Non-tariff and tariff impediments affecting spatial competition between the United States and Brazil for soybean shipments to China

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Abstract

Purpose – This study's purpose is to analyze the effects of trade interventions and non-tariff impediments between the exporters (the United States and Brazil) and China for soybean trade.

Design/methodology/approach – A spatial model is developed and solved using an optimized Monte Carlo simulation (OMCS) and is used to minimize the costs of supplying soybeans to China. The costs included the origin basis; transportation to ports, including trucks, railways and barges; demurrage; and ocean freight. The sum of these charges determines the delivered costs to China from each origin. Most variables are random and correlated. Time-series distributions are based on historical data. Production and exports are highly seasonal and important.

Findings – Base-case flows are highly seasonal, are risky and reflect actual trade. Sensitivities illustrate the effects of mitigating the quality differentials and interpreting a term of the Phase One agreement that purchases would be made so long as the prices are competitive. The results are also used to illustrate the influence of diversifying from the United States as a supplier. Finally, the policy implications are discussed.

Research limitations/implications – Removing the quality discounts for US soybeans raises the US market share by 9%. These results also illustrate that diversification of supply sources is important for the importing country. Indeed, if China were to pursue less diversification import costs and/or risks would escalate. Hence, these results suggest that diversification is an appealing element of an import strategy. The results suggest a large distribution of prices and costs, particularly in Brazil. On average, the United States is most likely to be competitive for only a few months of the year, and the results are highly seasonal.

Practical implications – Competition in supplying soybean to China is extremely competitive and the underlying factors impacting spatial competition are risk, correlated and spatially dependent. In addition to these, there are quality differences, and there are trade policies and strategies that affect competition. The empirical model and results illustrate the intensity of competition in this market as well the impacts of these non-tariff barriers and trade strategies in this market.

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All remaining errors are ours.

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Social implications – Important policies have been taken and continue to be under review regarding competition and trade among these countries. These results illustrate the impacts of these policies on market shares and competition.

Originality/value – This problem is important to the world soybean trading sector, and the methodology captures important seasonal and random variables that affect trade flows. The OMCS model is appropriate for this problem and has only been used minimally in the recent literature about commodity trade.

Keywords Soybean, Trade interventions, China, Brazil, Logistics

Paper type Research paper

Introduction

The world soybean trade revolves around two main producing origins which are the United States and Brazil, as well as China, which is, by far, the world's largest soybean importer, and these three countries are highly interdependent. Both the United States and Brazil had decades of growth for their soybean production. Numerous factors affect soybean shipments to China, including trade interventions and non-tariff pressures, such as China's 2018 import tariffs on US soybeans, soybean quality differences between the United States and Brazil, and strategies for diversification.

This study's purpose is to analyze the effects of quality differences and trade interventions on US and Brazilian soybean shipments to China. The analysis is short term and includes extensive logistical functions and costs which have escalated in importance (Valdes *et al.*, 2023). The interventions addressed in this study include quality differences, China's 25% import tariff on US soybeans in 2018, interpretation of the Phase One agreement, and strategies to diversify. A model is developed to analyze these interventions using detailed data about logistical functions and quality. The costs for both internal and offshore shipments are derived and included in an empirical model to derive market shares, to illustrate the distribution of costs and to conduct sensitivities for the important variables.

Interior costs for shipments through the US Gulf and the US Pacific Northwest (PNW), as well as several ports in Brazil, are included along with the ocean shipping costs. Some of these variables are random and vary seasonally. Quality differences are important and persist in the market through discounts based on specific origins, and their effect is demonstrated to illustrate their influence on US competitiveness. The trade dispute between the United States and China caused US exports to China to fall below previous averages; it was not until 2020/21 that US exports to China rose back to previous levels.

Including the effects of seasonal production, exports, logistical functions and costs are important when analyzing how these non-tariff pressures and trade interventions influence competition. The empirical model is specified as an Optimized Monte Carlo Simulation (OMCS), which has some key features but has not been commonly used to analyze spatial competition. The model is a short-run, minimum-cost, stochastic optimization of soybean shipments to China from five suborigins in each exporting country. Costs include the basis at five interior origins for each country, interior transportation costs (for the United States: truck, barge and rail tariffs as well as secondary-car market values that can restrict trade; for Brazil: truck costs), congestion and delay costs in Brazil, and ocean rates. The model includes relationships that allow it to reflect quality differences and trade intervention. Many variables are random and correlated, are represented as stochastic in the model and reflect the risks with these markets.

This study contributes to the literature on the factors that affect spatial competition, the evolving influence of Chinese strategies on trade and the effects of non-tariff pressures and interventions on shipments and market shares. We use an innovative approach by implementing OMCS modeling to derive the optimal commodity flows. This approach is appealing for problems involving risk, which is prevalent with most studies involving spatial competition. This model can be applied to many types of spatial analyses where competition is influenced by randomness for the input variables. In this study, the OMCS model is applied to a commodity (soybeans) for which concerns regarding non-tariff barriers and interventions are important factors which influence international competition and flows.

Background and previous studies

China imports more than 60% of the world's soybeans while the United States and Brazil supply the world with 80% of the soybean exports. Shipments to China are the main drivers of the soybean industry's growth, and Gale *et al.* (2019) describe the three countries as interdependent. With China's growing demand, it is expected to continue being the dominant importer for the world soybean market. The United States Department of Agriculture (USDA, 2022) projected that Chinese imports will grow 3–4%/year and from 105 to 142 mmt by 2031/32. There is mutual interdependence with US-China trade relationships, but this interdependence has been rocky in recent years and has affected agricultural trade. Recently, the US House has been trying to "reset" the relationship and has attempted to "even the playing field," which is an aspiration for US trade negotiators (Aquino, 2023).

Brazil poses a challenge to US soybean exports and has been the subject of recent studies (Muhammad, 2015; Gale *et al.*, 2019; Chen *et al.*, 2021; Padilla *et al.*, 2023). An important feature of the competition has been an escalation with the importance of marketing functions and logistics, which affect intercountry competitiveness (Valdes *et al.*, 2023; Kamrud *et al.*, 2022). There have been improvements with Brazil's transportation infrastructure, ultimately resulting in reducing the shipping costs by $21/mt, relative to US origins. Taken together, the changes have important implications for competition between these countries for shipments to China. Basis differences at the origins and ports, logistical risks and efficiency will continue and will affect competition. Additionally, seasonal differences for production and marketing are critical and, no doubt, will persist in the future. Each of these will have long-term effects on competition between these countries.

