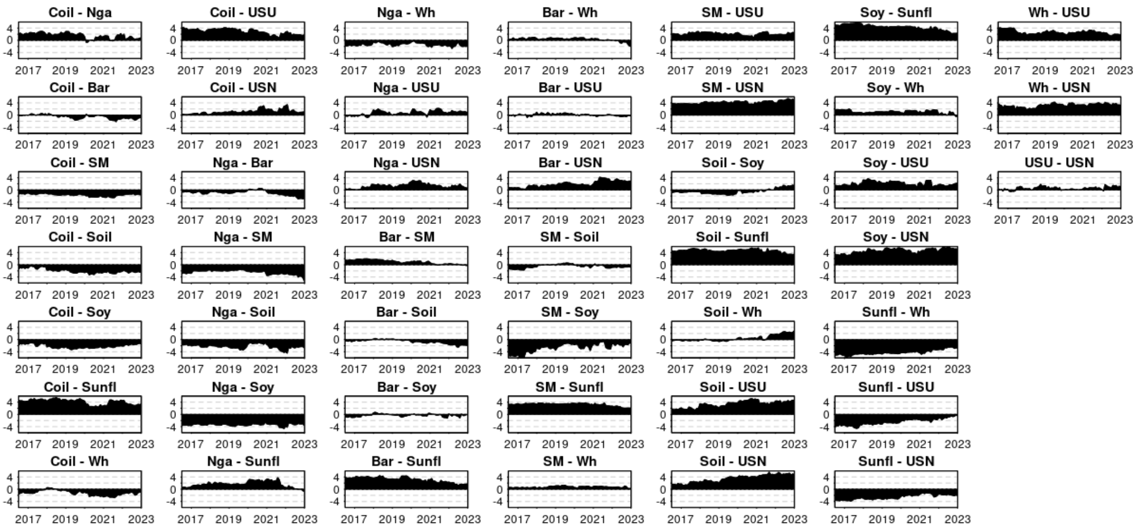


Chart 7 illustrates the Network Plot for the 0.1 quantile, representing the intricate interconnections among different agricultural commodities within this range. For this quantile, which represents negative shocks; Soybeans and Soybean sub-products continue to dominate as leading net transmitters. This trend is not evident in Ghosh and Paparas (2023) investigation, where soybeans, wheat, and palm oil equally dominate. This discrepancy could be due to the longer time span covered in their research.

It becomes evident that Crude Oil has also started to assume a transmitter role following the line of Balcilar, Gabauer and Umar (2021). Barley and Wheat have emerged as the second most influential group following Soybeans and Soybean sub-products. Just and Echaust (2022) has pointed the same regarding the growing influence of Barley post Pandemic and during the Ukrainian and Russian war. Additionally, Sunflower oil has seen a drastic surge in its position as a net receiver , receiving substantial influence from almost all commodities in line with (Santeramo, Di Gioia and Lamonaca, 2021).

<u>ECIV 3.6.7. Net pairwise directional connectedness (NPDC) lower quantile (Q 0.1)</u>

ECIV Chart 8. Net Pairwise Directional Connectedness (NPDC) (Q 0.1)



From the Net Pairwise Directional Connectedness chart (Chart 8), it can be inferred that soybean generally holds the most influence position within the lower Quantile of commodities. This finding contrast with Babar, Ahmad and Yousaf (2023) that investigated the return and volatility spillover among agricultural commodities and emerging stock markets, including soybean. They identified soybean as a large recipient of spillover over time, indicating it may not predominantly act as a net transmitter in this scenario. The variance in results could be attributed to the distinct methodology employed by Babar, Ahmad and Yousaf (2023) specifically the Global Vector Autoregressive (GVAR) model. Additionally, the inclusion of stock prices from various futures markets in their sample might have contributed to the differences observed.

However, this influence can vary depending on the rolling windows being considered. For instance, the Barley-Soybean pairwise directional connectedness fluctuated notably at the start of 2018, and again in 2021, with soybean regaining its dominant role afterwards. This transient emergence of barley as a significant transmitter of shocks was previously detailed by Just and Echaust (2022).The same is clearly observed in the pair Crude Oil and Barley where a shift on causality happen around mid-2018 , emerging Barley as the main shocks transmitter. Interestingly Zivkov, Kuzman and Subic (2019) found a strong transmission effect from oil only in the tail quantiles (Q1 and Q2) in longer time horizons, particularly for barley. This suggests that barley prices may be affected by oil in periods of increased market turbulence. In summary, the relationship between soybeans and barley seems to remain stable with occasional fluctuations likely due to changes in trade, weather, global demand, and energy prices.

A similar pattern is observable in the Soybean Oil-Soybean pairing. Here, soybean has typically been the primary shock transmitter until 2022, when soybean oil began to exert greater influence over soybean, this last behaviour is in line with Simanjuntak *et al.* (2020) findings. Furthermore, soybeans played a leading role in transmitting shocks to wheat. However, as of the start of 2023, wheat has begun to surpass soybean in terms of net shock transmission. This last fact might be related with the influence of Russian-Ukranian war as before explained by Just and Echaust (2022). In summary, the stable relationship between soybeans and soybean oil reflects the direct processing link, but fluctuations arise due to factors like biodiesel demand, trade policies, and global vegetable oil market shifts.

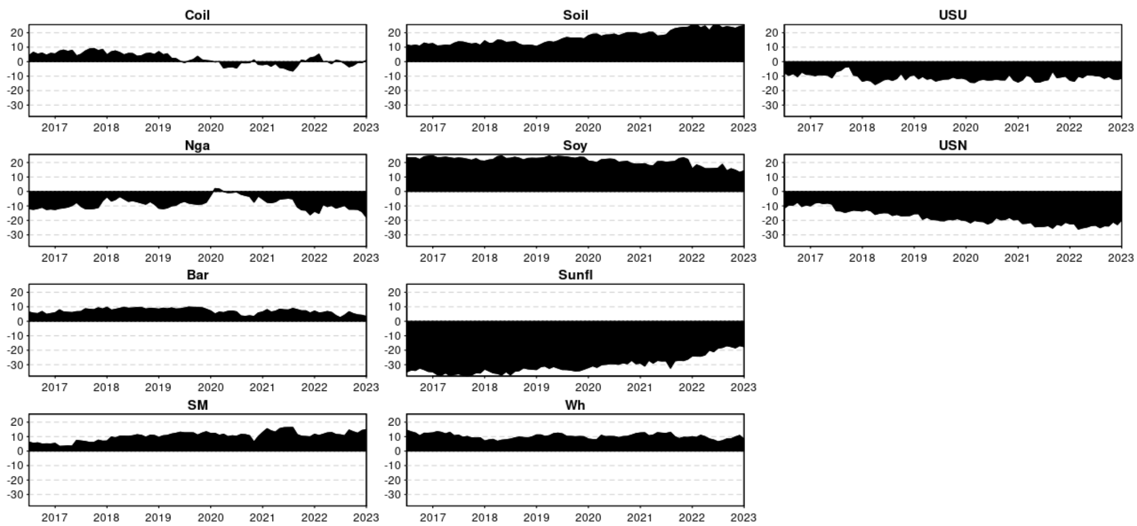
Upon examining the energy commodities more closely, for the considered Quantile, Crude Oil predominantly led the spillover transmission over Natural Gas for almost the entire research period, barring an early peak when the net transmission was briefly positive for Natural Gas over Crude Oil. Crude Oil maintained its position as the chief conduit for spillover transmission to both energy commodities and fertilisers. This phenomenon can be considered time varying depending time windows selected for example Batten, Ciner and Lucey (2017) for the period 1994 to 2014 studied time-varying price spillovers between natural gas and crude oil markets, finding that, contrary to earlier research, natural gas prices led the price of crude oil with spillover effects lasting up to two weeks. However, after 2006, the price dependencies between these two energy commodities weakened, suggesting increased independence in price determination. In summary, the relationship between crude oil and natural gas generally remains stable due to their interconnected roles in the energy sector. Fluctuations arise from substitution effects, production dynamics, and global economic or geopolitical factors.

Natural Gas, meanwhile, proved to be a consistent net transmitter of shocks to fertilisers, specifically Urea and Phosphate, throughout the entire period. While direct research on the spillover effects of natural gas prices on urea prices is limited, the existing studies emphasize the critical role of natural gas as a primary input in urea production. This suggests that fluctuations in natural gas prices are likely to have a significant impact on the production costs and market price of urea (Zhang *et al.*, 2021) .In summary, natural gas has a direct and strong influence on urea due to its role in production, while it influences phosphate fertilisers more indirectly through overall energy costs and market factors.

Although there is a low degree of directional connectedness between the fertilisers Urea and Phosphate within the lower Quantile, Urea emerges as the net shock transmitter in line with Lakkakula (2018).

ECIV 3.6.9. Net total directional connectedness (NTC) lower quantile

ECIV Chart 9. Net Total Directional Connectedness (NTDC) Lower Quantile (Q 0.1)

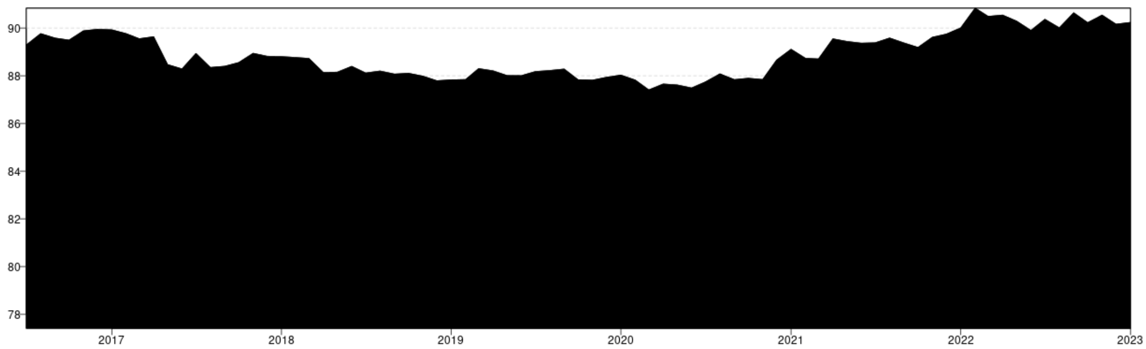


The Total Directional Connectedness for the lower Quantile demonstrates a shift in the behaviour of crude oil around mid-2019. This finding are in line with Balcilar, Gabauer and Umar (2021). Crude oil not only influences other commodity markets, but it is also equally affected by other commodities innovations. Crude oil began to alternate roles between acting as a net transmitter and a net receiver of shocks. Prior to this period, crude oil was consistently classified as a net transmitter. This represents a stark contrast to its behaviour within the middle Quantile, where it was predominantly characterized as a net receiver. This can be clarified by stating that during market turbulence, crude oil can either transmit volatility to other commodities or absorb it from them. For this lower Quantile, Natural Gas, Urea, Phosphate, and Sunflower oil function as net recipients of spillovers. Contrary to their behaviour in the middle Quantile, Wheat and Barley emerge as net shock transmitters in this Quantile. Furthermore, Soybean continually manifests itself as the primary transmitter of spillovers in the studied commodity markets, despite a downward trend in its connectedness. In stark contrast, Soybean Oil and Soybean Meal have displayed an increasing trend in net connectedness. Lastly, while Sunflower's susceptibility to external shocks has grown compared to the middle Quantile, the trend indicates a decrease in its impact from the year 2020 onwards.

ECIV 3.7. Upper Quantile (Q 0.9)

ECIV 3.7.1. Total connectedness index (TCI) (Q 0.9)

ECIV Chart 10 Total Connected Index (TCI) (Q 0.9)



Analyzing the TCI in upper quantile, specifically the 0.9 quantile or the 90th percentile, provides insights into the behaviour of the dependent variable in the upper segment of its distribution. The 0.9 quantile helps in understanding the connectedness of the variables under more favorable or more extreme upper-end conditions. This could include scenarios like market booms, high demand, or high prices. In the context of our research on agricultural and energy commodities, the 0.9 quantile TCI allows us to understand the dynamics of these commodities during periods of significant market booms or upturns. For example, examine how a substantial increase in natural gas prices influences the prices of fertilisers or agricultural commodities in the upper end of their price distribution.

The chart 10 illustrates the total connectedness among different commodities for the upper Quantile, currently at 87%. This relatively high level of connectedness, although slightly lower than the 91% observed in the lower Quantile, signifies an intense interplay among various commodities. Contrary to expectations, the overall trend demonstrates stable connectedness throughout the COVID-19 pandemic, this is in line with Ghosh and Paparas (2023) Q 0.9 results. However, an escalation was seen during the intensification of the Ukrainian-Russian conflict, leading to a peak in the connectedness. The conflict caused a major shift in the supply and price of key commodity markets. This change has been one of the most significant since the 2008 financial crisis, indicating a heightened level of connectedness among these commodities and global financial markets (Alam *et al.*, 2022). The upper quantile exhibits a propensity to absorb positive shocks. This suggests that during the period of conflict, the disturbances in prices were predominantly positive, leading to inflationary pressure on prices.

Timeline & Key events.

1. 2017-2018 (Trade War Onset): Early stages of the U.S.-China trade war. The market disruptions due to tariffs likely led to interconnectedness shifts as supply chains adapted to the new trade environment. However, the TCI remained relatively stable, indicating a consistent level of connectedness during this period or lag effect (200 days rolling windows).

2. 2018-2019 (Trade War Escalation): Escalation of trade tensions and tariffs, as tariffs continued to increase, global commodity markets experienced volatility. The TCI showed a slight increase in connectedness, indicating that commodities became more intertwined, likely as markets reacted to changes in trade policies.

3. 2020 (COVID-19 Pandemic): Despite the global economic turmoil, the TCI remained relatively stable. This aligns with findings from similar research (Ghosh and Paparas, 2023), suggesting that during market downturns, the interconnectedness may not increase significantly or a lag effect.

4. 2021 (Post-Pandemic Recovery): Recovery efforts and supply chain issues.The TCI slightly fluctuated but maintained a high level of connectedness, reflecting the impact of heightened demand and ongoing supply chain disruptions in various markets.

5. 2022 (Russia-Ukraine Conflict): The TCI showed a peak during this period, indicating heightened interconnectedness due to supply disruptions and increased prices for key commodities like energy, fertilisers, and agricultural products. The conflict's impact caused one of the most significant market shifts since the 2008 financial crisis, driving inflationary pressures and positive price shocks.

The TCI (Q 0.9) chart highlights that the connectedness between commodities generally remained high and stable, reflecting the interconnected nature of these markets. Significant peaks during the Russia-Ukraine conflict underline the substantial market changes and inflationary pressures that followed, suggesting that during periods of conflict and market booms, commodity markets are highly interdependent.

ECIV 3.7.3. Total connectedness index upper quantile (Q 0.9)

ECIV Table 4. Total Connectedness Index (TCI) Upper Quantile (Q 0.9)

	Coil	Nga	Bar	SM	Soil	Soy	Sunfl	Wh	USU	USN	FROM
Coil	22.28	7.83	8.22	8.89	11.56	9.91	5.68	7.67	8.81	9.16	77.72
Nga	9.13	19.96	8.65	9.78	9.15	9.31	7.11	8.69	9.82	8.4	80.04
Bar	8.46	6	19.16	12.21	11.18	12.88	6.44	11.12	6.38	6.15	80.84
SM	7.14	6.64	10.37	18.43	11.29	16.66	5.74	11.42	6.12	6.19	81.57
Soil	9.31	6.16	9.5	10.94	18.5	14.32	6.19	10.37	7.62	7.1	81.5
Soy	7.31	5.76	10.66	15.97	13.94	17.87	5.34	11.2	6.15	5.8	82.13
Sunfl	7.67	5.86	8.44	8.49	10.25	8.58	28.66	7.05	5.97	9.03	71.34
Wh	6.92	7.27	10.4	12.47	12.26	12.99	4.19	19.53	6.93	7.05	80.47
USU	8.75	8.38	9.08	9.09	9.88	9.7	6.39	8.9	19.68	10.15	80.32
USN	8.68	7.38	8.06	10.28	11.45	11.25	6.29	8.89	11.7	16.02	83.98
TO	73.38	61.28	83.37	98.11	100.96	105.6	53.37	85.3	69.51	69.04	799.9
Inc.Own	95.65	81.24	102.53	116.54	119.46	123.48	82.02	104.83	89.19	85.06	TCI=87%
NET	-4.35	-18.76	2.53	16.54	19.46	23.48	-17.98	4.83	-10.81	-14.94	
NPT	3	0	4	7	8	9	2	6	3	3	

Table 4, which outlines the TCI in the upper quantile (Q 0.9), reflects how interconnected various commodities are, especially under conditions of market booms, high prices, or high demand. This level of analysis helps in understanding which commodities influence others the most and the intensity of their impact in the commodity market ecosystem. The TCI value is 87%, indicating that commodities have a significant spillover effect on each other, revealing high levels of interconnectedness during favorable market conditions.

Soybean remains the most influential commodity in the upper quantile with a total spillover of 105.6% and a net transmission of 23.48%. Its influence permeates through the market, significantly impacting other commodities, particularly soybean oil (19.46%) and soybean meal (16.54%). The importance of soybeans in global food supply chains and biodiesel production is a major factor in its significant influence. These findings approximate to Ghosh and Paparas (2023) results and are in line with Babar, Ahmad and Yousaf (2023) results. Soybean maintains its influential position across all quantiles examined. This consistency highlights its importance in both lower and higher market conditions, affirming the critical role it plays in global agriculture and energy sectors.

Soybean oil holds the second position with a total spillover of 100.96% and a net transmission of 19.46%. This shows that soybean oil's influence is also substantial, impacting not only other vegetable oils (Sunflower 13.94%) and the soybean complex (Soybean 13.94%, Soymeal 18.43%) but also the broader agricultural market due to its role in the food and energy sectors (Barley 11.18% , Wheat 12.26%, Natural Gas 9.15%, Crude Oil 11.56%, USU 9% and USN 11.45%). Its strong influence remains consistent across quantiles, further highlighting its importance. The soybean oil industry’s ties to both food processing and biodiesel production contribute to its significant impact.

Soybean meal ranks highly with a spillover of 98.11% and a net positive balance of 16.54%. This illustrates its significant impact on animal feed and agricultural markets. The livestock industry’s reliance on soybean meal as a protein source underscores its importance. Soybean meal’s influence surpasses that of barley and Wheat (NET 2.53% & 4.86%), particularly in the upper quantile, showcasing its critical role in higher market conditions due to its extensive use in livestock feed.

Wheat and barley are notable in the secondary sphere of influence, with wheat having a spillover of 85.3% and barley at 83.37%. The net transmission rates are 4.83% for wheat and 2.53% for barley. These cereals significantly impact the food sector and are key to food security globally. Their consistent position in the secondary sphere across all quantiles demonstrates their steady influence on the global market. Wheat and barley are staples that retain their importance regardless of market conditions.

With a total spillover of 73.38% and net transmission of -4.35%, crude oil remains a significant player in the commodity market. Despite being a net receiver at this quantile, it transitions to a net transmitter at lower quantiles, showing the versatility of its influence depending on market conditions. Total spillover for Sunflower oil is at 53.37% and net transmission at -18%. Its relatively lower impact compared to soybean oil reflects its smaller share in the global edible oil market.

Phosphate Fertilizer (USN) and Urea (USU) with spillovers of 69% and 69.51%, respectively, and negative net transmissions (-14.94% and -10.81% respectively), these fertilisers are net receivers. Their dependency on energy markets for production costs ties their influence closely to commodities like crude oil (9.16%v8.68% and 8.81%v8.75% respectively) and natural gas (8.4%v7.38% and 9.82%v8.38%, respectively).

Natural Gas (Nga**)** with a total spillover of 61.28% and net transmission of -18.76%, natural gas is a significant energy commodity but remains a net receiver in this quantile. The gas dispute with Russia has notably increased market volatility, causing it to receive more shocks rather than transmit them (Alam *et al.*, 2022).

The soy complex, comprising soybeans, soybean oil, and soybean meal, shows significant influence across the quantiles. Their combined impact on global agriculture and energy markets is crucial due to their roles in food supply chains and biodiesel production. Wheat and barley maintain a stable secondary sphere of influence across quantiles, highlighting their critical roles as global staple crops. Their influence remains relatively consistent, reflecting their importance in global food security. The tertiary sphere, which includes commodities like crude oil, sunflower oil, natural gas, and fertilisers, primarily acts as a net receiver of positive shocks. However, their influence fluctuates significantly across quantiles. For instance, crude oil transitions from a net transmitter in lower quantiles to a net receiver in higher quantiles, reflecting its changing dynamics in different market conditions. The significant volatility in the natural gas market, particularly due to geopolitical issues like the Russia-Ukraine conflict, has had ripple effects on the fertilizer market, affecting urea and phosphate prices. This reinforces the interconnectedness between energy markets and agricultural inputs.

In the upper quantile, commodities demonstrate varying degrees of interconnectedness, heavily influenced by their respective roles in the global market. The soybean complex retains its dominant influence, while staple grains like wheat and barley maintain steady secondary influence. The tertiary sphere, including crude oil and fertilisers, reflects the intricate relationships between energy markets and agricultural inputs. Understanding these interconnected relationships can help market participants navigate the complex dynamics of global commodity markets, especially in favorable or extreme conditions.

