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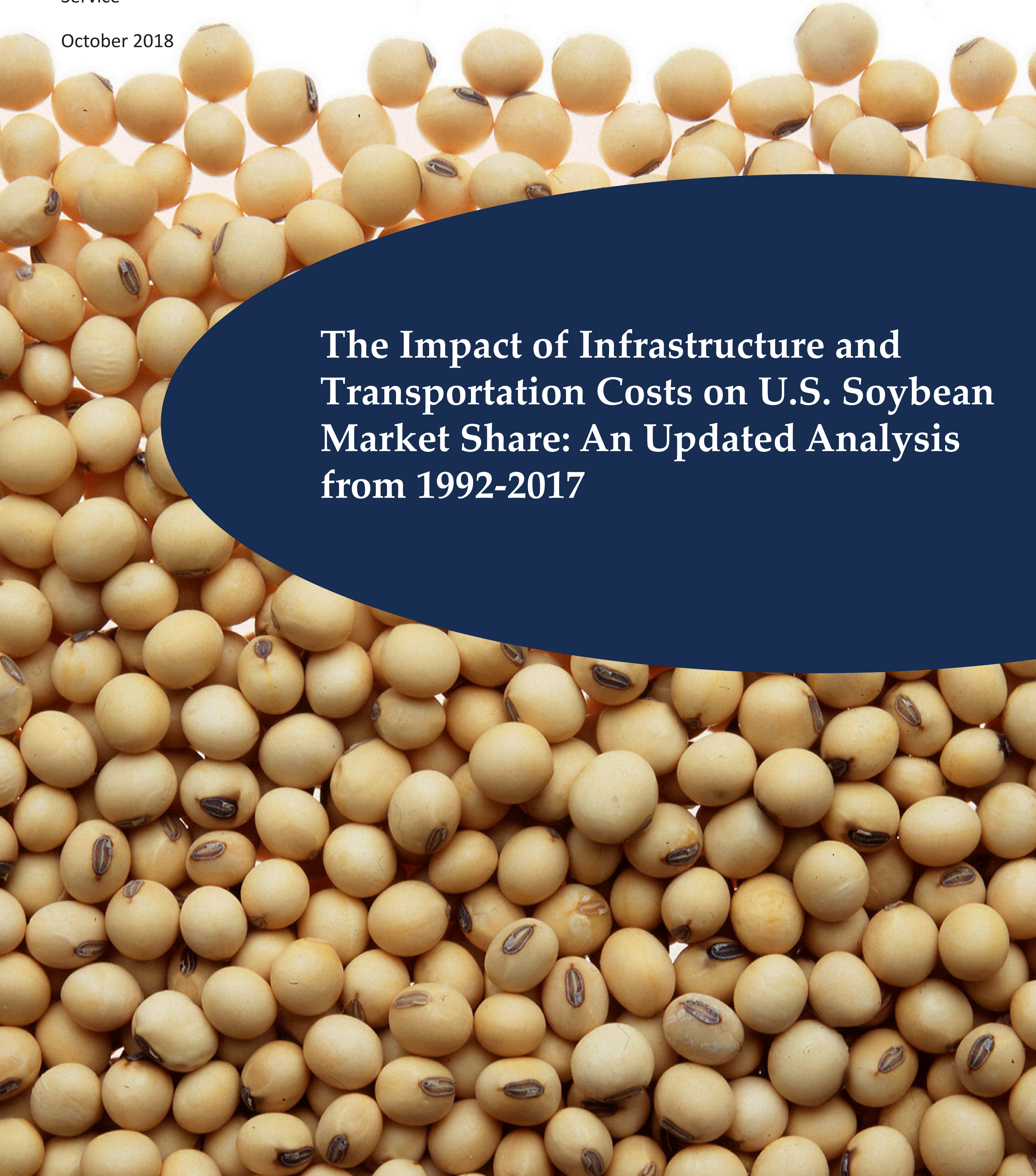
October 2018

The Impact of Infrastructure and Transportation Costs on U.S. Soybean Market Share: An Updated Analysis from 1992-2017



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Abstract

This paper follows up on an analysis published by the authors in 2015 titled, "Eroding U.S. Soybean Competitiveness and Market Shares: What is the Road Ahead?" The update examines new transportation routes that have emerged in Brazil and updates the data and analysis. Although the United States produces the largest volume of soybeans in the world, the U.S. market share of soybean world trade is declining. Using a dynamic econometric model and multivariate sensitivity analysis, export market shares' economic attributes are estimated retrospectively. This study quantifies the decline resulting from changes in ocean freight rates and the continued development of Brazil's transportation infrastructure. The results suggest the U.S. world market share could decline an additional 12 percentage points assuming there are no significant improvements in U.S. transportation infrastructure serving the soybean supply chain, from farm to port. A decline of 1 percent in the U.S. soybean market share is equivalent to more than half a billion dollars lost in export sales; based on a world soybean trade volume of 152 million metric tons and today's price of soybeans. Over the study period, 1992-2017, soybean market shares globally converge to an equilibrium indicating the stability of the market.

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Executive Summary

Since the 1990's, the United States, the world's leading producer of soybeans, has lost market share to Brazil.[1] U.S. market share declined from 66 percent in 1992 to 40 percent in 2017. U.S. competitiveness, relative to South America, declined during a period of strong global growth in soybean demand, however, the United States remains the second-largest exporter. For the last 17 years, China, the world's largest soybean importer, has been responsible for nearly all of the growth in global soybean trade. In 2017, per-bushel total production costs in the main producing areas of the U.S. Midwest averaged $9.29 per bushel; compared with $7.52 per bushel in Argentina, $7.53 per bushel in the Brazilian State of Mato Grosso and $8.01 per bushel in Paraná. Although variable costs in the United States are lower, fixed costs—due to land values and capital costs—are much higher than in Mato Grosso and Paraná.

As the largest producer of soybeans in the world, one of the challenges for the United States partially depends on competing countries' ability to improve their infrastructure capacity and reduce their transportation costs. Differences in transportation costs can make South American soybean exports more profitable than those of the United States, diverting trade from the United States to Brazil or Argentina at key junctures of the most lucrative marketing periods. The Brazilian government began a comprehensive infrastructural improvement strategy in 2007, with major institutional and regulatory changes to facilitate agricultural exports. 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 North Mato Grosso (MT) to China, Europe, the Middle East, and Mexico. This new export route provided more balance for Brazil's transportation system from farm to port, including all major modes, like the U.S. Gulf export route. Since 2013, Brazil has surpassed U.S. soybean exports, becoming the world's top soybean exporter. The road ahead for U.S. soybean competitiveness is uncertain. It is not clear how much Brazil's infrastructure will improve, or when, or by how much freight rates might be reduced for South America in relation to those for the United States. All that is known is Brazil is increasing its production, intensifying its efforts to improve its transportation infrastructure, and has been gaining in global soybean market share as a result.

This study quantifies the changes of the United States' 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 infrastructural development/improvements on the U.S. position in the soybean global market by using multivariate sensitivity analysis.[3] The analysis considers three scenarios reducing Brazil freight rate by three different levels. First, is a reduction of $12 per metric ton (mt). Second, is a reduction of $20/mt. Third, is a reduction that is comparable to the transportation costs in the United States' Pacific Northwest (PNW) region, or a reduction of $28/mt. Due to data availability, the base estimated model uses ocean freight rates and trade data for the period between 1992 and 2017.

1 Until 2013, the United States was the dominant country in the world soybean market in terms of market share/power, including production volume, quality, and exports. However, in terms of exports the U.S. lost market share but remains the largest soybean producer in the world market. For more information see Salin, Delmy L. and Agapi Somwaru. Eroding U.S. Soybean Competitiveness and Market Shares: What Is the Road Ahead? U.S. Dept. of Agriculture, Agricultural Marketing Service, September 2014. Web. <http://dx.doi.org/10.9752/147.09-2014>.

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 overtime. The market shares converge to 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 conversion.

3 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 and when; it is only known that it is improving. It is unknown by how much Brazil's 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 2017 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 used subsequently to re-estimate the model and compare the models' outcomes to the results when the actual data are used.

The dynamic model's results indicate the United States remains the largest producer country in the world soybean market. Brazil and Argentina are considered the major competing countries in the world soybean market. Other competing countries are Paraguay and Canada. The dynamic model's analysis shows the market shares converged over the period of the study. This implies the stability of the market where the United States maintains its leading position as the largest producer of soybeans, despite the variability of ocean freight rates over the period under study.

The results also suggest that, under current conditions, the U.S. market share could be stable, as the overall market grows. However, the initial position of the largest producer country eroded and the market shares of the competing countries grew faster than the leading producer country. Similar results were obtained when changes in ocean freight rates over the estimated period were considered. Further, the model's outcomes suggest the ocean freight rates are less of a force in the shares of the world soybean market than other factors such as reduction of inland transportation costs. With the overall increase of the global soybean market, Argentina and Brazil attained a larger market share, but there is no indication that either country might limit production to maintain a stable international market price environment.

The sensitivity analysis findings indicate the U.S. world soybean market share could further decline by 12 percentage points, without significant improvements in the U.S. transportation infrastructure from the farm to port (under scenario 3) that would reduce U.S. costs to a commensurate degree with Brazil's cost reductions.[4] In the future, if Brazil's infrastructure improves and there is a reduction in ocean freight rates, like the rates from the U.S. PNW, then, the multivariate sensitivity analysis in scenario 3 suggests Brazil's exports will more likely increase relative to those of the United States. In this case, the analysis shows Brazil's global export market shares for the period between 1992 and 2017 would have increased from 19 percent in 1992 (or 40 percentage points) to 50 percent (or 16 percentage points) in 2017, primarily a result of possible structural improvements in Brazil. Furthermore (under the same scenario) the multivariate sensitivity analysis shows the United States' world market share would have declined by 6 percentage points in 1992 to 12 percentage points in 2017, because of assumed structural changes in Brazil and no improvements in the U.S. infrastructure. For example, assuming world soybean trade is 152 million metric tons (mmt) (WASDE, February 2018), a 1-percent decline in the U.S. soybean market share is equivalent to more than half a billion dollars lost in export sales (1.7 mmt X $388/mt).

The sensitivity analysis shows that market penetration depends on the underlying technology and infrastructure for transporting from farm to port. This implies that the United States' infrastructural improvements are critical to maintain its competitiveness and market position in the global soybean market, over the long term. Potential improvements in U.S. infrastructure, from farm to port, could boost the odds of maintaining the United States' leading role in the global soybean market. Other things equal, this would result in higher income for farmers.