There are many factors that affect competition between these countries. In addition to the seasonal behavior of production and exports, logistical functions, constraints and costs, some of the most critical factors include quality differences, varying trade interventions and diversification. Moreover, interpretation of the terms in the Phase One agreement would prospectively influence trade.

Quality differences

Soybean-quality differences are an important feature for the soybean trade between China and its partners. Producing countries affect quality decisions regarding germplasm development, including research funding, variety of release procedures and the requirements for origin and/or export grading and standards. Hence, a multitude of mechanisms affect quality. It is common knowledge that international grain traders and buyers regard US soybeans as deficient relative to Brazilian soybeans. As such, the typical understanding of discounts is as follows (R.J. O'Brien and Associates, 2017).

> Given predominantly tropical conditions in Brazilian growing regions, Brazilian soybeans tend to sport higher protein and oil content than soybeans in the US as well as Argentina. Basis Brazilian soybeans at *quality par* in the eyes of Chinese and EU industrial crushers: US Gulf soybeans at 10c per bu discount (but subject specific seed fill weather in a specific year . . . have seen this discount has high as 25c). US PNW soybeans at 15c per bu discount (have seen as high as 30c discount). Argentina soybeans at 20-25c per bu discount (have seen has high as 35c discount). Again, all relative to Brazilian soybean quality at par.

These discounts have been widely regarded and have persisted in recent years. Thomson Reuters (2018a, b) described how Brazilian soybeans often receive a premium of $5 to

$10 USD/mt, which is a sizeable premium for a margin-based industry. Issues regarding the quality differences were recently highlighted (Thomson Reuters, 2021a, b, c), indicating that the higher average protein levels make soybeans from Brazil "more attractive." Discounts for US soybeans can vary by year and are generally based on the reported protein content but can also include foreign-matter discounts [1].

Quality differences in soybeans have been important for a long time, as discussed in previous studies (e.g. Breene *et al.*, 1988; Fehr *et al.*, 2002; Helms and Orf, 1997; Hurburgh *et al.*, 1990; Naeve *et al.*, 2014). Generally, these studies point to the trend toward a lower protein content for soybeans as the planted area increases, which varies between northern and southern origins. In recent years, quality problems have been exacerbated due to the changing geography of soybean production, related quality differentials and the changing composition of importers. Recent studies have analyzed quality differences and have determined the optimal strategies to mitigate the effects on expected end-use requirements (Hertsgaard *et al.*, 2018; Wilson *et al.*, 2019). Owing to the heterogeneity of quality across spatial markets, traders face risks for implicit and explicit discounts that are applied to entire regions that are commonly thought to have lower protein and the risk of rejected shipments (Hertsgaard *et al.*, 2018).

Trade interventions

The US-China trade war has been the subject of numerous studies. Besides those related to the current study, other studies have addressed the trade war's effect on price discovery (Bandyopadhyay and Rajib, 2023) and transmission (Turvey *et al.*, 2022), intermarket dependency, land markets (Lee and Westoff, 2020) and market power (Fedoseeva and Zeidan, 2022)

One of the issues addressed in the current study is the trade war's influence on market shares. In 2018, China imposed tariffs of 25% on US soybeans, allowing Brazilian soybean imports to increase (Padilla *et al.*, 2023). Gale *et al.* (2019) indicated that, as a result of all the changes occurring after the trade war, "Brazil will again account for most of the growth in global soybean exports during the next decade." Muhammad and Smith (2018) showed that "exports could drop by $1.4 to $7.7bn if a 25% tariff is applied to US soybean exports to China, resulting in a potential farm-level loss of $0.33 to $1.76 per bushel." Davis and Wei (2022) reviewed the US-China trade war and concluded that neither party won, but Vietnam was the beneficiary. Trade tensions between the United States and China have heightened their importance for the soybean trade. Indeed, the impact of a trade war continues to be important. In early 2024 ideas were circulated of imposing tariffs on US imports, and the US House Selected Committee on Chinese Communist Party indicated China would retaliate (Lighthizer, 2024).

An effect of the Chinese tariff on US soybeans was a preference shift toward Brazilian soybeans (Adjemian *et al.*, 2021). The trade intervention lowered prices at the US Gulf by 74 c/bu for about 5 months and increased the Brazil price by 97 c/bu. The market adjusted, but the US export volume did not recover until the end of the following year. The retaliatory tariffs on US agriculture were estimated by Carter and Steinbach (2020) by using a difference-in-difference estimation framework to analyze the trade war. There were negative direct effects with the tariffs for the US imports from China, but in the short run, the winners were not obvious. Finally, Dhoubhadel *et al.* (2023) conducted an ex-post analysis to illustrate that China diverted its imports from the United States to China.

Diversification

The trade dispute as well as the multitude of other developments in world trade and agriculture have prompted interest in diversification for both private companies as well as the importing and exporting countries. The trade dispute reduced the Chinese buyers' willingness to rely on the United States, and while the three countries were still very interdependent, the dispute, along with Brazil's infrastructure investments, increased Brazil's position as a major supplier (Thompson Reuters, 2021a). Trade tensions heightened the need for diversification or concentration among China's soybean suppliers.

Diversification has been a long-term goal and is apparent in other commodities, notably corn and wheat. China is vulnerable to trade tensions with the United States and global commodity price hikes. Further, as Tang (2021) indicates, "The soybean trade . . . is closely related to political factors and diplomatic relations." In response to these changes, the Chinese government adopted the objective of increasing domestic production and reducing the reliance on soybean imports (Lee, 2021) in addition to approving GM technology for domestic production in 2023.

Multiple studies have addressed the impetuses for trade diversification. White *et al.* (2023) conducted a broader examination of diversification and concentration for trade. They defined soybeans, among other traded commodities and products, as "global concentration" and indicated that agriculture and food are among the most concentrated sectors for international trade. The implications of this concentration for Chinese imports were highlighted by President Xi Jinping who stated, "food security is an important foundation for national security" and linked national security to food security. Blenkinsop (2024) illustrated how their results of bi-lateral trade flows suggested an increase in "friend-shoring," which has been used to "encourage countries to diversify supply chains away from China." However, Hongzhou (2020) indicted that China's use of food as a foreign policy instrument is probably not very effective. More recently, Donnellon-May and Hongzhou (2023) suggested that the status of food security in China is much less certain.