<u>ECIV 3.7.5. Network connectedness (NC) upper quantile (Q 0.9)</u>

ECIV Chart 11. Network Connectedness (NC) (Q 0.9)

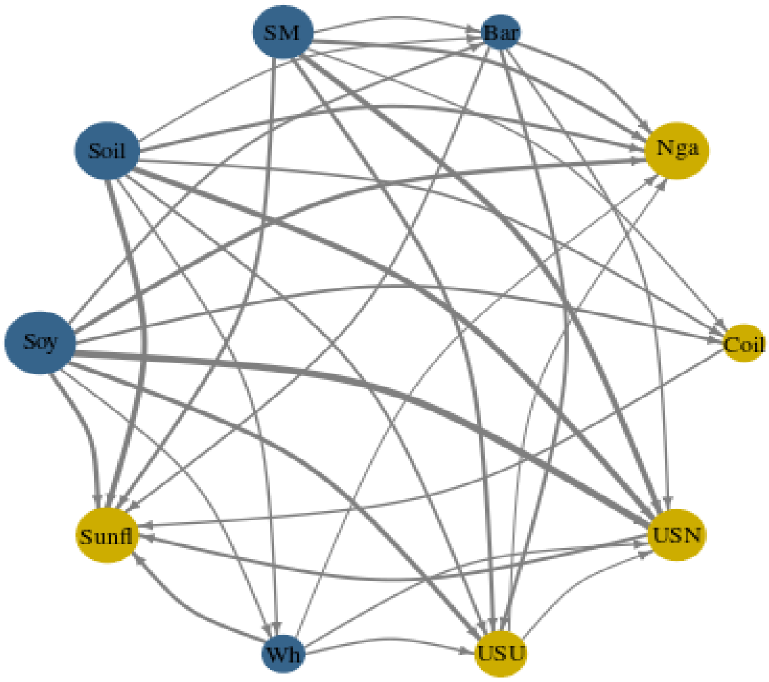


Chart 11 provides a visual representation of the Network Plot for the 0.9 quantile, highlighting the complex links between various agricultural commodities within this bracket. Once more, for these Quantiles and throughout all of them, Soybean and Soybean products hold the position of leaders in the transmission of price shocks, affecting other markets. The roles of Barley and Wheat as net transmitters resurface in this Quantile, as well as in the lower Quantile, in line with Just and Echaust (2022) although this trend is not observed in the middle Quantile. Crude Oil reverts to being a net receiver, as in the middle Quantile, and only remains a net transmitter in the lower Quantile. There is a noted lack of interconnection between Crude Oil, Natural Gas, and Phosphate Fertilizer. In contrast with Sanyal, Malczynski and Kaplan (2015) investigation that evaluated how volatility in crude oil and natural gas prices affects fertilizer price variations. It was found that changes in oil and natural gas prices increased fertilizer prices after a crisis period, indicating a significant effect of energy prices on fertilizer prices.As previously described, Sunflower oil appears to be considerably impacted by most commodities. Finally, a spillover effect is evident between Natural Gas and Urea, which seems to flow from Natural Gas to Urea.

ECIV 3.7.7. Net pairwise directional connectedness (NPDC) upper quantile

ECIV Chart 12. Net Pairwise Directional Connectedness (NPDC) Upper Quantile (Q 0.9)

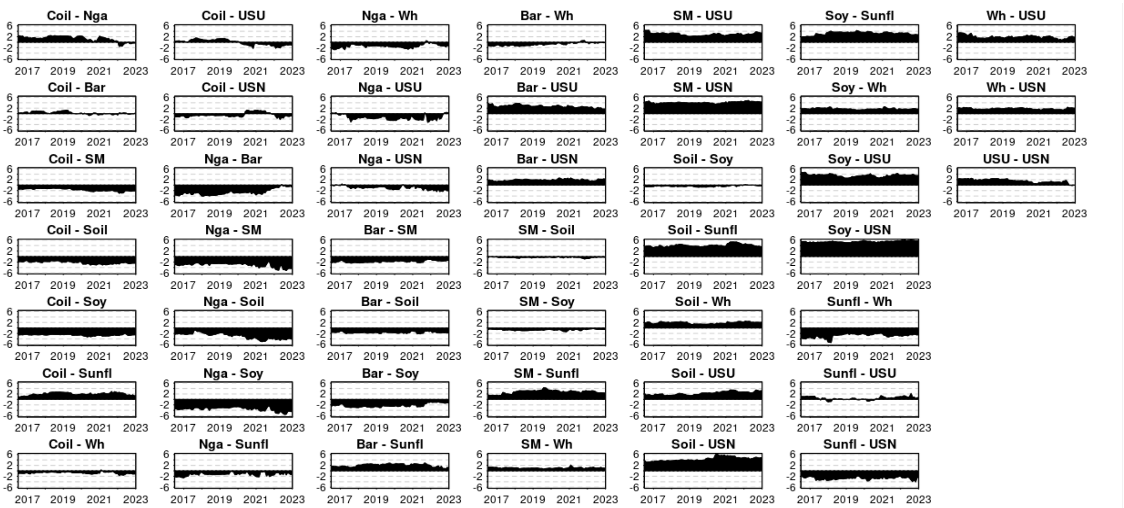


Chart 12 in detail provides a comprehensive understanding of the interconnectedness between commodity pairs under extreme upper-market conditions. This chart captures the influence between commodities, especially during favorable market conditions like market booms and high prices. By understanding each pair’s relationship, we can discern the broader market dynamics in the agricultural and energy sectors.

Around 2022, natural gas emerged as a significant net transmitter compared to crude oil, a shift influenced by geopolitical tensions. The Russia-Ukraine conflict and the subsequent dispute between Russia and Europe severely disrupted the natural gas market. Europe’s dependency on Russian gas led to significant supply chain disruptions when Russia reduced or halted gas supplies, causing a surge in natural gas prices (Skrzyński, 2023). As a result, natural gas became a major influencer in the commodity market, impacting the prices of fertilisers and agricultural commodities that rely on it for production. Crude oil, while still influential, saw its relative impact diminish in favor of natural gas during this period. Hartley, Medlock and Rosthal (2008) proposed this phenomenon, highlighting that supply shocks can induce deviations from long run equilibrium.

The relationship between crude oil and urea also shows a significant shift. By the end of 2020, urea emerged as a more significant net transmitter than crude oil. This could be linked to the gas dispute between Europe and Russia during the Ukraine-Russia war. The influence of urea grew in the market, reflecting the increasing cost pressures in the fertilizer industry (Khan, Khan and Khan, 2020; Awasthi, 2023). As agricultural production relies heavily on fertilisers like urea, any increase in fertilizer prices directly impacts agricultural costs, creating ripple effects throughout the food supply chain.

The connection between crude oil and phosphate fertilisers reveals an oscillating relationship in net transmission. These fluctuations highlight the delicate balance between energy prices and fertilizer production (Olagunju, Feng and Patton, 2021). Phosphate fertilisers depend on energy inputs, and shifts in global energy markets affect their production and pricing. The interplay between crude oil and phosphate fertilisers demonstrates how global market volatility can influence these commodities' roles as either transmitters or receivers.

Moving to the agricultural sector, soybeans consistently operate as a net transmitter, particularly affecting soybean oil. This strong relationship is due to soybeans being the primary input for soybean oil production, and it has already been described by Simanjuntak *et al.* (2020). The stability of this relationship underscores the fundamental nature of their connection. Soybeans' influence on soybean oil remains consistent regardless of market conditions, reflecting their integral role in the global food supply chain. Even during favorable market conditions (0.9 Q), where demand for both soybeans and soybean oil remains high, soybeans continue to exert a significant impact in contrast with Simanjuntak *et al.* (2020).

In examining the soybean-barley relationship, soybeans consistently emerge as net transmitters. The demand for soybeans, driven by their extensive use in animal feed and biodiesel production, impacts other grains like barley. This interconnectedness is maintained throughout the entire study period, reflecting the consistent global demand for soybeans and their effect on other grains. The agricultural sector's reliance on soybeans ensures their influence extends to related markets like barley, particularly in periods of high demand and favorable prices. Previous empirical evidence neither supports nor refutes this finding. However, the research conducted by Alvarez Prado *et al.* (2013) suggests a positive correlation between double-cropping systems involving soybeans and barley, indicating an interconnected relationship between the two commodities. Contrary to the lower Quantile, there is no fluctuation in the net pairwise connectedness sign between Barley and Soybean over the entire period studied. Instead, Soybean consistently operates as a net transmitter, exerting influence on Barley. For the upper Quantile, the increase in connectedness is not as clear as it is in the lower Quantile, nor as it was demonstrated in previous empirical research by Just and Echaust (2022).

Wheat and soybeans also share a stable relationship in the upper quantile. Unlike the lower quantile, there is no significant shift in causality in this upper quantile, indicating a consistent relationship between these staple crops. Their stable relationship is influenced by their roles as global staples, with steady demand across market conditions. The significance of both wheat and soybeans in ensuring global food security cannot be overstated. Their mutual importance is evident through the symbiotic relationship fostered by the double-cropping system and their intertwined role in animal feed production (Kyei-Boahen and Zhang, 2006; Santos Hansel *et al.*, 2019).

Crude oil's relationship with other commodities, like sunflower oil and barley, also provides insights into the broader market dynamics. The influence of crude oil on these commodities (Barley (Zivkov, Kuzman and Subic, 2019), Sunflower (Potori and Stark, 2015)) is indicative of the integral role energy prices play in agricultural production. As energy prices fluctuate, so do the production and transportation costs for agricultural commodities, affecting their supply and pricing. This relationship remains consistent, demonstrating how changes in energy markets influence agricultural commodities. Potori and Stark (2015) assessed the influence of crude oil futures on sunflower seed futures in Hungary. The study highlighted a significant correlation between crude oil and sunflower seed prices, emphasizing the impact of crude oil on the sunflower oil market. The findings align with Potori and Stark (2015) conclusions until 2020, after which the relationship becomes less distinct and more variable.

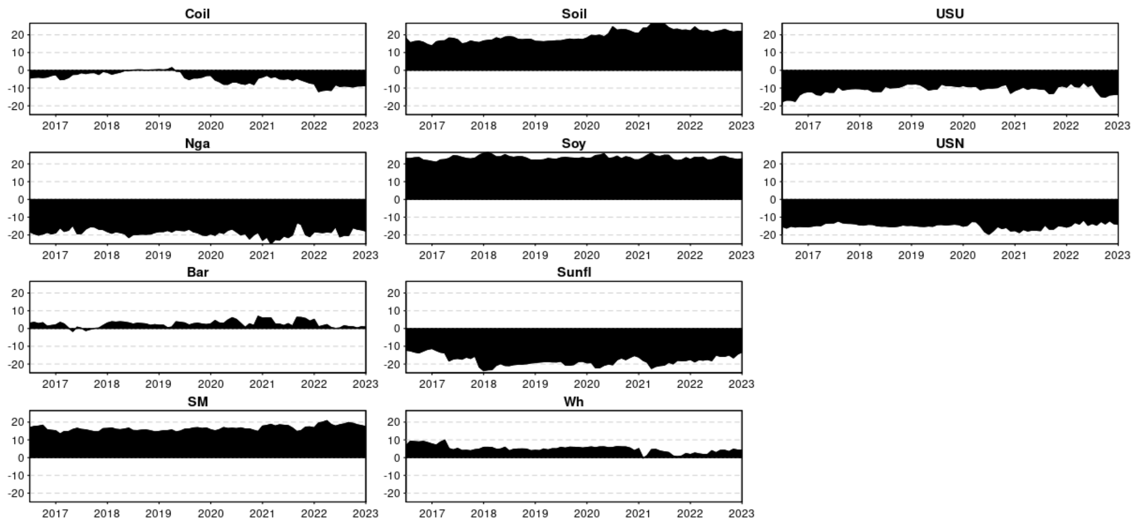
Barley and wheat show a close relationship, with barley often acting as a net receiver to wheat. This interconnectedness is influenced by their roles as staple grains in the global food supply chain. Both commodities are subject to similar market pressures (Kifle, 2016), including trade policies (Kingwell, 2020), weather events (Lobell and Field, 2007), and global demand shifts. Their stable relationship across market conditions demonstrates the importance of staple grains in global food security.

Soybean meal's influence also stands out in the upper quantile, reflecting its critical role in the livestock feed industry (Tomičić *et al.*, 2020). The relationship between soybean meal and other commodities, like barley and wheat, is influenced by the interconnectedness of the feed industry. The consistent demand for soybean meal, driven by its high protein content, ensures its influence extends across the agricultural sector. Its connection to soybeans and other grains reflects the integrated nature of the feed and food supply chains.

Soybeans and their derivatives, such as soybean oil and soybean meal, consistently influence other commodities due to their critical roles in global food supply chains and biofuel production. The energy sector, particularly natural gas and crude oil, also plays a significant role, influencing agricultural commodities through their impact on production costs. The chart reveals how market dynamics, influenced by geopolitical events, energy prices, and global demand shifts, create intricate relationships between commodities, reflecting the complex interplay between agriculture and energy in the global market.

ECIV 3.7.9. Net total directional connectedness (NTDC) upper quantile (Q 0.9)

ECIV Chart 13. Net Total Directional Connectedness (NTDC) Upper Quantile (Q 0.9)



The chart 13 displays the net total directional connectedness (0.9 Q) for selected commodities from 2017 to 2023, Crude oil predominantly remains a net receiver of market volatility throughout the period, except for brief intervals in late 2018 and mid-2019 when it acts as a net transmitter. This implies that crude oil often reacts to changes in other commodities, with limited instances of influencing others significantly. This finding reveals a negative correlation between crude oil and agricultural commodities (soybean and its derivatives, barley, and wheat) (0.9 Q). This correlation aligns with the observations made by Tiwari *et al.* (2021) , which highlighted similar dynamics. Furthermore, the presence of this negative correlation suggests a potential for hedging opportunities. Soybeans consistently exhibit characteristics of a net transmitter, affecting other commodities throughout the entire period. Its role in global agriculture and susceptibility to supply-demand changes ensure that its price fluctuations significantly influence interconnected markets in line with Ghosh and Paparas (2023).

Following a similar pattern to soybeans, soybean oil also remains a net transmitter. This reflects the considerable influence of soybean oil in food and biofuel markets, where its price shifts create substantial spillover effects. Nazlioglu and Soytas (2011) have found significant spillover effects from soybean oil prices to related markets, indicating its role as a transmitter of market information. For instance, correlations between soybean oil and other vegetable oils, such as palm oil, highlight the interconnectedness of these markets and the transmission of price changes. Soybean meal mirrors soybeans in consistently acting as a net transmitter, emphasizing its significance in global markets. Its influence primarily stems from its crucial role as animal feed (Nazlioglu and Soytas, 2011). Wheat typically functions as a net transmitter, though its level of influence is significantly lower than that of the soybean complex. Its connectedness varies moderately, which corresponds to changes in supply and demand. Building upon the findings of Jia *et al.* (2016), which proposed that the transmission of volatility from the US wheat futures market to China requires more time compared to soybean futures, implying a diminished level of spillover from wheat to other commodities

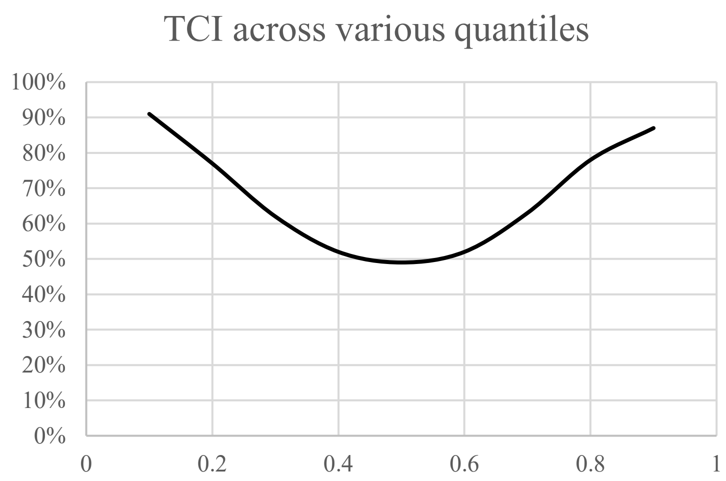
Natural gas demonstrates high volatility, often absorbing external shocks from other commodities (Net receiver). This volatility reflects the inherent instability in the global natural gas market. Natural gas prices exhibit high volatility compared to other energy commodities, primarily due to external shocks that arise from fluctuations in supply and demand, geopolitical events (Hailemariam and Smyth, 2019; Zhu, 2023). Sunflower oil exhibits a similar pattern to natural gas, being highly susceptible to external shocks and prone to market instability. Its connectedness with other markets underlines its vulnerability to broader commodity market trends. For instance Ukraine's sunflower oil market has experienced growth before hostilities and export capacity expansion, but hostilities have negatively impacted the market due to supply chain disruptions and volatile prices Makarchuk (2022). Barley consistently shows characteristics of a net transmitter, though its influence is more subdued compared to soybeans. This suggests that barley's impact on market interconnectedness, while present, is less pronounced.

Fertilizer prices, specifically Urea and DAP are reflected in the chart as USU and USN, respectively. These fertilizer markets influenced mostly net spillover receivers, present varying levels of connectedness, signifying their responses to changes in supply and demand exogenous shocks and other commodities spillovers (Rezitis, 2015; Olagunju, Feng and Patton, 2021).

Overall, the chart demonstrates the complex web of interconnectedness among various commodities, with soybeans and their derivatives prominently impacting global price volatility. Conversely, crude oil, natural gas, and sunflower oil are generally more affected by external market factors.

ECIV 3.9. TCI over various quantiles

ECIV Chart 14. TCI Over Various Quantiles



The Chart 14 represents how connectedness varies across different market conditions, specifically by examining the 0.1 (lower), 0.5 (median), and 0.9 (upper) quantiles. The TCI indicates how interconnected different commodities are, providing insights into their influence on each other across various market conditions. The chart shows that connectedness is highest in the extreme quantiles (0.1 and 0.9), and it gradually decreases towards the median quantile. In simpler terms, this suggests that commodity markets exhibit greater interconnectedness during extreme market conditions, whether in downturns or booms, compared to average conditions.

This pattern indicates a significant degree of similarity in market behaviour during periods of high volatility, whether it is a negative shock (such as a downturn or market crash) or a positive shock (like a market boom or bull run). Both the upper and lower quantiles exhibit relatively similar connectedness values, reflecting the absence of asymmetric price transmission among the commodities studied. This implies that when prices change significantly in one direction, it tends to uniformly affect the prices across all commodities.

An example of this uniformity can be seen in the peaks and falls of the TCI across the quantiles. During periods of significant market events, such as the COVID-19 pandemic or the Russia-Ukraine conflict, the commodities exhibit increased interconnectedness. For instance, the global supply chain disruptions during the pandemic impacted energy and agricultural commodities alike, leading to widespread increases in connectedness. Similarly, the Russia-Ukraine conflict created spikes in interconnectedness, particularly in the agricultural and energy sectors.

The median quantile, representing more stable market conditions, shows a relatively lower TCI, indicating reduced interconnectedness among commodities. This reflects a more stable and predictable market environment, where commodity prices are less prone to extreme spillover effects. This pattern highlights the uniform nature of price changes across commodities, suggesting that market disruptions, regardless of their direction, tend to have a broadly similar impact on interconnectedness among commodities.

ECIV 3.10. Granger causality test

ECIV Table 5. Granger Causality Matrix

	Soy	SM	Soil	Wh	Bar	Sunfl	Coil	Nga	USU	USN
Soy		O	→	O	O	O	O	O	O	↔
SM	O		O	O	O	O	O	O	O	O
Soil	←	O		O	→	O	O	O	O	→
Wh	O	O	O		O	O	O	O	O	←
Bar	O	O	←	O		←	O	O	←	O
Sunfl	O	O	O	O	→		O	O	O	O
Coil	O	O	O	O	O	O		→	O	O
Nga	O	O	O	O	O	O	←		↔	→
USU	O	O	O	O	→	O	O	↔		←
USN	↔	→	←	→	O	O	O	←	→	

O *indicates no causal relationship.

← *indicates that the series in the left row is affected by the time series in the selected column.

→ *indicates that the series in the left row Granger-causes the time series in the selected column.

↔ *indicates that the series in the left row has a bidirectional causality with the time series in the selected column.

Table 5 presents all pairwise causal relationship among the time series in granger causal sense (g-causality). This approach Granger causality is a statistical concept used to determine whether one time series can predict another time series. It is important to note that the term "causality" in this context does not imply a cause-and-effect relationship in the traditional sense; instead, it focuses on the predictive capacity of one series over another. Thus, it cannot be directly compared with the connectedness index approach. However, it remains valuable for contrasting these results with those of the connectedness analysis and complementing the findings. The first notable observation is the almost absence of Granger-causal relationships within the soybean complex. Historically, this crop and its derivatives have exhibited significant influence over most commodities. According to this methodology, these commodities may not serve as reliable predictors for others. While soybean has demonstrated an influence on soybean oil (Soil), leading to a Granger-causal relationship with the latter, this relationship is also confirmed by the connectedness approach. However, in lower Quantiles, the relationship can shift, revealing a bidirectional causality.

Soymeal (SM) stands out as the only commodity in our sample that does not display a causal relationship with other commodities. This absence could be due to a lack of statistical power in the Granger test, especially considering that soybean meal is derived from soybeans. Intuitively, it should possess a causal relationship with its primary source.

