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The Impact of Brazil's Infrastructure and Transportation Costs on U.S. Soybean Market Share: An Updated Analysis from 1992-2019

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Abstract

This paper follows up on an analysis published by the authors in 2018 titled, "The Impact of Infrastructure and Transportation Costs on U.S. Soybean Market Share: An Updated Analysis from 1992-2019." The updated data and analysis take into account the new transportation routes that have emerged in Brazil, as well as possible future developments. The United States has lost market share to Brazil but remains the second-largest producer and exporter of soybeans. Using a dynamic econometric model and multivariate sensitivity analysis, the authors retrospectively estimate the economic attributes of changes in export market shares. This study quantifies the impact resulting from changes in the export market shares of soybeans under the continued development of Brazil's transportation infrastructure. The results suggest the U.S. world market share could decline an additional 3-6 percentage points, if U.S. farm-to-port transportation infrastructure does not significantly improve. A decline of 1 percent in the U.S. soybean market share amounts to just over half a billion dollars in lost export sales—based on a world soybean trade volume of 166 million metric tons and today's price of soybeans. Over the back casted study period, 1992-2019, soybean market shares globally converge to an equilibrium, indicating the stability of the market.

Contents

Executive Summary

Since the 1990s, the United States has lost market share to Brazil.[1] U.S. market share declined from 66 percent in 1992 to 32 percent in 2019. U.S. competitiveness, relative to Brazil, declined during a period of strong global growth in soybean demand. However, the United States remains the second-largest exporter, followed by Argentina, Paraguay, Canada, Ukraine, and Uruguay. China drives global soybean trade, accounting for more than half of soybean imports worldwide. Brazil has lowered its transportation costs by continually improving its transportation infrastructure, making the country more competitive in the world market. Brazil's position has also benefited from low production costs, increases in planted area, high productivity, a weak national currency, and recently, the U.S.-China trade dispute. At the farm level, in the main producing areas of the U.S. Midwest, per-bushel total production costs are higher than in Brazil and Argentina. Despite having higher production costs than South American soybeans, U.S. soybeans are still globally competitive because U.S. total costs (including transportation costs, from point of production to the destination in Asia) are generally lower than for South American soybeans. Nonetheless, Brazil's infrastructure has improved, narrowing the cost difference between shipping to Shanghai, China, from Sorriso, Mato Grosso, and from Davenport, Iowa.

As one of the largest producers in the world soybean market, the United States faces stiff competition from other major soybean-producing countries. The major competing countries improved infrastructure capacity and reduced transportation costs increased their competitiveness. When differences in transportation costs make South American soybean exports more profitable than U.S. soybean exports, then trade can be diverted from the United States to Brazil or Argentina at key junctures of the most lucrative marketing periods. Since 2007, the Brazilian government began a comprehensive strategy of infrastructure improvement, involving multiple transportation modes, with major institutional and regulatory changes to facilitate agricultural exports. In 2011, the Brazilian government introduced a law requiring railroads to sell other railroads the rights to use idle capacity if they do not use their rail tracks at full capacity. Two years later, an intermodal grain terminal was built facilitating the flow of grain from Rondonópolis, Mato Grosso, to the southern port of Santos. In 2014, Brazil's agribusiness sector created a new export route from Miritituba to Barcarena (Vila do Conde), adding a new northern gateway for grain exports from Mato Grosso to China, Europe, the Middle East, and Mexico. After the BR-163 highway to connect Sorriso, Mato Grosso, to Itaituba/Miritituba, Pará, was fully paved in late 2019, the "first leg" of grain exports journey was reduced from several days, or even weeks, to about 35 hours. Twelve years of strategic infrastructure and regulatory overhauls set the stage for a balanced Brazilian transportation system that includes all major modes (truck, barge, and ocean vessel). Similar to the U.S. Gulf export route, Brazil's grain-export routes now offer efficient, cost-effective transport options from farms to major foreign markets. The road ahead for U.S. soybean competitiveness will be challenging. In 2018, when demand for U.S. soybeans declined after China raised its duty on U.S. soybeans by 25 percent, Brazil became not only the world largest producer, but also the largest exporter.

This study quantifies the changes of the U.S. market share over time in the world soybean market, using a dynamic econometric model.[2] The study also examines the effects of ocean freight spreads, and evaluates the possible impact of Brazil's infrastructure development on the U.S. position in the soybean global market by

1 Until 2013, the United States was the dominant country in the world soybean market in terms of market share/power, including production volume and exports. Although, in terms of exports, the United States has lost market share since 2013, the nation remains one of the largest soybean producers in the world market. For more information, see Salin et al. (2018) and Salin and Somwaru (2015).

2 The dynamic model accounts for the interactions of each of the major soybean producer/exporter countries in the world market, estimating the behavior and stability of the market shares over time. The market shares converge to an equilibrium, implying that opposing market forces are balanced. As a result, the global soybean market is stable and converges. Consequently, the results presented are the estimates of the converged models.

using multivariate sensitivity analysis.[3,4] The analysis considers scenarios, reducing Brazil freight rates to two different levels. Assuming Brazil's infrastructure improvements began to reduce costs in 1992, these scenarios attempt to simulate the progressive effects of a generic reduction in Brazil's domestic transportation costs. The assumed reductions by $18/metric ton (mt) and by $28/mt equaled estimates of reductions from the recent completions of BR-163 highway and Ferrogrão Railroad (EF-170), respectively. Due to data availability, the base estimated model uses ocean freight rates and trade data for the period between 1992 and 2019.

The United States is one of the largest soybean-producing countries. Brazil and Argentina are major U.S. competitors in the world export soybean market. Other competitors are Paraguay, Canada, Ukraine and Uruguay. The dynamic model's analysis shows the export market shares converged over the period of the study. This implies world market shares are stable when the U.S. is one of the largest soybeans producers, despite the variability of ocean freight rates over the study period.

The results also suggest, under the base model (current conditions), the world soybean market is in a steady equilibrium and the U.S. market share will become smaller over time, as the overall market grows. The initial position of the United States erodes, and the market shares of the competing countries grow faster than the leading producer country's share. Similar results were obtained when changes in ocean freight rates over the estimated period were considered as the model converged to an equilibrium. The model's conversion indicates the market's stability. With the overall increasing global soybean production and rising export market demand, Brazil attains a larger market share than the United States.

Under scenarios 1 and 2, the findings indicate the U.S. world soybean market share in 2019 could decline by 3 and 6 percentage points, respectively. U.S. market share could decline without significant farm-to-port upgrades in U.S. transportation infrastructure that would reduce U.S. costs, in line with Brazil's cost reductions.[5] In scenario 2, the analysis shows Brazil's global export market shares for 2019 increase 9 percentage points from 50 percent to 59 percent, primarily a result of potential structural improvements in Brazil. Assuming the world soybean trade is 166 million metric tons (mmt) (World Agricultural Supply and Demand Estimates (WASDE) and FAS September 2020), a 1-percentage-point decline in the U.S. soybean market share equals just over half a billion dollars lost in export sales (1.7 mmt × $332/mt).

According to the sensitivity analysis, market penetration depends on the underlying technology and infrastructure for transporting grain and soybeans from farm to port. Thus, infrastructure improvements are critical to maintaining U.S. competitiveness and global market position, over the long term. Other things equal, improved U.S. infrastructure would result in higher income for farmers.

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3 Ocean freight spread is the cost difference between two vessel routes to the same destination.

4 Multivariate sensitivity analysis is an economic modeling tool to analyze probable events by considering alternative possible outcomes. In this case, it is uncertain how much Brazil's infrastructure will improve within the next 10 years and by how much freight rates will be reduced over time. Unlike scenario analysis, which assesses one uncertain condition at a time, sensitivity analysis can assess changes of several uncertain conditions at the same time to evaluate an outcome. This analysis simulates, retrospectively, Brazil's infrastructure and transportation improvements from 1992 to 2019 from the farm to the port and develops new estimated market shares for Brazil, while the shares of the remaining countries in the global soybean market adjust. The new market shares are then used to re-estimate the model and compare the models' outcomes to the results when the actual data are used.

5 Note that scenario 2 assumes the completion of Ferrogrão Railroad (EF-170), connecting Sinop, Mato Grosso, to Miritituba, Pará. It also assumes the southern ports of Santos, Paranaguá, Rio Grande, and Sao Francisco do Sul modernize their facilities to compete for cargo with the Northern Arc ports. Of the two scenarios, scenario 2 captures the largest change in export market shares.