There are several examples in international agricultural trade where importers sought diversification in response to trade interventions: (1) Russia trade embargo in 1980, (2) Brazil and Europe's increased poultry shipments to China in 2009 as a response to the US-China trade dispute and (3) China's response to the US commercialization of a genetically modified (GM) corn trait that was not approved in China. More recently, there have been high-profile initiatives to effectuate greater diversification for China's food imports. These include relaxing the phytosanitary requirements for corn imports from Brazil in 2022. Issues with these restrictions have been subject to negotiation for decades, but following the Russian invasion of Ukraine, these issues were quickly resolved, and Brazil became a major importer of Brazilian corn (Wilson *et al.*, 2024). China has also become a major wheat importer. In early 2024, China relaxed its phytosanitary requirements for wheat imports from Argentina. In addition to these, China made overt efforts to diversify its soybean imports via increased, although minor, trading with Canada, Russia and Benin and recently approved imports of hogs from Russia.

Not only do importers seek to explore diversification, so do exporting countries. The United States has sought to diversify its customers. In early 2024, Taylor indicated that market diversification is a priority (Reidy, 2024). This strategy was prompted, in part, because four markets (China, Canada, Mexico and the European Union [EU]) consumed 60% of agriculture exports from the United States. In a recent empirical study, Wang and Liu (2023) found that export-market diversification could reduce market volatility.

Phase One agreement and price competitiveness

Finally, the Phase One agreement required China to increase its purchases from the United States in order to reach the target levels. Tang (2021) indicated that China's 2020 purchase of US soybeans increased to 39% (using Chinese customs data), which was well below the targets of the Phase One agreement. However, China was 17% short (Zumbrun, 2021) of its agricultural goal, creating a dilemma for US trade policy. Wang (2022) said that the parties are at a stalemate.

A critical term in Chapter 6 (pp. 6–1) of the Phase One agreement is as follows:

> the parties recognize that the United States produces and can supply high-quality, competitively priced goods and services, while China needs to increase the importation of quality and affordable goods and services to satisfy the increasing demand from Chinese consumers. (USTR, 2020)

It was unclear what "competitively priced goods and services" meant in this specific case. To support the importance of this term, Cowley (2020) suggested that "China is committed to purchasing US agricultural commodities only if market conditions are favorable." The results of this study provide an interpretation of this term.

Empirical model

The empirical model builds on earlier studies about spatial competition (e.g. Skadberg *et al.*, 2015) that analyzed arbitrage subject to logistical risks and focused on competitiveness, which has emerged as a subject of recent studies (e.g. Padilla *et al.*, 2023; and as discussed at International Agricultural Trade Research Consortium (2022)). This method differs from multilateral trade models, which are typically used for welfare analysis and trade diversions, relying on equilibrium conditions across multiple suppliers and buyers. The framework used for this study is a short-run, cost-minimizing spatial-optimization model that captures important features. These include seasonal production and exports, logistical costs and functions, secondary values for rail cars, which are seasonal and can restrict exports, quality differences and risks. Each factor is essential to address the issues in this study.

To illustrate, the model is specified as a representative commodity supplier that is shipping soybeans to China. The trading firm sells 1 mmt/month to China on forward contracts. This specification represents the typical contract or supply relationship between the Chinese buyers and trading firms. The decision maker is the trading firm, and procurement decisions would typically have concurrence with the buying firm or organization. (In the case of China, there are private buyers and COFCO.) Soybeans can be purchased at any specified origin, shipped through the interior and exported through specified ports for ocean shipping to China. Costs are incurred throughout the supply chain.

Model specification

The model is an optimized Monte Carlo simulation (OMCS), which differs from the more frequently used Monte Carlo optimization and risk-programming approaches [2], and has been used with recent studies about spatial competition for commodities (Kamrud *et al.*, 2022; Wilson *et al.*, 2024). The model assumes that the decision maker knows the ex-post realized values of the random variables and then makes optimized decisions accordingly. The model sequence begins by generating random values for each iteration and then finds the optimal solution for the cost-minimization problem. The optimal results from each iteration can be used to derive the outcome distributions.

A key feature of the OMCS model is that the decision maker repeatedly solves the optimization problem based on the simulated input and parameter values from iterations of the Monte Carlo model. Therefore, the optimization problem is solved under a condition of certainty, and a Monte Carlo simulation is used to provide a range of alternate scenarios where the optimization occurs. This would be similar to a spreadsheet scenario analysis where the user inputs the scenario values and observes the resultant application of the decision/optimization rule. The Monte Carlo simulation provides a more robust method to generate sample scenarios.

This study's use of the OMCS differs from the traditional multilateral, general-equilibrium trade models that utilize econometric multi-equation models. In this case, the model is for a soybean supplier to China that is making short-run procurement and shipping decisions in competition with other suppliers. This supplier is subject to shipping costs, restrictions, seasonality and random behavior in addition to non-tariff barriers and trade interventions that affect trade. Due to the short-run nature of the problem, demand is treated as an exogenous, but randomly generated, variable. Therefore, the specification is a partial equilibrium, stochastic cost-minimization model; and its focus is on the microeconomics of transactions, including the features described previously.

The OMCS specification is particularly appealing because the data are shorter in duration, seasonal, highly random and correlated. Many of the model's price and cost components are represented as linked (through correlations or regressions) stochastic distributions, allowing the determination of plausible historical or projected future scenarios. In summary, the OMCS model is appropriate for three reasons: (1) it is based on deterministic optimization; (2) there are a large number of plausible scenarios; and (3) this study's goal is to isolate the effects of the logistical costs and policies on trade flows, given the plausible scenarios that are represented by the random variables' distributions. Specification models soybean procurement and shipping decisions for each month.

The mathematical expression for the optimization model is as follows:

$$\min_{x_{i,t}} C = \sum_{i=1}^{n} \sum_{t=1}^{12} \widetilde{c}_{i,t} \cdot x_{i,t}, \tag{1}$$

subject to

$$x_{i,t} \geq 0 \text{ for all } i, t;$$

$$\sum_{i=1}^{n} x_{i,t} \geq \overline{Q}_t \text{ for all } t,$$

where.