Argentina as the leading exporter of soybean meal, commanding a substantial 33% share of the global market, this country plays a pivotal role in shaping international trade dynamics for this commodity. The Argentine government's interventions in the soybean sector specifically through export tariffs and the manipulation of the currency exchange market can create significant distortions in the price formation mechanisms of soybean meal. Such state-led actions can fundamentally reconfigure the market landscape, precipitating shifts in the economic structure that are not readily discernible through conventional econometric models, including the Granger causality analysis.

These policy instruments wield the power to mold market expectations and incite speculative behaviour among traders and other market participants. As agents within the market strive to pre-emptively respond to anticipated policy manoeuvres (Change of government, tariff decrease or increase, flexibilization of the currency market), resulting speculative activity can induce price movements that are decoupled from underlying market fundamentals, thereby fading genuine causal linkages or cointegration relationships. Furthermore, the element of policy-induced uncertainty injects a heightened degree of volatility into the market. This volatility does not merely complicate the task of detecting stable time series relationships it calls for a more nuanced analytical framework that can accommodate the complex interplay of policy interventions, market responses, and the resultant economic ramifications.

Soybean oil is Granger-caused by soybean (SOY) and in turn Granger-causes DAP (USN) and barley (Bar). This relationship is corroborated in the pairwise directional connectedness (Q.1 & Q.9). However, other causal relationships evident in the Connectedness approach are not present in the Granger test. This discrepancy appears for the majority of the studied commodities, hinting at a potential limitation in the statistical power of the Granger approach. Similarly, wheat does not exhibit any causality with other crops or energy commodities, being solely influenced by phosphate fertilizer (USN). This is counterintuitive, especially considering that the primary fertilizer for wheat production is urea, yet the observed causal relationship is only with DAP (USN).

Barley (Bar) emerges as the most Granger-caused commodity in the matrix, influenced by soybean oil (Soy), sunflower oil (Soil), and urea (USU). The causal relationship with urea is intuitive from a cost perspective, given that urea is a primary input in barley production. However, the pairwise directional connectedness suggests a bidirectional causality, with barley often driving the price spillover. As previously noted, sunflower oil only Granger-causes barley and does not manifest other causal relationships. Yet, the connectedness approach reveals that the sunflower oil market is highly unstable and significantly impacted by other commodities, positioning it as one of the top net receivers.

Crude oil (Coil) exhibited only one causal relationship, Granger-causing natural gas. While this relationship may initially seem intuitive, since the price of natural gas (Nga) in the European market closely linked to the price of crude oil, given the present significance of conventional long-term contracts that are indexed to the cost of petroleum products (Ramberg and Parsons, 2012). The intricate relationship between crude oil and natural gas prices has been a focal point of various empirical studies. Through the application of the NARDL model, research highlights that crude oil prices exert influence on gasoline and natural gas prices, although this influence is neither direct nor linear. Instead, it is characterized by its asymmetric and nonlinear nature, leading to diverse price transmission mechanisms that hold substantial implications for policy (Atil, Lahiani and Nguyen, 2014). Furthermore, the role of global economic trends and dynamics cannot be overlooked. Ji, Geng and Fan (2014) suggest that the global economic milieu, coupled with fluctuations in international crude oil valuations, critically shapes the long-term relationship of regional natural gas import prices. This reiterates the intricate weave of global economies and their impact on energy markets. However, when delving deeper into the interconnections of these markets, the researchers suggest that the primary factors influencing their interactions are demand-side shocks. Interestingly, these shocks have a more pronounced effect than any shifts or alterations in the crude oil supply (Zamani, 2016). Empirical evidence by Hartley, Medlock and Rosthal (2008) indicates that this nexus is mediated through the competition at the margin between natural gas and residual fuel oil. This nuanced understanding suggests that market dynamics are shaped by a multitude of competing forces, each with its own set of influences and implications.

The absence of other causal relationships of crude oil (Coil) with other commodities contradicts the connectedness approach, which indicates that crude oil actively influences other commodities. This discrepancy also contrasts with previous empirical findings (Margarido, Araujo Turolla and Ferreira Bueno, 2014;

Stavroyiannis, 2020; USDA, 2023), however is in line with Zhang and Reed (2008) and Gilbert (2010).The bidirectional causal relation between natural gas (Nga) and urea (USU) appears logical. Yet, the pairwise directional connectedness primarily shows that its natural gas driving the shock transmission, with occasional shifts in causality during the studied period. Lastly, urea (USU) is Granger-caused by USN (DAP). The connectedness approach indicates this only occurs in the middle Quantile, with a notable causality shift in 2021. However, in extreme Quantiles, urea dominates over USN. This results are in contrast with by Lakkakula (2018) that found that the price of urea Granger causes all other fertilizer prices, including DAP.

Interestingly, USN emerges as the commodity with the most causal relationships, Granger-causing soybean (Soy), soymeal (SM), wheat (Wh), urea (USU), and even itself, while being influenced by natural gas (Nga), soybean oil (Soil) , and natural gas (Nga). The connectedness approach indicates that USN is a net receiver, strongly connected with most commodities. However, its net directional connectedness balance remains consistently negative, revealing a commodity highly susceptible to shocks across various markets.

Finally, it is imperative to acknowledge the bidirectional causality observed among certain commodities, particularly between Soybean (Soy) and DAP (USN). Notably, Soybean and DAP exhibit a bidirectional causal relationship. This phenomenon can be attributed to the interdependence of these commodities, where DAP (USN), as a key input in soybean cultivation, influences and is influenced by soybean production dynamics. However, when examining the net pairwise directional connectedness across different market conditions ,specifically at the median (Q0.5), lower (Q0.1), and higher quantiles (Q0.9) a distinct pattern emerges. The connectedness analysis reveals a consistent spillover effect from Soybean to USN, indicating that, irrespective of market fluctuations, Soybean predominantly acts as the source of net price spillover. This insight underscores the nuanced interactions between these commodities and their significant impact across various market scenarios. For example, Silva *et al.* (2017) suggested that the expansion of soybean production in Brazil, driven by international trade dynamics with China, indirectly impacted the fertilizer market significantly increasing the demand for phosphate fertilisers.

ECIV 4. Conclusion

The research discerned pronounced patterns in the extreme quantiles (0.1 & 0.9) during the studied period, approximately 91% and 87% of connectedness. This study discovered that complexity intensifies as it approaches the extreme quantiles (Appendix I). The interconnectedness and dynamics of the soybean market reflect a web of relationships with significant global implications. Analyzing the interplay among various agricultural and energy commodities offers deep insights into market trends and influences, particularly in the context of recent geopolitical events, like the conflict between Ukraine and Russia and the post pandemic era.

Our research findings indicate that soybeans and their derivatives consistently hold a leading position in international markets, acting as the primary source of price spillovers. This was particularly pronounced in the upper quantile (0.9 Q), where the influence of soybeans and soybean meal remained stable, while the risk of spillovers from soybean oil, barley, and wheat intensified, especially during geopolitical conflicts (Ukranian-Russian conflict).

The symmetric nature of spillover effects was evident, with both extreme tails exhibiting high connectedness (0.1 & 0.9) and highlighting the symmetric price transmission. Examining quantiles further clarified the complexities within the interconnectedness of global commodity markets. In the medium quantile (0.5), the Total Connectedness Index (TCI) was lower, indicating a more stable environment with reduced volatility in price spillovers (Normal market conditions). However, the upper quantile revealed a starkly different picture. Here, connectedness surged, reflecting a spike in interdependence across commodities due to market volatility. This phenomenon was heavily influenced by geopolitical crises, like the Russia-Ukraine conflict, which led to significant supply chain disruptions and price increases in both energy and agricultural sectors. The shifting dynamics of price transmission also showcased the impact of energy markets on agricultural commodities. Crude oil consistently acted as a shock transmitter to other energy commodities and fertilisers, particularly natural gas and urea at the lower quantile (0.1 Q). This relationship is reflective of the broader interconnectedness between global energy and agricultural markets.

Interestingly, the interplay between fertilisers and energy commodities demonstrated varying degrees of influence across quantiles. Urea dominated in transmitting shocks to natural gas in the lower quantile, but this relationship reversed later, with natural gas becoming the primary shock transmitter. This suggests a complex interplay influenced by factors like supply chain disruptions and geopolitical tensions that shape the dynamics of agricultural input markets.

Finally, the global soybean market and its interconnectedness with other commodities vividly highlight the cascading effects of major geopolitical events on market dynamics. The pandemic, US-China trade war, and the Russian-Ukrainian conflict each played a significant role in shaping the global commodity markets. The pandemic caused unprecedented disruptions in supply chains, leading to unpredictable shocks, and underscoring the vulnerability of global trade networks. The US-China trade war revealed the resilience of markets, as trade flows adapted to circumvent tariff barriers, yet still left a lasting impact on agricultural prices and supply chains. The Russian-Ukrainian conflict, however, had the most profound spillover effect, markedly intensifying market interconnectedness across energy and agricultural commodities, as seen in the significant spikes in prices and volatility. Together, these events underscore the importance of understanding and managing interconnectedness and risk spillovers in an increasingly complex and unpredictable global market.

ECIV 4.1. Policy implications

In an increasingly globalised market, the interconnectedness of agricultural and energy commodities presents intricate dynamics, as demonstrated by the connectedness approach in this study. This research sheds light on these dynamics, highlighting the systemic importance of these commodities not only in international trade but also in national security and welfare. Recent geopolitical disturbances, such as the Russia-Ukraine conflict, exemplify the interconnected nature of these markets and the far-reaching consequences of such conflicts. Spillover effects can occur across different types of commodities, even without direct relationships between them.

ECIV 4.1.1. Primary material commodities (soybean, barley, wheat)

- Systematic Reevaluation: Given the pivotal role of primary commodities like Soybean in transmitting market shocks, a systematic reevaluation of their importance is crucial.

- Diversification Strategy: Nations heavily dependent on specific commodities should expand their sourcing strategies and consider alternative options or investigate potential substitutes. This diversification is vital for fostering resilient economies, as exemplified by soybeans, which are a primary protein source for animal feed. The global reliance on soybeans has elevated its prominence among other crops and energy commodities, potentially leading to soybean assuming a role of price leadership and influencing price dynamics across various markets.
- Encouraging the adoption of sustainable practices such as the Round Table on Responsible Soy (RTRS) certification and promoting deforestation-free soybean production are vital strategies to mitigate environmental challenges. These approaches help prevent deforestation, particularly in vulnerable regions like the Amazon and Cerrado, by enforcing strict land-use criteria. Additionally, RTRS certification promotes best agricultural practices, including efficient fertilizer management, which reduces nitrogen pollution and soil degradation. By prioritising RTRS-certified and deforestation-free soybeans, we can significantly diminish the environmental footprint of soybean cultivation, addressing both contamination and deforestation issues, while fostering a more sustainable and responsible agricultural sector.

ECIV 4.1.2. Derived products (Soybean Oil, soybean meal and sunflower oil)

- Risk Profile Assessment: The escalating risk profile of derived products like Soybean Oil in geopolitical contexts necessitates targeted strategies to manage these risks. Another significant issue is the pronounced volatility in the sunflower oil market, which is a net receiver of spillover. This instability is heavily influenced by fluctuations in the majority of other commodity markets.

ECIV 4.1.3. Substitutes

- Encouraging research into substitutes for primary commodities is essential, particularly given the context of market volatility and supply chain disruptions. Similarly, developing alternatives to soy meal for animal feed is crucial for reducing global reliance on soybeans and mitigating the environmental impact of soybean cultivation.

- Policy Support: Implement policies that support the adoption and scalability of these substitutes, ensuring they are economically viable and accessible.

ECIV 4.1.4. Fertilisers commodities (DAP & urea)

- Ensuring Availability: Policymakers must ensure the consistent availability of essential fertilisers like DAP & Urea through domestic production incentives, strategic trade partnerships, or subsidy frameworks.
- Risk Profile Assessment: Agricultural enterprises, farmers, and financial institutions must recognise the interconnections among various agricultural commodities, energy resources, and fertilisers. This is particularly crucial concerning the relationship between natural gas and urea. Price shocks in natural gas directly impact urea prices. Furthermore, urea and DAP (Diammonium Phosphate) are integrally linked with all agricultural crops, with fertilisers often acting as the primary receiver of price spillovers in these markets

Furthermore, the study underscores the need for a paradigm shift in energy policies, advocating substantial investments in renewable energy sources to balance environmental stewardship with strategic imperatives. The role of essential fertilisers in agricultural productivity emphasises their indispensability in this matrix.

The insights concerning extreme quantile behaviour, which often delineate market volatility patterns, could be instrumental in establishing robust early warning systems. Financial institutions and regulatory bodies must consider these interconnectedness insights, refining financial instruments, derivatives, and risk evaluation methodologies.

Having presented a detailed analysis of the international soybean market through various empirical lenses, including price transmission, market integration, and dynamics connectedness, we now transition to a discussion of these findings. This discussion aims to synthesise the insights gleaned from the empirical chapters, highlighting the broader implications of geopolitical events, market interventions, and structural shifts within the global soybean market. By integrating these results, we can better understand the complex interactions and emerging trends that define the market's current landscape.

Chapter 7: Discussion.

This discussion provides a comprehensive integration of the findings across multiple empirical chapters , with a focus on understanding the dynamics of the soybean market and related agricultural commodities in light of geopolitical events such as the US-China trade war and the Ukrainian-Russian conflict. The chapter evaluates market efficiency, price transmission, and the effects of government interventions on different markets. This chapter lays the foundation for practical implications and policy recommendations derived from these findings.

7.1. Market Efficiency and Integration in Soybean Markets: A Comparative Analysis

Empirical research emphasises the vital role of market Liberalisation in facilitating efficient and symmetrical price transmission, as well as enabling rapid responses to international demand fluctuations. The contrasting developments in soybean production between Brazil and Argentina vividly illustrate this point. In Brazil, the government's non-interventionist stance allowed the soybean industry to prosper, resulting in substantial economic gains and establishing the country as a global price leader in soybeans. Carneiro Filho and Costa (2016) attribute this growth to the absence of restrictive policies, which permitted Brazil to fully exploit opportunities in the international market.

In stark contrast, Argentina's soybean sector has been impeded by various government-imposed restrictions, including export tariffs and fixed export quotas. Phélinas and Choumert (2017) note that these interventions have limited Argentina's ability to sustain growth and achieve its economic potential in the soybean industry. The restrictive policy environment led to the migration of farmers and capital to neighbouring countries with more favourable market conditions, such as Paraguay and Uruguay, as observed by Vassallo *et al.* (2011). These divergent trajectories underscore the profound impact of government policies on market efficiency and international competitiveness.

When examining market integration, mixed outcomes from different cointegration tests highlight the superior statistical power of the Johansen cointegration test, as suggested by Bilgili (1998). While the Engle-Granger test produced inconsistent results in the presence of market interventions, the Johansen test, along with the Enders and Siklos (2001) cointegration test accounting for asymmetry, effectively detected cointegration. This implies that market interventions introduce exogenous shocks that can erode cointegration relationships over time, but the Johansen test is more adept at adjusting for structural breaks. The initial phase of the second chapter concluded that, despite some tests failing to identify cointegration, the Johansen and Enders and Siklos tests indicated a high degree of market integration with long-term relationships among the series studied.

Regarding asymmetric price transmission, the application of Momentum Threshold Autoregressive (MTAR) and Threshold Autoregressive (TAR) models found no evidence of asymmetry across all examined markets, following the variable arrangements from the first empirical chapter. This suggests that although market interventions may temporarily disrupt market equilibrium, efficient arbitrage mechanisms eventually restore symmetrical long-term relationships. These findings contrast with those of Penone and Trestini (2022), who utilized a Threshold Vector Error Correction Model (TVECM) and identified asymmetric price transmission between the Chicago Board of Trade and the Italian spot market. The differing results may be attributed to variations in the markets analysed or the methodologies employed.

The finding that price transmission is symmetric and that the various soybean market prices remain cointegrated even in the face of exogenous shocks like government intervention or climatic disruptions speaks to the market's remarkable resilience and adaptability. It suggests that despite temporary perturbations or structural breaks, arbitrage processes work effectively to restore long-run equilibrium, ensuring that shocks are transmitted evenly across markets. This equilibrium, in turn, provides market participants with confidence that prices will eventually converge, reinforcing the fundamental tenet of the law of one price. The efficient, symmetric adjustment of prices implies that the international soybean market possesses an inherent ability to absorb and adapt to disturbances, ultimately preserving a stable and integrated global trading system.

In the contemporary global trading system, governments are increasingly attempting to balance the advantages of market freedom with targeted interventions aimed at protecting and promoting strategic industries (Boschiero and Silingardi, 2023). Recent policy trends reveal that while market Liberalisation remains the cornerstone of international economic cooperation, many countries are now embracing a more nuanced approach that permits selective state intervention (Kolesnikova and Stepnov, 2023). This hybrid strategy appears to align with the evidence that unrestricted market openness tends to foster efficient and symmetrical price transmission, while carefully calibrated interventions can provide necessary safeguards without permanently disrupting market integration.In practice, nations that adopt open-market policies tend to enjoy the benefits of rapid adjustment and effective arbitrage, as demonstrated by the resilient performance of Brazil's soybean market. Brazil’s non-interventionist stance has not only allowed its soybean sector to flourish but has also reinforced the global principle of the law of one price. However, In recent years, Brazil has witnessed a notable intensification of governmental intervention in its soybean sector, marked by the implementation of tax policies at both federal and state levels. In June 2024, President Luiz Inácio Lula da Silva enacted a provisional measure that restructured the tax credit system for commodity exporters and processors, effectively increasing their fiscal obligations(The Cattle Site, 2024).

Concurrently, state governments have introduced additional fiscal measures targeting soybean exports. Notably, the states of Maranhão and Pará have imposed export taxes of 1.8% and a fixed rate per bag, respectively. (S&P Global Commodity Insights, 2025). Tax changes affecting soybean exports can influence Brazil's competitiveness in the international arena. For example, adjustments in tax policies may render Brazilian soybeans less competitive compared to those from other producers, such as the United States, potentially leading to shifts in global supply chains.

The experience of countries that impose significant restrictions, such as Argentina, highlights the risk that overzealous government intervention may hinder growth, distort price signals, and ultimately undermine international competitiveness . Paradoxically and in stark contrast to Brazil. Argentina has adopted a divergent approach by implementing policies aimed at reducing export taxes and providing preferential exchange rates to bolster its soybean sector. In January 2025, the Argentine government announced a temporary reduction in export taxes on key agricultural commodities, including soybeans. Effective from January 27 to June 30, 2025, the export tax on soybeans was decreased from 33% to 26%, while taxes on soybean oil and meal were reduced from 31% to 24.5% (USDA, 2025). This policy shift aims to alleviate the financial strain on producers caused by low global commodity prices, high production costs, and adverse weather conditions, thereby enhancing the profitability and global competitiveness of Argentine farmers.

While international bodies like the World Trade Organisation continue to promote free trade as the default policy framework, many governments are supplementing this framework with measures designed to protect national interests. Such measures include targeted subsidies, export controls, and temporary regulatory adjustments aimed at mitigating external shocks or addressing domestic structural weaknesses.

Recent changes in the U.S. administration, marked by Donald Trump's re-election, have reignited trade tensions between the United States and China. Although soybeans have not been directly subjected to new tariffs, the evolving trade environment has significantly impacted purchasing behaviors. Chinese buyers have increasingly favored Brazilian soybeans, driven by concerns over potential future tariffs and a strategic shift toward securing more stable supply chains. This transition has also been reinforced by the competitive pricing of Brazilian soybeans, influenced by advantageous weather conditions and the depreciation of the Brazilian real, further solidifying Brazil's position as China's preferred supplier (Reuters, 2025).

The current global policy environment indicates a growing recognition that unilateral trade barriers may have limited long-term disruptive effects if markets retain their fundamental integration. Many of the protective measures implemented during trade conflicts have been shown to be transitory, with efficient arbitrage mechanisms eventually restoring equilibrium.

In this context, current global trade policies appear to embody a pragmatic blend of Liberalisation and intervention. Policymakers are increasingly aware that a purely laissez-faire approach may not adequately address the complex challenges posed by geopolitical tensions, technological disruptions, and environmental imperatives. Instead, there is a concerted move towards policies that support domestic industries while still preserving the essential benefits of an open market system. This trend is evident not only in agricultural markets but also in sectors such as technology, energy, and manufacturing, where targeted state support has been crucial in fostering competitiveness and innovation (Aubard and Julien, 2024).

Ultimately, the integration of market freedom with measured government intervention serves as a safeguard for international trade, ensuring that temporary shocks do not translate into long-term instability. By promoting policies that enhance market liquidity, encourage transparent price signals, and provide strategic support where necessary, governments can help maintain a stable and resilient global trading system. This delicate balancing act represents a logical extension of the lessons learned from the soybean market, reinforcing the idea that well-calibrated state intervention, when combined with the foundational principles of free trade, can contribute positively to overall economic stability and growth.

7.2. Impact of the US-China Trade War on the Soybean Market

The initial empirical chapter focused on the effects of the US-China trade war on the soybean market. By applying Augmented Dickey-Fuller (ADF) tests and the Bai-Perron test for multiple structural breaks, a singular structural disruption was identified within the Dalian Futures market. This finding suggests that the trade war precipitated a notable but isolated shift in the market's equilibrium dynamics.