Objectives and Organization

This study: (1) quantifies the dynamic changes of the United States' market shares in the world soybean market, (2) examines the effects of ocean freight spreads rates on the underlying market structures where the United States initially operates as a dynamic dominant firm/country model,[5] and (3) analyzes the impact of Brazil's potential infrastructural development on the world soybean market.

4 Note that scenario three assumes the lowest U.S. transportation rates, which are comparable to the rates in the PNW, and captures the largest change on the export market shares.

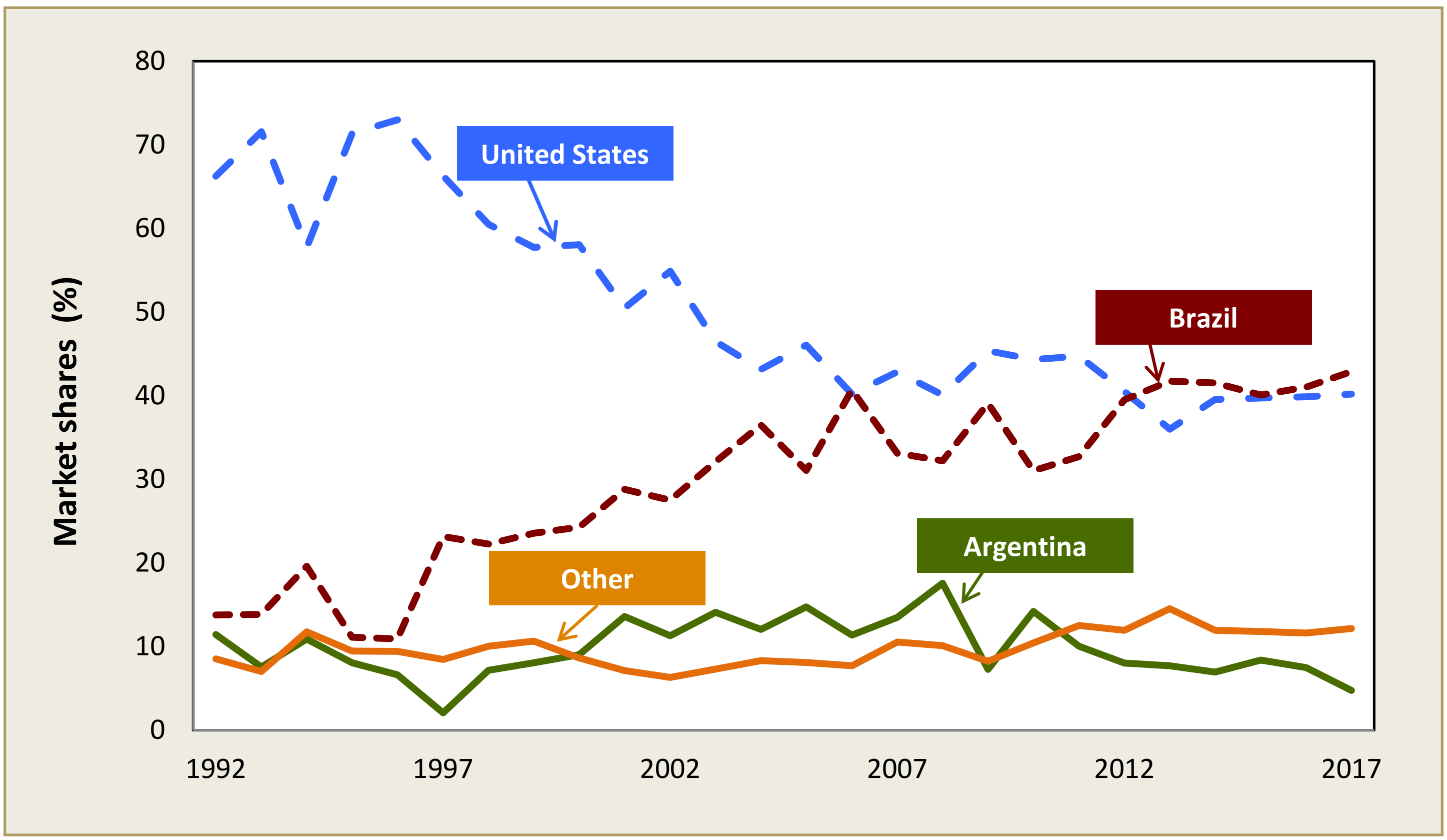
5 Model specification, Salin and Somwaru 2015 Report, entitled Eroding U.S. Soybean Competitiveness and Market Shares: What Is the Road Ahead? (pages 22-25). Web. <http://dx.doi.org/10.9752/147.08-2014>.

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 the United States and South America ocean freight spreads. Third, a dynamic model analyzes the behavior of the underlying market interactions in a world market. The model estimates the impact of changes in ocean freight spreads on the behavior of the dominant, and the competing, countries in the global soybean market. Fourth, it performs a sensitivity analysis of the potential impact of Brazil's infrastructural 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 the international soybean trade. Argentina and Brazil have been smaller competitors of the United States. However, since the 1990s, Brazil has captured a growing share of the international soybean market. In 2017, these two countries accounted for about 48 percent of the world's soybean market and the United States accounted for 40 percent.[6] The United States' market shares declined from 66 percent in 1992, stabilized 8 years later at 58 percent, and stood at 40 percent in 2017 (figure 1 and table 8). While the market grew, nominal prices for soybeans in the global market increased until 2012; and declined to $401 per metric ton in 2017, as measured by CIF Rotterdam prices (figure 2).[7]

Figure 1. The United States lost market shares to Brazil in the world soybean market

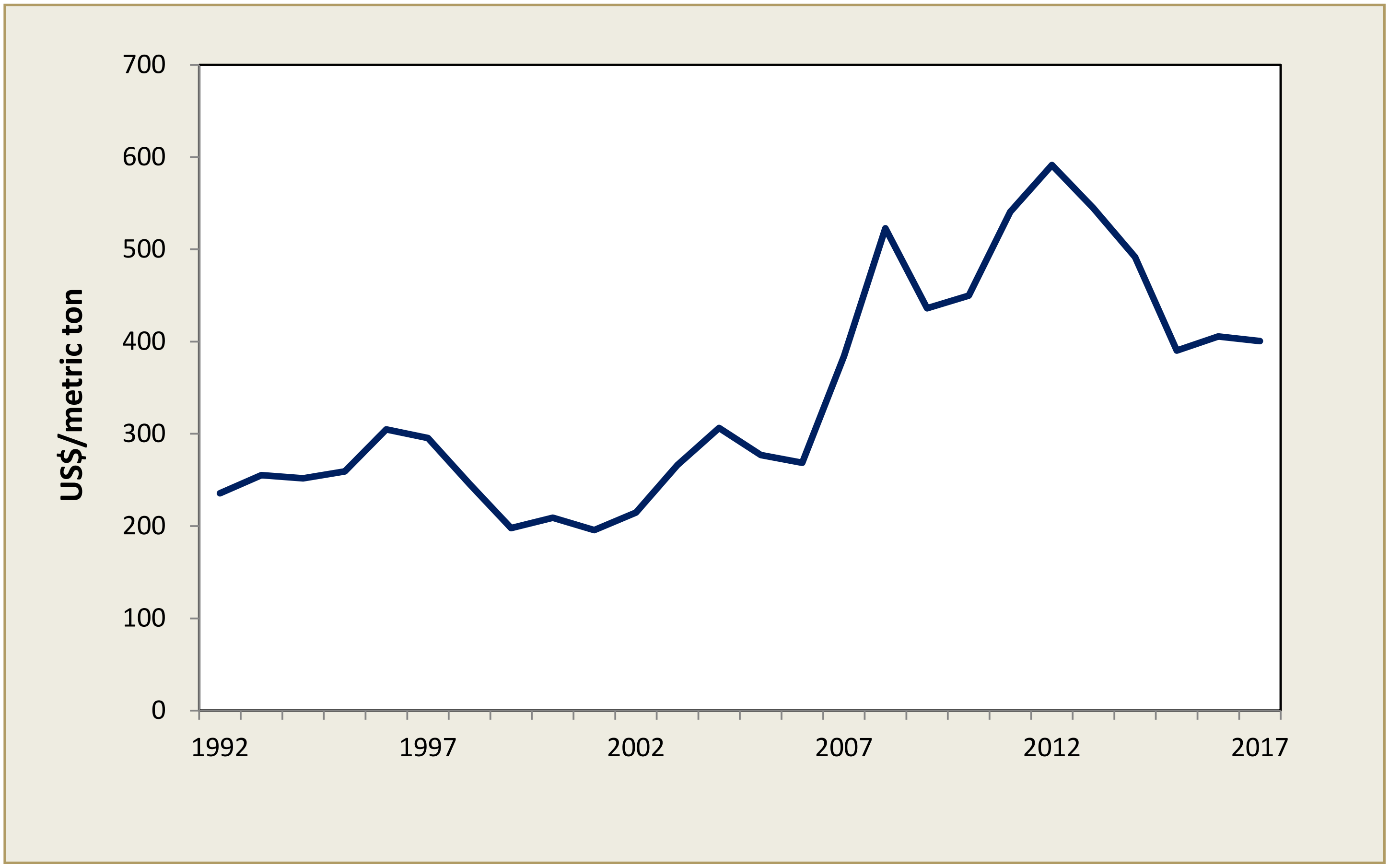


Source: USDA/Foreign Agricultural Service/Production Supply and Distribution (PSD)

6 Other major competing countries include Paraguay, Canada, Ukraine, and Uruguay (FAS 2018).

7 The cost of the goods, insurance, and freight delivered to Rotterdam.

Figure 2. CIF* Rotterdam price for soybeans declined 33 percent in 2017 from the peak of 2012