C = Chinese buyer's total purchase cost (USD/bushel)

i = subscript for origin ($i = 1, \ldots, n$)

t = subscript for the month of the year ($t = 1, \ldots, 12$)

$x_{i,t}$ = quantity purchased for export at origin i in month t (in bushels)

$\widetilde{c}_{i,t}$ = randomly generated net-purchase cost from origin i in month t (including all elements of the procurement costs in USD/bushel)

$\overline{Q}_t$ = total required quantity purchased in month t (=1 mm).

The constraint requires that the quantity shipped from each country be between 0 and the maximum constrained value, which is also known as the total monthly shipping requirement for this model. Across all the simulations, the maximum constrained value was 1 mm for each month.

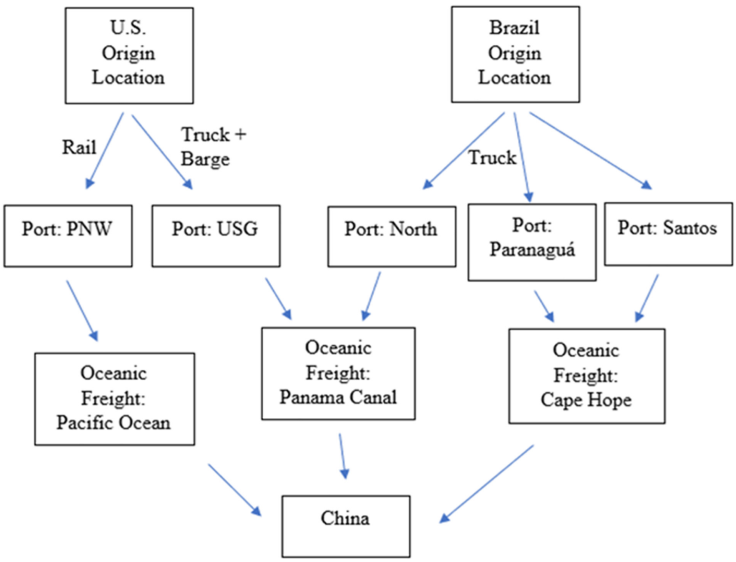
Data and distributions

The US origins stretch along the eastern state lines of North Dakota to Missouri (Ayr, ND; Jasper, MN; Ida Grover, IA; and St. Joseph, MO). The origins in Brazil are the robust soybean-producing states of Bahia, Goiás, Mato Grasso and Paraná (Barreiras, Bahia; Rio Verde, Goiás; Rondonópolis, Mato Grosso; Sorriso, Mato Grosso; and Ponta Grossa, Paraná). The US ports are the US Gulf (USG) and PNW. For this analysis, Santos, Paranaguá and Brazil's northern arc of ports are referred to as one "North" port. Finally, the costs (detailed below) include all pertinent interior, exterior shipping and handling costs. Figure 1 illustrates the routes to each destination.

Origin basis values are from the Data Transmission Network's (DTN) *Prophet X* for the US origins and Thomson Reuters Eikon for the Brazilian origins. The US origins are shuttle elevator locations, whereas the Brazilian origins are represented by the city's soybean basis as reported by Bloomberg by Escola Superior de Agricultura Luiz de Queiroz (ESALQ). Figure 2 shows the basis values for both the US and Brazilian origins. The following observations are important: (1) the basis values are somewhat comparable in value and are correlated; (2) generally, the US values are less volatile than the Brazilian values; (3) while the basis value for both countries is highly seasonal, the apparent extreme seasonality with the Brazilian values has lessened over time; and (4) the overall volatility (risk) of the basis has lessened over time.

US truck costs are from the USDA's Agricultural Marketing Service (AMS) and the North Central Region. The barge rates are also from the USDA. US rail tariffs are from the Burlington Northern Santa Fe (BNSF) Railway and the Union Pacific (UP) Railway, and the fuel service charges were added to the rail tariff. The daily car value (DCV) for rail is the average of the bid and ask values from weekly TradeWest brokerage reports. These are important because they are an added shipping cost; are seasonal, are random; are correlated with basis values; and, as shown in other studies (names withheld), have a negative influence on exports.

Brazil's interior transportation data are obtained from the Brazilian National Company of Supply (CONAB) and the Instituto Mato-Grossense de Economia Agropecuária (IMEA). The least-costly transportation routes to the ports within each country comprise the local origin



Source(s): Authors' own creation

Figure 1.
Soybean path from the US and Brazilian origins to China

Source(s): Escola Superior de Agricultura Luiz de Queiroz (ESALQ)

Figure 2.
Origin basis time-series used in this study

and the shipping costs to each port. Brazil's logistical costs also include specifications for the wait time and demurrage at ports, which are well-known to have restricted flows from Brazil. The vessel's wait time refers to the vessels waiting to be filled at Brazilian ports. The vessel's demurrage costs are incurred for waiting; the demurrage costs are specific to Brazil at ports that are partially caused by trucking/shipping inefficiencies. The average wait times are sourced from Agência Marítima Cargonave Ltda. (CARGONAVE, Brazil). The ocean shipping rates are obtained from the USDA's AMS; the routes are the USG via the Panama Canal, PNW, Brazil via the Panama Canal and Brazil around Cape Hope, all with a destination in China.

Random variables were modeled as time-series distributions and fit using BestFit @Risk (Palisade Corporation, 2020). The projected values changed with each iteration of the simulation, reflecting the distribution parameters. The best-fitting time-series distribution for each value was chosen based on the Akaike information criterion (AIC). Graphical analysis indicated that the series were stationary and homoscedastic; therefore, no differencing was performed, and wide-tailed distributions were excluded from the BestFit application. The data behind the distributions were for the years 2013–2019 and were converted into monthly averages. The BestFit time-series distribution predicted values 12 months forward. Tables 1 and 2 contain a list of random inputs, the means and data sources for the US and Brazilian segments of the model, respectively [3].