Objectives and Organization

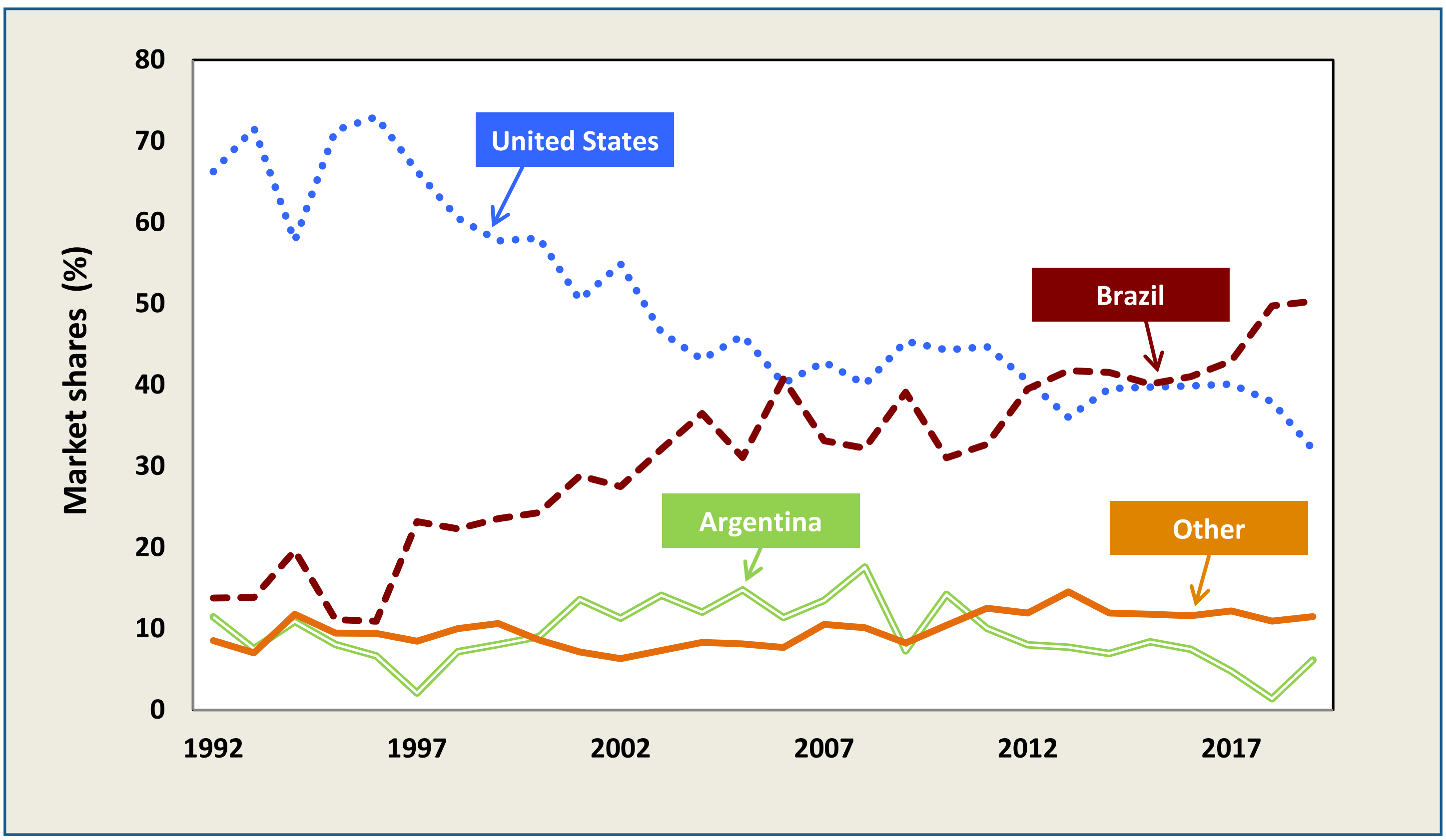
This study: (1) quantifies the dynamic changes of U.S. market shares in the world soybean market; (2) examines the effects of ocean freight spreads rates on the global soybean export market; and (3) analyzes the impact of Brazil's potential infrastructure development on the world soybean market on the underlying market structures where the United States initially operates as a dynamic dominant firm/country model.[6]

The study begins with an analysis of the U.S.-South American market shares in the world soybean market structure. Second, it examines the characteristics of U.S. and South American ocean freight spreads. Third, a dynamic model analyzes the behavior of the underlying market interactions in a world soybean export market. The model performs a sensitivity analysis of the potential impact of Brazil's infrastructure development on the soybean global market. The final section contains conclusions and recommendations for further research.

Market Shares in the World Soybean Market

For decades, the United States had the dominant market share of international soybean trade, with Argentina and Brazil as smaller competitors. However, since the late 1990s, Brazil's market share has grown. In 2019, Argentina and Brazil accounted for 56 percent of the world's soybean market, and the United States accounted for 32 percent.[7] From 1992 to 2017, the U.S. soybean export market share declined from 66 percent to 40 percent. Following China's retaliatory tariffs on U.S. soybeans, that share dropped further to 32 percent in 2019 (fig. 1 and table 8).

Figure 1. The United States is one of the world's largest soybean producer, but has lost market share to Brazil since the late 1990s

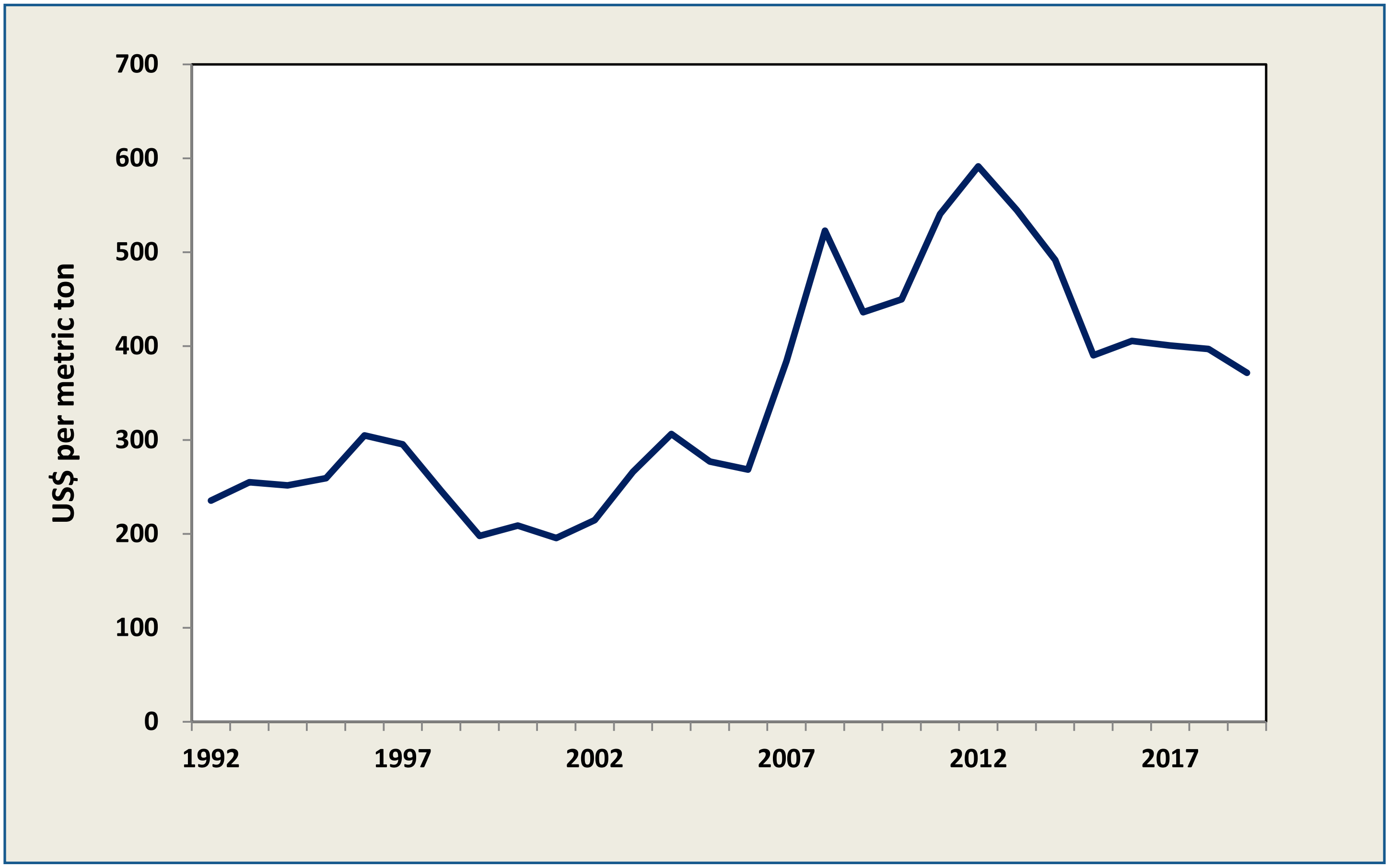


Source: USDA, Foreign Agricultural Service's Production Supply and Distribution (PSD Online).

6 Model specification, Salin and Somwaru (2015).

7 Other major competing countries include Paraguay, Canada, Ukraine, and Uruguay (USDA/FAS, 2020).

Figure 2. CIF* Rotterdam price for soybeans declined 37 percent in 2019 from the peak of 2012