Consistent with the findings of Wang *et al*. (2023) but contrasting with Qiao and Ahn (2022), the results indicate that the international market effectively leveraged arbitrage opportunities to mitigate the impact of Chinese tariffs. This efficient adjustment reduced price dislocation and is attributed to a highly integrated global market where most markets were cointegrated. Consequently, while trade war shocks may induce short-term price dislocations, their long-term impact appears limited as markets tend to adjust and reestablish equilibrium over time.

The first chapter concluded that the US-China trade war did not significantly disrupt the soybean market, highlighting the market's ability to efficiently navigate around tariffs. Similarly, the fourth chapter reinforced this conclusion by demonstrating that the trade war had a relatively insignificant impact on the connectedness of agricultural and energy markets within the studied quantiles. This finding contrasts with Xia *et al*. (2019), who reported more significant disruptions.

Aligning with the first and second chapters, these findings suggest that the market's efficient circumvention of tariffs primarily affected the U.S. market while benefiting others, particularly in the soybean sector. From a trade perspective, the imposition of retaliatory tariffs led to trade diversion. China reallocated its import sources away from the United States towards alternative suppliers, diminishing the U.S. share in China's import market. These tariffs precipitated a contraction in trade by curtailing the aggregate volume. The resultant increase in domestic prices within China suppressed consumption and curtailed production growth, further exacerbating the trade contraction (Elobeid et al., 2021).

The limited impact of the US–China trade war on soybean market dislocation offers a number of instructive insights for managing future trade conflicts in agricultural markets. The resilience exhibited by the soybean market during the trade war demonstrates that highly integrated and efficient markets possess an inherent ability to absorb external shocks through robust arbitrage mechanisms and efficient price transmission processes. Despite initial concerns over significant disruptions, price transmission analyses have shown that the market managed to adjust, maintaining efficiency and preserving long-term cointegration. This indicates that even when unilateral trade barriers such as tariffs are imposed, the underlying market forces enable prices to converge back to their equilibrium levels over time.

One of the most important lessons from this experience is the significance of market integration and liquidity. In a globalised market, the law of one price is upheld by the rapid flow of information and the ease with which traders can arbitrage discrepancies. For example, during the US–China trade war, Chinese importers diversified their sourcing strategies by increasing purchases from alternative suppliers like Brazil and Argentina. This diversification not only mitigated the impact of the tariffs but also underlined the importance of having multiple supply sources in place. Such flexibility ensures that trade conflicts do not lead to prolonged market dislocations, as traders are able to reroute supplies quickly and efficiently (Liu *et al.,* 2020).

The ability of the market to absorb shocks is also linked to the role of arbitrage. Even though US soybean exporters experienced short-term losses due to higher tariffs, the market's natural arbitrage processes allowed for a reallocation of exports to other regions, thereby restoring equilibrium in the long run (Lin, 2019; Sabala and Devadoss, 2019). This observation emphasises that future policy measures should prioritise maintaining open and competitive markets, where price discovery remains transparent and accessible. Ensuring that market participants have access to real-time pricing information and facilitating cross-border trade can help dampen the adverse effects of any future trade conflicts.

Diversification emerges as a critical risk management strategy in this context. The trade war highlighted that reliance on a single trading partner or source of supply can be detrimental in times of geopolitical tension. By diversifying trade relationships and fostering partnerships with multiple suppliers, countries can build a more resilient agricultural sector capable of withstanding external shocks. This approach not only protects against the risks associated with trade conflicts but also contributes to the overall stability of global markets (Wu *et al.* 2020; Li, 2023).

Another vital insight is the limited long-term effectiveness of government interventions such as subsidies. While such measures provided short-term relief for US farmers during the trade conflict, the market forces eventually re-established equilibrium. This suggests that while policy support mechanisms are necessary to cushion the initial impact of trade disputes, they should not be relied upon as a long-term solution. Instead, structural policies that promote supply chain resilience and market flexibility should be prioritised (Giri *et al.* 2018; Feng *et al.* 2022).

Furthermore, the experience of the soybean market underscores the need for transparent and timely market signals. Efficient price discovery mechanisms, such as those found in futures markets, enable market participants to adjust their strategies in real time. The availability of such information reduces uncertainty and facilitates rapid responses to market dislocations. This transparency is crucial for the development of adaptive policies that can mitigate the effects of future trade conflicts by ensuring that market signals accurately reflect the underlying economic realities.

Finally, the resilience of the soybean market also points to the benefits of multilateral cooperation. Unilateral measures, while sometimes necessary, are often less effective in the context of a globally integrated market. Strengthening multilateral frameworks and adhering to international trade rules can help prevent the escalation of trade conflicts and reduce their potential impact on global agricultural markets. The experience of the trade war thus suggests that fostering international collaboration and reducing unnecessary trade barriers will be essential for maintaining market stability in the face of future conflicts.

The soybean market's response to the US–China trade war teaches that maintaining market integration, promoting diversification, ensuring transparent price signals, and encouraging multilateral cooperation are key strategies for managing future trade conflicts in agricultural markets. These lessons highlight the importance of relying on the self-correcting nature of efficient markets while complementing them with supportive, yet restrained, policy measures.

7.3. Influence of the Ukrainian-Russian Conflict on agricultural Commodity Markets

The initiation of the Ukrainian-Russian conflict in 2021 has significantly disrupted global agricultural commodity markets, leading to heightened volatility and uncertainty. This period was marked by substantial increases in shock spillovers, particularly affecting commodities that are primary exports of these nations, such as wheat, maize, barley, and sunflower oil.

Just and Echaust (2022) observed a peak in the Total Connectedness Index (TCI) during the conflict, indicating a surge in market interconnectedness and the transmission of shocks across commodities. The TCI's escalation was most pronounced in the upper quantiles, reflecting positive price shocks and inflationary pressures on commodity prices. These shocks were especially impactful on wheat and barley markets, where supply chain disruptions led to increased connectedness and market disturbances (Voora et al., 2024).

The sunflower oil market experienced a notable decline in exports due to the closure of processing plants and ports in Ukraine, a leading producer of sunflower oil. This disruption caused a significant decrease in sunflower oil availability, prompting a surge in demand for alternative oils like soybean oil as market participants sought substitutes (CBI, 2022). This shift underscores the intricate interconnectedness of global commodity markets and the ripple effects that arise from regional conflicts.

The fertilizer market experienced severe disruptions due to the Russia-Ukraine conflict, primarily driven by trade restrictions and geopolitical sanctions. Russia , a dominant global exporter of phosphate fertilisers (accounting for approximately 14% of global phosphate supply), faced export constraints (Financial & Logistical) that significantly reduced global availability and drove prices upward (USDA, 2023).

Similarly, sanctions imposed on Belarus, which previously supplied nearly 20% of the world's potash, further restricted access to potassium fertilisers, exacerbating supply shortages and price volatility (FAO, 2023).

The global fertilizer prices surged by over 80% between early 2021 and mid-2022, with phosphate-based fertilisers (DAP) reaching a 15-year high due to limited supply and increased production costs (World Bank, 2023). The sharp rise in fertilizer costs placed significant financial pressure on farmers, particularly in developing economies, where fertilizer affordability is critical for food security.

In response, many farmers shifted acreage away from wheat and other high-input crops toward less fertilizer-intensive alternatives, such as soybeans, which rely less on nitrogen-based fertilisers due to their biological nitrogen fixation capability (Voora *et al.,* 2024). This shift introduced further market uncertainty, influencing global grain supplies and trade balances, particularly in import-dependent regions. The cascading effects of these disruptions reshaped agricultural production decisions, increased food price volatility, and underscored the fragility of global input supply chains

The Russian-Ukranian conflict influenced the causal relationships between various commodities. Notably, the connection between natural gas and wheat prices shifted, with natural gas transitioning from a net receiver to a net transmitter of market shocks post-2020. This change is attributed to the Russian-Ukrainian war and disputes between Russia and the European Union, which disrupted natural gas supplies and escalated prices (Skrzyński, 2023). Given that fertilisers are significant inputs in wheat production, rising natural natural gas prices indirectly increased wheat production costs, thereby impacting wheat prices (Hartley *et al.*, 2008).

Barley Following the Russian attacks on Ukrainian grain facilities, barley and wheat prices became more closely linked as severe disruptions in Ukraine's wheat exports sent shockwaves through global trade. Empirical studies show that these export disruptions amplified price transmission effects—wheat price shocks cascaded into barley markets, reinforcing the interdependence between the two commodities (Aliu *et al.* 2023). Conversely, Hamulczuk *et al.* (2023), employing ARDL and Granger causality models, documented a weakening of the integration between Ukrainian grain markets and the global market during the conflict. In fact, while overall market integration declined, dynamic connectedness in the medium and high quantiles—

representing periods of positive price shocks—peaked when Ukrainian supply was most distorted. This dual effect indicates that the Russian–Ukrainian war both introduced a substantial supply shock that increased overall international market connectedness and, at the same time, decoupled Ukrainian grain prices from global price trends for several months. This state of disruption persisted until July 22, 2022, when the signing of the Black Sea Grain Initiative restored export capacity and gradually normalized price transmission, thereby reintegrating Ukrainian grain into the international market.

A consistent decrease in connectedness from the lower quantile (Q0.1) was observed over the period, even amidst significant global events like the US-China Trade War, the COVID-19 pandemic, and the Ukrainian-Russian conflict. This decline correlates with negative price shocks, suggesting that the predominant external disturbances during these events were positive shocks impacting the upper quantile and inducing inflationary pressures (Ghosh and Paparas, 2023).

Conversely, the upper quantile (Q 0.9) exhibited a surge in connectedness during the intensification of the conflict, reflecting increased interdependence due to market volatility and positive price shocks. This escalation was one of the most significant since the 2008 financial crisis, indicating a heightened level of connectedness among commodities and global financial markets (Md. Kausar Alam et al., 2022). The disturbances in prices were predominantly positive during this period, leading to inflationary pressures on commodity prices.

Natural gas emerged as a significant net transmitter in the higher quantile, with a total spillover of 61.28% and a net transmission of -18.76%. The geopolitical tensions resulting from the Russia-Ukraine conflict and disputes between Russia and Europe severely disrupted the natural gas market. Europe's dependency on Russian gas led to supply chain disruptions when Russia reduced or halted gas supplies, causing a surge in natural gas prices (Skrzyński, 2023). This shift in the natural gas market had ripple effects on the fertilizer market, particularly affecting urea and phosphate prices, and reinforced the interconnectedness between energy markets and agricultural inputs.

Crude oil's role also shifted during this period. It transitioned from being a net transmitter in lower quantiles to a net receiver in higher quantiles, reflecting changing dynamics under different market conditions. The influence of urea grew in the market, becoming a more significant net transmitter than crude oil by the end of 2020. This change is linked to the increased cost pressures in the fertilizer industry due to the gas dispute and the impact of higher natural gas prices on fertilizer production costs (Awasthi, 2023; Khan *et al*, 2020).

Overall, the Ukrainian-Russian conflict has profoundly impacted agricultural commodity markets, reshaping causal connections and market dynamics. The conflict underscored the significant influence of geopolitical events on global commodity prices, supply chains, and the interconnectedness of energy, fertilizer, and agricultural sectors. The shifts in market behaviour highlight the susceptibility of commodity markets to external shocks and the importance of monitoring global events that can lead to significant market disruptions.

7.4. Argentina Future role in the international soybean market.

Argentina's role in the global soybean market has been shaped by a series of government interventions that began in 2002. The Argentine government implemented stringent trade measures, including export tariffs and, from 2012 onward, rigorous foreign exchange controls (Margarido *et al.,* 2001; Vassallo *et al.,* 2011; dos Reis *et al.,* 2020). These policies have distorted price transmission, particularly affecting the speed of adjustment in the Error Correction Model (ECM). While tariffs acted as fixed costs enabling some degree of price transmission, they also introduced barriers that questioned the viability of Argentina's soybean industry within domestic markets.

Despite these interventions aimed at discouraging soybean exports to promote the domestic crushing industry (Margarido *et al.,* 2007; Vassallo *et al.,* 2011), there have been signs of improved market efficiency. The Rosario Spot market, for instance, has demonstrated efficient behaviour by adjusting to shocks from major markets: Paranaguá (31.86% ECT), Chicago (25.30% ECT), Rotterdam (21.36% ECT), and Rosario Futures (20.37% ECT). This improvement is slight but notable when compared to previous studies (Margarido, Turolla, and Bueno, 2007). The government's interventions, acting as fixed costs, have allowed international price increases to proportionally impact the domestic market, suggesting some resilience within the market mechanisms.

The future of Argentina in the international soybean market remains ambiguous. The presidential elections in October 2023 introduced a potential shift toward economic Liberalisation under President Javier Milei. He has indicated intentions to remove currency and export restrictions, a move that could enhance Argentina's market efficiency and integration into the global arena, thereby maximizing its soybean export capabilities. However, if these Liberalisations fail to materialize, Argentina's position could be further compromised, potentially diminishing its influence in the international market.

Interestingly, despite substantial domestic government intervention, the Argentine Futures market has emerged as a pivotal force on the global stage. It has asserted itself as a price leader and significant influencer of other major markets, such as Paranaguá, Chicago, and Rotterdam. This development highlights Argentina's capacity to impact global soybean prices, even when domestic policies are restrictive.

7.5. Brazil’s Ascendance as a Global Soybean Leader.

The international soybean market has witnessed a notable shift in leadership in recent years, driven by Brazil's rising dominance. While the United States has historically led global soybean production and trade, Brazil has steadily emerged as a key competitor, fuelled by both structural changes in global demand and significant domestic economic stability. Central to this shift is the market represented by Paranaguá, a vital hub in Brazil's soybean industry, which has increasingly become a significant player in international price formation and transmission.

One of the critical factors underpinning Brazil’s rise in the soybean market is its lack of government intervention, which contrasts sharply with Argentina market. Brazil’s non-restrictive policy environment has allowed its agricultural sector, particularly soybean production, to flourish. This market freedom has attracted investment, driven technological advancements, and enabled Brazil to capitalize on international opportunities. As a result, Brazil's domestic market has grown significantly, positioning the country as a global price leader (Carneiro Filho and Costa, 2016).

In regions like Mato Grosso, Paraná, and Rio Grande do Sul, soybean farming has expanded rapidly. By the 2019/2020 season, Brazil had cultivated an area of 36.95 million hectares (CONAB, 2020), reinforcing its competitive edge against the United States. In contrast, Argentina's soybean cultivation during the same period covered approximately 14.92 million hectares (INASE, 2022), illustrating the stark differences in growth trajectories between the two countries.

The Brazilian market, represented by Paranaguá, plays a pivotal role in connecting Brazil’s soybean production to international markets. Paranaguá has demonstrated strong cointegration with major global markets such as Chicago and Rotterdam. The Vector Error Correction Models (VECM) applied in the studies reveal Paranaguá’s fast adjustment to external shocks, with Chicago influencing it by 26.08% and Rotterdam by 27.32%. This integration highlights the dynamic nature of Brazil’s market and its responsiveness to global price changes.

Paranaguá's ability to transmit shocks to major markets further cements Brazil’s leadership in the international soybean market. With a total spillover "TO" other markets at 83.75%, Paranaguá plays a critical role in transmitting global market shocks to Chicago, Rotterdam, and Rosario Futures, showcasing Brazil’s influential role in global soybean pricing (Margarido *et al.,* 2001; Mafioletti, 2001). As a result, Brazil’s growing influence in the global soybean market is becoming more evident, with Paranaguá reinforcing Brazil’s position as a net transmitter of global market shocks (Correia das Neves, 1993; Da Silva et al., 2005).

Brazil’s infrastructure development has been a crucial factor in its rise within the international soybean market. Improvements in transportation, particularly ocean freight rates, have enhanced Brazil’s competitive advantage, allowing it to export soybeans efficiently and cost-effectively. Studies predict that without significant improvements in U.S. infrastructure, Brazil could continue to increase its share in the global soybean market, potentially reducing the U.S.'s dominance by up to 20 percentage points (Salin and Agapi, 2014).

Additionally, Brazil's infrastructure improvements have enabled the country to leverage seasonal advantages. Research highlights that while the U.S. typically dominates the soybean market in the second half of the year, Brazil’s dominance in the first half of the year gives it a competitive edge, especially during key planting and harvesting periods (Soon and Whistance, 2019). This seasonal price transmission underscores the flexibility and efficiency of the Brazilian soybean market, which has proven adept at capitalizing on international opportunities and responding quickly to external shocks (de Paula *et al.,* 2018).

Looking ahead, Brazil is well-positioned to continue its leadership in the international soybean market. The country’s consistent economic stability, combined with its ability to efficiently produce and export soybeans, positions it as a long-term competitor to the United States. While infrastructure improvements and market freedom have been key to Brazil's success, the role of Paranaguá in global market dynamics cannot be overstated. As a significant player in transmitting global price shocks, Paranaguá will likely continue to shape global soybean prices and maintain Brazil's competitive edge in the years to come (De Paula *et al.,* 2018). Unless the new Lula administration initiates a new cycle of government intervention.

7.6. The Complex Dynamics of China's Soybean Market

The Chinese soybean market presents a complex interplay between government intervention, market integration, and international price dynamics. This research and empirical studies indicate that while there exists a cointegration link between China's soybean futures and international markets, the correlation is notably weaker compared to markets like the U.S., where integration is more robust (Long, 2024). Research further suggests that China's futures market is efficient in responding to domestic price shocks but remains partially insulated from global price movements (Zheng and Wang, 2013). Cointegration between futures and spot prices within China itself has also been found to be weak, indicating inefficiencies that further limit market integration (Liu and De Tours, 2017). Although the methodology used in the second Chapter did not adequately capture non-linear adjustments, it appears that the impact of international price fluctuations on China's domestic soybean market is asymmetric (Ma and Diao, 2017). Global futures markets significantly influence Chinese spot prices, while China's domestic market has limited influence on international prices. Additionally, speculation in China's futures market contributes to domestic spot price volatility, but constraints such as short-sale limitations inhibit full market integration, further reinforcing the market's partial insulation (Han, 2011). This is in line with the findings from empirical chapters first and second. These findings suggest that, despite China's dominant position as a major soybean importer, its domestic pricing mechanisms remain only loosely connected to international price dynamics, reinforcing a degree of market segmentation that persists even in the face of increasing globalization.

Further evidence of this insulation is provided in the third empirical chapter, which demonstrates that the Chinese domestic market, represented by the China Spot price, has the lowest Total Connectedness Index (TCI) among the markets studied. A low TCI indicates weaker integration with other markets. However, it's important to note that Chinese markets are characterized as net receivers. This means that while they have a low TCI, they still absorb influences from global markets to some extent, reflecting an asymmetric relationship where international prices impact China's market more than the reverse.

The observed insulation of China's soybean market can largely be attributed to government interventions. These interventions diminish the cointegration vectors between China's market and international markets, aligning with the findings of Zheng and Wang (2013). Empirical analyses by Xu *et al.* (2019) indicate that while recent market-oriented reforms have enhanced the price discovery function in China's soybean futures market, ongoing price stabilization policies tend to weaken this function. The third empirical chapter corroborates this by showing that the Chinese domestic market exhibits the lowest TCI in both total connectedness and dynamic pairwise connectedness measures.

Historically, the situation was different. Before 2012, China's soybean market exhibited significantly higher spillovers with international markets, as indicated by higher TCI values. This period implied less government intervention and greater market integration. Ma and Diao (2017) found that volatility spillover effects between international and Chinese domestic soybean markets were more pronounced before 2012, supporting the notion of a previously more integrated market. After 2012, however, increased government regulation led to a marginal decrease in TCI, suggesting a trend toward a more isolated market.

Despite this relative insulation, the Chinese spot market maintains significant long-term relationships with the Chicago Board of Trade (CBOT) futures. This suggests that Chinese authorities continue to reference Chicago prices when setting domestic prices, a finding consistent with Jamet and Chaumet (2016). This reliance on international benchmarks indicates that, despite interventions, China acknowledges global price trends in its domestic pricing strategies.

In an effort to enhance food security and reduce dependence on imports, the Chinese government has embarked on an ambitious plan under its 14th Five-Year Plan. The Ministry of Agriculture and Rural Affairs aims to elevate soybean output from 16.4 million tonnes in 2021 to 23 million tonnes by 2025, reflecting a 40%

increase (Wang and Siqi, 2022). To achieve this, China is implementing a comprehensive policy framework designed to support soybean cultivators. This includes subsidies, expanded credit facilities, and insurance provisions to safeguard farmer incomes and cover operational expenses.

These initiatives target agricultural engagement across diverse geographical regions, from the North to the Southeast and along the Yangtze River basin, incorporating pilot schemes such as intercropping soybeans with corn. Furthermore, the introduction of advanced technological inputs innovative agronomic techniques, modern machinery, and enhanced seed varieties is projected to amplify yield efficiencies (Wei, 2023 (China Daily)). These strategies aim to augment domestic production capacity, potentially reducing reliance on imported soybeans, which could impact global soybean demand and price dynamics.

However, despite these ambitious targets, the anticipated increase in domestic production may only account for approximately 22.5% of China's total soybean imports. This underscores potential shortfalls in meeting projected targets and suggests that China will continue to be heavily reliant on international markets to satisfy domestic demand. Additionally, the effectiveness of these efforts in diminishing domestic soybean prices and fortifying China's position in both domestic and international markets hinges on the adoption of price Liberalisation policies (Xu *et al.,* 2019). Without such policy shifts, improvements in market integration and price transmission effectiveness may be limited.