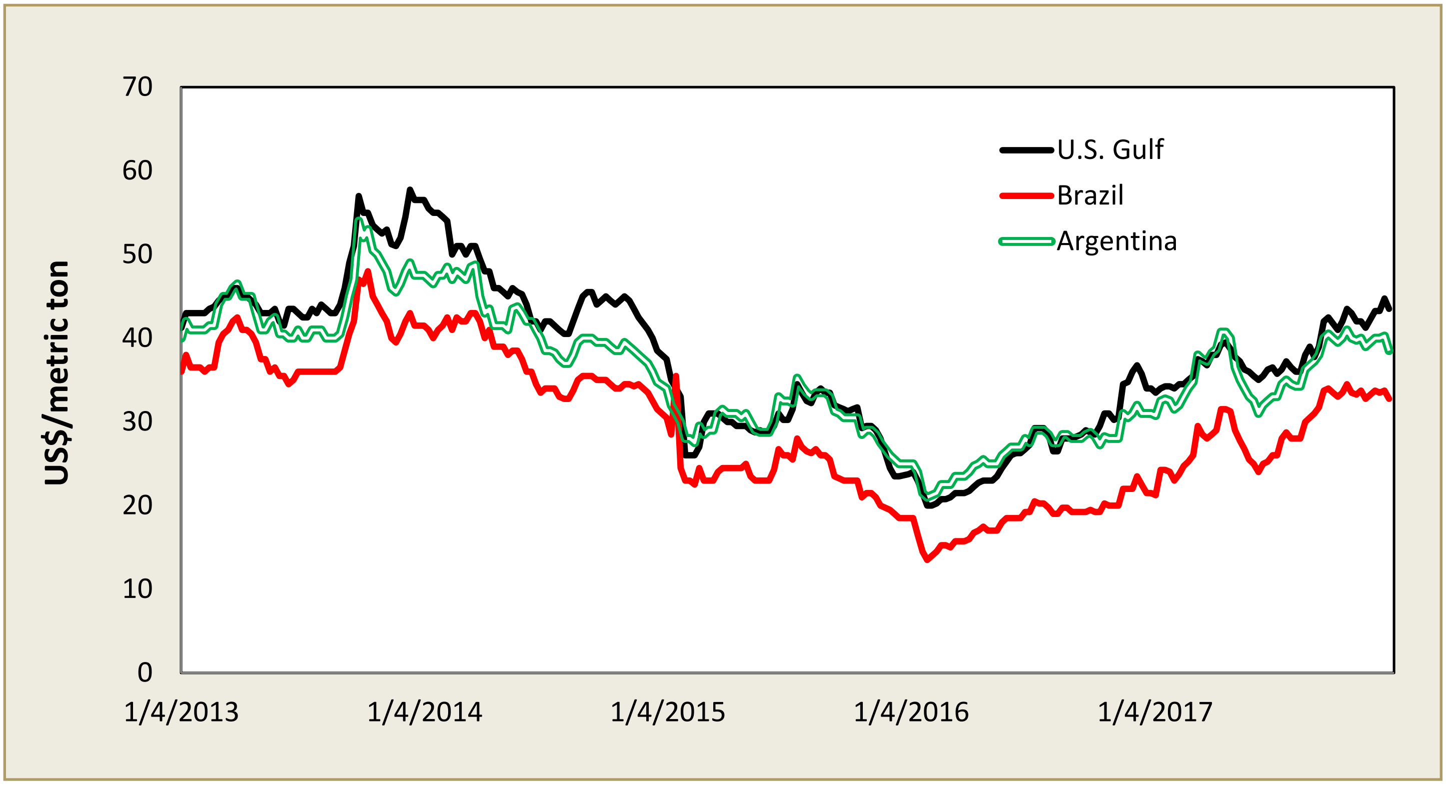
*The cost of the goods, insurance, and freight delivered to Rotterdam.
Source: Oil World

The United States has lost its cost advantage over South America, but still retains a significant share of global soybean exports (figure 1). From 2005-2017, the world soybean trade volume more than doubled, from 64.8 to 147.2 mmt, respectively (FAS 2018). Argentina and Brazil's costs of producing and transporting soybeans are competitive with the United States, making their exports also competitive (Meade et al. 2016, USITC 2012; Schnepf, R., E. Dohlman, and C. Bolling, 2001; and Dohlman, 2000). The exports of both countries have been rising.

At the farm, per-bushel total production costs in the main producing areas of the U.S. Midwest averaged $9.29 per bushel (ERS 2018), compared with $7.52 per bushel in Argentina (BCR 2017). Per-acre costs in Brazil demonstrate a similar comparative advantage. For example, the cost is $7.53 per bushel in the Brazilian State of Mato Grosso (CONAB 2017) and $8.01 per bushel in Paraná (SEAB 2017). Although variable costs in the United States are lower, fixed costs—due to land values and capital costs—are much higher than in Mato Grosso and Paraná (Meade et al. 2016). However, transportation costs can, at times, give South American soybean exports a competitive edge over U.S. soybeans (figure 3).[8]

8 For more information about the United States-South American Ocean Freight Spreads see Salin, Delmy. United States–South America Ocean Grain Freight Spreads (Summary). January 2018. U.S. Department of Agriculture, Agricultural Marketing Service. Web. <http://dx.doi.org/10.9752/TS213.01-2018>; and O'Neil, Jay. U.S.–South America Ocean Freight Rates. March 2015. International Grains Program Institute (IGP), Kansas State University (KSU). Web.<http://hdl.handle.net/2097/18876>.

Figure 3. U.S. Gulf weekly ocean freight rates to Shanghai, China, are higher than Brazil and Argentina rates



Source: O'Neil Commodity Consulting

China soybean imports represent two-thirds of global soybean trade (FAS 2018), up from 22 percent in 2000. For the last 17 years, China's increased imports have been responsible for nearly all the growth in global soybean trade. China is the United States' largest agricultural export market, accounting for 20 percent of total U.S. agricultural exports, valued at $19.6 billion (FAS 2018). For this reason, the analysis focuses on the soybean trade with China as the destination. U.S. soybean exports account for 39 percent of the Chinese soybean market. Brazil and Argentina soybean market shares of China's imports are 48 and 7 percent, respectively. Soybeans account for 74 percent of U.S. bulk agricultural exports to China, representing 32 mmt in 2017, valued at $12.3 billion. Transportation costs account for about 18 to 20 percent of the total landed cost of shipping U.S. soybeans to Shanghai, China, from the U.S. Gulf and 21 percent from the PNW (Olowolayemo 2018) cost.[9] Transportation costs of shipping Brazilian soybeans to Shanghai, China, from the Southern ports represented 15 to 29 percent of the total landed cost and 16-23 percent from the northern, and northeastern ports (Salin 2018).

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

On an annual basis, South American and U.S. soybeans are comparable with one another, and each exports genetically modified (GM) soybeans.[10] However, in 2017 two events brought some product differentiation between the U.S. and Brazilian soybeans (Plume 2017 and 2018; Polansek and Hirtzer 2017; and Wilson and Freitas 2017). The first was adverse weather resulting in higher yields, which lowered protein levels in the U.S. 2017 soybean crop.[11] The second event was the implementation of a new procedure in which all U.S. soybean shipments to China, exceeding 1 percent of foreign material, receive an additional declaration on the Animal and Plant Health Inspection Service phytosanitary certificate that says, “This consignment exceeds 1 percent foreign material” (AMS 2018 and APHIS 2017).[12]

U.S. soybean production is supported by a complete and balanced transportation system that includes all major modes of transportation (truck, rail, barge, and ocean vessel), from the farm to major export markets. As result, the production cost advantages of Brazil and Argentina did not undermine the largest producer position held by the United States, in the world soybean market. However, developments in Brazil’s infrastructure are lowering its transportation costs, making it more competitive in the world soybean market.

The challenge to the United States, as the largest/leading producer, in the world soybean market depends on competing countries’ ability to improve their infrastructure capacity and reduce their transportation cost. Consequently, transportation cost and infrastructure improvements are critical factors in the world soybean trade structure. Small differences in transportation costs can make South America soybean exports more profitable than U.S. soybeans, diverting soybean trade from the United States to Brazil or Argentina, or vice versa.

In 2007, the Brazilian government began implementing a comprehensive infrastructural improvement strategy, with major institutional and regulatory changes to facilitate agricultural exports (Salin 2013-14). A major transportation infrastructure improvement occurred in 2014, when Brazil’s private investment from global grain trading and Brazilian barge companies on barge terminals (Salin 2017 and 2018) created a new export route from Miritituba to Barcarena (Vila do Conde), adding a new northern gateway to grain exports from North Mato Grosso (MT) to China, Europe, the Middle East, and Mexico (Salin 2017-18). This new export route provided a greater balance of Brazil’s transportation system from farm to port, including all major modes, like the United States.

Since 2013, Brazil has surpassed the U.S. in soybean exports, becoming the top world soybean exporter. The road ahead for U.S. soybean competitiveness is uncertain. Brazil is intensifying its efforts to increase production and improve transportation infrastructure, and it has gained soybean market share. Brazil’s freight rates may also be reduced in the future because of improvements to its transportation infrastructure.

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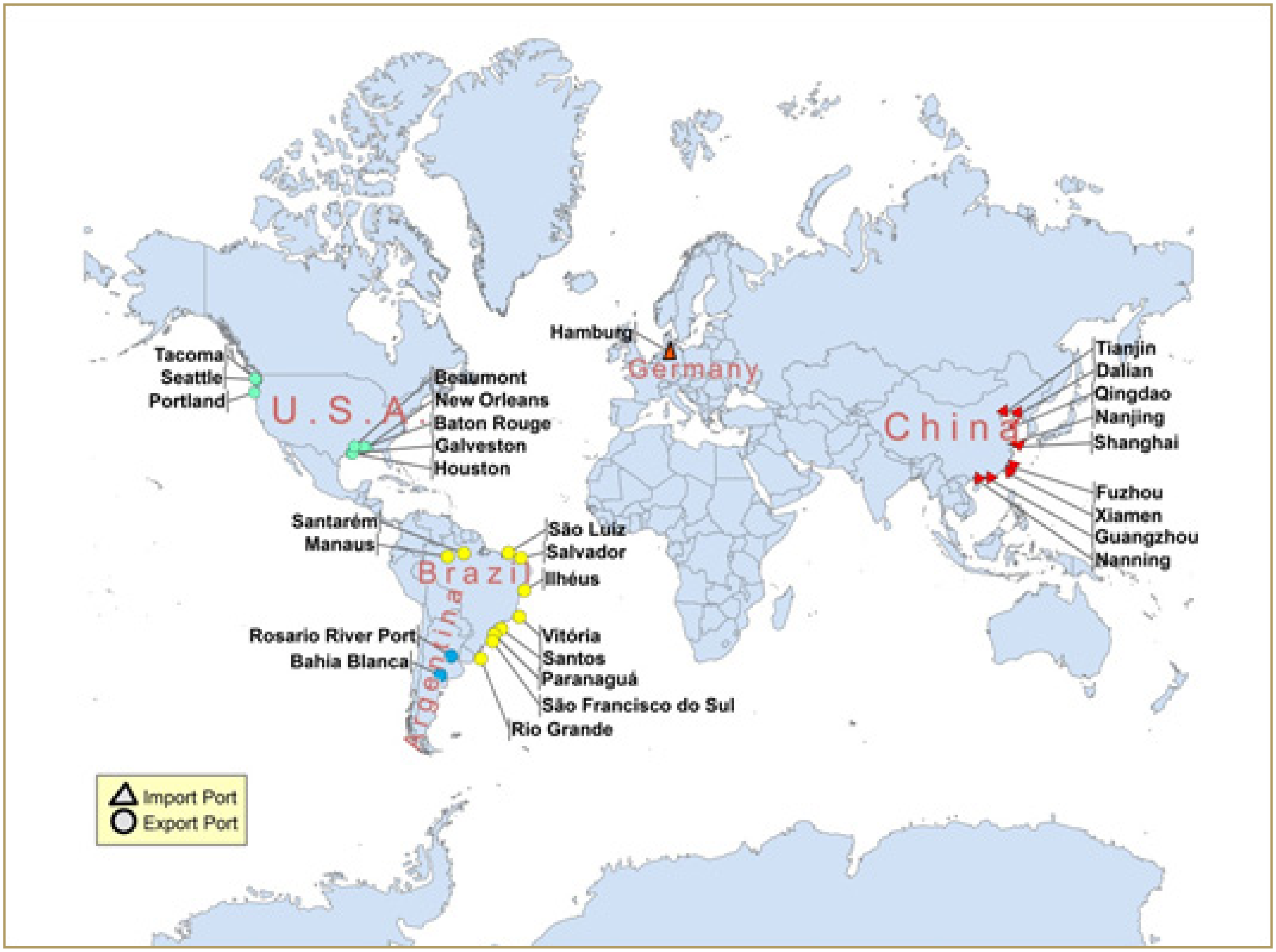
10 The Brazilian soybeans peak export season – March through July – complements the U.S. peak shipping season – October through December. This may mitigate the competition. However, this study doesn’t account for seasonality because we use yearly data.