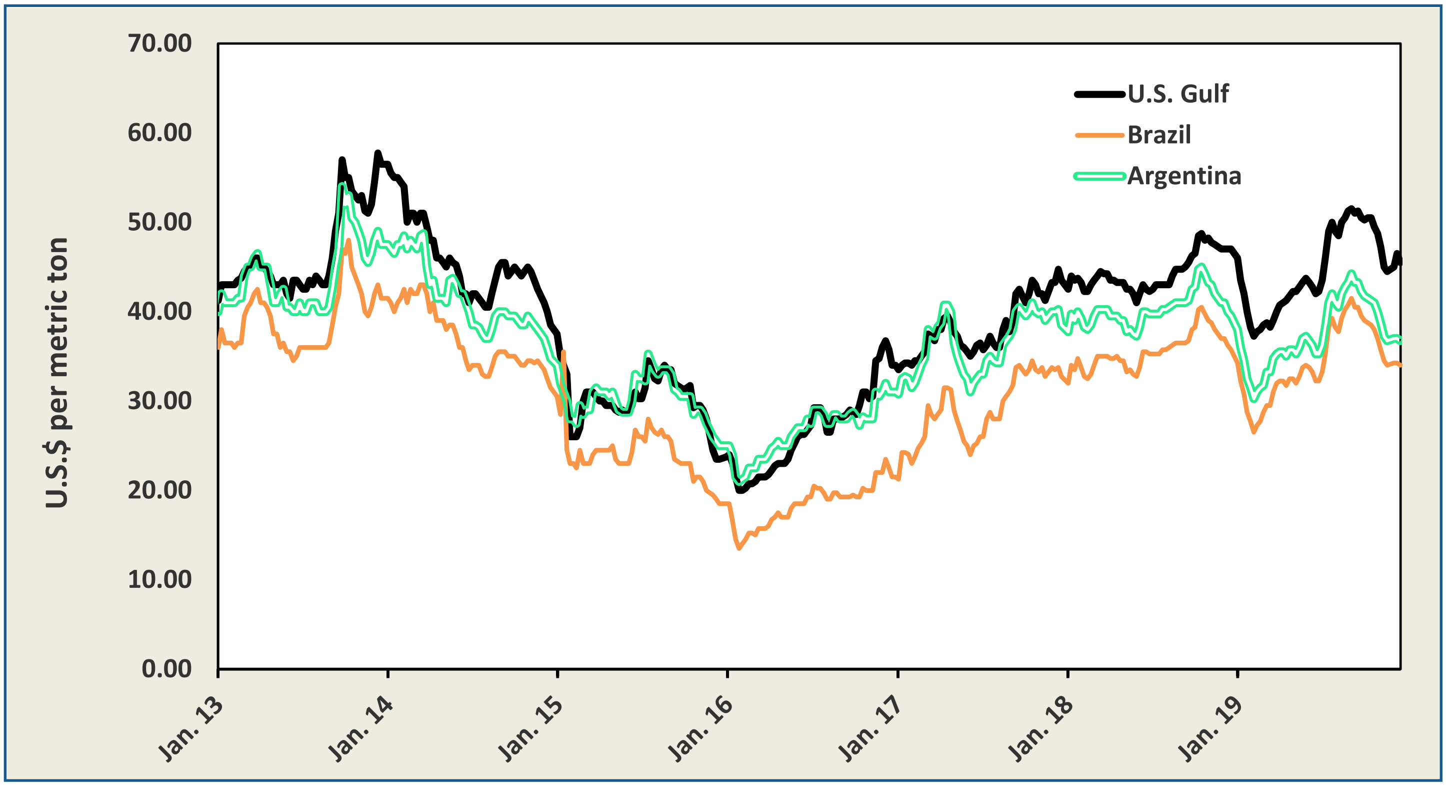
*The cost of the goods, insurance, and freight delivered to Rotterdam.
Source: Oil World.

From the late 1990s to 2012, nominal prices for soybeans in the global market increased, but then declined to $372/mt in 2019, as measured by CIF Rotterdam prices (fig. 2).[8] The United States has lost its cost advantage over South America, but still retains a significant share of global soybean exports (see fig. 1). From 2005 to 2019, the world soybean trade volume more than doubled, from 64.8 mmt to 148.3 mmt (FAS, 2020). With production and transport costs competitive with U.S. costs, Argentina's and Brazil's soybean exports are also competitive in the world market (Salin and Somwaru, 2018; Meade et al., 2016; USITC, 2012; Schnepf et al., 2001; and Dohlman, 2000). The exports of both countries have been rising.

At the farm level, per-bushel total production costs of the main U.S. producing areas are higher than Brazilian and Argentinian costs (Salin and Somwaru, 2018). Although variable costs in the United States are lower than in Mato Grosso and Paraná, fixed costs are much higher because of land values and capital costs (Meade et al., 2016). Even though U.S. production costs are higher than those of South American soybeans, U.S. soybeans can compete because their landed costs (including transportation costs, from point of production to the destination in Asia) are generally lower. However, developments in Brazil are lowering transportation costs, making the country more competitive in the world market (Salin, 2013, 2017a and b, 2018b, and 2020a). Transportation costs can, at times, give South American soybean exports a competitive edge over U.S. soybeans (fig. 3).[9]

8 The cost of the goods, insurance, and freight delivered to Rotterdam.
9 For more information about U.S.-South American ocean freight spreads, see Salin (2020b) and O'Neil (2015).

Figure 3. Weekly ocean freight rates to Shanghai, China, were higher from the U.S. Gulf than from Santos, Brazil, and Bahia Blanca, Argentina, in 2019



Source: O'Neil Commodity Consulting.

China soybean imports represent 61 percent of global soybean trade (USDA/FAS, 2020), up from 23 percent in 2000. For the last 19 years, China is the top source of growth in global soybean trade. In 2017, China was the largest U.S. soybean export destination, accounting for 57 percent of total U.S. soybean exports, valued at $12.2 billion (USDA, FAS, 2020). Starting in 2018 and continuing through 2019, China imposed a 25-percent duty on U.S. soybeans, reducing U.S. world market share from 40 percent in 2017 to 38 percent in 2018, and to 32 percent in 2019. Even though U.S. soybean exports to China increased to $8 billion in 2019 over 2018, total soybean export value in 2019 remained at 65 percent of 2017 values.[10]

In 2019, transportation costs accounted for about 22-25 percent of the total landed cost of shipping U.S. soybeans to Shanghai, China, from the U.S. Gulf and 24 percent of total landed costs from the Pacific Northwest (PNW) (Olowolayemo, 2020).[11] Transportation costs of shipping Brazilian soybeans to Shanghai, China, represented 16-28 percent of the total landed costs from the Southern ports and 16-23 percent of total landed costs from the northern and northeastern ports (Salin 2020).

South American and U.S. soybeans are comparable. The United States, Brazil, and Argentina all export genetically modified (GM) soybeans.[12] U.S. soybean production is supported by a transportation system that includes all major modes of transportation (truck, rail, barge, and ocean vessel), from farm to major

10 On January 15, 2020, China and the United States signed a Phase One economic and trade agreement. China agreed to purchase and import, on average, at least $40 billion of U.S. food, agricultural, and seafood products annually for a total of at least $80 billion over the next 2 years. Products will cover the full range of U.S. food, agricultural, and seafood products (USTR, 2020).

11 The landed cost is the total cost of goods to a buyer, including the cost of transportation without handling costs.

12 The Brazilian soybeans peak export season, March through July, complements the U.S. peak shipping season, October through December. This complementarity may mitigate the competition.

export markets. As a result, the production-cost advantages of Brazil and Argentina have not yet undermined the U.S. position in the world soybean market. However, as developments in Brazilian infrastructure lower Brazil's transportation costs, the country becomes more competitive in the world soybean market.

The future U.S. position in the world soybean market hinges on U.S. and competing countries' ability to improve their infrastructure capacity and reduce their transportation cost. Small differences in transportation costs can make South America soybean exports more or less expensive than U.S. soybeans, diverting soybean trade from Brazil or Argentina to the United States, or vice versa.

Overall, Brazil's infrastructure is improving, narrowing the cost difference between shipping to Shanghai, China, from Mato Grosso and from Iowa. In 2010, when soybeans shipped to Shanghai from Sorriso, Mato Grosso, using trucks for the first leg, the rates were about $73-80/mt more than for U.S. soybeans shipped through the U.S. Gulf and PNW routes. Four years later, for the same route, Sorriso soybean shippers paid only $42-$44/mt more than U.S. exporters. In 2019, shipping soybeans to Shanghai by truck for the first leg, the route from Sorriso, Mato Grosso, cost about $22/mt more than the routes from the U.S. Gulf and PNW. However, the cost advantage to U.S. shippers narrowed to $10/mt when Mato Grosso soybeans were shipped by rail to Santos for the first leg and to $9/mt when shipped by barge to Barcarena for the first leg (Salin, 2020c).

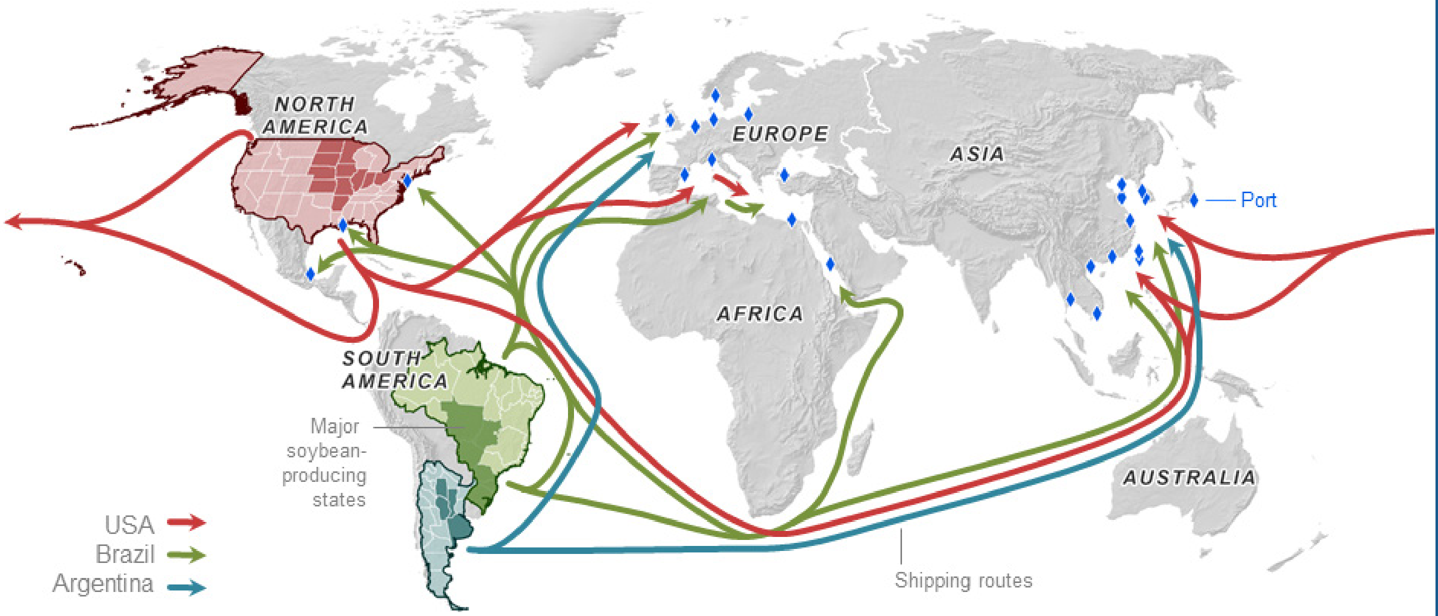
During the 2019 peak harvest season, loading delays and vessel backups were similar in Brazilian ports and the U.S. Gulf, averaging 3-10 days—narrowing the time spread between the regions. Brazil's Northern Arc ports had fewer loading delays and vessel backups than the southern ports of Santos and Paranaguá. Barcarena had vessel loading delays of only 3-4 days, which nearly offset the roughly 3-day-longer voyage time to Shanghai from Barcarena, compared with voyage time from the ports of Santos and Paranaguá. In 2019, the ocean freight spread was about $1-$2/mt between routes to Shanghai from the northeastern ports of Barcarena ($34.96/mt) and São Luís ($34.81/mt), as one option, and from the Port of Santos ($33.65), as another option (Salin, 2020a and c).