Despite being the world's largest soybean importer, China has not effectively leveraged this position to exert significant influence over global market dynamics. Its futures and domestic markets remain largely segregated from global pricing mechanisms, limiting their ability to affect international soybean prices and maintaining their roles predominantly as market recipients. The Dalian Futures Exchange, for instance, despite being the second-largest agricultural futures market globally, still lags considerably in establishing price leadership and enhancing market efficiency.

Wang *et al.* (2023) have noted that volatility spillovers between Chinese and American soybean futures markets have diminished over time. This trend is particularly influenced by global geopolitical events such as the Russia-Ukraine conflict, trade tensions between the U.S. and China, and the impacts of the global pandemic. These factors have contributed to the increasing isolation of China's soybean market from international volatility.

Interestingly, the U.S.-China trade war highlighted the resilience and stability of the global soybean market. Despite the challenges posed by the trade conflict, the Total Connectedness Index (TCI) remained consistent, indicating that the market was able to absorb the shocks without significant disruption. This stability underscores the limited impact that Chinese market interventions have on international price dynamics and highlights the robustness of global market mechanisms in maintaining equilibrium amidst geopolitical tensions.

In summary, while China has made strides toward enhancing its domestic soybean production and has implemented policies aimed at market reform, significant challenges remain. Government interventions continue to insulate China's soybean market from international influences, diminishing its potential to act as a price leader. Efforts to increase domestic production are ambitious but may not substantially reduce reliance on imports in the near term. Consequently, China's ability to influence global soybean prices remains limited, and its market continues to function predominantly as a net receiver within the international soybean trade network.

7.7. The Decline of U.S. Leadership and Rotterdam's Influence in the Soybean Market

This research suggest a significant shift in the global soybean market, where the traditional dominance of the United States is being increasingly challenged by Brazil. While it may be too early to conclusively state that the U.S. has been surpassed, several factors contribute to this emerging trend. Key among these are Brazil's advancements in infrastructure and changes in ocean freight rates.

Salin and Agapi (2014) highlight that the U.S. share in global soybean trade is declining due to these infrastructural improvements in Brazil and fluctuations in shipping costs. Their study predicts that without substantial enhancements to U.S. infrastructure, the country's market share could diminish by an additional 20 percentage points. This supports observations from earlier analyses indicating a shift in price leadership within the soybean market.

Furthermore, research by Soon and Whistance (2019) reveals a seasonal dynamic in market dominance: the U.S. leads in the second half of the year, while Brazil dominates in the first half. This pattern suggests a shifting balance of market power throughout the year, influenced by harvesting seasons and global demand cycles.

De Paula *et al.* (2018) examined Brazilian soybean exports from 2004 to 2014 and found that Brazil has developed a strong competitive edge internationally. This advantage is attributed to high efficiency, technological innovations, and significant agricultural expansion. These factors contribute to the rapid market adjustments observed in Brazil, aligning with findings from previous empirical studies.

However, it's important to note that Brazil's soybean industry faces challenges. Cavalett and Ortega (2009) discuss that although soybean production and processing in Brazil are economically beneficial on a macro level, they come with environmental costs and lower profitability for farmers. High input costs and low soybean prices have squeezed margins, affecting the sustainability of farming operations.

Despite these challenges, the cumulative effect of Brazil's infrastructural improvements, competitive export strategies, and seasonal advantages is contributing to a decline in U.S. market dominance. Muhammad (2015) also notes Brazil's emergence as a significant competitor in the global soybean market.

Simultaneously, Rotterdam's role as a leading price setter in the soybean market has diminished. Influenced by factors such as Chicago Futures, Paranaguá, and Rosario Futures, Rotterdam has transitioned to being a net receiver of market influence, though it maintains a slightly negative net balance. Despite this shift, Rotterdam still generates market shocks and spillovers, particularly affecting the Chicago and Rosario spot markets.

Understanding this decline requires examining Rotterdam's representation of the European Union's soybean demand dynamics. Over the past two decades, the EU's demand for soybeans has remained relatively stable. In contrast, China's demand has surged dramatically, making it the world's primary soybean importer. China now accounts for 65% of global soybean imports, significantly altering international demand patterns and diminishing Rotterdam's historical position as a price leader (Salin and Agapi, 2014).

This substantial increase in Chinese demand has reshaped global soybean trade flows and price-setting mechanisms. The shift underscores the impact of changing global consumption patterns on traditional market structures and highlights the importance of adapting to evolving international dynamics. Following this the realignment of price leadership from established European and North American hubs such as Rotterdam and Chicago to emerging South American ports like Paranaguá and Rosario has considerable economic and geopolitical ramifications for the international soybean trade. This transition reflects the growing dominance of Brazil and Argentina, whose capacity to produce and export large volumes of soybeans has amplified their influence over global price formation. The empirical evidence suggest that this development is partly attributable to logistical and cost advantages in South America, where proximity to major growing regions reduces transport expenses and strengthens competitiveness (Ikeda *et al.* 2020). As a result, South American ports have become pivotal nodes in the worldwide supply chain, displacing Rotterdam's historical role as the primary reference point for price discovery (Avileis and Mallory, 2021).

From an economic perspective, the rise of Paranaguá and Rosario as price leaders has heightened volatility spillovers, linking Latin American and North American markets more closely than before (Candila and Farace, 2018). This interdependence is further reinforced by structural shifts in Brazilian agriculture, where expansion of soybean cultivation has engendered faster adjustments to international price shocks (Cruz *et al.,* 2016). The increased prominence of Brazil and Argentina has also reconfigured trade routes, as importers in Asia and elsewhere redirect procurement strategies to capitalise on these new pricing hubs. In this context, investments in South American infrastructure, particularly in port facilities and transport corridors, have accelerated in order to accommodate larger export volumes and manage the resulting logistical demands (Giraudo, 2022).

Geopolitically, the shift has bolstered the bargaining power of Brazil and Argentina, prompting realignments in trade relations with major importers such as China (Xue *et al.,* 2024). By diversifying away from the United States, China has consolidated its links with South American suppliers, thereby reducing its reliance on traditional sources and reshaping global power balances in agricultural trade. This trend may weaken the position of Rotterdam and, by extension, the European Union, where soybean demand has remained relatively static, curtailing its previous capacity to dictate international price trends. In parallel, the United States retains a significant role in price discovery through Chicago, yet its dominance is challenged by South America's ongoing ascendancy (Avileis and Mallory, 2021).

In terms of global supply chains, reliance on South American ports has created a more diversified yet and more connected market, as disruptions in Brazil or Argentina whether political, climatic or infrastructural could reverberate across world markets (Jiang *et al.,* 2017). The interconnectedness index indicates that shocks in these regions now have greater spillover effects, thereby increasing the vulnerability of distant markets to localised instability (Babar *et al.*, 2023). Concurrently, South American governments face growing scrutiny over environmental practices linked to agricultural expansion, a factor that may influence trade policies and bilateral agreements, especially with importers prioritising sustainability (Giraudo, 2022). Overall, the ascendancy of Paranaguá and Rosario underscores the shifting landscape of international agricultural trade, as newly empowered South American producers and exporters reshape supply chains, adjust longstanding trade relations and potentially recalibrate the geopolitical contours of the global food system.

7.8. A Shift in Leadership in the International Soybean Market

The first and the third empirical chapters identifies Chicago Futures as the most pivotal market for China's domestic soybean market, a finding corroborated by the research of Liu *et al.* (2015) and Ma and Diao (2017). The Chinese domestic market is predominantly influenced by major international markets such as Chicago, Rotterdam, and Paranaguá, with Chicago exerting the most substantial impact. Previous research posits that this influence may stem from Chinese policymakers utilizing Chicago prices as benchmarks for setting domestic prices, as suggested by Zhao *et al.* (2010). Chinese policymakers might need to reevaluate their reference market and consider adopting Paranaguá, as suggested by Cao *et al.* (2016)

However, empirical evidence continues to highlight the significance of the U.S. market. The U.S. has long benefited from substantial market freedom and a well-established trading environment, with the Chicago Board of Trade pioneering the futures markets for soybean contracts as early as 1984.

Global market dynamics have shifted due to factors such as the decline of the U.S. in price leadership, exacerbated by the U.S.-China trade war, increased Brazilian production, and China's market interventions. While the U.S. remains an important player, Brazil's growing dominance and China's policy-driven market isolation have reshaped interactions in the soybean market. Argentina's future role in the soybean market remains uncertain due to ongoing government policies and economic challenges. However, potential economic Liberalisation could enhance its market efficiency and integration. Meanwhile, Brazil has benefited significantly from the growth in soybean cultivation, which has bolstered its domestic market and allowed it to compete with the United States in soybean exports. The continuous economic stability and market freedom in Brazil have promoted the spread of soybean farming in fertile regions like Mato Grosso, Paraná, and Rio Grande do Sul, achieving an area of 36.95 million hectares in the 2019/2020 season (CONAB, 2020). In the same period, Argentina's soybean cultivation covered approximately 14.92 million hectares (INASE, 2022), establishing it as a leader in pricing and a global standard in soybean production. The third empirical chapter delves deeper into this shifting dynamic, using the connectedness approach based on the Time-Varying Parameter Vector Autoregression (TVP-VAR) model to reveal the dynamic interconnectedness of these markets. This analysis highlights the decline of Rotterdam as a price leader and the rise of Brazil and Argentina as major players, further illustrating these market shifts. Most of the studies have shown that the US has traditionally held price leadership in this market (Margarido *et al.*, 2007), but recent research diverges. The third empirical chapter highlights a significant shift in the global soybean market dynamics, focusing on the decline of Rotterdam as a price leader and the simultaneous rise of Brazil and Argentina as major players. Rotterdam's influence as a price leader has diminished. Rotterdam's influence on the Brazilian market of Paranaguá is only 13.56% (TO), contrasting with previous studies that suggested a strong influence. Additionally, Rotterdam receives more spillovers from other markets (73%) than it transmits to others (67.37%), making it a net receiver with a negative net transmission of 5.63%. The risk of spillover of Rotterdam on Chicago is 18.5%, while Chicago's influence on Rotterdam is slightly higher at 20%, indicating that Rotterdam has transitioned from a leader to a follower in terms of price setting. Paranaguá rise as a significant net transmitter, with a total spillover "TO" other markets at 83.75%, indicating its role as a major player in transmitting market shocks. Paranaguá influences Chicago (19.3%), Rotterdam (18.93%), and

Rosario Futures (16.18%). Rosario Futures is identified as a net transmitter, with an 84.95% transmission "TO" other markets and a 14% positive net transmission of spillovers. It significantly influences Paranaguá and other major markets, reinforcing its role as a price leader.

Several factors contribute to these market shifts; Firstly, the role of Rotterdam, representing the European Union's demand side, has diminished over the past two decades. This is mainly because the European Union's demand for soybeans has stagnated, while China's demand has grown significantly, accounting for 65% of international soybean imports. As a result, Rotterdam's influence in the international soybean market has waned, transitioning from a price leader to a price taker, influenced by other markets like Chicago, Paranaguá, and Rosario Futures

In contrast, Brazil and Argentina have emerged as crucial players due to different economic and policy strategies. Brazil's lack of government intervention in soybean production has allowed it to capitalize on economic benefits, strengthening its domestic market and competing with the United States in soybean exports. This has enabled Brazil to expand its soybean production significantly, surpassing the US and establishing itself as a price leader. Brazil's market freedom and stability have contributed to this growth, allowing it to become a reference point in soybean production

7.9. Resilience in Agricultural Markets: Lessons from the Soybean Trade

Exogenous shocks such as climatic issues and geopolitical events exert a significant influence on the stability and cointegration of agricultural markets, introducing temporary disruptions that can lead to structural breaks in price time series and affecting the long-run equilibrium relationships among market prices. Climatic disturbances like droughts, excessive rainfall, or the irregular patterns associated with phenomena such as El Niño and La Niña not only alter local supply conditions but also propagate through international markets by affecting production yields and transport logistics, leading to heightened price volatility. For instance, research indicates that extreme weather events have a direct impact on the variability of prices in markets such as corn and soybeans, causing periods where prices deviate sharply from their long-term trends, thereby temporarily fracturing the cointegrated relationships that would normally exist under stable conditions (Peri, 2015; Nam, 2021).

Geopolitical events further compound these market dynamics by introducing uncertainties that disrupt trade flows and supply chains. Incidents such as trade disputes, sanctions, or conflicts like the Russia–Ukraine war have a pronounced effect on commodity prices, particularly in the case of commodities that are heavily traded on global markets. These events can lead to supply shortages or logistical challenges that force market participants to adjust prices rapidly, thus breaking the equilibrium that is typically maintained by efficient arbitrage mechanisms. For example, during the US–China trade war, the soybean market experienced notable periods when prices in one region diverged significantly from those in others, reflecting a temporary breakdown in the cointegration relationship among different market segments. Nonetheless, the inherent market mechanisms, driven by robust arbitrage opportunities and the law of one price, typically act to restore long-term equilibrium as market participants capitalise on the discrepancies to realign prices (Merener, 2013; Goyal *et al.,* 2024).

The soybean market, being highly liquid and internationally integrated, offers a valuable case study for understanding how these exogenous shocks operate. Despite the occurrence of short-term dislocations, the market tends to demonstrate resilience; structural breaks in cointegration are often transitory as efficient price transmission mechanisms eventually re-establish the long-run equilibrium. This pattern of temporary instability followed by a reversion to equilibrium is not unique to soybeans. Other agricultural commodities exhibit similar behaviour, as many of these markets share common features such as the use of standardised futures contracts, transparent price discovery processes, and active risk management practices. Such characteristics enable these markets to absorb external shocks and adjust through error correction mechanisms that measure the speed at which prices converge back to their long-term relationships. Empirical studies have shown that while the impact of shocks can be dramatic in the short term, the self-correcting nature of these markets, as observed in the soybean market, suggests that similar dynamics are at work in other sectors, including maize and wheat (Rui, 2012; Peri, 2017).

Moreover, the interaction between climatic and geopolitical shocks often creates complex scenarios where multiple sources of uncertainty intersect, thereby amplifying volatility. When climatic events occur concurrently with geopolitical tensions, the compounded effects can lead to more pronounced disruptions in market stability. However, the global integration of supply chains and the transparency provided by modern market instruments enable traders and policymakers to monitor these structural breaks effectively and to predict the re-stabilisation phase. This reversion process, driven by market efficiency and the continuous flow of information, ensures that even when markets are temporarily destabilised, the long-run cointegration persists as a fundamental characteristic of these well-integrated systems.

The impact of exogenous shocks on agricultural markets is profound yet generally transient. Climatic variability and geopolitical risks may cause temporary deviations from the expected long-term price relationships, but the resilient structure of these markets, as demonstrated by the soybean market, typically facilitates a return to equilibrium.

The lessons learned from the soybean market offer a valuable framework for analysing other commodities, highlighting the importance of monitoring structural breaks and employing error correction models to assess market recovery speeds. By understanding these dynamics, policymakers and market participants can better manage risk and implement strategies that safeguard market stability in the face of unpredictable external shocks.

7.10. The Role of Soybean in the International Commodities Market

The empirical evidence regarding the role of soybeans in the international commodities market reveals a complex landscape where this crop occupies a position of considerable significance. This discussion examines how current findings align with previous research while highlighting unexpected results and inconsistencies that merit further investigation.

Recent findings consistently identify soybeans as a dominant net transmitter of price shocks across agricultural commodity markets, confirming earlier studies on market connectedness. Across all examined quantiles (0.1, 0.5, and 0.9), soybeans persistently function as a central node in transmitting volatility throughout the broader agricultural network (Gosh and Paparas, 2023). This position is further substantiated by the robust behavior exhibited over six decades of market data, establishing soybeans as a structurally pivotal commodity in terms of price influence and market integration.

This dominant role extends to soybean derivatives, with soybean oil and soybean meal consistently occupying the second and third positions respectively as net transmitters of market volatility. Such findings corroborate established theories of vertical price transmission from raw commodities to their processed forms while emphasizing the extended influence these derivatives exert across related markets (Fousekis, 2023). The vertical transmission mechanisms observed in the soybean complex highlight how processing and value addition contribute significantly to determining market power dynamics.

These findings align with research by Guo and Tanaka (2020), which documented soybeans' leading role in price discovery and their outsized influence on price movements across related agricultural commodities. Similarly, Ke *et al.* (2019) confirmed that U.S. agricultural futures markets, particularly soybeans, play a dominant role in transmitting risk and volatility globally. The observed lead-lag relationships between futures and spot prices further indicate that soybeans often lead price movements in agricultural markets (Liu *et al.*, 2020).

7.10.1. Dual Role and Market Complexity

The complexity of soybean market dynamics is amplified by its dual role as both a crucial food crop and a key input in energy production, particularly for biodiesel. This duality creates multifaceted transmission mechanisms operating both vertically (from raw soybeans to processed derivatives) and horizontally (affecting related commodities like corn and wheat). As highlighted by Gardebroek *et al.* (2016), soybeans exhibit significant volatility spillovers with other major crops, though these spillovers vary in intensity across different market conditions.

The horizontal spillovers to other major crops underscore the substitutability and interdependence among agricultural commodities, particularly during periods of high market uncertainty. The horizontal spillovers to other major crops underscore the substitutability and interdependence among agricultural commodities, particularly during periods of high market uncertainty. The evidence from connectedness analyses employing the QVAR model further substantiates soybeans' dominant market position. Under median quantile (Q 0.5) conditions, which offer a robust understanding of typical market behavior, soybeans emerge as the most significant shock transmitter with a notable transmission of price volatility. Supporting this finding, soybean oil and soybean meal rank as the second and third most influential price transmitters respectively, with soybean oil transmitting approximately 70.58% of spillover effects with a net transmission of 14.21%, while soybean meal exhibits an overall transmission of 68.49% with a net transmission of 5.39%. This confirms the entire soybean complex's dominance in price formation mechanisms. Network connectedness analyses reinforce this hierarchy, with the soybean triumvirate exerting substantial influence across both agricultural and energy markets, particularly during periods of relative market stability.

These dynamics become more pronounced when external shocks—such as geopolitical events, trade policy shifts, or climate-related disruptions—alter established patterns of connectedness, potentially creating new transmission channels that traditional models struggle to anticipate (Jiang et al., 2017).

1.10.1. *Results Inconsistencies*

Several findings challenge conventional understanding and warrant further investigation. Most notably, the role of crude oil presents a significant departure from previous assumptions. While earlier research, particularly before 2013, suggested that crude oil exerts considerable influence on soybean prices due to the biofuel connection, current findings reveal that crude oil markets sometimes act as net receivers rather than transmitters of spillovers, especially during certain market conditions. This contradicts established narratives about energy-agriculture linkages and suggests a more nuanced relationship than previously theorized.

Research examining the relationship between crude oil markets and agricultural commodity returns reveals a complex, dynamic interaction rather than a simple one-way influence. Studies show that while crude oil prices do affect agricultural commodity prices, especially for biofuel-linked crops like corn and soybeans, the strength of this influence fluctuates over time and weakens for non-biofuel crops (Zafeiriou *et al.,* 2018). Furthermore, evidence suggests that agricultural markets can also exert influence on crude oil markets through biofuel demand, particularly in periods of high food prices or supply shocks, indicating a bidirectional flow of influence (Dahl *et al.,* 2020). This reverse influence is more pronounced during times of economic or environmental disruption, when food security concerns elevate agricultural prices to levels that affect biofuel production decisions (Szenderák, 2018). Overall, while oil traditionally plays a dominant role in shaping commodity prices, modern biofuel policies and the growing integration of food and energy markets have introduced a feedback loop where agricultural prices, particularly for biofuel feedstocks, can significantly influence crude oil prices as well.

Equally perplexing is the near absence of significant Granger-causal relationships within the soybean complex, despite clear evidence of connectedness from other methodologies. This methodological inconsistency suggests that conventional metrics used to assess causality and market influence may be insufficient to capture the full complexity of these dynamics. Alternative approaches, potentially incorporating elements of behavioral finance and network theory, may be required to develop a more comprehensive understanding of the factors at play.

The roles of wheat and barley exhibit notable instability across different quantiles, transitioning from net receivers to net transmitters and then reverting to their earlier roles. This non-static behavior underscores the dynamic nature of commodity markets and the influence of transient factors such as weather patterns, government policies, and global economic shifts (Gardebroek *et al.,* 2016). Similarly, sunflower oil has emerged as a pronounced net receiver of spillovers, heavily influenced by fluctuations in the majority of other commodity markets, representing another deviation from expected market dynamics.

1.10.2. *Financial Speculation and Market Distortion*

The growing role of speculative trading in soybean markets, driven by exchange-traded funds (ETFs), commodity index funds, and algorithmic strategies has been associated with sharper price swings and heightened volatility, potentially undermining traditional supply-demand mechanisms that shape agricultural prices (Zafeiriou et al., 2018). Such speculative activity amplifies volatility spillovers between crude oil and soybean markets, particularly given soybeans' dual function as a food commodity and a critical biofuel feedstock, which tightly links agricultural and energy sectors (Szenderák, 2018). As a result, soybeans have assumed a more prominent role in guiding wider agricultural price trends, with financial inflows creating self-reinforcing loops that magnify market movements (Silvennoinen & Thorp, 2016). However, the extent to which financialization has fundamentally altered the pricing structure of physical commodities, including soybeans, remains a central question, especially in light of institutional investors' expanding influence and the proliferation of automated trading systems (Natanelov, 2014).