Most variables were correlated and were captured using Spearman rank-order correlation coefficients. The origin's basis values were positively correlated with the port's basis values. For Brazil, it was important that the basis values were negatively correlated with the waiting time between −0.33 and −0.43 across locations. For the United States, the DCV was negatively correlated with the origin's basis values (approximately −0.18), and the port's basis values were positively correlated (approximately +0.37). The correlation between the DCV and the other variables was of great significance. A negative correlation with the origin's basis values represented the effects of the secondary market's volatility on the

Model input	Mean value	Original units	Converted units	Source
Basis: Ayr, ND	−0.9815	USD/bu	Basis in USD/bu	DTN *ProphetX*
Basis: Alberta, MN	−0.7061	USD/bu	Basis in USD/bu	DTN *ProphetX*
Basis: Jasper, MN	−0.6598	USD/bu	Basis in USD/bu	DTN *ProphetX*
Basis: Ida Grove, IA	−0.5404	USD/bu	Basis in USD/bu	DTN *ProphetX*
Basis: St. Joseph, MO	−0.3113	USD/bu	Basis in USD/bu	DTN *ProphetX*
Ocean: USG to China via the Panamá Canal	0.9940	USD/mt	USD/bu	Thomson Reuters Eikon
Ocean: PNW to China	0.4831	USD/mt	USD/bu	Thomson Reuters Eikon
Port Basis: USG	0.7356	USD/mt	USD/bu	Thomson Reuters Eikon
Port Basis: PNW	1.0003	USD/mt	USD/bu	Thomson Reuters Eikon
Barge: Twin Cities	0.8426	USD/bu	USD/bu	USDA (2013–2019)
Barge: Mid-Mississippi	0.6710	USD/bu	USD/bu	USDA (2013–2019)
Barge: Lower Illinois River	0.5668	USD/bu	USD/bu	USDA (2013–2019)
Barge: St. Louis	0.3862	USD/bu	USD/bu	USDA (2013–2019)
Barge: Cincinnati	0.4942	USD/bu	USD/bu	USDA (2013–2019)
Barge: Lower Ohio	0.4243	USD/bu	USD/bu	USDA (2013–2019)
Barge: Cairo–Memphis	0.2691	USD/bu	USD/bu	USDA (2013–2019)
Daily Car Value	0.1345	USD/bu	USD/car	Thomson Reuters Eikon

Source(s): Authors' own creation

Table 1.
Random inputs for US origins, routes and modes

Model input	Mean value	Original units	Converted units	Source
Basis: Barreiras	−0.8344	Real/60 kg bag	Basis in USD/bu	Thomson Reuters Eikon
Basis: Sorriso	−1.7205	Real/60 kg bag	Basis in USD/bu	Thomson Reuters Eikon
Basis: Rio Verde	−0.7332	Real/60 kg bag	Basis in USD/bu	Thomson Reuters Eikon
Basis: Ponta Grossa	0.06589	Real/60 kg bag	Basis in USD/bu	Thomson Reuters Eikon
Basis: Rondonópolis	−0.9361	Real/60 kg bag	Basis in USD/bu	Thomson Reuters Eikon
Ocean: Brazil to China via Cape Hope	0.82213	USD/mt	USD/bu	Thomson Reuters Eikon
Ocean: Brazil to China via the Panamá Canal	1.0512	USD/mt	USD/bu	Thomson Reuters Eikon
Port: Santos	0.6967	USD/mt	USD/bu	Thomson Reuters Eikon
Port: Paranaguá	0.7670	USD/mt	USD/bu	Thomson Reuters Eikon
Port: North (Pecém)	1.4559	USD/mt	USD/bu	Thomson Reuters Eikon
Exchange Rate	3.1081	USD/BRL	USD/BRL	Thomson Reuters Eikon
Waiting Time: Paranaguá	4.1204	Days	Days	Agencia Maritima Cargonave Ltda (2013–2019)
Waiting Time: North (Santarem)	4.7112	Days	Days	Agencia Maritima Cargonave Ltda (2013–2019)
Waiting Time: Santos	7.1053	Days	Days	Agencia Maritima Cargonave Ltda (2013–2019)

Source(s): Authors' own creation

Table 2.
Random inputs for Brazil's origins, routes and modes

origin's basis. The DCV was also positively correlated with both the freight-on-board (FOB) at the USG and PNW.

Nonrandom inputs included the US truck cost, US rail tariff and Brazilian interior transportation costs. Due to the limited availability of these data (only available for the years from 2017 to 2019), the utilized values were monthly averages. Table 3 shows the nonrandom variables for the United States, and Table 4 includes those variables for Brazil. Other nonrandom variables included the quality discounts for US soybeans (R.J. O'Brien and Associates, 2017) and the required monthly shipments. Table 5 lists the parameters.

Base-case definition and simulation procedures

The intuition behind this model was that of a supplier planning to sell monthly shipments to China. Soybeans could originate from any of the five origins in the United States and Brazil. Soybeans were purchased at the origin, and shipments from the origin to the port occurred by utilizing rail and trucks/barges in the United States and by utilizing trucks in Brazil. The

Model input	Mean	Original units	Converted units	Source
US: Origins Truck Cost to 6 Barge Locations	$1.56	USD/mile	USD/mile × number of miles traveled	USDA AMS
Rail Tariff: Ayr, ND	$1.09	USD/car	USD/bu	BNSF Ag Price Documents
Rail Tariff: Alberta, MN	$1.10	USD/car	USD/bu	BNSF Ag Price Documents
Rail Tariff: Jasper, MN	$1.11	USD/car	USD/bu	BNSF Ag Price Documents
Rail Tariff: Ida Grove, IA	$1.18	USD/car	USD/bu	BNSF Ag Price Documents
Rail Tariff: St. Joseph, MO	$1.10	USD/car	USD/bu	BNSF Ag Price Documents

Source(s): Authors' own creation

Table 3. Nonrandom inputs for the U.S. truck cost and rail tariffs

Model input	Mean	Original units	Converted units	Source
Barreiras to Santos	$1.97	Real/mt	USD/bu	Thomson Reuters Eikon (Canarana to Santos)
Sorriso to Santos	$2.22	Real/mt	USD/bu 3-year monthly average	CONAB
Rio Verde to Santos	$1.39	Real/mt	USD/bu 3-year average	USDA AMS
Rondonópolis to Santos	$1.65	Real/mt	USD/bu 3-year monthly average	CONAB
Sorriso to Paranaguá	$1.97	Real/mt	USD/bu 3-year monthly average	CONAB
Rio Verde to Paranaguá	$1.44	Real/mt	USD/bu 3-year average	USDA AMS
Ponta Gross to Paranaguá	$0.74	Real/mt	USD/bu 3-year monthly average	Thomson Reuters Eikon (Campo Murao to Paranaguá)
Rondonópolis to Paranaguá	$1.47	Real/mt	USD/bu 3-year monthly average	CONAB