The United States exports about 25 percent of its grain[13]. Grain and oilseeds (including soybeans) are mostly exported through ports in the U.S. Gulf (55 percent) and PNW (28 percent) (fig. 4) (USDA/AMS, 2020). The major grain ports in the U.S. Gulf are New Orleans, Baton Rouge, Houston, Beaumont, and Galveston.[14] The PNW grain ports are Portland, Seattle, Tacoma, and Kalama. Brazil's largest ports for soybean exports are Santos, Paranaguá, and Rio Grande. Argentina's ports are Bahia Blanca and Rosario River. China's main entry gateways for U.S. grain are the ports of Shanghai, Qingdao, Nanjing, Nanning, Tianjin, Dalian, Huangpu, Xiamen, Fuzhou, and Guangzhou.

13 Grain: in this study grain refers to grain and soybeans.

14 The U.S. Gulf includes the East Gulf, Mississippi River, and North and South Texas.

Figure 4. U.S.-South America selected ocean routes for soybeans



Source: USDA, Agricultural Marketing Service and USDA, Foreign Agricultural Service.

The United States–South America Ocean Freight Spread

Ocean freight spread is the cost difference between two vessel routes to the same destination, such as the U.S. Gulf and PNW versus South America to Asia (China and Japan), or the U.S. Gulf versus South America to Europe and China (fig. 4 and table 1). Despite longer voyages than from the U.S. Gulf, the ocean freight rates for grain cargos from South America to Asia are often less expensive because of dry-bulk-vessel route patterns, lower cost port charges, no Panama Canal tolls or delays, and less burdensome navigation restrictions (O'Neil, 2015; Salin, 2020b). South America shipments provide some natural competitive advantages for Brazilian and Argentinean grains and oilseeds by sailing around Cape of Good Hope in large vessels. Thus, these shipments can gain economies of scale and avoid the Panama Canal (and its fees and delays) when the need exists. Brazilian ports also provide less expensive berthing (dockage) costs for vessels than U.S. ports. However, recently, Panamax and Post-Panamax soybean vessels from the U.S. Gulf to China have also gained economies of scale by going around the Cape of Good Hope, bypassing the Panama Canal to avoid fees, waiting times, and the uncertainty of getting a slot to transit the new expanded Locks.[15] U.S. Gulf grain transits the Panama Canal mostly in Handymax, Supramax and Ultramax vessels— and some Panamax vessels with a cargo capacity of under 69,000 mt.[16] Unlike container, auto, and liquefied natural gas (LNG) vessels, dry-bulk vessels are not allowed to preschedule their lock times in transiting the Neo Panama Canal locks. Grain vessels must wait for an opening if they wish to go through the new locks.

Currently, loading delays and vessel backups in South America resemble those in the United States. The cost of any resulting vessel demurrage, however, significantly affects the value of the free on board (FOB) cargo and the price received by South American producers.[17] For example, "FOB Santos" shows that the Brazilian seller will pay for transporting the grain to the Port of Santos and the cost of loading the grain onto the ship, including inland haulage, customs clearance, origin documentation charges, and demurrage. Once all the grain is on board, the buyer pays for all costs beyond that point. The ocean rates from PNW and the U.S. Gulf to Japan are higher than rates to China because of higher Japanese port fees and berth restrictions that limit the size of the receiving vessels (fig. 5).[18]

15 Post-Panamax are vessels with a capacity of 85,000-100,000 deadweight tonnage (dwt); Panamax vessels have a capacity of 75,000-78,000 dwt; Handymax vessels have a capacity of 40,000-65,000 dwt. New vessels can load more cargo on lower drafts. Dwt carrying capacity is the weight that a cargo ship can carry when immersed to the appropriate load line, expressed in tons, including total weight of cargo, fuel, fresh water, stores, and crew.

16 Supramax are vessels with a capacity of 48,000-60,000 dwt; Ultramax vessels have a capacity of 60,000- 65,000 dwt. It should be noted that, by the Panama Canal´s size classifications, Supramax and Ultramax vessels are considered Panamax because they may register a 32-meter beam size.

17 Demurrage costs are the charge levied when a shipment is not loaded or unloaded within the allowed time. FOB Origin indicates that the sale is considered complete at the seller's shipping dock, and thus, the buyer is responsible for freight costs/liability.

18 Ocean rates from PNW and the U.S. Gulf to China are not available from 1992-2006. For that reason, ocean rates from PNW and the U.S. Gulf to Japan were used.

Table 1. Vessel costs to Shanghai, China, from the U.S. Gulf versus from Argentina and Brazil, October 15 to November 15, 2019

	U.S. Gulf	U.S. Gulf	U.S. Gulf	Rosario, Argentina	Bahia Blanca, Argentina	Santos, Brazil	São Luís/ Itaqui, Brazil	São Luís/ Itaqui, Brazil
Cargo mean quantity	58,000 mt[1]	68,000 mt	68,000 mt	55,000 mt	60,000 mt	66,000 mt	65,000 mt	65,000 mt
Vessel type	Panamax	Post-Panamax	Post-Panamax	No Top-Off[2]	2 Port With Top-Off	Varied	Varied	Varied
Route via	Panama Canal	Neo-Canal[1]	Cape of Good Hope	Cape of Good Hope	Cape of Good Hope	Cape of Good Hope	Panama Canal	Cape of Good Hope
Nautical miles	10,013	10,013	14,973	11,541	11,610	11,056	11,087	11,708
Voyage days (at 12 knots)	35	35	52	40	40	38	38.5	40.5
Panama Canal wait time	2	4	0	0	0	0	2	0
Laytime both ends	15	15	15	20	26	20	20	20
Total voyage duration days	52	54	67	60	66	58	60.5	60.5
U.S. Gulf daily hire rate ($18,000 X total voyage days)	$936,000	$972,000	$1,206,000	-	-	-	-	-
Brazil and Argentina daily hire rate ($16,500 X total voyage days)	-	-	-	$990,000	$1,089,000	$957,000	$998,250	$998,250
Ballast Bonus[3]	$800,000	$800,000	$800,000	$650,000	$650,000	$650,000	$650,000	$650,000
Singapore Bunkers[4] ($12,500/day)	$437,500	$437,500	$650,000	$500,000	$500,000	$475,000	$481,250	$506,250
Port Fees	$232,025	$280,300	$280,300	$260,000	$434,000	$56,000	$80,000	$80,000
Panama Canal Fees (one way)	$198,783	$239,783	-	-	-	-	$239,783	
Total vessel costs	$2,604,308	$2,729,583	$2,936,300	$2,400,000	$2,673,000	$2,138,000	$2,449,283	$2,234,500
Freight rate per mt:	**$44.90**	**$40.14**	**$43.18**	**$43.64**	**$44.55**	**$32.39**	**$37.68**	**$34.38**

[1] Metric tons. Neo-Canal = new Panama Canal locks.

[2] No top-off: the port of Rosario channel draft is not deep enough to load full Panamax and Post-Panamax vessels. Sellers have to decide to load up to 55,000 mt of cargo at Rosario (No top-off); or two ports with top-off—i.e., to load 45,000-50,000 mt at Rosario and finish loading (top-off) an additional 10,000-15,000 mt at Bahia Blanca.