11 Studies on swine and poultry found that U.S. soybean meal had more digestible amino acids than that of Brazil, Argentina, and China when the feed ration is processed properly. For more information about U.S. soybean quality see The U.S. Soybean Export Council (USSEC), United States Soybean Quality Annual Report 2017. Prepared by Jill Miller-Garvin and Dr. Seth L. Naeve. Web. <https://ussec.org/wp-content/uploads/2017/12/2017.12.21-U.S.-Soy-Quality-Report.pdf>.

12 U.S. soybeans with a maximum of 1 percent foreign material (dirt and weed seeds) is graded as U.S. No. 1 and U.S. No. 2 if it has a maximum of 2 percent of foreign material (AMS 2007 and 2018). The new procedure applies to both bulk and container shipments of raw, unprocessed soybeans to China and it is effective January 1, 2018 (APHIS 2017).

The United States exports about 25 percent of its grain production. Grain and oilseeds are mostly exported through ports located in the U.S. Gulf (57 percent) and the PNW (28 percent) (figure 4). The major grain ports in the U.S. Gulf are New Orleans, Baton Rouge, Houston, Beaumont, and Galveston (figure 4).[13] The PNW grain ports are Portland, Seattle, Tacoma, and Kalama. Brazil's largest soybean export ports are Santos, Paranaguá, and Rio Grande. Argentina's ports are Bahia Blanca and Rosario River (figure 4). China's main entry gateways for U.S. grain are the ports of Shanghai, Qingdao, Nanjing, Nanning, Tianjin, Dalian, Huangpu, Xiamen, Fuzhou, and Guangzhou (figure 4).

Figure 4. Major export and import ports for world soybeans



Source: USDA/Agricultural Marketing Service (AMS)

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

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 the PNW versus South America to Asia (China and Japan), or the U.S. Gulf versus South America to Europe and China (table 1). The ocean freight rates for grain cargos from South America to Asia are often less expensive than from the U.S. Gulf because of dry-bulk vessel route patterns, lower cost port charges, higher Panama Canal tolls, and less burdensome navigation restrictions (O'Neil 2015 and Salin 2018). Market conditions at any time may change the estimated route voyage cost (table 1). The estimated vessel freight trade can be above or below these straight cost calculations. Prices are ultimately determined by market forces. Seasonal port backlogs impact the logistical flow of commodities and shipper costs, but in a supply push market (markets where commodity supply is abundant), these extra costs generally get passed back to the local producers rather than the shipper or commodity buyer and therefore have a smaller effect on ocean freight rate spreads. This is true whether commodities are sold free on board[14] (FOB) or cost and freight (CNF).[15]

South American shipments provide some natural competitive advantages for Brazilian and Argentinean grains and oilseeds, by sailing around Cape of Good Hope and avoiding the Panama Canal, when the need exists. South American shippers can load vessels too large to fit through the Canal, gaining economies of scale and avoiding Canal fees and delays. Brazilian ports also provide less expensive berthing (dockage) costs for vessels. However, Post-Panamax soybean vessels from the U.S. Gulf to China have recently begun going around the Cape of Good Hope and bypassing the Panama Canal to avoid fees and waiting times.[16] The Panama Canal does not allow Dry-Bulk vessels to pre-schedule lock times going through, as it does for the Container, Auto, and Liquefied Natural Gas (LNG) vessels. 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 are like those in the United States. The cost of any resulting vessel demurrage, however, does have a significant impact on the value of the FOB cargo and the price received by South American producers. For example, "FOB Santos" shows 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. There is no readily available public data identifying the ocean freight spreads between the United States and South America.

The ocean rates from the PNW and U.S. Gulf to Japanese are higher than the rates to China because of higher Japanese port fees and berth restrictions that limit the size of the receiving vessels (figure 5).[17]

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14 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.

15 CNF refers to a common type of shipping agreement where the seller pays for delivering the item to the port closest to the buyer. CNF shipping terms does not include the cost of cargo insurance.

16 Post-Panamax are vessels with a capacity of 85,000 to 120,000 dwt; Panamax vessels have a capacity of 65,000 to 85,000 dwt (Olowolayemo 2018). Deadweight carrying capacity (dwt) 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.

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

Table 1. Vessel costs from U.S. Gulf versus Argentina and Brazil to Shanghai, November-December 2017

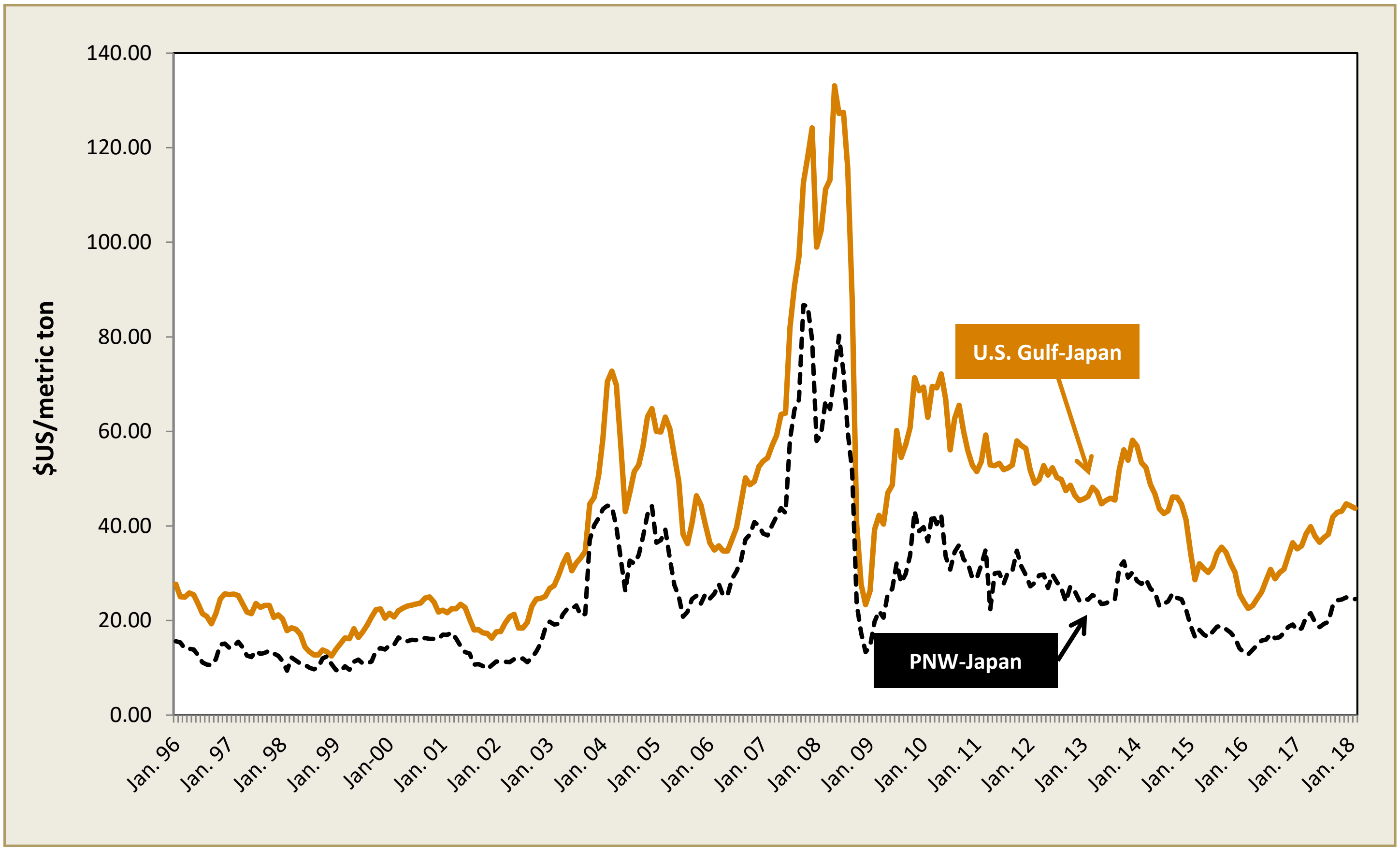
	U.S. Gulf	U.S. Gulf	U.S. Gulf	Rosario, Argentina	Bahia Blanca, Argentina	Santos, Brazil	São Luís/ Itaqui, Brazil	São Luís/ Itaqui, Brazil
Cargo mean quantity	62,000 mt[1]	66,000 mt	66,000 mt	55,000 mt	60,000 mt	66,000 mt	65,000 mt	65,000 mt
Vessel type	Panamax	Post-Panamax	Post-Panamax	No Top-Off[2]	2 Port With Top-Off	Varied	Varied	Varied
Route via	Panama Canal	Panama Canal	Cape of Good Hope	Cape Horn	Cape Horn	Cape of Good Hope	Panama Canal	Cape of Good Hope
Nautical miles	10,013	10,013	14,973	11,450	10,870	11,056	11,087	11,708
Voyage days (at 12 knots)	35	35	52	40	38	39	39	41
Panama Canal wait time	2	3	0	0	0	0	2	0
Laytime both ends	18	18	18	22	26	21	21	21
Total voyage duration days	55	56	70	62	75	60	62	62
Vessel operating costs	$2,271,250	$2,522,500	$2,522,500	$2,078,000	$2,260,000	$2,033,000	$2,061,000	$2,061,000
Port Fees	$269,775	$284,925	$284,925	$265,000	$439,000	$40,400	$75,175	$75,175
Panama Canal Fees (one way)	$220,000	$220,000					$220,000	
Total costs	$2,761,025	$3,027,425	$2,807,425	$2,078,000	$2,260,000	$2,033,000	$2,356,175	$2,136,175
Freight rate:	**$42.48**	**$45.87**	**$42.54**	**$37.78**	**$37.67**	**$30.80**	**$36.25**	**$32.86**

[1] Metric tons. Previous classification of vessel sizes.