Financialization also poses challenges for diversification efforts, as soybeans increasingly display correlated volatility with other agricultural commodities, reducing their utility as a diversification asset (Boonyanuphong, 2014). This heightened interconnectedness stems not only from shared exposure to macroeconomic factors—such as energy markets and biofuel policies—but also from the growing presence of institutional investors and commodity index funds that treat agricultural commodities as a single asset class rather than evaluating individual supply-demand fundamentals (Silvennoinen and Thorp, 2016). Consequently, shocks to a single crop, including soybeans, can swiftly reverberate across other commodity markets, raising pressing concerns about effective risk management within an increasingly integrated and finance-driven global commodity system (Dahl *et al.,* 2020). Recognizing and monitoring these shifting correlations is essential for devising more robust hedging strategies in agricultural markets.

7.11. Policy Implications

The findings from the initial empirical chapter highlighted the exceptional ability of international soybean markets to reorganise and navigate around tariffs. Adhering to the principles of spatial arbitrage and the Law of One Price (LOOP), global trade routes were redirected to bypass tariffs, resulting in the equalization of international prices. Market participants quickly seized arbitrage opportunities, prompting price convergence across markets. From a policy perspective, China misjudged the soybean market's capacity to adapt and underestimated the actual impact of tariffs on U.S. soybeans. In contrast, the Trump administration's demagogic decision to subsidize farmers distorted prices, despite the fact that prices had already equilibrated swiftly due to arbitrage. This trade conflict underscored the efficacy of free markets, rendering the event statistically insignificant. However, the soybean trade war was only one of several disputes between the world's leading economies, ultimately reducing economic welfare for end consumers.

The second empirical chapter offers profound insights into market dynamics and policy implications. The findings highlighted the significant influence of government interventions and market power on price transmission mechanisms. One critical implication was the impact of government interventions on market efficiency. Markets with significant interventions, such as China and Argentina, exhibited a lack of cointegration with other international markets, leading to inefficiencies. Policymakers in these countries should consider gradually reducing interventions to enhance market efficiency, allowing market forces to improve price integration with global markets. However, the study fails to find evidence of APT in markets with high levels of intervention. APT prevents prices from fully reflecting market conditions, resulting in suboptimal decisions by producers and consumers, ultimately reducing economic welfare. To mitigate welfare losses, governments should minimize policies contributing to APT, such as reducing export tariffs and eliminating price support mechanisms, while ensuring exchange rates are market-determined. Enhancing market transparency and reducing information asymmetries can help align domestic prices with international conditions.

The presence of structural breaks, often caused by sudden policy changes or external shocks, was another significant finding. These breaks can lead to temporary market dislocations, disrupting long-term equilibrium and causing volatility. Policymakers should strive for stability and predictability in their interventions, avoiding sudden shifts and communicating necessary changes well in advance to allow market participants to adjust. Establishing robust legal and regulatory frameworks can help create a stable environment, minimizing the risk of structural breaks. The study's use of non-linear models, such as Threshold Autoregressive (TAR) and Momentum Threshold Autoregressive (MTAR) models, provided a nuanced understanding of price transmission mechanisms. These models are particularly useful in capturing the complexities of markets with significant interventions or non-linear dynamics. Policymakers and regulatory bodies should incorporate non-linear models in their analytical frameworks to better understand market dynamics and the impact of their policies, leading to more effective policy design and implementation.

This investigation also highlighted the importance of international market integration for achieving price stability and efficiency. Well-integrated markets tend to exhibit symmetrical price transmission, indicative of efficient market functioning. Governments should actively promote policies that enhance international market integration by negotiating trade agreements that reduce barriers to trade, harmonizing regulations with international norms, and investing in infrastructure that facilitates cross-border trade. Addressing market power is also crucial, as large corporations or state entities can lead to APT and market inefficiencies. Regulatory authorities should enforce anti-trust laws and promote competition within the soybean market and other agricultural markets, ensuring a level playing field to mitigate the adverse effects of market power. Lastly, the findings underscore the need for long-term strategies that go beyond immediate policy interventions. Sustainable market development requires a holistic approach, considering various factors influencing price transmission and market efficiency. Policymakers should develop comprehensive strategies aimed at enhancing market infrastructure, improving access to market information, and fostering innovation in agricultural practices.

Empirical evidence from the third empirical chapter indicates that market freedom is crucial for the efficient transmission of market signals and rapid adaptation to international demand. The development of soybean production in Brazil and Argentina illustrates this concept effectively. While the Argentine government introduced multiple barriers, including export tariffs and fixed exports, the Brazilian government maintained a non-interventionist approach towards the expansion of soybean cultivation. Consequently, Argentina faced challenges in sustaining its soybean sector growth, which negatively impacted its economic prospects, leading to a migration of farmers and capital to neighbouring countries that offered better conditions for agricultural development and exportation. In contrast, Brazil leveraged the economic advantages of expanding soybean production, which strengthened its domestic market and enhanced its competitive stance against the United States in soybean exports. This prolonged period of market freedom and economic stability facilitated the growth of Brazil’s domestic market and its soybean crop production, positioning Brazil as a leading price setter and a global benchmark in soybean production

The decline in US leadership in the global soybean market relative to Brazil prompts an analysis of the underlying causes. While it is premature to conclude a complete shift in market dominance, several key factors have influenced the changing dynamics. Firstly, the trade tensions between the US and China have rerouted trade flows, positioning Brazil as the primary soybean supplier to China for a significant period. Secondly, the growth of soybean production in Brazil has not only continued but has surpassed that of the US by 2019, with projections indicating even greater increases by 2023. Lastly, the intervention of the Chinese government in its domestic market through various price support policies has served to shield its market from global price volatilities. This intervention has been so significant that previous studies have had difficulty detecting or maintaining cointegration models, suggesting a weakening of the cointegration relationship due to these governmental actions. This isolation aligns with the low total connectedness index (TCI) for the Chinese domestic market, indicating a more isolated market with decreased integration over time. The Chinese government's intervention policies need revaluation, especially concerning the reference market for fixing domestic prices. Chinese policymakers might consider using Paranaguá as the new price reference instead of Chicago, as using an outdated reference can lead to higher market distortions. The Chinese government, through its five-year plans, aims to boost soybean production to ensure food security. However, these attempts at self-sufficiency may fall short, as the projected increase in production still represents a small fraction of total imports. New policies aim to increase subsidies, extend credit lines, and offer insurance to cover costs and ensure incomes, engaging farmers in innovative cultivation methods and technologies. These policies could increase domestic production, potentially substituting imports and leading to lower international prices, affecting domestic prices as well.

Rotterdam's decline as a price leader and price maker is evident, with the market now serving as a net receiver influenced by Chicago Futures, Paranaguá, and Rosario Futures. The European Union's role as a major soybean importer has diminished over the past two decades, overtaken by China's growing demand. This shift has weakened Rotterdam's price leadership. Argentina's current and future role in the international market is clouded by uncertainty due to strict trade restrictions, currency manipulation, and regional droughts. The new libertarian Argentine president (From 2024), Javier Milei, is currently implementing a government reform aimed at promoting market Liberalisation. His reforms include ending the "cepo cambiario" (government-fixed exchange rate), deregulating the economy, and eliminating export tariffs on soybeans. This may bring end increase of market efficiency and integration, boosting Argentina’s role in the international market. Despite the reforms, Argentina still has significant domestic market intervention. Nevertheless, the Argentine futures market has positioned itself as a price leader and a net transmitter of shocks and spillovers.

The dominance of Chicago and Rotterdam as primary hubs for price formation in the international market appears to have diminished, with Paranaguá and Rosario Futures now emerging as significant leaders alongside Chicago. China, despite being the largest importer of soybeans, has not effectively utilized its position to influence global markets, remaining somewhat isolated and detached from mainstream market interactions. Furthermore, Dalian Futures, despite its status as the second most significant agricultural futures market globally, continues to trail in terms of price leadership and market efficiency.

The innovative approach adopted in this study has yielded a more profound comprehension of the international soybean market's dynamics over time. It reveals that causality within the market is not static but is bidirectional and evolves over time. Shocks can be disseminated from peripheral markets to central markets, and the connectedness index underscores that such shocks can originate anywhere within the global market and spread horizontally.

The interdependence of agricultural and energy commodities underscores their critical role in international trade, national security, and global welfare. Geopolitical conflict, such as the Russia-Ukraine war, illustrate the extensive repercussions such conflicts can have on these interconnected global markets. Essential commodities for human food security such as soybeans are key transmitters of market shocks, highlighting the need for a comprehensive reassessment of their significance and diversification strategies for countries that rely heavily on specific commodities. Promoting sustainable agriculture practices and deforestation-free soybean production is crucial to addressing environmental challenges, preventing deforestation, and reducing nitrogen pollution, soil degradation and water contaminations. By prioritising the cultivation of sustainable soybeans, we can significantly mitigate the environmental impacts associated with soybean production and advance the development of a more environmentally responsible agricultural sector.

Overall, highlighting the complex dynamics of the international soybean market and the significant impact of government interventions, market power, and geopolitical events on price transmission mechanisms. Policymakers must consider these factors in their efforts to enhance market efficiency, minimize welfare losses, and promote stable and integrated international markets. By implementing the recommended policies and strategies, governments can improve market functioning, ensure economic stability, and support sustainable development in the agricultural sector.

Moving from the detailed discussion on the practical implications derived from our comprehensive analysis of the international soybean market, we now turn to acknowledge the limitations of this study and propose avenues for future research. This section will critically evaluate the methodological and data-related constraints that may have influenced our findings, while also suggesting potential directions for further investigation to build upon the insights gained from this research and enhance the robustness of our conclusions in the context of global agricultural commodity markets.

7.12. **Hypothesis Evaluation**

US-China Trade War Hypothesis.

- Market Cointegration and structural breaks.

It has been previously stated that the trade war might have significantly impacted soybean market prices, potentially causing a structural break in the time series. This research question investigates whether the onset of the trade war has indeed induced a structural break and affected the long-term relationship between markets. The following hypotheses were formulated:

1. **Null Hypothesis (H0):** The markets have not been dislocated, there is cointegration between the markets.
2. **Alternative Hypothesis (H1**): The markets have been dislocated, there is not cointegration between the markets.

Empirical evidence from the first chapter unequivocally revealed that the effects of the trade war on the international soybean market were minor. The market demonstrated a remarkable capacity to circumvent the retaliatory tariffs imposed by China. Structural breaks identified in the analysis were predominantly attributable to significant events such as the subprime crisis, with no clear evidence of long-term price dislocation caused by the US-China Trade war. Therefore, it is not possible to reject the null hypothesis, indicating that there is full cointegration among the markets during this geopolitical conflict.

- The market efficiency affectation.

As before mentioned a complete price transmission and a fast speed of adjustment to long term equilibrium are strong indicators of market efficiency. Additionally, the adherence to the Law of One Price further validates this efficiency. The research question aims to determine whether the market's efficiency has been affected. This question leads to the formulation of several null hypotheses.

1. **Null Hypothesis (H0):** The price transmission among the market has not been affected.
2. **Alternative Hypothesis (H1):** The price transmission among the market has been affected.

There is no clear evidence that price transmission was significantly affected by the trade war. The results indicate that the speed of adjustment of the error correction term remains consistent with previous studies. However, it is important to note that the price transmission between Western and Eastern markets is considerably slower, potentially indicating incomplete price transmission. Although it is not possible to reject the null hypothesis that the trade war has affected the international market, these findings suggest the presence of persistent market inefficiencies across different regions.

- Market Power.

China, the largest consumer of soybeans, and the United States, the second-largest market and leading producer, are pivotal players in the global soybean market. China's strategic efforts to diminish the United States' market dominance through various trade policies have established it as a major influencer. Additionally, the emergence of Brazil as the leading producer has further reshaped the market power distribution among these key players. It is crucial to assess whether there has been a significant shift in market power dynamics.

1. **Null Hypothesis (H0):** Chicago and Rotterdam do not longer hold the causality of the prices.
2. **Alternative Hypothesis (H1):** Chicago and Rotterdam still hold the causality of the prices.

In terms of Granger causality, Chicago and Rotterdam continue to predominantly influence the market. However, the short-term regressor for the Error Correction Model (ECM) in most markets has begun to show a lack of significant short-term causality, as previously explained. The connectedness approach reveals that Rotterdam has further lost its influence, acting as a net receiver of influence, while Rosario Futures and Paranaguá have emerged as net transmitters. Consequently, the results vary depending on the methodology employed, therefore it is not possible to reject the null hypothesis for Granger causality. However, it can be rejected in terms of spillover risk, positioning Chicago, Rosario Futures, and Paranaguá as new centres of price formation. The influence of the Chinese market is not evident in these studies, although it may be indirect; Chinese buyers potentially influence the market by acting as import buyers in the international market.

- Asymmetric price transmission.

Market power and government intervention can lead to asymmetric price transmission, resulting in a loss of economic welfare and market efficiency. Therefore, it is crucial to determine whether the soybean market exhibits symmetrical or asymmetrical price transmission, and to assess the extent to which the US-China trade war may have exacerbated any existing asymmetries.

1. **Null Hypothesis (H0):** The international soybean market exhibits symmetrical price transmission.
2. **Alternative Hypothesis (H1):** The international soybean market exhibits asymmetrical price transmission.

The empirical evidence suggests that price transmission across and among different markets exhibits a nonlinear nature. However, it is not possible to reject the null hypothesis, as the price transmission remains symmetrical.

- Spillover Effects of Trade War on Agricultural Commodities.

The international agricultural markets are highly interconnected, making it plausible to assume that shocks in one market can lead to spillover effects or contagion in others. Empirical evidence and economic theory support the notion that price shocks in certain products can transfer to other goods. Consequently, it is reasonable to hypothesize that the spillover effects of the trade war have been transmitted from primary commodity markets to other regional markets and from agricultural markets to energy markets.

3. **Null Hypothesis (H0):** The US-China trade war has not caused spillover effects from the main soybean commodities market to other agricultural commodities markets.
4. **Alternative Hypothesis (H1):** The US-China trade war has caused spillover effects from the main soybean commodities market to other regional markets.

3. **Null Hypothesis (H0):** The US-China trade war has not caused spillover effects from agricultural to energy commodities markets.
4. **Alternative Hypothesis (H1):** The US-China trade war has not caused spillover effects from agricultural to energy commodities markets.

The dynamic connectedness analysis utilizing the QVAR model has conclusively demonstrated that the spillover effects of the trade war were minimal and have not propagated to other commodities markets and energy market. Consequently, it is not possible to reject either pair of null hypotheses.

- Connectedness Index during the US-China Trade War.

The US-China trade war has introduced numerous disruptions and uncertainties in international trade, with the soybean market being particularly affected due to its pivotal role in the conflict unfolding. It is crucial to examine whether the trade war has heightened the connectedness index of the soybean market, reflecting stronger interdependencies between soybeans and other related markets.

1. **Null Hypothesis (H0):** The US-China trade war has not increased the connectedness index of the soybean market.
2. **Alternative Hypothesis (H1):** The US-China trade war has increased the connectedness index of the soybean market.

The connectedness index throughout the US-China trade conflict has remained stable, exhibiting no significant variations. Consequently, the null hypothesis cannot be rejected. Thus, the US-China trade war has not resulted in an increase in the overall connectedness index.

- Validity of the Law of One Price for International Soybean Markets Due to the US-China Trade War.

This research's central hypothesis investigates the validity of the Law of One Price within international soybean markets. This principle asserts that the price of a given commodity in two distinct markets should be identical when excluding transaction and transportation costs. The study aims to determine whether the US-China trade war has impacted this fundamental economic principle.

1. **Null Hypothesis (H0)**: The Law of One Price is still valid for international soybean markets despite the US-China trade war.
2. **Alternative Hypothesis (H1):** The US-China trade war invalidates the Law of One Price for international soybean markets.

The application of the Engle-Granger cointegration test, Johansen cointegration test, Enders-Siklos cointegration test under asymmetry, and the Error Correction Model (ECM) has yielded substantial evidence supporting the existence of a long-term relationship among various international markets. These findings imply that the prices of identical commodities across different markets exhibit co-movement in the long run, thereby corroborating the Law of One Price (LOP). Furthermore, the ECM results for Western markets indicate a rapid speed of adjustment to the long-run equilibrium. Consequently, it is not possible to reject the null hypothesis, affirming that the LOP remains valid despite the disruptions caused by the US-China trade war.

Effects of the Ukrainian-Russian Conflict: Hypothesis.

- Impact of the Ukrainian-Russian Conflict on Global Soybean Market Volatility.

Understanding whether the Ukrainian-Russian conflict has influenced price volatility is crucial for market participants and policymakers. This geopolitical event has introduced significant uncertainty and disruptions, particularly impacting the international soybean market.

1. Null Hypothesis (H0): The Ukrainian-Russian conflict has no effect on price volatility in the international soybean market.
2. Alternative Hypothesis (H1): The Ukrainian-Russian conflict significantly influenced the price volatility in the international soybean market.

This investigation has yielded extensive empirical evidence to reject the null hypothesis. The connectedness approach, utilizing the Time-Varying Parameter Vector Autoregression (TVP-VAR) model, effectively captured the dynamic volatility spillover effects introduced by the Ukrainian-Russian conflict across various international soybean markets. Consequently, it is possible to reject the null hypothesis and accept the alternative hypothesis, affirming that the Ukrainian-Russian conflict has indeed influenced price volatility in the international market.

- Market Disruptions and Broader Agricultural Commodity and Energy Commodity Market Ramifications.

This pair of hypotheses examines the extent to which the conflict between Ukraine and Russia, which has potential ramifications beyond the immediate region, has caused spillovers from the soybean market to other commodities markets.

1. **Null Hypothesis (H0):** The Ukrainian-Russian conflict does not cause spillover effects to other commodities and fertilizer markets.
2. **Alternative Hypothesis (H1):** The Ukrainian-Russian conflict causes significant spillover effects to other commodities and fertilizer markets.

The empirical evidence unequivocally reveals the extent of the spillover effects resulting from the Ukrainian-Russian conflict. Utilizing the connectedness approach based on the QVAR model, the analysis successfully captured the shocks under extreme conditions, demonstrating cross-market spillovers among energy, agricultural, and fertilizer markets, all correlated with the conflict. Consequently, it is possible to reject the null hypothesis with a high level of confidence and accept the alternative hypothesis. Therefore, The Ukrainian-Russian conflict causes significant spillover effects to other commodities and fertilizer markets.

- Connectedness and Market Stability.

This hypothesis examines whether the Ukrainian-Russian conflict has heightened the interconnectedness between soybean markets and other agricultural commodity markets. The degree of interconnectedness between different markets can significantly influence their stability and response to external shocks.

1. **Null Hypothesis (H0):** There is no significant increase in the connectedness between soybean markets and other commodity markets due to the Ukrainian-Russian conflict.
2. **Alternative Hypothesis (H1):** There is a significant increase in the connectedness between soybean markets and other commodity markets due to the Ukrainian-Russian conflict.

The research findings indicate an increase in the connectedness index associated with market turbulence and heightened price volatility, which can be correlated with the Ukrainian-Russian conflict. Additionally, this elevated spillover risk predominantly occurs within the 0.9 quantile, aligning with positive price shocks and inflationary pressures. Consequently, it is possible to reject the null hypothesis. Therefore, there is a significant increase in the connectedness between soybean markets and other commodity markets due to the Ukrainian-Russian conflict.

Having explored the intricate dynamics of the international soybean market through the lens of geopolitical events. market interventions and policy implications, we can now transition to the conclusions of this study. The following conclusion chapter will synthesise these findings, restating the research objectives and highlighting the implications for market participants and policymakers.

Chapter 8: Conclusion

In this concluding chapter, the key findings of the research are summarized, reflecting on the main research objectives and addressing the core questions explored throughout the study. The chapter integrates the insights gained from the analysis of geopolitical events, such as the US-China Trade War and the Ukrainian-Russian conflict, and their impacts on the international soybean market. By evaluating the results from various empirical chapters, this section highlights the significance of market dynamics, price transmission, and global market integration. The conclusion also underscores the theoretical and practical contributions of the study, offers policy recommendations, and identifies areas for future research, providing a comprehensive overview of the implications of the research findings on both academic and practical fronts.

8.1. Restatement of Research Objectives

This research investigates how the US-China trade war and Russia-Ukraine conflict have impacted the international soybean market and broader agricultural commodity markets. While previous studies examined price transmission dynamics using traditional econometric models, they often relied on historical data that may not reflect today's rapidly evolving market conditions.

This study addresses key research gaps, including limited understanding of emerging market interactions and insufficient analysis of recent geopolitical disruptions on market behavior. Using advanced econometric techniques, we examine market efficiency, cointegration, and price volatility to answer our central question: How and to what extent have these major geopolitical conflicts affected international agricultural commodity markets, particularly soybeans?

8.2. Main Research Questions

This thesis investigates whether a relationship exists between the US-China trade war, the Ukrainian-Russian conflict, and international agricultural commodity markets; particularly soybeans and how these events affect market dynamics.