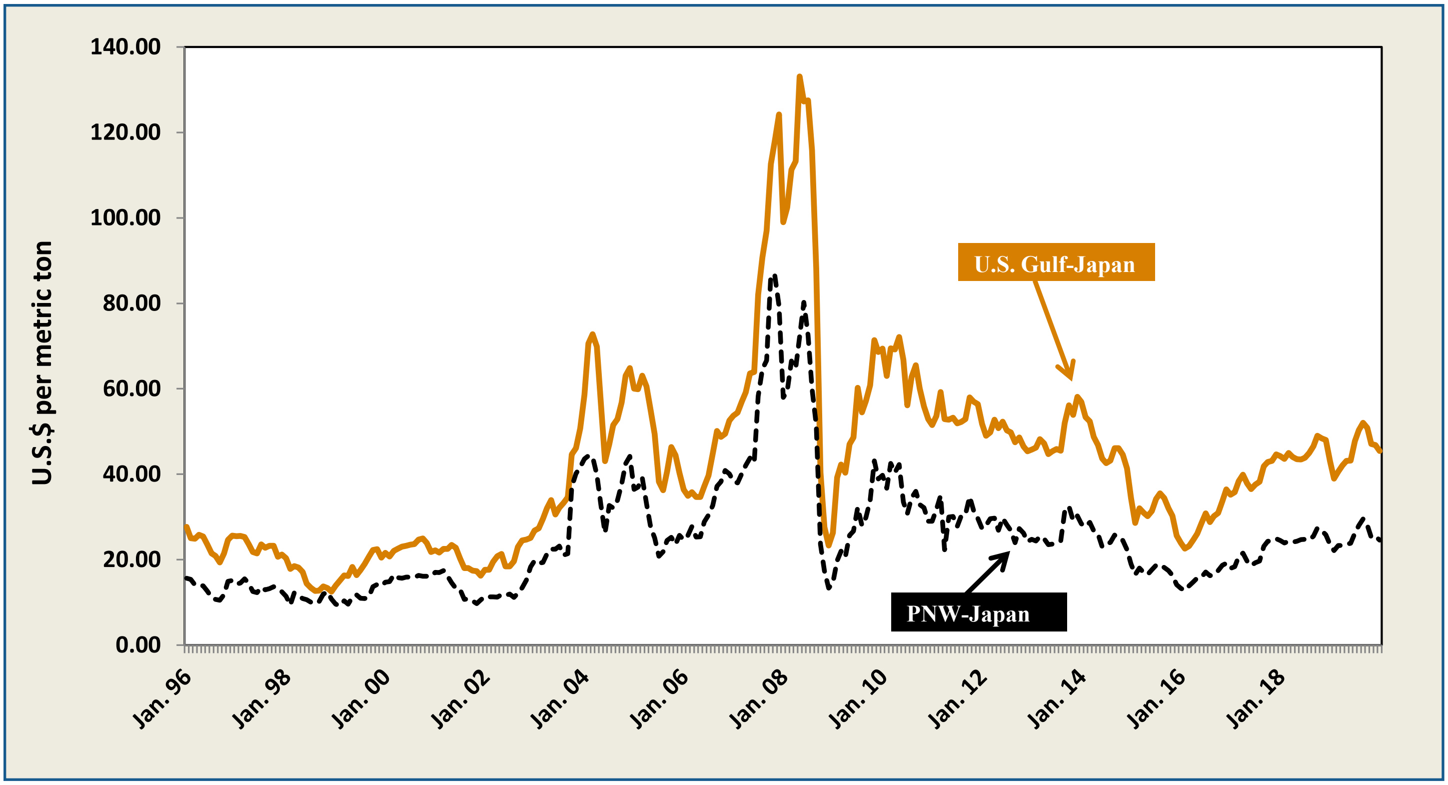
[3]Ballast Bonus is a special payment above the chartering price when a ship has to sail a long way on ballast to reach the loading port.

[4]The fuel cost estimates include the costs of the global Sulphur limit of 0.50 percent mass by mass (m/m) to comply with the International Maritime Organization (IMO) regulation of 0.50 percent m/m, called IMO 2020, effective January 1, 2020. Vessel fuel cost is an estimate for a laden Panamax vessel steaming at 12 knots and consuming 25 tons of intermediate fuel oil (IFO) per day.

Note: the above estimates assume that a vessel is simply waiting for a transit slot and not paying extra for a reserved schedule to transit through the Neo-Panama locks.

Source: O’Neil Commodity Consulting.

Figure 5. Monthly freight rates from the U.S. Gulf and Pacific Northwest to Japan, 1996-2019



Source: O'Neil Commodity Consulting, The Baltic Exchange, and Drewry Maritime Research.

Analyzing World Soybean Market Shares: Model and Results

To better understand the underlying forces of the world soybean market, we performed an extensive econometric analysis using a dynamic approach. A dynamic model best addressed the purpose of this study—to evaluate changes in market shares over time. We specified and empirically estimated a difference equation system and made use of techniques in the specialized field of economics called "econometrics." This empirically estimated system enables analysis of how the underlying world soybean market shares behave, over time. The model developed for this paper includes the theoretical specification, model layout, and empirical framework used for capturing the dynamic changes of the world soybean market (Salin and Somwaru, 2015). The base model uses ocean freight rates and trade data from 1992 to 2019. The Appendix presents detailed results on the empirical estimation of the export market shares, estimation of ocean freight rates' effects on market shares, and performance of the sensitivity analysis. Several statistical tests were performed to analyze and validate the behavior of world soybean market shares and gain insights into how Brazil's infrastructural improvement affected U.S. competitiveness, keeping the U.S. infrastructure constant. Brazil is the leading producer in the world soybean market followed by United States and Argentina. Other competing countries are Paraguay, Canada, Ukraine, and Uruguay.

Results

On the demand side, the model validated that China is the major driver of the world soybean trade. On the supply side, the United States is one of the world's leading producing countries, and Argentina and Brazil are modeled as the two main competing countries (Appendix). The model results suggest that, under current conditions, the U.S. market share could be stable as the overall market grows (Appendix table A-1). The estimated parameters of this dynamic model of the world soybean market are widely known as *β converge* and *σ converge*. Considering changes in ocean rates over time, the model converges to an equilibrium and leaves the ranking of the countries' market shares unchanged (Appendix table A-2).

This model's outcomes suggest the stability of the market and validates (indirectly) the export market shares analysis (see Appendix table A-2 and Salin and Somwaru (2015)). In the future, as the competing countries of Argentina and Brazil acquire larger market shares, whenever any change in price or supply management is initiated solely by one top producer, the change will likely become less effective and costlier to administer over time. In sum, the dynamic analysis indicates that the market shares converge (see *β converge* estimates in the Appendix and Salin and Somwaru (2015)) to a so-called global market equilibrium, although the interplay between the United States, Argentina, and Brazil in the world soybean market is very important.

Sensitivity Analysis – Brazil's Transportation Infrastructure Improvements

To estimate the long-term U.S. position in the world soybean market and provide insights into the impact of Brazil's infrastructure improvements, we performed a sensitivity analysis (see Appendix for details). The sensitivity analysis simulates two scenarios because Brazil is intensifying efforts to improve transportation infrastructure and has gained soybean market share in the world market.

Sensitivity analysis is a way to predict outcomes under different conditions. In this case, the world market shares change in response to two scenarios other than the status quo. We assumed that Brazil's infrastructure improves, and its freight rates are reduced by two different amounts. The first scenario has a rate reduction of $18/mt. For the second scenario, we assumed Ferrogrão Railroad (EF-170) is built, connecting Sinop, Mato Grosso, to Miritituba, Pará. We also assumed the southern ports of Santos, Paranaguá, Rio Grande, and Sao Francisco do Sul modernize their facilities to compete for cargo with the Northern Arc ports. These changes amount to a reduction of $28/mt for the second scenario. The base estimated model uses ocean freight rates and trade data from 1992 and 2019 (see columns 6 and 7 in table 2, and tables 3 and 4).

It is uncertain how much Brazil's infrastructure will improve within the next 10 years and by how much freight rates will be reduced over time. Nevertheless, we know that the completion of paving for the BR-163 highway reduced transportation costs and facilitated exports via the Northern Arc ports. Sensitivity analysis, which is also known as "what if" analysis, is used to evaluate the model's outcomes when key factors, under certain assumptions, change.

In this case, using data from 1992 to 2019 and applying the assumptions that Brazil's infrastructure advances reduced its transportation freight rates (at two different levels), the model estimated "new" exports and export shares for Brazil and its competitor countries (see columns 6 and 7 in table 2, and tables 3 and 4) to conduct the sensitivity analysis. Note that scenario 2 assumed the largest reduction of $28/mt. Using the assumed export market shares, the analysis re-estimated the model to capture the effect of scenario 2 on the world soybean market (see Appendix tables A-3 and A-4), because scenario 2 captures the largest change on the export market shares. Since the analysis assumed more than one change, this sensitivity analysis is called a multivariate sensitivity analysis. The sensitivity analysis aims to shed light on the effects to world market shares of Brazil's potential transportation infrastructure improvements and possible competitive ocean freight rates.

In constructing the sensitivity analysis, the following are accounted for:

1. **Improved Transportation Infrastructure** - We assumed Brazil's domestic transportation infrastructure (farm to port) greatly improves, increasing Brazil's ability to export soybeans to China in two scenarios (see columns 6 and 7 in table 2). These scenarios attempt to simulate the progressive effects of a generic reduction in Brazil's domestic transportation costs if they had begun in 1992, initiated by Brazil's infrastructure improvement. The assumed reductions by $18/mt and by $28/mt were chosen because they are estimates based on the recent completion of BR-163 highway and on the future completion of Ferrogrão Railroad (EF-170), respectively. In particular, the scenarios are specified as follows:

   - **Scenario 1:** Assumes the completed pavement along highway BR-163, connecting Sorriso, Mato Grosso, to Miritituba, Pará. This improvement reduces transportation costs by $18/mt. The resulting changes are measured in market share percentages (see column 6 in table 2, and table 3).

   - **Scenario 2:** Assumes Ferrogrão Railroad (EF-170) is built, connecting Sinop, Mato Grosso, to Miritituba, Pará, and the southern ports of Santos, Paranaguá, Rio Grande, and Sao Francisco do Sul modernize their facilities to compete for cargo with the Northern Arc ports. It is then assumed these changes reduce the transportation costs by $28/mt. The resulting changes are measured in market share percentages (see column 7, table 2, and table 4).

2. **Unchanged Exports with Different Market Shares** – The analysis assumes exports from the United States, Argentina, and the rest of the world remain the same, but market shares change (see columns 2, 4, and 5 in tables 3 and 4) because Brazil's exports under the sensitivity analysis change (column 3 in tables 3 and 4).[19]

It is worth noting that, instead of designing a sensitivity analysis, where one factor at a time is changed, an analysis is performed to allow for changes to all factors at the same time. In this way, the multivariate analysis accounts for the compounded impact of all possible improvements of Brazil's competitiveness in the world soybean market (see tables 2, 3, 4, and Appendix for details).

The sensitivity analysis considered the two scenarios described above and produced the following results:

Scenario 1: (reduced transportation costs of $18/mt)

- Resulted in Brazil's global export market shares for the period 1992 to 2019 increasing from 17 percent in 1992 to 55 percent in 2019 (see column 6 in table 2, and table 3); and

- At the same time, the U.S. world market share declined by 2 percentage points in 1992 and by 3 percentage points in 2019, as a result of infrastructural improvements in Brazil.