[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 2 port with top-off: to load 45-50,000 mt at Rosario and finish loading (top-off) an additional 10-15,000 mt at Bahia Blanca.

Source: O'Neil Commodity Consulting

Figure 5. Monthly freight rates from the U.S. Gulf and PNW to Japan



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

Analyzing World Soybean Market Shares: Model and Results

To understand the behavior of the underlying forces of the world soybean market, an extensive econometric analysis was performed using a dynamic approach. We used a dynamic model because the purpose of this study is to evaluate changes in market shares over time. This is accomplished by the specification and empirical estimation of a difference equation system and by making use of techniques in the specialized field of economics called "econometrics." This empirically estimated system enables analysis of the behavior of the underlying market, over time, in which the United States is the leading producer in the world soybean market. The model developed for this paper includes the theoretical specification, the model layout and the empirical framework used for capturing the dynamic changes of the world soybean market (see the Appendix for details). Due to data availability, the base model uses ocean freight rates and trade data for the period from 1992 to 2017. The Appendix presents detailed results on the empirical estimation, the impact of ocean freight rates on market shares, and the performance of the sensitivity analysis. Several statistical tests were performed to analyze and validate the behavior of the world soybean market shares and gain insights into the impact of Brazil's infrastructural improvement on the United States competitiveness, keeping the U.S. infrastructure constant. The United States is the leading producer in the world soybean market followed by Brazil and Argentina. Other competing countries are Paraguay and Canada.

Results

On the demand side, the model identified China as the major driver of the world soybean trade. On the supply side, the United States is the leading producer country in the world soybean market 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 (see 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 leaves the ranking of the countries' shares unchanged in the world soybean market (Appendix table A-2). The β *converge* shows the United States remains the leading country in the world market. This model's outcomes suggest the ocean freight rates are not a significant force in the shares of the world soybean market (see Appendix table A-2, and Salin and Somwaru 2015). In the future, as the competing countries—Argentina and Brazil—acquire a larger market share, any price or supply management policy, initiated solely by the United States, would be more likely to become less effective and costlier to administer. In sum, the dynamic analysis indicates that the market shares converge (see β *converge* estimates in the Appendix) to a so-called global market equilibrium while the interplay between the United States, Argentina, and Brazil in the world soybean market is very important.

Sensitivity Analysis – Brazil's Transportation Infrastructure Improvement and Pacific Northwest Ocean Freight Rates

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

Sensitivity analysis is a way to predict the outcome. In this case, the world market shares in response to three different situations other than the status quo are modeled. The assumptions made were that Brazil's infrastructure improves and its freight rates are reduced by three different levels. First, is a reduction of $12 per metric ton. Second, is a reduction and $20/mt. Third, is a reduction that is comparable to the transportation costs in the United States' PNW region, or a reduction of $28/mt (see columns 6 through 8, table 2, and tables 3, 4, and 5).

It is uncertain how much Brazil's infrastructure will improve and when; it is only known that it is improving. It is unknown by how much Brazil's freight rates will be reduced over time. 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 2017 and applying the assumptions that Brazil's infrastructure advancements reduced its transportation freight rates (at three different levels), the model estimates "new" exports and export shares for Brazil and its competitor countries (see columns 6 through 8, table 2 and tables 3, 4, and 5) to conduct the sensitivity analysis. Note that scenario three assumes the lowest U.S. transportation rates, which are comparable to the rates in the PNW. Using the assumed export market shares, the analysis re-estimated the model to capture the effect of scenario three of the sensitivity analysis on the world soybean market (see Appendix tables A-3 and A-4) because scenario three captures the largest change on the export market shares. Since the analysis assumes more than one change, this sensitivity analysis is called a multivariate sensitivity analysis. The sensitivity analysis conducted in this paper aims to shed light on the impacts of Brazil's potential transportation infrastructure improvements and possible competitive ocean freight rates on the world soybean market shares.

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

1. **Improved Transportation Infrastructure** - Assume Brazil's domestic transportation infrastructure (farm to port) greatly improves, increasing Brazil's ability to export soybeans to China in three scenarios: (see column 6, 7, and 8, table 2).

    - **Scenario 1:** Assumes the pavement along highway BR-163, connecting Sorriso, North MT to Miritituba, Pará (PA) is finished, which reduces transportation costs by $12/mt. The resulting changes are measured in market share percentages (see column 6, table 2, and table 3).

    - **Scenario 2:** Assumes BR 163 and Ferrogrão Railroad (EF-170) are built, connecting Sorriso, North MT to Miritituba, Pará (PA), 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 $20/mt. The resulting changes are measured in market share percentages (see column 7, table 2, and table 4).

    - **Scenario 3:** Assumes Brazil's ocean freight rates are equivalent to the U.S. PNW ocean freight rates, which is a reduction on average of $28/mt.[18] The resulting changes are measured in market share percentages (see column 8, table 2, and table 5).

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, tables 3, 4, ad 5) because Brazil's exports under the sensitivity analysis change (column 3, tables 3, 4, and 5).[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 (conditions) on all factors at the same time. In this way, the analysis accounts for the compounded impact (biggest change) of all possible improvements of Brazil's competitiveness in the world soybean market (see tables 2, 3, 4, and 5, and Appendix for details).

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

Scenario 1: (reduced transportation costs of $12/mt)

- Resulted in Brazil's global export market shares for the period 1992 to 2017 increasing from 16 percent in 1992 (or 15 percent points) to 46 percent (or 6 percent points) in 2017 (see column 6, table 2, and table 3); and

- At the same time, the United States' world market share declined by 2 percentage points in 1992, and almost 5 percentage points in 2017, as a result of infrastructural improvements in Brazil.

Scenario 2: (reduced transportation costs of $20/mt)

- Resulted in Brazil's global export market shares for the period 1992 to 2017 increased from 17 percent in 1992 (or 23 percent points) to 47 percent (or 9.5 percent points) in 2017 (see column 7, table 2, and table 4); and

- At the same time, the United States' world market share declined by nearly 4 percentage points in 1992 to 7 percent in 2017, as a result of structural improvements in Brazil.

18 The average of the PNW rates from 1992-2017 is $28/mt. The model used actual rates.

19 Given Brazil's new market shares, the United States, Argentina and other countries shares adjust because we keep the total observed export data from 1992-2017.

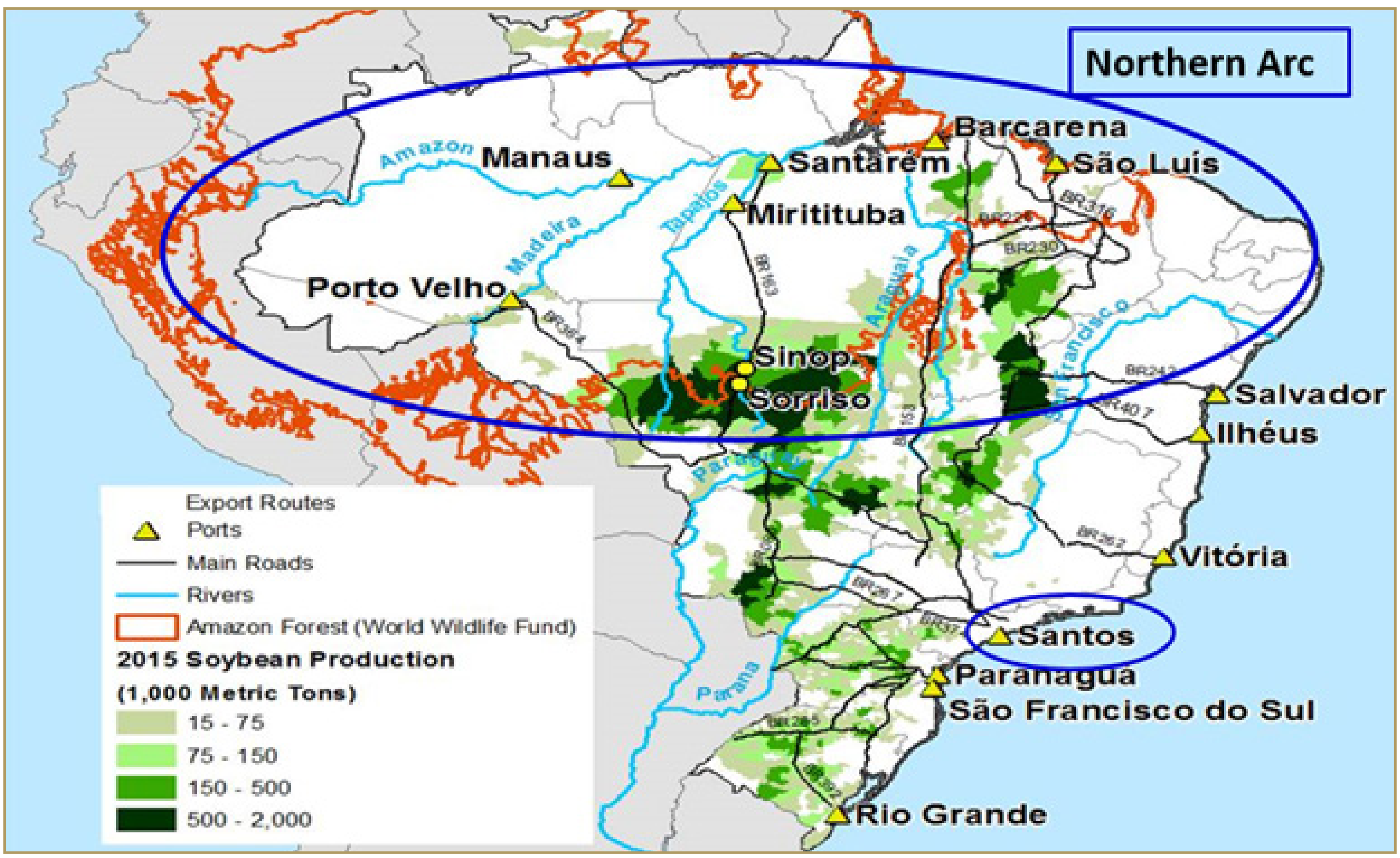
Scenario 3: (reduced transportation costs of $28/mt)

- Resulted in Brazil's global export market shares for the period 1992 to 2017 increased from 19 percent in 1992 (or 40 percentage points) to 50 percent (or 16 percentage points) in 2017 (see column 8, table 2, and table 5); and
- At the same time, the United States' world market share declined by 6 percentage points in 1992 to 12 percentage points in 2017 as a result of structural improvements in Brazil.