Source(s): Authors' own creation

Table 4. Nonrandom inputs for Brazil's interior shipping

Model input	Base-case value	Original units	Converted units
Required monthly shipment	36,743,700	1 mmt	Bushels
US Gulf discount to Brazil	$0.10	USD/bu	USD/bu
PNW discount to US Gulf	$0.25	USD/bu	USD/bu

Source(s): Authors' own creation

Table 5. Additional inputs for base-case scenario

ocean shipping costs were then accrued. The model chose the least costly origin/route in each country to each port. These route costs were added to the ocean shipping costs. The random variables were viewed as risky and were managed, as appropriate, by the trading firm. At the time of the sale or shipment planning, the trader knew the value of the random or risky variables. These were taken from the distributions, and many of the variables were correlated. For each distribution, the values were determined for every variable, and an optimal solution was derived. This process was repeated, and the optimal solutions were summarized in a distribution that can be used to determine the least-costly strategy and the costs' distribution.

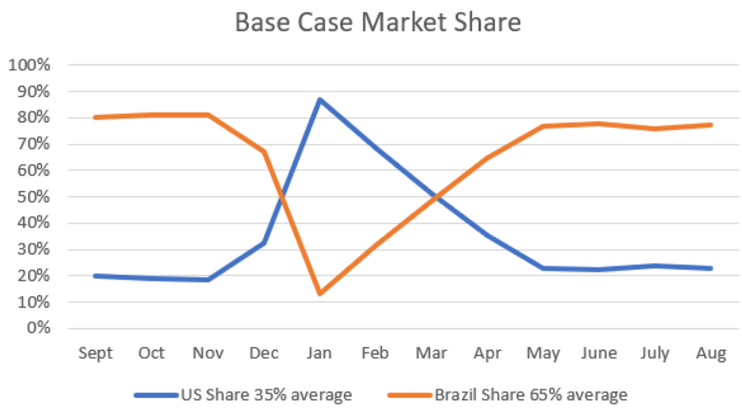
Altogether, there were 10 representative origins, 5 ports and 20 possible routes from the origin to China. Equation (1) was applied to each origin, month and port by using the corresponding basis, minimized transportation cost and ocean freight charge. The model derived the total cost of soybean procurement through the ports and determined the least-costly option for each exporting country. The model selected the optimal origin to purchase the monthly quantity. The OMCS repeated the procedure to determine the outcomes' distribution. Convergence testing was performed for 1% and 3% tolerances at a 95% confidence level. The model converged when the mean did not change by more than the tolerance level during the previous 100 iterations. For both 1% and 3%, convergence occurred at 200 iterations. The model simulation used 500 iterations to increase the convergence confidence.

Results

Base-cases

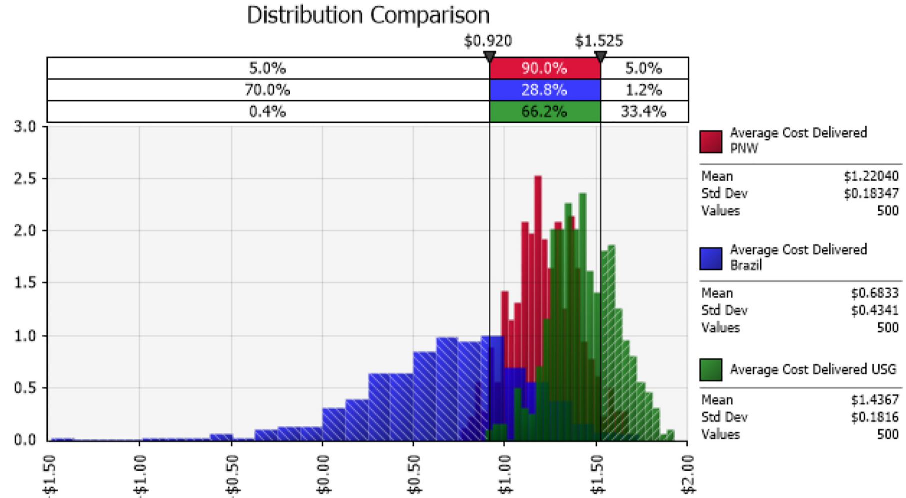
The results can be interpreted as the least-costly market share, by origin, for each month. Figure 3 shows each country's market share throughout the US crop year (September to August). March, December and January were highly competitive months. In December, US soybeans dominated exports to China, and Brazil began to dominate in April. On average, the US share for the crop year in the base case was 35% of China's imports, whereas Brazil captured 65%. These results were consistent with Salin and Somwaru (2020), who found that the US market share was 32% in 2019.

The values were the averages across all origins and months for each port. The cost distributions (Figure 4) illustrated that, while Brazil has the lowest average cost, it also had



Source(s): Authors' own creation

Figure 3. Monthly distribution of mean market shares (US versus Brazil) for base case model



Source(s): Authors' own creation

Figure 4. Distribution of cost for soybeans delivered to China from Brazil, the USG and the PNW for base case model

far more risk. Brazil's expenses had a greater downside potential relative to the costs in the United States. Thus, although Brazil was, on average, lower in cost, there was a large range where the costs were comparable, and Brazil had a larger standard deviation for costs (i.e. was riskier), and these differences varied seasonally.

Sensitivities

Detailed sensitivities were simulated to analyze the trade interventions that are important for this market. Tables 6 and 7 summarize the results.