Scenario 2: (reduced transportation costs of $28/mt)

- Resulted in Brazil's global export market shares for the period 1992 to 2019 increasing from 19 percent in 1992 to 59 percent in 2019 (see column 7 in table 2, and table 4); and

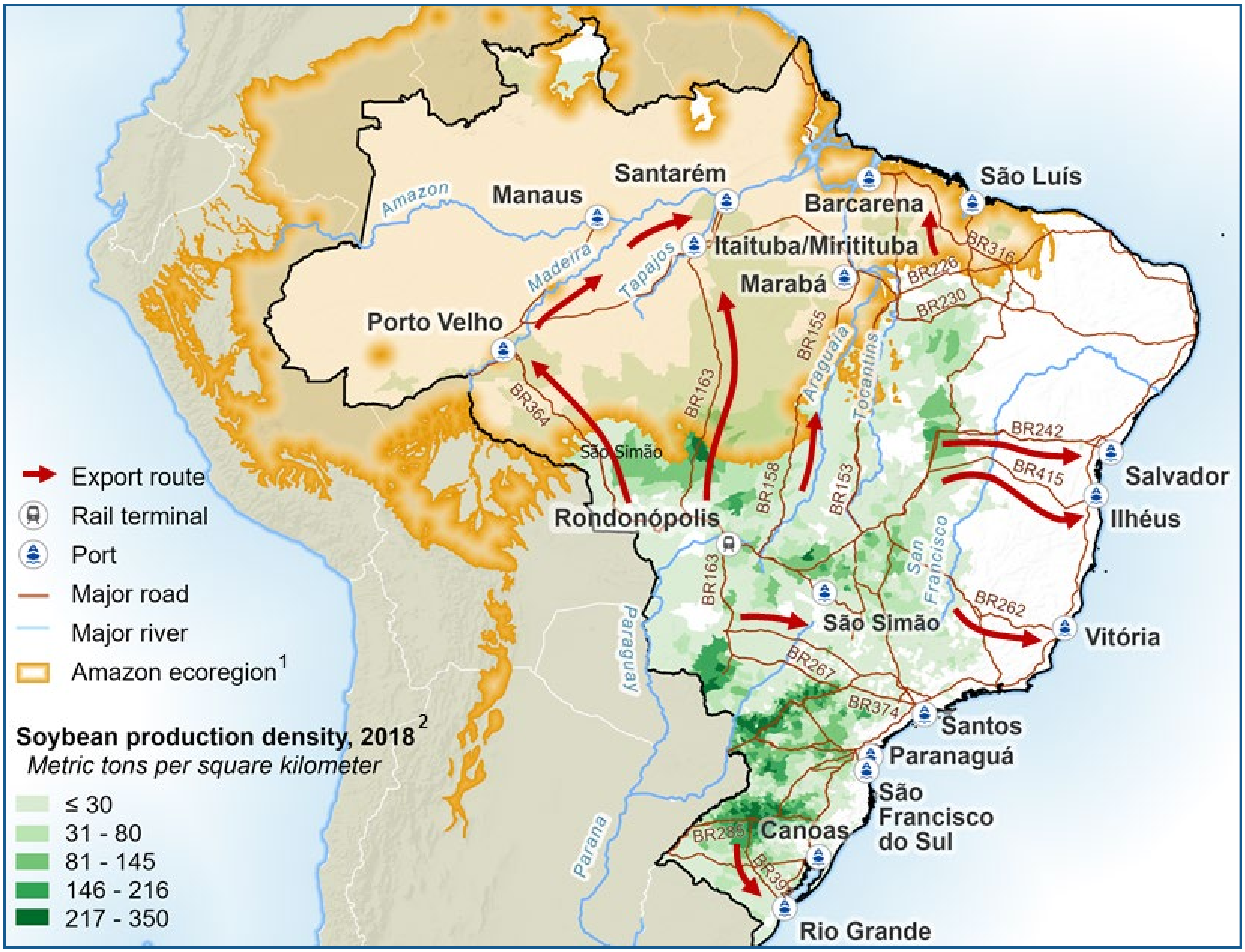
- At the same time, the U.S. world market share declined by 4 percentage points in 1992 and by 6 percentage points in 2019 as a result of structural improvements in Brazil.

19 Given Brazil's new market shares, the shares of the United States, Argentina and other countries adjust because we keep the total observed export data from 1992-2019.

For clarity, using the shares developed for the sensitivity analysis for scenario 2, the analysis took the extra step of re-estimating the model and presenting the result of scenario 2. This extra step was taken because this scenario accounts for the largest changes in Brazil's transportation and infrastructure (see Appendix and tables A-3 and A-4). The sensitivity results (Appendix tables A-3 and A-4) show the estimated market shares depend on the countries' exporting capacity, which in turn, depends on the underlying technology and infrastructure from farm to port, as well as the competitiveness of ocean freight rates in the case of world soybean market.

Figure 6 shows the Northern Arc ports complex that includes the following: Itacoatiara/Manaus (Amazon River), Santarém (Amazon River), Barcarena (Pará River), São Luís (Maranhão, MA), Salvador (Bahia), Porto Velho (Madeira River) and Miritituba (Tapajós River). The Madeira and Tapajós River run through the Amazon Rainforest and are major tributaries of the Amazon River. The distance by truck from Sorriso, Mato Grosso, to Itaituba/Miritituba is 663 miles (1,067 km), via BR-163. Currently, it takes about 35 hours to ship grain to Miritituba (ESALQ-LOG, 2020; FAS, 2020).

Figure 6. Brazilian soybean main export ports



[1]World Wildlife Fund.
[2]Brazilian Institute of Geography and Statistics—Produção Agricola Municipal.
Source: USDA, Agricultural Marketing Service and USDA, Foreign Agricultural Service.

It is worth noting that Brazil's production costs—particularly in Mato Grosso and Paraná —were below Iowa's costs, because of lower land prices and capital costs. Brazilian and U.S. soybeans directly compete with one another because both countries leverage the same technological advances. Brazil can import or develop its own technology and increase planted area to increase exports. Brazil expanded its export capacity and balanced its transportation system like the United States, including all major modes. Thus, Brazil lowered its transportation costs and opened new export gateways, making the country more competitive.

In 2011, the Brazilian government introduced a law requiring railroads to sell to other railroads the rights to use any idle capacity (Salin and Somwaru, 2015). This major step significantly increased railway use. It should be noted that U.S. railroads have no obligation to allow other railroads to use their rails. Instead, access is negotiated with competing railroads at an agreed-upon price. In 2013, an intermodal grain terminal was built in Rondonópolis, Mato Grosso, to facilitate the flow of grains to the southern port of Santos. In 2014, Brazil's agribusiness sector and barge companies created a new export route from Miritituba to Barcarena (Vila do Conde), adding a new northern gateway for grain exports from Mato Grosso to China, Europe, the Middle East, and Mexico (Salin, 2017a and 2018b).

The agricultural exporters in the Center-West of Brazil gained a major competitive boost from strategic port improvements, extended railway miles, and the completion of the pavement along the BR-163 highway, connecting Sorriso, Mato Grosso, to Itaituba/Miritituba, Pará, at the end of 2019. The pavement of BR-163 ended truck drivers' uncertainty about how long it will take to haul grain to Miritituba during the rainy season (Cordonnier, 2020). Now, truck drivers know that the trip's first leg takes about 35 hours, versus the several days or weeks that the same trip took before the road's completion (ESALQ-LOG, 2020; USDA/FAS, 2020).

Over the last 5 years, soybean exports from the Port of Barcarena nearly quadrupled, from 1.1 mmt in 2014 to 5.8 mmt in 2019. Barcarena quickly became the fifth-largest Brazilian soybean exporting port after Santos, Rio Grande, Paranaguá, and São Luís. Truck rates from Sorriso, Mato Grosso, to Rondonópolis (rail terminal) and to the northern river ports of Santarém and Itaituba/Miritituba (barge terminal) decreased. Industry analysts expect transportation costs to drop further, by as much as $6/mt (or R$30/mt) for the route from Sorriso to Itaituba (Salin, 2020c).[20] Expanded use of the northern ports helped to ease congestion at southern ports, as well. Much of the cost savings—from these upgrades, as well as others implemented over the last 12 years—are passed on to Brazilian farmers as higher prices for their products.

Many improvements in U.S. infrastructure and technology—critical to maintaining U.S. competitiveness in the world soybean market—are under consideration or are already underway. Some examples of critical infrastructure improvements include lengthening the locks on the Mississippi River and its tributaries to permit larger barge tows, enhance maintenance of locks and dams along the inland waterway system, increase investment to improve rural bridges that connect farms with the original point of sale, dredging to deepen the water channels, and developing a better intermodal system with wider use of containerized shipments throughout the country. Improved U.S. infrastructure would result in an increase in market share, a more competitive U.S. export sector, and higher income for farmers, just as they have in Brazil.

For example, assuming world soybean trade is 166 million metric tons (mmt) (WASDE and FAS September 2020), a 1-percent decline in the U.S. soybean market share amounts to just above half a billion dollars in lost export sales (1.7 mmt × $332/mt).[21]

20 Exchange rate of 5.5293 real per U.S. dollar, September 1, 2020.

21 This statement is based on the concept known as "elasticity." The coefficients are considered elasticities because the estimated equation is expressed in double logarithmic form (see Appendix). For example, the coefficient value for the entire estimation period, 1992-2019, is 0.0236 percent (see Appendix, table A-1). After Brazil's infrastructural improvements, for the entire estimation period sensitivity analysis, the coefficient declines to 0.0114 (Appendix, sensitivity analysis table A-3). This amounts to 1.22-percent declines in market shares (0.0236 - 0.0114 = 0.0122).