For clarity, using the shares developed for the sensitivity analysis for scenario 3, the analysis took the extra step of re-estimating the model and presenting the result of scenario 3. 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: Itacoatiara/Manaus (Amazon River), Santarém (Amazon River), Barcarena (Pará River), São Luís (Maranhão, MA), Porto Velho (MT) and Miritituba (PA) (barge terminals). The distance by truck from Sorriso, North MT, to Miritituba is 663 miles (1,067 km), via BR-163. Currently, it takes 3 days to ship grain to Miritituba because of the poor condition of the last 62 miles (100 km of unpaved road) of BR-163 connecting Sorriso to Miritituba. Travel time will be reduced to 1.5 days after paving of this section is finished.

Figure 6. Brazilian soybean main export ports



Source: USDA/Agricultural Marketing Service (AMS) and Foreign Agricultural Service (FAS)

It is worth noting that in 2017, Brazil's production costs—particularly from Mato Grosso (MT) and Paraná (PR)—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 use the same technological advancements. However, in 2017, two events brought some product differentiation between the U.S. and Brazilian soybeans. The first was that the U.S. soybean crop protein level was reduced compared with Brazilian soybeans due to adverse weather conditions and higher yields. Second, for the next 2 years, U.S. exporters must comply with a new procedure in which all U.S. soybean shipments to China, exceeding 1 percent of foreign material, will receive an additional declaration on the Animal and Plant Health Inspection Service (APHIS) phytosanitary certificate that says, "This consignment exceeds 1 percent foreign material." The majority of U.S. soybeans shipments to China are graded "U.S. soybeans No. 2 or better (2 O/B)" (AMS 2018 and APHIS 2017).[20] This means the shipment meets the standards for a No. 2 quality but may have factors that meet the requirement for a U.S. No. 1 grade. The five factors required for grading U.S. soybeans are: minimum test weight (pounds per bushel), total damaged kernels (includes the percentage of heat), foreign material, splits, and soybeans of other colors (AMS 2018). Since there is a premium for U.S. soybeans No. 1 shipments, in this case importing countries buying No. 2 are getting good quality U.S. soybeans without paying a premium for it.

Brazil can import or develop its own technology and increase planted area to increase exports. Brazil's export capacity is expanding, balancing its transportation system like that of the United States that includes all major modes of transportation (truck, rail, barge, and ocean vessel), thus lowering its transportation costs and opening new export gateways, and making it more competitive in the world soybean market. In 2014, Brazilian private investment from global grain trading and Brazilian barge companies on barge terminals (Salin 2017 and 2018) created a new export route from Miritituba to Barcarena (Vila do Conde), adding a new northern gateway to grain exports from North Mato Grosso (MT) to China, Europe, the Middle East, and Mexico (Salin 2017-18). This new export route balanced Brazil's transportation system from farm to port, like the U.S. Gulf export route in the United States. Mato Grosso's transportation costs as a percentage of the total landed cost to Shanghai had declined from 45 percent in 2006 to 29 percent in 2017, but were still higher than Iowa's. However, exporters in Rio Grande do Sul have lower transportation costs than the United States' routes to China through the PNW and from Iowa through the U.S. Gulf to Shanghai (Salin 2018 and Olowolayemo 2018).

The United States infrastructural and technological improvements are critical to maintain U. S. competitiveness in the world soybean market. Some examples of critical infrastructure improvements to maintain U.S. competitiveness in the world market are lengthening the locks on the Mississippi River and its tributaries to permit larger barge tows, dredging to deepen the water channels, and developing a better intermodal system with wider use of containerized shipments through the PNW on agricultural exports. Improved U.S. infrastructure would result in an increase in market share, a more competitive U.S. export sector, and higher income to farmers. For example, assuming 2017 world soybean trade is 152 mmt (WASDE, February 2018), a 1-percent decline in the U.S. soybean market share is equivalent to more than half a billion dollars lost in export sales (1.7 mmt X $388/mt).[21]

20 For quality grading information, see page 6.

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 (Appendix). For example, the coefficient value for the entire estimation period, 1992–2017, is 0.0150 percent (Appendix, Table A-1). After Brazil's infrastructural improvements, for the entire estimation period sensitivity analysis, the coefficient declines to 0.0041 (Appendix, Sensitivity analysis table A-3). This is equivalent to 1-percent declines in market shares (0.0150 - 0.0041 =0.0109). When we account for fluctuations in ocean freight and we considered the period from 2013 to 2017, the coefficient declines from 0.0101 rates (Appendix, Table A-2) to 0.0091 percent (Appendix, Sensitivity analysis table A-4). In this case, the loss of U.S. soybean sales would be larger, equivalent to nearly 1.0 percent (0.0101 – 0.0091 = 0.001), assuming improvements in Brazil's infrastructure and transportation, scenario 3.

Table 2. Market shares data: actual and for Brazil's sensitivity analysis*

Actual market shares					Brazil market shares, sensitivity analysis*		
Year	United States (%)	Brazil (%)	Argentina (%)	Other** (%)	Scenario 1 (%)	Scenario 2 (%)	Scenario 3 (%)
1992	66.25	13.78	11.43	8.54	15.81	16.93	19.34
1993	71.59	13.84	7.55	7.02	15.88	17.00	19.42
1994	57.72	19.60	10.90	11.78	22.26	23.71	26.77
1995	71.34	11.13	8.05	9.48	12.82	13.76	15.81
1996	73.00	10.92	6.64	9.44	12.79	13.82	16.05
1997	66.30	23.17	2.08	8.45	26.64	28.49	32.32
1998	60.52	22.28	7.17	10.03	26.35	28.50	32.89
1999	57.74	23.55	8.07	10.64	27.29	29.27	33.35
2000	58.06	24.29	9.02	8.63	28.47	30.66	35.13
2001	50.47	28.80	13.60	7.13	33.26	35.57	40.21
2002	54.88	27.50	11.30	6.32	31.47	33.55	37.79
2003	46.48	32.10	14.10	7.33	37.26	39.88	45.03
2004	43.14	36.50	12.05	8.31	41.31	43.74	48.55
2005	46.06	31.06	14.76	8.12	35.10	37.20	41.47
2006	40.20	40.72	11.39	7.70	46.48	49.30	54.66
2007	42.85	33.12	13.48	10.55	38.16	40.72	45.76
2008	40.07	32.23	17.58	10.11	36.37	38.51	42.85
2009	45.39	39.09	7.29	8.23	43.55	45.81	50.30
2010	44.32	31.04	14.22	10.43	34.89	36.90	41.00
2011	44.73	32.71	10.05	12.51	36.79	38.91	43.19
2012	40.52	39.51	8.03	11.95	43.83	46.03	50.41
2013	36.00	41.75	7.71	14.54	46.10	48.30	52.66
2014	39.56	41.54	6.96	11.94	45.84	48.02	52.34
2015	39.73	40.10	8.38	11.79	44.33	46.48	50.78
2016	39.88	41.03	7.49	11.61	43.90	45.41	48.55
2017	40.18	42.88	4.77	12.16	45.55	46.96	49.88

*Scenario 1: Assumes that if the pavement along highway BR-163, connecting Sorriso, North MT to Miritituba, Pará (PA) is finished, transportation costs will more likely to reduce by $12/metric ton, measured in market shares (percentage).

Scenario 2: Assumes that BR 163 and Ferrogrão Railroad (EF-170), connecting Sorriso, North MT to Miritituba, Pará (PA), 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, then transportation costs will more likely to reduce by $20/metric ton, measured in market shares (percentage).

Scenario 3: Assumes Brazil's infrastructure and transportation cost is as competitive as the U.S. PNW transportation cost, measured in market shares (percentage).

**Other competing countries include Paraguay and Canada.

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

Year	United States (%)	Brazil (%)	Argentina (%)	Other** (%)
1992	64.69	15.81	11.17	8.34
1993	69.89	15.88	7.37	6.86
1994	55.81	22.26	10.54	11.39
1995	69.98	12.82	7.90	9.30
1996	71.47	12.79	6.50	9.24
1997	63.30	26.64	1.99	8.07
1998	57.35	26.35	6.80	9.50
1999	54.91	27.29	7.68	10.12
2000	54.85	28.47	8.53	8.15
2001	47.31	33.26	12.75	6.68
2002	51.88	31.47	10.68	5.97
2003	42.94	37.26	13.03	6.77
2004	39.87	41.31	11.14	7.68
2005	43.36	35.10	13.89	7.64
2006	36.29	46.48	10.28	6.95
2007	39.62	38.16	12.46	9.75
2008	37.63	36.37	16.51	9.49
2009	42.07	43.55	6.75	7.63
2010	41.84	34.89	13.42	9.84
2011	42.01	36.79	9.44	11.75
2012	37.62	43.83	7.45	11.09
2013	33.31	46.10	7.14	13.45
2014	36.66	45.84	6.45	11.06
2015	36.92	44.33	7.79	10.96
2016	37.94	43.90	7.12	11.04
2017	38.31	45.55	4.55	11.59

*Scenario 1: Assumes that if the pavement along highway BR-163, connecting Sorriso, North MT to Miritituba, Pará (PA) is finished, transportation costs will more likely to reduce by $12/metric ton, measured in market shares (percentage).

**Other competing countries include Paraguay and Canada.

Table 4. Scenario 2: New market shares for conducting sensitivity analysis*

Year	United States (%)	Brazil (%)	Argentina (%)	Other** (%)
1992	63.83	16.93	11.02	8.23
1993	68.96	17.00	7.27	6.76
1994	54.77	23.71	10.34	11.18
1995	69.23	13.76	7.81	9.20
1996	70.62	13.82	6.43	9.13
1997	61.71	28.49	1.94	7.87
1998	55.68	28.50	6.60	9.23
1999	53.41	29.27	7.47	9.85
2000	53.17	30.66	8.27	7.90
2001	45.67	35.57	12.31	6.45
2002	50.30	33.55	10.36	5.79
2003	41.15	39.88	12.49	6.49
2004	38.21	43.74	10.68	7.36
2005	41.96	37.20	13.44	7.39
2006	34.38	49.30	9.74	6.58
2007	37.98	40.72	11.95	9.35
2008	36.36	38.51	15.95	9.17
2009	40.38	45.81	6.48	7.32
2010	40.55	36.90	13.01	9.54
2011	40.61	38.91	9.13	11.36
2012	36.15	46.03	7.16	10.66
2013	31.95	48.30	6.84	12.90
2014	35.18	48.02	6.19	10.62
2015	35.49	46.48	7.49	10.54
2016	36.91	45.41	6.93	10.75
2017	37.32	46.96	4.43	11.29

*Scenario 2: Assumes that BR 163 and Ferrogrão Railroad (EF-170), connecting Sorriso, North MT to Miritituba, Pará (PA), 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, then transportation costs will more likely to reduce by $20/metric ton, measured in market shares (percentage).