Table 6. Mean sensitivity results for all origins and months

Model scenario	Crop-year share		Cost delivered to China		
	US	Brazil	From Brazil	From USG	From PNW
Base-case	35%	65%	$1.02	$1.55	$1.26
25% Import duty on the United States	25%	75%	$1.02	$1.93	$1.58
No US quality discount	44%	56%	$1.02	$1.45	$1.01

Source(s): Authors' own creation

Table 7. Selected simulation results showing effects of diversification by origin

Model scenario	Simulation mean	SD (Risk)	US share	Brazilian share
Base-case	$211,848,219	$161,369,438	35%	65%
25% Tariff on US soybeans	$245,659,731	$172,325,758	25%	75%
100% from Brazil	$341,243,451	$161,417,977	0%	100%
100% from the United States	$503,117,345	$70,975,165	100%	0%

Source(s): Authors' own creation

Quality differences

A structural parameter is that US soybeans are of lower quality than Brazil's soybeans, and a discount is accrued. The base-case scenario treats the USG as having a 10 c/bu discount relative to Brazilian ports and the PNW as having a 15 c/bu discount relative to the USG. Improving quality and removing these discounts would increase the US market share. Table 6 and Figure 5 show the results of removing the discounts. Without a discount, the PNW's delivered cost would be, on average, within a cent per bushel of the Brazilian ports. This change would shift China's US purchases from 35 to 44%. Figure 5 shows the results of removing the discounts for all months. Even in the off-months when Brazil is capturing nearly 80% of China's purchases, having no quality discounts would increase the US market share by 10%. Taken together, the aggregate costs of this loss in market share are about $3.5-$4.0 billion.

2018 Trade War

The base case assumed nil import tariffs on US soybeans. Modeling a 25% import duty for US soybeans demonstrated the effects of the 2018/19 trade tensions that took place between US leaders and the Chinese government. A 25% tariff lowered the US market share in China by 10%, on average. Both US ports experienced an increase of over 30 c/bu for the cost of delivering soybeans to China. Table 6 and Figure 6 summarize the sensitivity of these trade interventions.

A 10% reduction in the market share should be interpreted as the tariff's effect on optimal shipments. Specifically, the base-case results are market shares across origins and months as a result of a minimum-cost assumption. By imposing a 25% tariff on soybean imports from the United States (inclusive of futures, basis and logistical costs), the United States' minimum-cost market share declines by 10%. The United States would still dominate from December to February (versus December to March with the base case).

Interpretation of the Phase One agreement's terms about "competitive" *prices*

An important part of the Phase One agreement is that China would expand its agriculture imports from the United States, but these terms are subject to several conditions, one of which

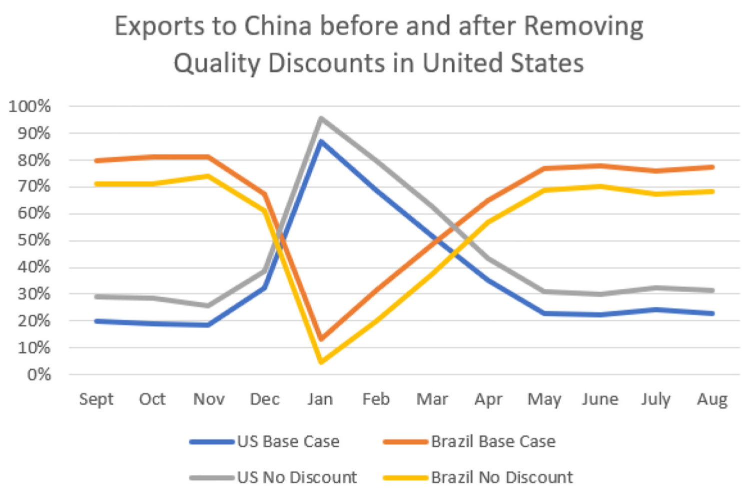


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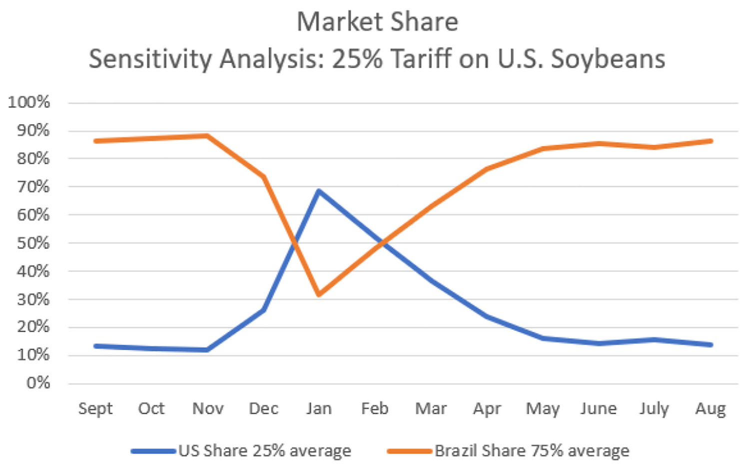
Figure 5.
Monthly distribution of mean market shares for base case versus no discount scenario



Source(s): Authors' own creation

Figure 6.
Monthly distribution of mean market shares (US versus Brazil) under 25% tariff on US soybeans scenario

is that purchases must be at "market competitive prices." However, the term's definition is unclear. This study's results can be used to provide an interpretation for the term t "market competitive prices." The results of this research provide documentation about the relevant costs that affect these competitive prices.

For a multitude of reasons, it is important that the delivered prices are largely non-transparent. Differences with the delivered prices vary seasonally. Further, trade terms differ between suppliers and buyers; hence, the terms are not directly comparable. The results shown in Figures 2 and 3 can be used to interpret the findings. These values are representative of the cost distributions (e.g. Figure 3). Further, the results in Figure 4 illustrate the probability of a price being less than the competitors' prices. More simply, the model determines the cost distribution for each origin, and the result of the minimization is the probability that a particular origin has the lowest cost. For example, the average market share for Brazil in September (80%) can be interpreted as an 80% probability that buying soybeans from Brazil would be a less-costly option for China during that month. For the key months of December and March, there is, effectively, a 50% chance that either origin would incur the least cost. From January to February, the United States has a greater probability of having lower costs, and from April to November, Brazil has a greater probability of being the lower-cost option. Importantly, neither country has a 100% likelihood of being less costly during any month.

These results indicate that the United States would, most likely, be a low-cost supplier in January and February, and Brazil would, most likely, be a low-cost supplier from April–November. In December and March, there is an almost equal chance that either origin would have the lowest costs. These results also show that, during the base period, the United States was predominantly the lowest-cost supplier for several months. These findings suggest that, although the relative delivered costs to China would vary, the United States would only be competitively priced for several months. Thus, the fact that China was under purchasing relative to its Phase One commitments may be because US soybeans are not competitively priced for a significant portion of the year. Finally, these results illustrate that the cost difference is highly seasonal; hence, one would expect that any interpretation of this term in the Phase One agreement would necessarily require evaluation at this level of detail. Undoubtedly, as the interpretation of the Phase One agreement continues, it is important to provide an interpretation of this term.