Table 2. Market shares data: actual and for Brazil's sensitivity analysis.[1]

Actual market shares					Brazil market shares, sensitivity analysis[1]	
Year	United States (%)	Brazil (%)	Argentina (%)	Other[2] (%)	Scenario 1 (%)	Scenario 2 (%)
1992	66.25	13.78	11.43	8.54	16.62	19.34
1993	71.59	13.84	7.55	7.02	16.70	19.42
1994	57.72	19.60	10.90	11.78	23.32	26.77
1995	71.34	11.13	8.05	9.48	13.51	15.81
1996	73.00	10.92	6.64	9.44	13.54	16.05
1997	66.30	23.17	2.08	8.45	27.99	32.32
1998	60.52	22.28	7.17	10.03	27.92	32.89
1999	57.74	23.55	8.07	10.64	28.74	33.35
2000	58.06	24.29	9.02	8.63	30.07	35.13
2001	50.47	28.80	13.60	7.13	34.95	40.21
2002	54.88	27.50	11.30	6.32	32.99	37.79
2003	46.48	32.10	14.10	7.33	39.18	45.03
2004	43.14	36.50	12.05	8.31	43.09	48.55
2005	46.06	31.06	14.76	8.12	36.64	41.47
2006	40.20	40.72	11.39	7.70	48.55	54.66
2007	42.85	33.12	13.48	10.55	40.04	45.76
2008	40.07	32.23	17.58	10.11	37.94	42.85
2009	45.39	39.09	7.29	8.23	45.21	50.30
2010	44.32	31.04	14.22	10.43	36.36	41.00
2011	44.73	32.71	10.05	12.51	38.34	43.19
2012	40.52	39.51	8.03	11.95	45.44	50.41
2013	36.00	41.75	7.71	14.54	47.71	52.66
2014	39.56	41.54	6.96	11.94	47.44	52.34
2015	39.73	40.10	8.38	11.79	45.91	50.78
2016	39.88	41.03	7.49	11.61	45.01	48.55
2017	40.10	42.94	4.78	12.18	46.63	49.94
2018	37.94	49.74	1.39	10.93	54.40	58.34
2019	32.07	50.30	6.14	11.49	55.27	59.41

[1]Scenario 1: Assumes completion of the pavement along highway BR-163, connecting Sorriso, Mato Grosso, to Miritituba, Pará. With the pavement finished, transportation costs will likely drop by $18/metric ton, measured in market shares (percentage).

[1]Scenario 2: Assumes Ferrogrão Railroad (EF-170) is built, connecting Sorriso to Miritituba and the southern ports of Santos, Paranaguá, Rio Grande, and Sao Francisco do Sul modernize their facilities to compete for cargo with the Northern Arc ports. In this case, transportation costs will likely drop by $28/metric ton, measured in market shares (percentage).

[2]Other competing countries include Paraguay, Canada, Ukraine, and Uruguay.

Sources: Columns 2 through 5, USDA, Foreign Agricultural Service, 2020; columns 6 and 7, Sensitivity analysis results—calculations by USDA, Agricultural Marketing Service and Economic Consulting.

Table 3. Scenario 1: New market shares for conducting sensitivity analysis[1]

Year	United States (%)	Brazil (%)	Argentina (%)	Other[2] (%)
1992	64.06	16.62	11.06	8.26
1993	69.21	16.70	7.30	6.79
1994	55.05	23.32	10.40	11.23
1995	69.43	13.51	7.84	9.22
1996	70.85	13.54	6.45	9.16
1997	62.14	27.99	1.95	7.92
1998	56.13	27.92	6.65	9.30
1999	53.82	28.74	7.52	9.92
2000	53.62	30.07	8.34	7.97
2001	46.11	34.95	12.43	6.51
2002	50.73	32.99	10.44	5.84
2003	41.63	39.18	12.63	6.56
2004	38.66	43.09	10.80	7.45
2005	42.34	36.64	13.57	7.46
2006	34.88	48.55	9.89	6.68
2007	38.42	40.04	12.09	9.46
2008	36.70	37.94	16.10	9.26
2009	40.83	45.21	6.56	7.40
2010	40.90	36.36	13.12	9.62
2011	40.98	38.34	9.21	11.47
2012	36.54	45.44	7.24	10.77
2013	32.32	47.71	6.92	13.05
2014	35.57	47.44	6.26	10.73
2015	35.88	45.91	7.57	10.65
2016	37.19	45.01	6.98	10.83
2017	37.51	46.63	4.47	11.39
2018	34.42	54.40	1.26	9.92
2019	28.86	55.27	5.52	10.34

[1]Scenario 1: Assumes—if the pavement along highway BR-163, connecting Sorriso, Mato Grosso to Miritituba, Pará is finished—transportation costs will likely drop by $18/metric ton, measured in market shares (percentage).

[2]Other competing countries include Paraguay, Canada, Ukraine, and Uruguay.

Source: Sensitivity analysis results—calculations by USDA, Agricultural Marketing Service and Economic Consulting.

Table 4. Scenario 2: New market shares for conducting sensitivity analysis[1]

Year	United States (%)	Brazil (%)	Argentina (%)	Other[2] (%)
1992	61.98	19.34	10.70	7.99
1993	66.95	19.42	7.06	6.57
1994	52.57	26.77	9.93	10.73
1995	67.58	15.81	7.63	8.98
1996	68.79	16.05	6.26	8.89
1997	58.40	32.32	1.83	7.44
1998	52.26	32.89	6.20	8.66
1999	50.33	33.35	7.04	9.28
2000	49.75	35.13	7.73	7.40
2001	42.38	40.21	11.42	5.99
2002	47.09	37.79	9.70	5.42
2003	37.63	45.03	11.42	5.93
2004	34.95	48.55	9.77	6.74
2005	39.11	41.47	12.53	6.89
2006	30.74	54.66	8.71	5.89
2007	34.75	45.76	10.93	8.55
2008	33.79	42.85	14.83	8.53
2009	37.04	50.30	5.95	6.72
2010	37.91	41.00	12.16	8.92
2011	37.76	43.19	8.49	10.56
2012	33.22	50.41	6.58	9.79
2013	29.26	52.66	6.27	11.82
2014	32.26	52.34	5.67	9.73
2015	32.65	50.78	6.88	9.69
2016	34.79	48.55	6.53	10.13
2017	35.18	49.94	4.19	10.68
2018	31.45	58.34	1.15	9.06
2019	26.19	59.41	5.01	9.38

[1]Scenario 2: Assumes that BR-163 and Ferrogrão Railroad (EF-170), connecting Sorriso to Miritituba, are built, and the southern ports of Santos, Paranaguá, Rio Grande, and Sao Francisco do Sul modernized their facilities to compete for cargo with the Northern Arc ports. In this case, transportation costs will likely drop by $28/metric ton, measured in market shares (percentage).

[2]Other competing countries include Paraguay, Canada, Ukraine, and Uruguay.

Source: Sensitivity analysis results—calculations by USDA, Agricultural Marketing Service and Economic Consulting.

Conclusions and Further Research

The world soybean market is growing, but the U.S. is losing market share. Brazil has surpassed U.S. soybean exports, becoming not only the top world soybean exporter, but also the top producer. Twelve years of strategic infrastructural developments and major regulatory changes set the stage for a balanced Brazilian transportation system, resembling the U.S. Gulf export route from farms to major export markets—a system integrating all the major modes (truck, barge, and ocean vessel). Brazil's position has also benefited from low production costs, increases in planted area, high productivity, and a weak national currency.

From 2012 to 2019, nominal prices declined in the international market as market supplies exceeded demand for soybeans. The empirical analysis shows that market shares converged to their so-called "steady-state values" or dynamic equilibrium values, even in the late 2000s. Based on the observed data, Argentina and Brazil behave as major "competing countries" in the international soybean market. There is no indication that Argentina or Brazil limited their production to maintain a stable international market price.

From 2011 to 2019, new policy, infrastructure, and routes revolutionized Brazil's transportation system. First, the government introduced a law extending railways miles and requiring railroads to sell other railroads the rights to use their rail tracks' idle capacity. In the United States, railroads have no such obligation to allow other railroads to use their rails. Nonetheless, access is often negotiated with competing railroads at an agreed-upon price. Second, an intermodal grain terminal was built facilitating the flow of grains from Rondonópolis, Mato Grosso, to the southern port of Santos. Third, the Brazilian's agribusiness sector created a new export route from Miritituba to Barcarena (Vila do Conde), adding a new northern gateway for grain exports from Mato Grosso to China, Europe, the Middle East, and Mexico. Finally, the agricultural exporters in the Center-West of Brazil gained another competitive boost when the pavement of BR-163, connecting Sorriso, Mato Grosso, to Itaituba/Miritituba, Pará, was completed at the end of 2019.

These new upgrades enhanced Brazil's transportation system from farm to port, including all major modes and making Brazil's soybeans more competitive with U.S. soybeans. Because Brazilian and U.S. producers use the same technological advances in production and produce very close soybean substitutes, infrastructure improvements are critical to keeping U.S. transportation costs low and keeping U.S. soybeans competitive worldwide.

The sensitivity analysis suggests the U.S. world market shares could show further decline in 2019 by 3 to 6 percentage points. From the empirical dynamic model's outcomes, we see a major exporter, even with no cost advantage, does not necessarily price itself out of the market (in an expanding market), but instead maintains a fairly constant market share over the long run. As long as the major players continue to operate as they have, market shares are expected to converge to an equilibrium, despite the variability or fluctuations of the ocean freight rates, over time.