**Other competing countries include Paraguay and Canada.

Table 5. Scenario 3: New market shares for conducting sensitivity analysis*

Year	United States (%)	Brazil (%)	Argentina (%)	Other** (%)
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	35.26	49.88	4.19	10.67

*Scenario 3: Assumes Brazil's infrastructure and transportation cost is as competitive as the U.S. PNW transportation cost, measured in market shares (percentage).

**Other competing countries include Paraguay and Canada.

Conclusions and Further Research

The world soybean market is growing, but the U.S. market share is lower than it was in 1980. After hitting a low in 1994, the U.S. market share stabilized, dominating the world market until 2013. Since then, Brazil surpassed U.S. soybean exports, becoming the top world soybean exporter. Exports are driven by Brazil's ability to expand soybean production area, increase yields, agribusiness direct investment on grain terminals, new barge terminals, as well as the Brazilian government's strategic infrastructural improvements and major regulatory changes. During the 2012-2017 period, 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 production in order to maintain a stable international market price.

A major transportation infrastructure improvement occurred in 2014 when 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 North Mato Grosso (MT) to China, Europe, the Middle East, and Mexico. This new export route enhanced Brazil's transportation system from farm to port, including all major modes, like the United States. Consequently, since Brazil and U.S. producers use the same production and technological advancements, making their soybeans relative substitutes, transportation costs and structural infrastructure improvements are critical factors to U.S soybean competitiveness worldwide.

Brazil can import or develop its own production technology and increase planted area to augment its exports. Brazil's export capacity is increasing and is now supported by a balanced transportation system that includes all major modes of transportation (truck, rail, barge, and ocean vessel) like that of the United States. Mato Grosso's transportation costs as a percentage of the total landed cost to Shanghai had declined since 2006 but were still higher than Iowa's. However, exporters in Rio Grande do Sul, the second largest soybean exporting State, have lower transportation costs than the United States' routes to China through the PNW and from Iowa through the U.S. Gulf to Shanghai.

The empirical analysis suggests the U.S. world market share could further decline by 12 percentage points without significant improvements in the U.S. transportation infrastructure for the soybean supply chain, from the farm to port, if Brazil continues to advance its transportation infrastructure. The empirical dynamic model outcomes also indicate that for an expanding market, a major exporter, even with no cost advantage, does not necessarily price itself out of the market, but instead maintains a constant market share over the long run. As long as the major players continue operating as they have, market shares are expected to converge to an equilibrium despite the variability or fluctuations of the ocean freight rates, over time.

The multivariate sensitivity analysis results indicate that in the long run, the United States, Brazil, and Argentina market shares in the global soybean market depend on the countries' exporting capacity, which, 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*) is getting smaller, indicating the global soybean market is in still in equilibrium, but converging with decreasing rates. The sensitivity analysis also shows the United States' infrastructural improvements are critical for maintaining its 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 the world soybean trade is 152 mmt (WASDE, February 2018), a 1-percent decline in the U.S. soybean market share is equivalent to more than half a billion dollars lost in export sales (1.7 mmt X $388/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 interaction of cash and future prices; storage versus transportation cost; and freight rates for truck, barge, rail, and ocean need to be captured and analyzed. Further research should also address the impact of lengthening the locks on the Mississippi River and its tributaries to permit larger barge tows, dredging to deepen the water channels, and developing a better intermodal system with wider use of containerized shipments through the PNW, on agricultural exports.

Appendix: Methodology

The model estimated the growth pattern, the speed of convergence and the stability of the global soybean market following Barro and Sala-i-Martin (1996).[22] This is assessed by estimating the following transitional equation:

$$log(s_{it} / s_{i,t-1}) = \alpha - (1 - e^{-\beta}) * \log(s_{i,t-1}) + u_{it}$$

Where s_{it} are the market shares of the dominant and competing countries. The subscript *i* denotes the country; the subscript *t* denotes the year; α and β are coefficients to be estimated and u_{it} is the random disturbance. Assuming the disturbance term has zero mean and its variance σ_u^2 is distributed independently over time and across countries (Barro and Sala-i-Martin, 1992). In estimating the transitional dynamics, we deviate from Barro and Sal-i-Martin because we do not impose any restriction(s) or condition(s) on the estimated coefficients. Unlike the neoclassical growth theory (Barro and Sala-i-Martin 1992), where the β coefficient is restricted $0<\beta<1$, we allow the β coefficient to take any value. If $\beta>1$, then it is observed an overshooting effect or so-called leapfrogging where a competing economy that starts out behind the leading producer country goes ahead at some future date.[23] The condition $\beta>0$ insures convergence of the growth rates. If $0<\beta<1$ holds, then it shows absolute convergence. After testing, the shares are stationary and this implies they do not have unit roots. A higher positive coefficient β reflects greater tendency toward convergence while the dispersion of the market shares rises with the variance σ_u^2 of the disturbance term. The smaller the variance σ_u^2, the smaller the variability of the market shares growth rates.

The NLIN procedure in SAS (SAS/STAT, 2012) is applied. The procedure fits nonlinear specifications and estimates the parameters using nonlinear least squares. This allows great flexibility in modeling the relationship between the dependent or response variable and independent variables. In estimating the parameters, the procedure uses an iterative process for finding those values of the parameters that minimize the weighted residual sum of squares. The NLIN procedure determines converge by using *R*, the relative offset measure by Bates and Watts (1981).

The data used in the empirical estimation are from O'Neil Commodity Consulting from 1992 to 2017 (figure 3). The periods and sub-periods (tables A-1 and A-2) were selected based on nonparametric tests results.

Performing nonparametric tests on these three ocean rates in SAS, found that the rates in the *first period* (1992–2004) are statistically different from those in the *second period* (2005–2008), and different from those in the *third period* (2009–2017) (tables A-1 and A-3). Specifically, the nonparametric procedure NPAR1WAY was used to perform tests for location (mean) differences on the raw data.

For the selection of sub-periods 1 through 5, the rates from U.S. Gulf and U.S. PNW to Japan were used. These rates are depicted in figure 5 above. Again, nonparametric tests were performed and found that the rates are statistically significant in the five sub-periods: 1992–2001 (first), 2002–2004 (second), 2005–2007 (third), 2008–2012 (fourth), and 2013–2017 (fifth) (see table A-2).

22 Extensive theoretical underpinning of the model specification is presented in Salin and Somwaru 2015 Report, "Eroding U.S. Soybean Competitiveness and Market Shares: What Is the Road Ahead?" (pp. 22-25). However, the information provided below recaptures the empirical framework applied to estimate the dynamics of the soybean world market (Salin and Somwaru, pp.26-33). U.S. Dept. of Agriculture, Agricultural Marketing Service, September 2014. Web. <http://dx.doi.org/10.9752/147.09-2014>.

23 Testing for convergence is beyond of the scope of the paper.

The estimation results of the nonlinear unconditional regressions clearly indicate the United States is the leading producer country in the world soybean market and the market shares of the United States, Argentina, and Brazil have converged and stabilized (tables A-1 and A-2). The estimated parameters of this dynamic model of the world soybean market are widely known as the β *converge* and σ *converge*. In the model, the β *converge* measures the growth of the competing countries' shares compared to the leading producer country's share. Depending on the magnitude of the estimate, β *converge* determines if the market shares will converge and stabilize in the long run. The σ *converge* measures the dispersion or variation of the magnitude of the market shares across the competing countries.

The β *converge* estimates for the entire period and for the three periods are positive, implying the market shares are converging (table A-1). From 1992–2017, the effect of the initial position of the leading producer country declined and the market shares of the competing countries grew faster than the leading producer country. Over time, the market shares of the competing countries have stabilized. The β *converges* of the first and second periods are 0.0293 and 0.00554, respectively, and have the smallest value in the third period (0.0038). For the entire period as well as the three periods under study, the positive values of the β *converge* clearly indicate that Brazil and Argentina export growth in the world market increased dramatically compared to that of the United States. The positive values of β *converge* estimates imply absolute convergence and the higher coefficient corresponds to a greater tendency toward convergence (table A-1).

The estimated variance, or σ *converge*, measured by the variance of the regression, captures the dispersion of the process or the degree of uneven growth of the market shares. For the entire period (1992–2012), the market converged with minimal dispersion of 0.0016 (table A-1). The estimated σ *converge* for the first period is the smallest (0.0024), compared with the third period (0.0015). The smallest σ *converge* value occurs in the second period (0.0002). This indicates the growth of the market shares during the second period increased with less variability than in the first and third periods.

The model suggests 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 a larger market share, any price or supply management policy initiated soley by the United States would become less effective and costlier to administer. Thus, the interplay between the United States, Argentina, and Brazil becomes a very important factor about soybeans in the world market.

Table A-1. Estimation results of the transitional dynamics of the world soybean market, 1992-2017

Year	Parameter	Estimate	Standard error	95% Confidence limits: lower bound	95% Confidence limits: upper bound
Entire period 1992–2017	α (Intercept)	0.0366	0.0744	-0.2836	0.3567
	β (strength of converge)	0.0150	0.0372	-0.1450	0.1751
	σ (converge—steady state) (second moment of the distribution)	0.0016			
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)	0.0024			
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)	0.0002			
Third period 2009–2017	α (Intercept)	0.0120	0.0675	-0.2786	0.3027
	β (strength of converge)	0.0038	0.0232	-0.0959	0.1034
	σ (converge—steady state) (second moment of the distribution)	0.0015			

Accounting for Ocean Freight Changes[24]

Transitional dynamics is also applied to the world soybean market while accounting for changes in ocean freight rates over the estimated period.[25] In this case, the estimated dynamics cover the following five sub-periods: 1992–2001 (first), 2002–2004 (second), 2005–2007 (third), 2008–2012 (fourth), and 2013–2017 (fifth) (see table A-2). The sub-periods follow fluctuations in freight rates observed during the study period (figure 5). The β *converge* of the sub-periods are positive, with values 0.0209, 0.0335, 0.0255, 0.0111, and 0.0101, respectively, implying that world soybean market shares absolutely converge given that the estimates of the β *converge* are positive (table A-2). Higher coefficients—0.03 and 0.026—in the second and third sub-periods, respectively, indicate a greater tendency toward convergence. Again, the effect of the initial position of the leading producer country declined and the market shares of the competing countries grew faster. Furthermore, the market shares of the competing countries stabilized over time despite the great variability in the ocean freight rates (figure 3). When the model accounted for observed changes or fluctuations in freight rates over the period under study, the β *converge* estimates indicate that sustained convergence is likely to remain for the competing countries (especially in the most recent period, because the lagging economies tend to grow faster (table A-2)).