Diversification

Diversification is an important goal for buyers and suppliers in international commodity trading. Strategically, diversification involves allocating purchase shares across origins and time in order to reduce costs and risks. Indeed, there are cases where buyers have sought to diversify their sources of internationally procured commodities.

The model was simulated to explore the prospective effects of not diversifying purchases, rather than purchases based on minimum costs (Table 7). The results were summarized in terms of the cost and the costs' standard deviation (as a measure of risk). Specifically, the model was simulated with two extreme cases where 100% of the shipments were constrained to originate from only Brazil or the United States. If imports were forced to be undiversified and exclusively from Brazil, the costs and risks would increase relative to the base case. Indeed, this situation has typically been the case, at least in recent years. For example, (1) from December to February 2022, there was concern about dryness in Brazil; and (2) in November 2023, there was concern about late planting, which would reduce the country's crop size and force more imports from the United States in later months (e.g. as in both 2022 and 2023). These results illustrated the developments for the 2023 Brazilian crop. Despite Brazil having a record crop, shipments were switched from Brazil to the United States for several months because of logistical problems. The findings were informative about logistical risks and illustrated that China (or suppliers to China) should rationally pursue strategies for spatial and temporal diversification, similar to the base-case results.

The results were slightly different if the Chinese imports only came from the United States. In this case, the average costs would increase substantially because the United States is a higher-cost supplier for most months. The risk would be reduced because the United States is a lower-risk supplier.

Summary and implications

The United States and Brazil are the two largest soybean producers in the world, and both countries depend on China for the vast majority of their exports. Numerous variables affect the competition between these countries. Of particular importance are quality differences and trade interventions, including the trade war, the interpretation of the Phase One agreement, and the economics of diversification. The effect of these variables on trade and competition has important implications for commodity suppliers as well as government policies and the agencies trying to influence competitiveness.

This study's purpose was to analyze the effect of non-tariff barriers, including quality differences and trade interventions, on soybean shipments from the United States and Brazil to China. The empirical model was specified as an Optimized Monte Carlo Simulation which was used to minimize the cost of supplying soybeans to China.

The base-case results indicated that Brazil had a lower average cost for most months, capturing a 65% market share, and that the United States' market share was 35%. The average market share could also be interpreted as the probability that a location is the least costly. Over the crop year, there was a 0.65 probability that Brazil would be the least-costly origin. The outcome distribution for the average delivered costs demonstrated that the PNW and USG are higher, but their costs had a much smaller standard deviation than Brazil. Therefore, although Brazil may have a lower mean cost, its origin posed a higher risk than the United States. Sensitivity analyses were performed to evaluate the effect of several interventions. Removing the quality discount increased the average market share for the United States. Implementing a 25% import duty on US soybeans decreased the United States' average market share by 10%. Finally, the consequences of diversification were analyzed and summarized in terms of risk and cost. Brazil was the lower-cost option, on average, but the standard deviation for the cost of importing soybeans from Brazil was much larger than for imports from the United States. The findings showed that the current market-based strategy results in a portfolio of imports from each origin and has a lower risk and/or cost than any strategy that involves concentrating on purchases from a single origin.

Implications

This study has several implications for importers, trading firms and policies. It is common knowledge that U.S soybeans are discounted, in terms of quality, relative to Brazilian soybeans. Removing the quality discounts for US soybeans raises the US market share by 9%, which would have a value of $3.5 to $4.0 billion/year. There are alternatives to improve quality (Hertsgaard *et al.*, 2018), including mechanisms to mitigate quality disparities, such as improving protein quality, testing for a buyer's quality preferences in the soybeans to avoid the shipment's rejection, and diversifying the geographic placement of originating locations to have more control over the final shipment's quality specifications when the crop is sent to a buyer.

There are several trade policy issues. The US-China trade war in 2018 resulted in trade disruptions and distorted prices. These issues are now lurking again in 2024 as proposals threaten to revert to the trade war regime. These results illustrate that the impacts would be substantial reduction in exports and prices in the United States. However, at least with the 25% tariff, China imports of US soybeans would not be eliminated, but the months in which the United States would be competitive would be reduced substantially. Diversification is an essential element of importer's strategy, and that for China in particular. These results illustrate that diversifying the supply sources is important for the importing country. If China were to pursue less diversification (e.g. concentrating more purchases from one of the origin countries), the import costs and/or risks would escalate. There is no doubt that this factor is a reason for China to escalate its diversification initiatives in recent years, in part by qualifying importers which were previously precluded from shipping to China. These results suggest that diversification is an appealing element of an import strategy. Finally, an important term in the Phase One agreement is that US products would be competitively priced. The findings suggest that there is a large distribution of prices and costs, particularly in Brazil. On average, the United States is most likely to be competitive for only a few months of the year, and the results are highly seasonal.

Notes

1. In addition to protein differences, another important quality disparity is foreign material (FM), which has escalated in importance. Details regarding FM in soybeans are included in https://www.soyquality.com/farmer-resources/, which demonstrates how farmers can address FM and provides some background about the FM issue between the United States and China; https://www.aphis.usda.gov/aphis/newsroom/news/sa_by_date/sa-2017/soybean-exports-to-china, which describes US soy's commitment to lower weed seeds and FM in exports; https://www.aphis.usda.gov/publications/plant_health/faq-soybeans-to-china.pdf, which describes China's concerns about weed seeds found in US soybean exports; and https://www.aphis.usda.gov/publications/plant_health/fs-soybeans-to-china.pdf, which describes the responsibility of "participants in the U.S. grain supply chain" to implement a systems approach to lower the presence of weed seeds in US soy exports.
2. The OMCS methodology is somewhat innovative for applications to logistics and trade modeling. Details about the model are discussed in Figueira and Almada-Lobo (2014), where they referred to *sequential simulation-optimization* (SSO) models.
3. A large number of empirical distributions were utilized with this study: one for each random variable. The distributions used for the empirical model are too voluminous to report here but are available from the authors at (names withheld).

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