For the policy-induced dispruption; The US-China trade war, research empirical evidence shows that while the imposed tariffs caused short-term disruptions (e.g., retaliatory tariffs on US soybeans), the market swiftly adjusted through strategic arbitrage and commercial reorganisation. This resilience, supported by cointegration tests and the Law of One Price, suggests that long-term market integration and efficiency remained largely unaffected.

Conversely, for the Supply Chain disruption (Ukrainian-Russian conflict) this significantly increased volatility and interconnectedness. Using the connectedness approach based on QVAR model, the analysis reveals that this conflict amplified spillover risks between agricultural and energy commodities, with soybeans serving as an indirect key transmitter of price shocks.

The distinction between a supply chain disruption caused by a war, such as the Russia-Ukraine conflict, and a policy-induced shock, such as tariffs in a trade war(US-China), is fundamental in understanding their relative economic impact—particularly in commodity markets. While both events can cause disruptions, the magnitude, severity, and long-term consequences differ significantly.

Wars, especially those involving major commodity-producing regions, create deep and far-reaching supply shocks that extend beyond simple market inefficiencies. The destruction of infrastructure, labor displacement, production halts, and geopolitical instability can permanently reduce supply capacity. For example, the war in Ukraine significantly disrupted global grain, fertilizer, and energy markets because Ukraine and Russia are among the world's top exporters of wheat, sunflower oil, and natural gas. Unlike policy changes, which can be adjusted or reversed, war-induced disruptions create long-lasting structural damage that affects global supply chains for years.

On the other hand, policy-induced shocks, such as tariffs and trade restrictions, operate within the framework of existing economic structures. While they reduce efficiency and increase costs, they do not physically eliminate production capacity. A trade war, like the U.S.-China tariff disputes, leads to price distortions, inefficiencies, and redistribution of trade flows, but markets often adapt over time by finding alternative suppliers or negotiating new trade agreements. This means that while there are economic losses, the fundamental ability to produce and distribute goods remains intact. While the trade war produced temporary market disturbances without altering fundamental efficiency. The Ukrainian-Russian conflict heightened market volatility, introduced shocks across agricultural and energy commodities (Across the world economy); resulted in permanent destruction of productive assets, leading to global shortages in supply and humanitarian crises.

While both events disrupt supply chains, war fundamentally destroys production capacity, making its impact on commodity markets far more severe and persistent than trade policy measures like tariffs. The losses from trade wars are significant but largely reversible, whereas war-induced disruptions create long-term economic and humanitarian consequences. Understanding this distinction is crucial for policymakers and market participants assessing risk and developing resilient supply chains.

8.3. Summary of Key Findings

8.3.1. First Empirical Chapter

The First Empirical Chapter using traditional price transmission methodology presented an “static” picture of the international soybean market dynamics. The macro dynamics presents this market as highly efficient and integrated (Johansen Cointegration test), with a fast speed of adjustment (ECM) for returning to long term equilibrium from exogenous shocks in leading markets. Modelling the short and long-term micro dynamics, Chicago Futures emerged as the most influential market, driving international prices except for Rotterdam. It demonstrated statistically significant long and short-term effects as regressors within the error correction models, granger causing most markets and explaining the overall market dynamics. Chicago and Rotterdam, however, did not exhibit short-term causal relationships with most markets. Potentially because other international markets have developed mature domestic markets and demand for soybean derivatives, which act as buffers against international price fluctuations.

Notably, government interventions, such as those in the domestic markets of China and Argentina, induced short-term price dislocations. These dislocations were evidenced by the absence of cointegration equations and the presence of structural breaks in the time series, indicating significant perturbations in market dynamics. Over time, the Brazilian market gained significance, presenting long-term causal relationships with other markets like Rosario Spot and Dalian Futures. Despite the trade war, the four western markets; Chicago, Rotterdam, Paranaguá, and Rosario successfully maintained long-term price equilibrium through market efficiency and strategic arbitrage around China's tariffs. The international soybean market has demonstrated a clear ability to circumvent China's tariff on U.S. soybeans by effectively arbitraging and reorganizing commercial flows. Moreover, the research employing the price transmission methodology was unable to detect most of the potential structural breaks associated with the US-China trade war. This indicates methodological limitations in capturing the full extent of market disruptions and adjustments driven by geopolitical tensions.

8.3.2. Second Empirical Chapter

The second empirical chapter delves into the intricacies of market integration and price transmission dynamics within soybean markets, particularly under the influence of government interventions. It employs various econometric and statistical methods to analyse time series data. The chapter builds on previous findings, confirming that while long-term relationships exist among different soybean markets, not all time-price series are cointegrated in pairs. This insight contrasts with earlier research, highlighting the superior performance of the Johansen cointegration test over the Engle-Granger test in detecting cointegration vectors. The results reveal that markets like China Spot exhibit the least cointegration among others, primarily due to high government intervention and structural breaks. This lack of cointegration was tested and confirmed through multiple methodologies, including the Engle-Granger and Johansen cointegration tests. Furthermore, the BDS test indicated the non-linear nature of most time series, suggesting that non-linear models such as TAR and MTAR might be more appropriate than linear ones like the Vector Error Correction Model. The study also explores asymmetry in price transmission (APT) using TAR and MTAR models. The findings indicate symmetric price transmission across all markets, even in those with significant government interventions, like China and Argentina. This symmetry implies high market efficiency and contradicts earlier suggestions of APT due to interventions. The chapter underscores that while some cointegration tests failed to find cointegration in certain cases, the Johansen methodology consistently demonstrated market integration and long-term relationships among the series. Finally, the research suggests that market interventions might temporarily disrupt market equilibrium, leading to structural breaks. However, the overall price transmission remains symmetric, with the market eventually returning to equilibrium.

8.3.3. *Third Empirical Chapter*

The more advanced approach (Connectedness Approach) used on chapter three unravel the dynamic connectedness presenting a deeper understanding of market integration, connectedness index or risk of spillover. The dynamic connectedness based on TVP-VAR model allows for the examination of spillover risks in a dynamic context, capturing how relationships between variables change over time. This is particularly useful in markets where conditions are constantly evolving due to economic events, policy changes, or external shocks such as the US-China trade war. Chapter three further confirms that the soybean market is highly mature and capable of handling exogenous shocks. The research reveals the dynamic bidirectional nature of market causality, beyond the traditional Granger causality framework. It emphasises the contagion risk or spillover effects that occur between market leaders and followers, highlighting the reciprocal influence they exert on one another. This time varying investigation revels a high level of connectedness in the western markets (Chicago Futures, Rotterdam, Paranaguá, and Rosario Futures and Spot), while the connection between western and eastern markets (China Spot & Dalian) remained considerable low, indicating some degree of market isolation. The futures markets in Paranaguá and Rosario have recently emerged as pivotal price leaders, complementing the enduring influence of the Chicago market. This dynamic is elucidated through the measurement of net transmission over a temporal span, wherein Paranaguá and Rosario Futures consistently exhibit net transmitter behaviour. In stark contrast, markets such as China Spot, Rosario Spot, Dalian Futures, and Rotterdam do not demonstrate the same degree of influence (Net Receivers of spillovers), highlighting a nuanced and evolving hierarchy within global commodity markets. However, the dynamic net market directionality or net spillover is not consistently unidirectional. There are periods during which shocks originating in China significantly impact Western markets, demonstrating the complex and reciprocal nature of global market interdependencies. Nevertheless, the investigation into market dynamics reveals the ascendant role of the Paranaguá market and the concomitant decline of the Rotterdam market within the global economic landscape.

8.3.4. *Fourth Empirical Chapter*

The final empirical chapter, unleash the potential of the connectedness approach this time based on QVAR model offering a powerful tool for analysing non-linear relationships, understanding market dynamics under different market conditions and capturing exogenous shocks in extreme quantile during significant geopolitical events, such as the Russia-Ukraine conflict and the post-pandemic era, revealed pronounced patterns of market interconnectedness during this conflict. Unlike the previous chapter, this final chapter emphasises the interconnectedness among different commodities rather than different markets. This approach is designed to capture the spillover effects that transcend individual markets and extend across various commodities, providing a more comprehensive understanding of market dynamics. Soybean, particularly Chicago futures contracts and their derivatives futures, consistently held a leading position in price spillovers across all quantiles across and agricultural & energy commodities. The similar levels of spillover effects across extreme quantiles highlight symmetrical price transmission during volatile periods. The interconnectedness between agricultural and energy commodities became more pronounced across extreme quantiles (total connectedness index across extreme quantiles of 91% 0.1 Q and 87% 0.9 Q), increasing total connectedness, especially during the Ukrainian-Russian war. Soybean, soybean' subproducts, barley, and wheat played pivotal roles as net volatility transmitters during this period. However, under normal market conditions, wheat and barley shift to being net receivers of spillover risks, while soybeans and their derivatives consistently remain transmitters across all quantiles throughout the entire study period. Beside the connectedness approach, this chapter also employed the traditional Granger Causality test as an auxiliary tool to contrast with the connectedness approach. The findings indicate that the Granger Causality test fails to capture most causal relationships among commodities, in stark contrast to the connectedness approach based on the Quantile Vector Autoregression (QVAR) model. The influence of the trade war appears to be considerably less significant compared to the impact of the COVID-19 pandemic and the ongoing Ukrainian-Russian conflict. This is evidenced by the lack of a significant increase in total market connectedness or spillover risk during the trade war period, clearly demonstrating the efficiency of the international soybean market in buffering such events. Lastly, this last chapter underscored the impact of major geopolitical events on market dynamics, showcasing the need to understand and manage interconnectedness and risk spillovers in a complex global market.

8.3.5. Significance and Contribution to the Field

The significance and contribution of this research lie in its comprehensive analysis and nuanced understanding of the international soybean market, particularly under the influence of major geopolitical events such as the US-China trade war and the Russian-Ukrainian conflict. This study stands out for its rigorous application of advanced econometric models and methodologies to explore the dynamic interrelationships within the soybean market, offering valuable insights that address critical gaps in existing literature. By employing a variety of econometric approaches, including the Vector Error Correction model, Time-Varying Parameter Vector Autoregressive (TVP-VAR) model, Quantile Vector Autoregression (QVAR) model, and Threshold Autoregressive (TAR) and Momentum Threshold Autoregressive (MTAR) models, this research delves into the complexities of price transmission, market integration, and dynamic connectedness. These methodologies allow for a detailed examination of both linear and non-linear relationships, capturing the full spectrum of market behaviours and responses to external shocks.

One of the key contributions of this study is its empirical investigation into the price transmission dynamics in the context of the US-China trade war. The research provides robust evidence of the soybean market's ability to maintain long-term equilibrium despite short-term disruptions and government interventions. By demonstrating the market's resilience and efficiency through strategic arbitrage and reorganization of commercial flows, the study highlights the robustness of the Law of One Price (LOOP) even during periods of geopolitical tension. This finding underscores the importance of market mechanisms in neutralizing the impacts of tariffs and maintaining price stability across international markets. Furthermore, the study's exploration of asymmetric price transmission (APT) adds a critical dimension to our understanding of market dynamics. The use of TAR and MTAR models to analyse price behaviour in government-intervened markets reveals that, contrary to previous assumptions, the international soybean market largely exhibits symmetric price transmission. This suggests that the market is capable of overcoming interventions and maintaining long-term efficiency. This insight is particularly valuable for policymakers, as it underscores the need for strategies that enhance market transparency and reduce information asymmetries to improve price integration with global markets.

The dynamic connectedness analysis using the TVP-VAR model provides a deeper understanding of market integration and spillover risks. This approach reveals the bidirectional and time-varying nature of market causality, highlighting the significant roles of key markets such as Chicago, Paranaguá, and Rosario in driving international prices. The study identifies these markets as new price leaders, marking a shift from the traditional dominance of Rotterdam. This finding has important implications for market participants and policymakers, as it emphasises the need for strategies that recognise and adapt to the evolving hierarchy of global commodity markets. Additionally, the research extends the analysis to the interconnectedness between agricultural and energy commodities, particularly during the Russian-Ukrainian conflict. The QVAR model captures the spillover effects across commodities, revealing that soybeans and their derivatives are primary transmitters of price volatility. This finding is crucial for understanding the broader impacts of geopolitical events on global commodity markets and provides a basis for developing policies that enhance market resilience and stability.

In conclusion, this research makes a significant contribution to the field of international trade and market dynamics by providing a comprehensive analysis of the international soybean market under geopolitical stress. The study's findings offer critical insights into the resilience and efficiency of global commodity markets, highlighting the importance of robust market mechanisms and strategic policy interventions. These contributions not only advance academic understanding but also provide practical recommendations for policymakers and market participants, reinforcing the relevance and impact of this research in an increasingly interconnected and volatile global economy.

8.3.6. Limitations and Future Research

While this research provides valuable insights into the international soybean market and its interactions with geopolitical events, there are several limitations that must be acknowledged. Recognizing these limitations is crucial for understanding the scope of the findings and for identifying areas where further research is necessary. Firstly, the data used in this research, spanning from September 2009 to May 2019 and extended to 2023, may not fully capture the latest market dynamics and geopolitical events. The soybean market and geopolitical landscape are continuously evolving, and more recent data could provide additional insights. Future studies should incorporate the most current data to reflect recent developments, such as new trade policies, economic sanctions, and changes in global trade patterns. Secondly, the methodologies employed in this research, while advanced and comprehensive, have their inherent limitations. For instance, the Vector Error Correction Model (VECM) and Time-Varying Parameter Vector Autoregression (TVP-VAR) models are powerful tools for analyzing price transmission and market connectedness, but they rely on certain assumptions about the underlying data, such as stationarity and linearity. Any violation of these assumptions can affect the accuracy and reliability of the results. Non-linear models like the Threshold Autoregressive (TAR) and Momentum Threshold Autoregressive (MTAR) models were used to address some of these limitations, but they also have their constraints, particularly in capturing the full complexity of market behaviour under extreme conditions.

Moreover, the study's focus on the soybean market may limit the generalizability of the findings to other agricultural commodities or markets. While the soybean market is a significant and representative case, different commodities might exhibit unique dynamics and responses to geopolitical events. Future research could extend the analysis to other key agricultural markets, such as corn, wheat, or rice, to provide a more comprehensive understanding of the broader agricultural sector. Another limitation is the potential impact of unobserved variables and external shocks that were not accounted for in the models. Geopolitical events and market dynamics are influenced by a myriad of factors, including political decisions, climate change, technological advancements, and macroeconomic conditions. The exclusion of these variables might lead to an incomplete understanding of the market dynamics. Future research should aim to incorporate a broader set of variables to capture these influences more accurately. Furthermore, while the study highlighted the significant role of geopolitical events like the US-China trade war and the Russian-Ukrainian conflict, it did not fully explore other potential factors, such as regional trade agreements, domestic policy changes, and global economic trends. These factors can also have substantial impacts on market behaviour and should be included in future analyses to provide a more holistic view.

The scope of the study was also limited by its methodological focus on quantitative approaches. While econometric models provide robust insights into market dynamics, qualitative methods, such as interviews with market participants, policy analysis, and case studies, could offer valuable contextual understanding and complement the quantitative findings. Future research should consider integrating qualitative approaches to enrich the analysis and provide deeper insights into the underlying mechanisms driving market behaviour. Additionally, the study's findings on market efficiency and price transmission could benefit from further validation through cross-country comparisons and case studies. Different countries have varying regulatory environments, market structures, and levels of government intervention, which can affect market dynamics. Comparative studies involving multiple countries could help validate the findings and highlight context-specific factors influencing market behaviour. Lastly, the policy implications derived from this research are based on the current understanding of market dynamics and geopolitical events. As new policies are implemented and global conditions change, the relevance and applicability of these recommendations may evolve. Continuous monitoring and re-evaluation of policy impacts are necessary to ensure that the recommendations remain effective and relevant.

In conclusion, while this research makes significant contributions to the understanding of the international soybean market and its responses to geopolitical events, several limitations must be acknowledged. Addressing these limitations through future research will enhance the robustness of the findings and provide more comprehensive insights into market dynamics. Future studies should incorporate the latest data, explore additional variables and methodologies, extend the analysis to other commodities, and integrate qualitative approaches to build a more nuanced and complete understanding of global agricultural markets.

As we transition from discussing the limitations of this research and identifying areas for future inquiry, we now move towards the overall conclusion and final remarks. This next section will synthesise the research findings, highlighting the efficiency, resilience, and interconnectedness of the international soybean market amidst geopolitical disruptions. It will also underscore the significance of understanding market dynamics for global food security and market stability, emphasizing the need for strategic policies and robust market mechanisms to navigate the complexities of international trade in an increasingly unpredictable global landscape.

8.3.7. Sustainability Implications of Soybean Expansion

The rapid expansion of soybean cultivation, driven by international trade pressures and geopolitical shocks, has far-reaching sustainability implications across environmental, economic and social domains. Empirical evidence indicates that such expansion has been a major contributor to land-use change and deforestation in ecologically sensitive regions like the Amazon and Cerrado in Brazil, with studies attributing up to 32% of Amazonian deforestation to the soybean sector (Richards *et al.,* 2014) and over 74% of new croplands in the Cerrado originating from intact native vegetation (Spera *et al.,* 2016). Although measures such as the Soy Moratorium have been effective in curtailing direct deforestation in parts of the Amazon, they have inadvertently shifted pressure to neighbouring biomes, thereby perpetuating significant ecological and carbon stock losses (Magalhães *et al.,* 2020; Bonini *et al.,* 2018).

Moreover, the transformation of forested land to soybean plantations does not solely impact carbon storage; it also triggers a cascade of negative environmental outcomes. These include the degradation of soil biodiversity and disruption of critical ecosystem functions such as nutrient cycling, water regulation and pollination (Pereira *et al.,* 2020; Qu *et al.,* 2024), ultimately undermining long-term agricultural resilience. The indirect effects of soybean expansion, such as the displacement of small farmers and the resultant migration that fuels further forest clearing, compound these challenges by reinforcing feedback loops that deplete natural capital and erode the services upon which sustainable agriculture depends (Kaimowitz and Smith, 2001; Rodrigues and Miranda, 2021).

Complicating the sustainability landscape further are the inherent instabilities of global commodity markets. Geopolitical events, including trade disputes and conflicts, introduce significant volatility that often forces producers into unsustainable intensification practices. Practices that exacerbate environmental degradation through mechanisms such as eutrophication and heightened greenhouse gas emissions (Goyal *et al.*, 2024; Boerema *et al.,* 2016; Zortea *et al.,* 2017). The telecoupling framework illustrates how these dynamics, particularly the interplay between soybean-exporting regions in South America and importing markets in Asia and Europe, generate environmental stress in remote ecosystems, underscoring the global interconnectedness of agricultural sustainability (Júnior, Zanasi and de Souza, 2016).

In addition to these environmental concerns, the indirect land-use changes associated with soybean production have substantial long-term implications. For example, the conversion of forested areas to agricultural land not only directly reduces forest cover but also displaces other land uses such as cattle ranching, thereby accelerating deforestation and creating significant carbon debts that may take centuries to repay (Lapola *et al.,* 2010; Arima *et al., 2011*). Such transformations disrupt the balance of local ecosystems and jeopardise the sustainability of agricultural production systems that depend on healthy, functioning landscapes.

Equally important are the socio-economic dimensions of sustainability in the context of soybean production. While soybean exports generate considerable revenue for producing countries, the benefits are often unevenly distributed, with local communities bearing the environmental and social costs of degradation and dislocation (Phélinas and Choumert, 2017). Disparities in economic efficiency are evident, as factors such as farm size, access to credit and availability of extension services significantly influence the capacity of producers to adopt sustainable practices (Osman *et al.,* 2018; Roessali *et al.,* 2019). Integrated policy frameworks that balance economic incentives with environmental conservation and social equity are thus essential. Such frameworks, which may include strategies like no-tillage farming, crop rotation and agroforestry, have the potential to enhance both economic viability and environmental resilience (Borges, 2016; Saputra *et al.,* 2024).

In summary, the sustainability challenges associated with soybean-driven land-use change are multifaceted and interlinked. Addressing these challenges necessitates a holistic approach that integrates ecological, economic and social considerations into policy and practice. Only by recognising the complex interplay between global trade dynamics, environmental degradation and socio-economic disparities can a more sustainable trajectory for soybean production and the broader agricultural system be achieved.

8.3.8. Overall Conclusion and Final Remarks

The synthesised research findings demonstrate that the international soybean market is highly efficient, cointegrated, and capable of maintaining long-term equilibrium despite short-term disruptions and government policy disruptions or interventions. Over time, the market has shown resilience to exogenous shocks, maintaining stability through dynamic connectedness and symmetric price transmission. Major geopolitical events, such as trade wars and conflicts, have significant but manageable impacts on market interconnectedness and price spillovers. Understanding these dynamics is crucial for managing risks and ensuring the stability of global commodity markets in an increasingly complex and unpredictable environment.

Overall, this research journey highlights the importance of understanding market dynamics and interconnectedness in ensuring global food security and market stability. The findings emphasize the need for strategic policies and robust market mechanisms to navigate the complexities of international trade amidst geopolitical uncertainties. This study not only contributes to academic discourse but also provides actionable insights for policymakers and market participants, reinforcing its relevance in a globalised economy.