According to the multivariate sensitivity analysis results, the market shares of the United States, Brazil, and Argentina in the global soybean market depend in the long term on the countries' exporting capacity. That capacity, in turn, depends on the underlying technology and infrastructure from farm to port and the competitiveness of ocean freight rates. As the U.S. market share declines, the sensitivity analysis shows the rate of convergence to equilibrium (declining values of *β converge*) gets smaller. This finding indicates the global soybean market is in still in equilibrium but converging with decreasing rates. The sensitivity analysis also shows U.S. infrastructure improvements are critical for maintaining the Nation's competitiveness in the world soybean market. Improved U.S. infrastructure would result in an increase in market share, more competitive U.S. exports, and higher income to farmers. For example, assuming world soybean trade were 166 million metric tons (mmt) (USDA/WASDE, 2020; USDA/FAS, 2020), a 1-percent decline in the U.S. soybean market share would amount to just above half a billion dollars in lost export sales (1.7 mmt × $332/mt).

Further research is needed to understand the underlying forces that move soybeans from the farms to markets and to the exporting ports. In this context, the interactions of cash prices with future prices; storage costs with transportation costs; and freight rates for truck, barge, rail, and ocean domestically with foreign competitors need to be captured and analyzed. Further research should also address the effects on agricultural exports of enhancing maintenance of locks and dams along the inland waterway system, increase investment to improve rural bridges that connect farms with the original point of sale, and developing a better intermodal system with wider use of containerized shipments throughout the country.

Appendix: Methodology

Salin and Somwaru (2015) (pp. 22-25) present extensive theoretical underpinning of the model specification, the estimation procedure used, and the statistical method employed. The ocean freight rates data used in the empirical estimation of the transitional dynamic model are from O'Neil Commodity Consulting 2020, the Baltic Exchange 2007, and Drewry Maritime Research 2006, from 1992 to 2019 (figs. 3 and 5). For the selection of the periods and sub-periods (tables A-1 and A-2), see Salin and Somwaru (2015).

The estimated parameters of this dynamic model of the world soybean market are presented in tables A1- and A-2. The model results suggest the U.S. market share could be stable as the overall market grows, but with a smaller share over time. In the future, as the competing countries—Argentina and Brazil—acquire larger market shares, any price- or supply-management policy initiated solely by one top producer would likely become less effective and costlier to administer. Thus, the interplay among the United States, Argentina, and Brazil becomes a very important factor to determining the behavior of the world soybean market.

Table A-1. Estimation results of the transitional dynamics of the world soybean market, 1992-2019

Year	Parameter	Estimate	Standard error	95% Confidence limits: lower bound	95% Confidence limits: upper bound
Entire period 1992–2019	α (Intercept)	0.0514	0.0677	-0.2399	0.3426
	β (strength of converge)	0.0236	0.0443	-0.1670	0.2141
	σ (converge—steady state) (second moment of the distribution)	0.5700			
First period 1992–2004	α (Intercept)	0.0804	0.0907	-0.3097	0.4705
	β (strength of converge)	0.0293	0.0449	-0.1637	0.2223
	σ (converge—steady state) (second moment of the distribution)	0.6300			
Second period 2005–2008	α (Intercept)	0.1679	0.0354	0.0157	0.3201
	β (strength of converge)	0.0554	0.0143	-0.0062	0.1169
	σ (converge—steady state) (second moment of the distribution)	18.7700			
Third period 2009–2019	α (Intercept)	0.0227	0.0630	-0.2485	0.2938
	β (strength of converge)	0.0076	0.0227	-0.0902	0.1054
	σ (converge—steady state) (second moment of the distribution)	0.1200			

Source: USDA, Agricultural Marketing Service and Economic Consulting, based on model results.

Table A-2. Estimation results of the transitional world soybean market accounting for freight rates and time intervals, 1992–2019

Year	Parameter	Estimate	Standard error	95% Confidence limits: lower bound	95% Confidence limits: upper bound
First period 1992–2001	α (Intercept)	0.0653	0.0965	-0.3501	0.4806
	β (strength of converge)	0.0209	0.0402	-0.1522	0.1940
	σ (converge—steady state) (second moment of the distribution)	0.3300			
Second period 2002–2004	α (Intercept)	0.1970	0.1366	-0.3906	0.7847
	β (strength of converge)	0.0626	0.0547	-0.1728	0.2979
	σ (converge—steady state) (second moment of the distribution)	1.5800			
Third period 2005–2007	α (Intercept)	0.1499	0.1170	-0.3535	0.6533
	β (strength of converge)	0.0486	0.0439	-0.1401	0.2373
	σ (converge—steady state) (second moment of the distribution)	1.4200			
Fourth period 2008–2012	α (Intercept)	0.00849	0.0468	-0.1405	0.1575
	β (strength of converge)	0.0095	0.0161	-0.0403	0.0625
	σ (converge—steady state) (second moment of the distribution)	0.1930			
Fifth period 2013–2019	α (Intercept)	0.0105	0.0167	-0.0428	0.0638
	β (strength of converge)	0.0084	0.0099	-0.0215	0.0417
	σ (converge—steady state) (second moment of the distribution)	0.1355			

Source: USDA, Agricultural Marketing Service and Economic Consulting, based on model results.

Accounting for Ocean Freight Changes

Transitional dynamics are also applied to the world soybean market while accounting for changes in ocean freight rates over the estimated period.[22] The estimated dynamics cover the following five sub-periods: 1992–2001 (first), 2002–04 (second), 2005–07 (third), 2008–12 (fourth), and 2013–19 (fifth). Table A-2 presents the parameter estimates, indicating the market shares (when we account for ocean freight rates and fluctuations) converge to an equilibrium. This result supports and indirectly validates the export market shares analysis (A-1) regarding the stability of the world soybean market. For more details see Salin and Somwaru (2015).

The empirically estimated model indicates the U.S. market share will be stable as the overall market grows. As the competing countries—in this case, Argentina and Brazil—acquire larger market shares, any price- or supply-management policy initiated solely by one top producer might become less effective and more costly to administer. Please note the United States has never had a support program for soybeans. Because the largest players in the world soybean market (United States, Argentina, and Brazil) compete with one another so tightly, the ways these countries interact with one another will have a large impact on the market.

Sensitivity Analysis – Brazil's Transportation Infrastructure Improvement

Table A-3 presents the parameter estimates under the sensitivity analysis for scenario 2. Table A-4 presents the parameter estimates of freight rates under the sensitivity analysis for scenario 2. The results in table A-4 indicate—when we account for observed changes or fluctuations in freight rates over time and improvements in Brazil's infrastructure—that competing countries tend to converge toward an equilibrium, and the rate of convergence is faster under the sensitivity assumptions.

The sensitivity results show the world soybean market is affected by the underlying technology and infrastructure from farm to port, as well as by the competitiveness of ocean freight rates. The analysis also concluded that improved U.S. infrastructure would result in an increase in market share, a more competitive U.S. export sector, and higher income for farmers.

22 For more information about U.S.-South American Ocean Freight Spreads see Salin (2020b); Salin (2018a); and O'Neil (2015).

Table A-3. Estimation results of the transitional dynamics of the world soybean market, 1992–2019*

Year	Parameter	Estimate	Standard error	95% Confidence limits: lower bound	95% Confidence limits: upper bound
Entire period 1992–2019	α (Intercept)	0.0279	0.0753	-0.2961	0.3520
	β (strength of converge)	0.0114	0.0341	-0.1352	0.1580
	σ (converge—steady state) (second moment of the distribution)	0.0016			
First period 1992–2004	α (Intercept)	0.0673	0.0999	-0.3623	0.4970
	β (strength of converge)	0.0243	0.0461	-0.1740	0.2227
	σ (converge—steady state) (second moment of the distribution)	0.0028			
Second period 2005–2008	α (Intercept)	0.1553	0.0420	-0.0253	0.3359
	β (strength of converge)	0.0507	0.0167	-0.0211	0.1225
	σ (converge—steady state) (second moment of the distribution)	0.0004			
Third period 2009–2019	α (Intercept)	0.0006	0.0771	-0.3312	0.3323
	β (strength of converge)	0.0004	0.0258	-0.1106	0.1115
	σ (converge—steady state) (second moment of the distribution)	0.0021			

* Note: The sensitivity analysis assumes Brazil's improved infrastructure and transportation cost; saving $28/mt.
Source: USDA, Agricultural Marketing Service and Economic Consulting, based on model results.

Table A-4. Estimation results of the transitional dynamics of the world soybean market accounting for freight rates and time intervals, 1992–2019*

Year	Parameter	Estimate	Standard error	95% Confidence limits: lower bound	95% Confidence limits: upper bound
First period 1992–2001	α (Intercept)	0.0285	0.1162	-0.4715	0.5285
	β (strength of converge)	0.0092	0.0426	-0.1742	0.1925
	σ (converge—steady state) (second moment of the distribution)	0.0500			
Second period 2002–2004	α (Intercept)	0.1192	0.1517	-0.5336	0.7719
	β (strength of converge)	0.0387	0.0567	-0.2055	0.2828
	σ (converge—steady state) (second moment of the distribution)	0.5200			
Third period 2005–2007	α (Intercept)	0.0777	0.1297	-0.4802	0.6357
	β (strength of converge)	0.0255	0.0458	-0.1714	0.1757
	σ (converge—steady state) (second moment of the distribution)	0.3400			
Fourth period 2008–2012	α (Intercept)	0.0296	0.0409	-0.0377	0.0924
	β (strength of converge)	0.0242	0.0179	-0.0327	0.1242
	σ (converge—steady state) (second moment of the distribution)	0.0700			
Fifth period 2013–2019	α (Intercept)	0.0383	0.0228	0.0008	0.0758
	β (strength of converge)	0.0208	0.0081	-0.0049	0.0464
	σ (converge—steady state) (second moment of the distribution)	0.1500			

* Note: The sensitivity analysis assumes Brazil's improved infrastructure and transportation cost; saving $28/mt.
Source: USDA, Agricultural Marketing Service and Economic Consulting, based on model results.

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