The estimated σ *converge* captures the dispersion of the process or the degree of uneven growth of the market shares. In the second sub-period, the market converged with the largest dispersion of 0.0293. The estimated σ *converge* in the first sub-period is the largest (0.0027) (table A-2). Note that the β *converge* lie within the 95-percent confidence limits of the lower and upper bounds for the estimates of all sub-periods, reflecting a statistical significance of 0.05 (table A-2).

In summary, the empirically estimated model indicates that the U.S. market share will be stable as the overall market grows. As the competing countries—in this case Argentina and Brazil—acquire a larger market share, any price or supply management policy initiated solely by the United States, the leading producer country, might become less effective and more costly to administer. In this regard, the interplay between the United States, Argentina, and Brazil becomes an important factor in the world soybean market.

24 See Salin, Delmy L. and Agapi Somwaru. Eroding U.S. Soybean Competitiveness and Market Shares: What Is the Road Ahead? U.S. Dept. of Agriculture, Agricultural Marketing Service, September 2014. Web <http://dx.doi.org/10.9752/147.09-2014>

25 For more information about the United States-South American Ocean Freight Spreads see Salin, Delmy. United States–South America Ocean Grain Freight Spreads (Summary). January 2018. U.S. Department of Agriculture, Agricultural Marketing Service. Web. <http://dx.doi.org/10.9752/TS213.01-2018>; and O'Neil, Jay. U.S.–South America Ocean Freight Rates. March 2015. International Grains Program Institute (IGP), Kansas State University (KSU). Web. <http://hdl.handle.net/2097/18876>.

Table A-2. Estimation results of the transitional world soybean market accounting for freight rates and time intervals, 1992–2017

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)	0.0027			
Second period 2002–2004	**α** (Intercept)	0.0952	0.3116	-1.2456	1.4361
	β (strength of converge)	0.0335	0.1144	-0.4586	0.5256
	σ (converge—steady state) (second moment of the distribution)	0.0293			
Third period 2005–2007	**α** (Intercept)	0.0777	0.1297	-0.4802	0.6357
	β (strength of converge)	0.0255	0.0458	-0.1714	0.2224
	σ (converge—steady state) (second moment of the distribution)	0.0042			
Fourth period 2008–2012	**α** (Intercept)	0.0121	0.1134	0.0112	0.0132
	β (strength of converge)	0.0111	0.0161	-0.0403	0.0625
	σ (converge—steady state) (second moment of the distribution)	0.0090			
Fifth period 2013–2017	**α** (Intercept)	0.0210	0.1342	0.0191	0.0235
	β (strength of converge)	0.0101	0.0099	-0.0215	0.0417
	σ (converge—steady state) (second moment of the distribution)	0.0033			

Sensitivity Analysis – Brazil's Transportation Infrastructure Improvement and Pacific Northwest Ocean Freight Rates

The values of the β *converge* (table A-3), under the sensitivity analysis for scenario 3, are positive. This indicates that the United States remains the leading producer country even though the competing countries' shares improved faster and converged in 2017. When the model accounts for observed changes or fluctuations in freight rates over time, the results indicate that the United States is still the leading producer country but the rate of convergence increases for the competing countries (table A-4). The competing countries tend to converge toward the United States and the rate of convergence is faster under the sensitivity assumptions.

The σ *converge* of the second moment of the distribution has smaller values, indicating that the growth of the market shares of the competing countries would increase with a smaller degree of variability under the sensitivity assumptions (tables A-3 and A-4).

We conclude by using the findings of conducting the sensitivity analysis that values of the *converge* coefficients are not the same as those when we use the observed data. The sensitivity results indicate that the underlying technology and infrastructure from farm to port as well as the competitiveness of ocean freight rates affect the world soybean market (tables 2, 3, 4, and 5). It is also concluded that the United States' infrastructural improvements are critical to maintain its competitiveness in the world soybean market. Improved U.S. infrastructure would result in an increase in market share and more competitive U.S. export sector and higher income for farmers.

Table A-3. Estimation results of the transitional dynamics of the world soybean market, 1992–2017*

Year	Parameter	Estimate	Standard error	95% Confidence limits: lower bound	95% Confidence limits: upper bound
Entire period 1992–2017	**α** (Intercept)	0.0087	0.0161	-0.0427	0.0600
	β (strength of converge)	0.0041	0.0455	-0.0704	0.0794
	σ (converge—steady state) (second moment of the distribution)	0.0010			
First period 1992–2004	**α** (Intercept)	0.0427	0.1099	-0.4303	0.5156
	β (strength of converge)	0.0157	0.0451	-0.1784	0.2098
	σ (converge—steady state) (second moment of the distribution)	0.0033			
Second period 2005–2008	**α** (Intercept)	0.1346	0.0490	-0.0765	0.3456
	β (strength of converge)	0.0433	0.0191	-0.0387	0.1253
	σ (converge—steady state) (second moment of the distribution)	0.0006			
Third period 2009–2017	**α** (Intercept)	0.0090	0.0186	-0.0502	0.0682
	β (strength of converge)	0.0027	0.0703	-0.1137	0.1175
	σ (converge—steady state) (second moment of the distribution)	0.0014			

* Note: The sensitivity analysis assumes Brazil's improved infrastructure and transportation cost is as competitive as PNW transportation cost.

Table A-4. Estimation results of the transitional dynamics of the world soybean market accounting for freight rates and time intervals, 1992–2017*

Year	Parameter	Estimate	Standard error	95% Confidence limits: lower bound	95% Confidence limits: upper bound
First sub-period 1992–2001	**α** (Intercept)	0.0434	0.0250	-0.0362	0.1230
	β (strength of converge)	0.0150	0.0676	-0.1003	0.1222
	σ (converge—steady state) (second moment of the distribution)	0.0025			
Second sub-period 2002–2004	**α** (Intercept)	0.1020	0.0376	-0.0176	0.2216
	β (strength of converge)	0.0320	0.1239	-0.1860	0.2218
	σ (converge—steady state) (second moment of the distribution)	0.0057			
Third sub-period 2005–2007	**α** (Intercept)	0.0722	0.0264	-0.0119	0.1563
	β (strength of converge)	0.0235	0.0752	-0.1197	0.1278
	σ (converge—steady state) (second moment of the distribution)	0.0028			
Fourth sub-period 2008–2012	**α** (Intercept)	0.0017	0.0470	-0.1480	0.1513
	β (strength of converge)	0.0095	0.1158	-0.1267	0.2544
	σ (converge—steady state) (second moment of the distribution)	0.0088			
Fifth sub-period 2013–2017	**α** (Intercept)	0.0073	0.0275	-0.0802	0.0947
	β (strength of converge)	0.0091	0.0859	-0.0214	0.2613
	σ (converge—steady state) (second moment of the distribution)	0.0030			

* Note: The sensitivity analysis assumes Brazil's improved infrastructure and transportation cost is as competitive as PNW transportation cost.

Recent and Forthcoming Brazil Infrastructure Improvements

In 2007, the Brazilian government began implementing a comprehensive infrastructure improvement strategy involving multiple transportation modes, with major institutional and regulatory changes to facilitate agricultural exports (Salin 2013-14). In 2011, the Brazilian government introduced new rail regulation. The new law requires Brazilian railroads to sell other railroads the rights to use idle capacity if they are not using their rail tracks at full capacity. This was a major step to increase railway use, within the next 15 years. In the United States, 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, the agricultural exporters in Midwestern Brazil gained a competitive boost from strategic port improvements and extended railways miles with a new intermodal grain terminal facilitating the flow of grains from Mato Grosso (MT) to the southern port of Santos (Salin 2014). Brazil surpassed U.S. soybean exports for the first time that year, becoming the top world soybean exporter. This trend continued in 2017. Another major private direct-investment transportation-infrastructure improvement occurred in 2014, when Brazil created a new export route from Miritituba to Barcarena (Vila do Conde), adding a new northern gateway to grain exports from North Mato Grosso (MT) to China, Europe, the Middle East, and Mexico (Salin 2017-18). Miritituba is a barge terminal on the Tapajós Rivers, which is part of the Amazon hydrographic basin. This new export route balanced Brazil's transportation system, including all major modes (truck, barge, and ocean vessel) similar to the U.S. Gulf export route from the farm to major export markets. Savings from efficiencies, gained at the Miritituba's barge terminal, offset the cost of shipping grain through the Panama Canal to China. Since 2014, North MT has shifted soybean shipments to Barcarena from the ports of Rio Grande (RS), São Francisco do Sul (SC), Vitória (ES), Paranaguá (PR), and São Luís (MA). Note these new developments were accounted for in scenarios 1 and 2 of the sensitivity analysis conducted for this paper.

Brazilian Transportation Improvement on the Horizon

Two major infrastructure improvements within 1-8 years will likely change Brazil's future competitiveness, significantly, in the agriculture world market:

1. **BR-163 Status**
   BR-163 is a highway connecting the Brazilian Northern and Southern regions. The construction of BR-163 is divided in three sections:

   - Sections 1 and 2: expansion is ongoing to add two more lanes, totaling two lanes on each side through concessions to the private sector. . Section 1 is in the State of Mato Grosso do Sul (MS). Section 2 is in the State of MT.

   - Section 3: located in the State of Pará (PA). The Brazilian Government is responsible for building this section through the Army Engineer Construction Battalion (BEC).

The Brazilian government has also announced that 40 of the 62 miles connecting Sorriso to Miritituba will be finished by December 2018.

2. **Ferrogrão Railroad (EF-170)-Selected infrastructure project improvements proposal**

Ferrogrão Railroad (EF-170) is a priority of Project Crescer and the Brazilian government's Investment Partnerships Program (Salin 2017-18). This railroad consolidates the new Brazilian export rail corridor of the Northern Arc by connecting Sinop (North MT), a main grain-producing region, to Miritituba, Pará (PA) (figure 6). The EF-170 is expected to increase transport capacity and competitiveness to the corridor, and alleviate traffic conditions on highway BR-163 by opening a new route for the soybean, soybean meal, corn, beef, and cotton exports.

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