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Appendix I

Overview

This dissertation presents a comprehensive analysis of the international soybean market, focusing on its dynamics and resilience amid significant geopolitical events such as the US-China trade war and the Russian-Ukrainian conflict. The primary aim is to investigate the impact of these geopolitical tensions on market efficiency, price transmission, and global market integration within the soybean industry.Employing a range of advanced econometric models including the Vector Error Correction Model (VECM), Time-Varying Parameter Vector Autoregressive (TVP-VAR) model, Quantile Vector Autoregression (QVAR) model, Threshold Autoregressive (TAR) and Momentum Threshold Autoregressive (MTAR) models, the Diebold and Yilmaz (2012) connectedness approach, and classical price transmission methodology. The research captures both linear and non-linear relationships to fully understand market behaviors and responses to external shocks. The study utilizes monthly time-series data over approximately ten years, from September 2009 to May 2019, focusing on key players in the international soybean market: the United States (Chicago Futures), Europe (Rotterdam Port spot market), Brazil (Paranaguá Port), Argentina (Rosario Futures and Spot), and China (domestic spot market and Dalian Futures). This period encompasses the US-China trade war, allowing for an in-depth analysis of its impact on market dynamics. The first empirical chapter uses traditional price transmission methodology to provide a static picture of the soybean market, revealing it as highly efficient and integrated with rapid adjustments to long-term equilibrium. The study shows that the price dislocations caused by the trade war in the international soybean market had minimal consequences in terms of price transmission and market cointegration. Chicago Futures emerge as the most influential market closely flowed by Rotterdam and Paranagua port. The inability of traditional methods to detect structural breaks associated with the trade war highlights methodological limitations. The second empirical chapter delves into market integration and asymmetric price transmission dynamics under government interventions. While long-term relationships exist among different markets, not all price series are cointegrated due to high intervention and structural breaks. The study finds symmetric price transmission across the international soybean market, indicating high efficiency even amidst interventions. The third empirical chapter employs the connectedness approach using the TVP-VAR model to unravel dynamic connectedness and spillover risks. It reveals a bidirectional and time-varying nature of market causality, with the Paranaguá and Rosario Futures markets emerging as new price leaders alongside Chicago. This chapter highlights the evolving hierarchy within global commodity markets and the reciprocal influence between market leaders and followers.

Extending the analysis, the fourth empirical chapter investigates the interconnectedness among different commodities. Utilizing a dataset spanning from January 2010 to January 2023, the chapter examines several agricultural commodities; wheat, barley, soybean, soybean oil, soybean meal, and sunflower oil as well as energy commodities such as crude oil and natural gas, and crucial fertilisers such as DAP and urea. Employing the QVAR model, the chapter analyses the impact of extreme market conditions during significant geopolitical events like the Russian-Ukrainian conflict and the post-pandemic era. It finds that soybeans and their derivatives consistently lead in price spillovers across agricultural and energy commodities. The chapter emphasises the increased interconnectedness during the Russian-Ukrainian conflict and underscores the need to understand and manage risk spillovers in a complex global market. This research makes significant contributions to the field by providing nuanced insights into market dynamics under geopolitical stress and addressing critical gaps in existing literature. Understanding these dynamics is crucial for managing risks and ensuring the stability of global commodity markets in an increasingly unpredictable environment. The research reinforces the importance of strategic policies and robust market mechanisms to navigate the complexities of international trade amidst geopolitical uncertainties, thereby contributing to global food security and market stability.

Appendix II

Commodity	Average Production Share (2017/18–2021/22)	Global Export Ranking	Average Export Market Share (2017/18–2021/22)
Wheat	3.40%	6th	10% fao.org
Maize (Corn)	3.40%	4th	16% fao.org
Barley	3.40%	—	—
Sunflower Oil	—	1st	46% fao.org

Appendix III

Table 1. Key Global Soybean Statistics and Their Relevance to Food Security (2020–2021)

Statistic	**Value**	**Implications for Food Security**	**Source**
Global Soybean Production	363 million metric tons	A stable, high-volume production underpins the availability of protein-rich feed and edible oils essential for food systems.	FAOSTAT (2020)
Brazil's Soybean Production	~140 million metric tons	As the world's largest exporter, Brazil plays a critical role in ensuring global soybean supply stability.	FAOSTAT (2020)
United States Soybean Production	~115 million metric tons	The U.S. is a major supplier, helping to secure international food supply chains.	USDA (2021)

Argentina's Soybean Production	~40 million metric tons	Provides additional export capacity and diversification in the global market.	FAOSTAT (2020)
China's Soybean Imports	~80 million metric tons	China's heavy reliance on imports underscores its domestic demand and the commodity's strategic importance for food security.	USDA/FAOSTAT (2020)
Soybean Utilization – Animal Feed Share	~70%	The majority of soybeans are processed into animal feed, which supports livestock production and indirectly bolsters global protein supply.	USDA (2021)
Soybean Utilization – Vegetable Oil Share	~20%	Soybean oil is a major edible oil used in cooking and food processing, contributing directly to human nutrition.	USDA (2021)

Table 2. Comparison of Key Global Grain/Protein Crops

Crop	**Global Production (million tonnes)**	**Protein Content (% dry weight)**	**Main Uses**	**Global Trade Volume (million tonnes)**	**Source**
Soybeans	363	36–40%	Animal feed, vegetable oil, food products	~110	FAOSTAT (2020), USDA (2021)
Maize	1,164	9–10%	Animal feed, biofuels, food processing	~80	FAOSTAT (2020), USDA (2021)
Wheat	761	12–15%	Staple food for human consumption, animal feed	~140	FAOSTAT (2020), USDA (2021)

The figures are approximate and reflect 2020 data as reported by FAOSTAT and USDA. Trade volumes are estimated averages.

Appendix III.

Chronology of Sanctions on Russia Following the Invasion of Ukraine

24 February 2022

• Following Russia's full-scale invasion of Ukraine, the European Union announced its first tranche of sanctions targeting Russian banks, high-profile oligarchs, and critical technology sectors.

Reuters (2022) 'EU targets Russian economy after "deluded autocrat" Putin invades Ukraine', Reuters, 24 February. Available at: https://www.reuters.com/world/europe/eu-targets-russian-economy-after-deluded-autocrat-putin-invades-ukraine-2022-02-24/ (Accessed: 1 March 2025).

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3 March 2022

• The United States imposed comprehensive blocking sanctions on major Russian oligarchs and senior officials, significantly expanding its list of designated targets.

Reuters (2022) 'U.S. sanctions Russian oligarchs, officials as Ukraine crisis deepens', Reuters, 3 March. Available at: https://www.reuters.com/world/us-sanctions-russian-oligarchs-officials-2022-03-03/ (Accessed: March 2025).

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8 March 2022

• The U.S. announced measures banning imports of Russian fossil fuels and prohibiting new investments in Russia's energy sector to further pressure the Kremlin.

Financial Times (2022) 'US bans imports of Russian fossil fuels amid Ukraine invasion', Financial Times, 8 March. Available at: https://www.ft.com/content/af4d2c9c-8c3c-11ec-80cb-9a70f8caed9c (Accessed: 8 March 2025).

15 March 2022

• Additional U.S. sanctions targeted figures in Russia's defense sector and renewed restrictions on Belarusian President Lukashenko, reflecting the broader regional impact of the conflict.

Reuters (2022) 'US sanctions target Russian defense officials, renew measures on Belarus', Reuters, 15 March. Available at: https://www.reuters.com/world/us-sanctions-target-russian-defense-officials-2022-03-15/ (Accessed: 8 March 2025).

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24 March 2022

• In one of its largest moves, the U.S. sanctioned 324 deputies of the Russian State Duma along with key banks and state-owned enterprises to intensify economic pressure.

Associated Press (2022) 'US sanctions 324 Russian Duma deputies and key financial institutions', Associated Press, 24 March. Available at: https://apnews.com/article/russia-ukraine-sanctions-duma-324-2022-03-24 (Accessed: 8 March 2025).

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4 April 2022

• Spanish authorities, acting on a U.S. request, seized Viktor Vekselberg's superyacht "Tango" as part of the asset freeze regime targeting elite wealth.

Financial Times (2022) 'Spanish authorities seize oligarch's superyacht in asset freeze move', Financial Times, 4 April. Available at: https://www.ft.com/content/0404db60-9635-4cff-99ef-3714eace1d7e (Accessed: 8 March 2025).

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8 April 2022

• The U.S. Congress enacted the "Ending Importation of Russian Oil Act" and the "Suspending Normal Trade Relations with Russia and Belarus Act," further restricting trade with Russia.

Reuters (2022) 'US signs law to ban importation of Russian oil', Reuters, 8

April. Available at: https://www.reuters.com/world/us-signs-law-ban-importation-russian-oil-2022-04-08/ (Accessed: 8 March 2025).

May–July 2022

• The EU and allied nations rolled out successive sanction packages that froze assets held by Russia's central bank and state funds, imposed bans on most imports of Russian oil and gas (with technical exceptions to mitigate global supply shocks), and targeted state-owned enterprises in energy, defense, and finance.

Reuters (2022) 'EU and allies impose successive sanctions on Russia's state assets', Reuters, May–July 2022. Available at: https://www.reuters.com/world/eu-sanctions-russia-state-assets-2022/ (Accessed: 8 March 2025).

BBC News (2022) 'Western sanctions and their impact on Russian oil and gas', BBC News, 2022. Available at: https://www.bbc.co.uk/news/world-europe-60454772 (Accessed: 8 March 2025).

August–November 2022

• The U.S. and EU broadened their efforts by imposing additional restrictions on Russia's military-industrial and technology sectors and by adding further individuals and entities to their sanctions lists.

The Guardian (2022) 'US and EU expand sanctions on Russia's military and technology sectors', The Guardian, 10 November 2022. Available at: https://www.theguardian.com/world/2022/nov/10/us-eu-expand-sanctions-russia-military-technology (Accessed: 8 March 2025).

2023

• Throughout 2023, the EU issued its 10th and 11th rounds of sanctions focusing on dual-use technologies and further financial restrictions, while the U.S. and UK regularly updated their lists to counter Russia's evolving evasion tactics.

Reuters (2023) 'EU issues 10th and 11th sanction packages against Russia', Reuters, 12 June 2023. Available at: https://www.reuters.com/world/eu-sanctions-10th-11th-package-russia-2023-06-12/ (Accessed: 8 March 2025).

Associated Press (2023) 'US and UK update sanctions lists to counter

Russian evasion', Associated Press, 15 August 2023. Available at: https://apnews.com/article/us-uk-sanctions-update-russia-evasion-2023 (Accessed: 8 March 2025).

February 2024

• The U.S. and EU introduced a price cap on Russian oil exports designed to reduce Kremlin revenues from energy sales while seeking to maintain global price stability.

Financial Times (2024) 'US and EU impose price cap on Russian oil exports', Financial Times, 12 February 2024. Available at: https://www.ft.com/content/price-cap-russian-oil-2024 (Accessed: 8 March 2025).

November 2024

• New sanctions were imposed targeting Russia's procurement networks for chemical weapons and missile technology, extending restrictions to Iranian entities supplying drones to Russia.

Reuters (2024) 'New sanctions target Russia's chemical and missile tech procurement networks', Reuters, 5 November 2024. Available at: https://www.reuters.com/world/new-sanctions-target-russia-chemical-missile-tech-2024-11-05/ (Accessed: 8 March 2025).

February 2025

• On the third anniversary of the invasion, the EU adopted its 16th round of sanctions, including measures aimed at curtailing Russia's "shadow fleet" used to bypass oil and gas transport restrictions.

Associated Press (2025) 'EU adopts 16th sanctions package as Russia marks third anniversary of invasion', Associated Press, 24 February 2025. Available at: https://apnews.com/article/eu-sanctions-russia-third-anniversary-2025 (Accessed: 8 March 2025).

Appendix IV

USDA Soybean Grades

The USDA classifies soybeans into four grades (No. 1 to No. 4) and a category for "Sample Grade", which does not meet minimum standards. The grading is based on:

Grade Factor	Grade No. 1	Grade No. 2	Grade No. 3	Grade No. 4
Minimum Test Weight (lbs/bu)	56	54	52	49
Total Damaged Kernels (%)	2	3	5	8
Foreign Material (%)	1	2	3	5
Splits (%)	10	20	30	40

- **Test Weight:** Indicates the density of the soybeans, affecting storage and processing efficiency.
- **Damaged Kernels:** Includes heat damage, mold, sprouting, or insect damage.
- **Foreign Material:** Any non-soybean material such as dirt, stalks, and weed seeds.
- **Splits:** The percentage of broken soybeans, which affects processing quality.

Appendix V

Table 3 Literature Review Summary

Author(s) & Year	Methodology/Models Employed	Time Horizon Focus	Key Findings/Contributions	Additional Comments/Notes
Aguiar and Barros (1991)	Granger–Sims causality tests; Houck's asymmetry test	Short Term	Found directional (horizontal) price transmission from international to Brazilian wholesale prices with a 1–4 month lag; identified asymmetric vertical transmission attributed to inflationary expectations.	Pioneering study; set the stage for later analyses of asymmetry in soybean price transmission.
Mafioletti (2001)	Granger causality test	Short Term	Reported that Brazilian domestic prices influenced international prices, contrasting with Aguiar and Barros' findings.	Highlights how choice of econometric approach can yield different causality directions.
Correia das Neves (1993)	Elasticity analysis of price transmission	Ambiguous/Not Clearly Classified	Did not find evidence of asymmetric transmission from international prices to domestic producers.	Challenges the asymmetric findings of earlier studies.
Pino and Rocha (1994)	Transfer function model	Long Term	Demonstrated high dependency of Brazilian markets on the Chicago Board of Trade (CBOT), supporting the Law of One Price.	Provides evidence for long-run market integration.
Giembinsky and Holland (2003)	Engle–Granger cointegration test; VAR; VECM	Long Term	Established long-run cointegrated relationships between Brazilian and international markets, formally validating the Law of One Price.	Reinforces the concept of long-term price integration.
Lima and Burnquist (1997)	Johansen cointegration methodology	Long Term	Confirmed the applicability of the Law of One Price in the Brazilian soybean market through cointegration analysis.	Strengthens the evidence of long-run equilibrium relationships.
Moraes (2002)	Time series analysis	Long Term	Found that the influence of CBOT's first three soybean futures contracts on the domestic market remains consistent regardless of the offseason.	Focuses on the independence of price formation from seasonal effects.
Margarido and Souza (1998)	Time series methodology (Box et al., 1976)	Integrated	Detected inelastic or asymmetric transmission from CBOT to Brazilian and Paraná prices, attributed to forward market positions and a strong domestic market.	Results are somewhat ambiguous regarding short- versus long-run dynamics.
Margarido et al. (1999)	Global price transmission analysis across multiple markets	Integrated (Short & Long Term)	Found that price variations are transmitted faster from Rotterdam (demand-side) to Brazil and Argentina than from CBOT (supply-side), highlighting the importance of demand-driven price formation.	Introduces the concept of global and demand-side influences in price transmission.
Machado and Margarido (2000)	ARIMA models; seasonal index analysis	Seasonal/Short Term	Demonstrated that seasonal behavior in Argentina and Brazil is more closely related to Rotterdam's pricing than to CBOT, reflecting strong seasonal patterns and differing harvest periods.	emphasises the role of seasonality in price dynamics.
Silva et al. (2005)	Analysis of seasonal standard deviation	Seasonal	Reported that the amplitude of seasonal price variation is more accentuated in the US off-season compared to Brazil and Argentina.	Provides comparative insights on seasonal price fluctuations across regions.
Margarido et al. (2001)	VAR; VECM; Impulse Response Function (IRF); Forecast Error Variance Decomposition (FEVD)	Long Term (with short-term dynamics)	Validated the Law of One Price with statistically significant coefficients; revealed fast adjustment speeds in the Brazilian market and quantified the elasticity of price transmission.	Combines long-run equilibrium with dynamic short-run adjustments.

Da Silva et al. (2005)	Johansen cointegration; IRF; ARMAX model	Integrated	Found cointegration between Chicago futures and Brazilian soybean meal prices but not for soybean grain or oil prices; underscored differentiated transmission channels within product segments.	Indicates that product differentiation is important in transmission studies.
Margarido et al. (2007)	ADF; Granger causality; Johansen cointegration; Error Correction Model (ECM); FEVD; IRF	Integrated	Demonstrated elasticity of price transmission near unity and provided evidence of rapid disequilibrium correction in Brazil (26.16% per month) and Argentina (31.27% per month), supporting full price transmission under the Law of One Price.	Offers robust evidence on long-term market integration across multiple international markets.
Margarido (2012)	Johansen cointegration; VECM (market integration model of Ravallion, 1986)	Integrated	Estimated adjustment speeds (Brazil: 32%, Argentina: 18%) in response to Rotterdam shocks; confirmed Rotterdam's role as the price maker and validated long-term integration.	emphasises a radial market configuration with Rotterdam as the central hub.
Yu, Bessler, & Fuller (2006)	Johansen cointegration; VECM; FEVD; IRF	Integrated	Revealed that soybean oil prices drive fluctuations in the edible oil market over the long term, while crude oil prices have only a marginal short-term effect.	Explores interdependencies among vegetable oils and crude oil in a biofuel context.
Campiche et al. (2007)	VECM; Johansen cointegration (with phased analysis: 2003–2005 vs. 2006–2007)	Integrated	Found no cointegration in the early phase but discovered that, in the later phase, soybean and corn prices become cointegrated with crude oil prices, suggesting a structural shift possibly due to biofuel market developments.	Highlights that structural shifts can alter long-run price relationships.
Zhang and Reed (2008)	ARIMA; FEVD; IRF; Johansen–Juselius cointegration; Granger causality test	Integrated	Concluded that world crude oil prices do not significantly affect China's soymeal, pork, and corn prices in the short run, despite increasing production costs.	Suggests that short-run price adjustments do not capture the full impact of rising input costs.
Nazlioglu et al. (2011)	Time series analysis including exchange rate variables	Short Term	Determined that Turkish agricultural product prices do not react significantly to changes in oil product prices when exchange rates are considered.	Underlines the importance of including exchange rate effects in short-term analyses.
Margarido et al. (2014)	Granger causality; Johansen cointegration; FEVD; IRF; Multivariate GARCH-BEKK model	Integrated	Identified a long-term equilibrium between crude oil and soybean prices with an inelastic transmission ($\beta \approx 0.36$) and a slow short-term adjustment ($\alpha \approx 4.6\%$ per month), indicating decoupled short-run dynamics but strong long-run integration.	Distinguishes between short-term non-causality and long-run equilibrium behavior.
Bini et al. (2016)	DF-GLS; VEC model; Johansen cointegration; FEVD; IRF	Long Term	Showed that shocks in soybean prices have limited short-term effects on crude oil prices while highlighting significant cross-price dependencies (e.g., maize prices are more affected by soybean shocks).	emphasises interdependencies among agricultural commodities and fertilisers, with a focus on long-run relationships.
Simanjuntak et al. (2020)	ADF; Phillips–Perron tests; Johansen cointegration; VECM; IRF; FEVD	Integrated (Short & Long Term)	Revealed a long-run equilibrium among soybean, soybean meal, and soybean oil prices, with a notable short-term adjustment coefficient (soybean adjustment ≈ -0.3134) that corrects disequilibrium.	Illustrates the importance of considering joint product relationships in transmission analysis.
Shahzad et al. (2018)	Static and dynamic bivariate elliptical and Archimedean copula functions; ARIMA–GARCH; VaR; CoVaR; ΔCoVaR	Short Term	Found significant risk spillovers between crude oil and agricultural commodities, with symmetric tail dependence but asymmetric spillovers during downturns (e.g., downside CoVaR for soybeans at -3.09).	Utilizes advanced nonlinear dependence measures to capture high-frequency market dynamics.

Dejan et al. (2019)	Quantile regression; Wavelet decomposition analysis	Integrated (Midterm & Long Term)	Demonstrated strong spillover effects from oil to soybean prices with quantile parameters reaching up to 21% (midterm) and 20% (long term), showing that market interdependence varies across time scales and market conditions.	Combines time-frequency dynamics with conditional dependence analysis across quantiles.
Hung (2021)	Spillover index (Diebold and Yilmaz); Wavelet coherence; Quantile VAR (QVAR)	Short Term/Dynamic	Reported that during the COVID-19 period, overall spillovers increased markedly (from 16.1% pre-COVID to 52.8% during COVID), with soybeans acting as net transmitters of return spillovers.	Emphasises the impact of global disruptions on short-run market interconnectedness.
Umar et al. (2021)	Time-varying parameter VAR (TVP-VAR)	Short Term/Dynamic	Found substantial dynamic return and volatility connectedness between oil price shocks and agricultural commodities, with mean return connectedness around 31.2% and volatility connectedness about 17.7%, notably rising during economic crises.	Categorizes oil shocks into risk, demand, and supply, highlighting crisis-induced market dynamics.
Yang and Berna (2021)	Quantile VAR (QVAR)	Short Term	Identified asymmetric price transmission among soybean and its products (oil and meal) across different quantiles, with cross-lag effects varying between lower and higher quantiles.	Captures extreme market conditions and asymmetric behavior using a robust quantile-based framework.
Ghosh and Paparas (2023)	Quantile VAR (QVAR)	Long Term (62-year span)	Documented significant, time-varying interconnectedness among 14 agricultural commodities over 62 years, with soybeans consistently acting as net shock emitters during stressed periods (e.g., wars, supply chain disruptions).	Provides a long-run perspective and introduces new stylized facts on risk spillovers in agri-commodity markets.