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LOGISTICAL COMPETITION FOR CORN SHIPMENTS FROM THE UNITED STATES AND UKRAINE TO TARGETED INTERNATIONAL MARKETS

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EXECUTIVE SUMMARY

What Is the Issue?

The global corn market has faced dramatic developments in recent years. Ukraine has emerged as a fast-growing corn exporter into markets traditionally dominated by the United States. Ukraine has emerged to be one of the dominant suppliers of corn to China and other key markets previously dominated by the United States alone.[1] Many factors affect this competition, including supplies and capacity, ocean shipping costs, logistical functions and costs (ocean and interior), quality, and trade interventions. Analyzing these factors for major corn-exporting countries is necessary to understanding competition among international origins. Given recent significant changes in the global corn-export market, including many recent trade interventions, it is especially important to analyze how these factors will affect competition in the near future.

What Did the Study Find?

Some important general patterns in global corn-export markets are apparent based on 2015-19 data of supplies, demand, and logistical costs. Results reported in this study were for May and November. May is representative of the peak spring shipping season for U.S. corn exports while November is representative of the fall harvest for the U.S. Overall, variability in ocean rates and barge shipping costs were two factors leading to changing market shares. Also, from 2015 to 2019, for exporting firms, as well as importing countries, diversification among origins were key elements of strategy to keeping costs down. Generally, most import countries diversify their origins and optimally buy from multiple origins for various reasons, including sanitary and phytosanitary regulations, political issues, existing business relationships, and quality issues.

Differences Between U.S. and Ukrainian Corn-Export Trades

The study's findings identified key distinctions between U.S. and Ukraine's advantages and disadvantages in the global corn-export market. Overall, the United States was likely the lowest cost supplier of corn exports in many markets. Costs were less volatile in shipments from the U.S. origins than from Ukraine. Thus, shipping from U.S. origins was less risky, but had slightly greater mean costs. However, rail shipping costs in Ukraine provided a substantial cost advantage over the United States and this advantage persists.

Both the United States and Ukraine had advantages in major markets. The United States had a logistical cost advantage over Ukraine in serving China and South Korea (from the U.S. Gulf) and Japan (from the Pacific Northwest (PNW)). From 2015 to 2019, there was a 0.80 probability U.S. Gulf's was the lowest-cost supplier for China and a 0.67 probability PNW was the lowest-cost supplier to Japan. Therefore, in the case of China, the U.S. Gulf and PNW should have been the dominant origins for corn shipments to China. However, during most of this period, Ukraine

[1] Other major exporting countries are Brazil and Argentina. The major import markets considered in the study are the EU, Japan, South Korea, North Africa, the Middle East, Indonesia, and Vietnam.

was the dominant supplier to China. Of the many potential reasons for China's preference for Ukrainian corn, most important are probably (1) China's goal of diversification, (2) China's non-price preference[2] for non-U.S. origin corn, and/or 3) China's desire for less transparent trading mechanisms.

Ukraine had a logistical advantage over the United States in serving the European Union (EU) and Indonesia. However, Ukraine's advantage in the EU was mostly due to the EU's additional 25-percent tariff applied to corn imports from the United States and due to the EU's restrictions against genetically engineered corn imports. There was a 0.80 probability Ukraine was the lowest-cost supplier for the EU.

Both the U.S. advantage in China and Ukraine's advantage in the EU are also impacted by limited shipments from Brazil and Argentina to these markets. Brazil and Argentina had lower corn-export market shares because of China's Sanitary and Phytosanitary Standards and the EU's import restrictions on genetically engineered corn. In the case of EU, each member state has flexibility to decide on the use of GE corn for food/feed.

Results of Scenarios on Logistical Competition and Trade Interventions

The study modeled various scenarios to analyze how market shares would change in response to changes in logistical competition and trade interventions. Results on logistical competition showed the following:

- **Ocean rates.** PNW has a substantial ocean-rate advantage to the Asian destinations. Increases in ocean rates increase market shares for PNW and Ukraine while decreasing them for the U.S. Gulf and Argentina.
- **Barge rates.** Increased barge rates do not affect U.S. market shares. However, reductions in barge rates have significant increases in U.S. market shares.
- **Rail Daily car values (DCV).** Increasing (decreasing) daily car values lowers (raises) the U.S. market share.
- **Export capacity.** As exports increase, shipments will more often be diverted from the least-cost origin due to constraints related to export capacity at ports. The greatest demand would be for more supply capacity at PNW, Ukraine, and Brazil.
- **Mississippi River dredging.** The United States has a project underway to dredge the Mississippi river to 50 feet. This improvement will allow ships to be loaded to a greater depth, and prospectively lower shipping costs on a per metric ton basis. Results show

[2] Non-price preference refers to the willingness to pay a premium for non-US origin corn. There are a number of potential reasons for this and typically related to perceptions of quality and/or GM content.

dredging's greatest impact would be to increase U.S. Gulf shares to China and South Korea and to decrease shares (mostly) from PNW.

Though the focus of this study was on logistical functions and costs, trade interventions have impacts on trade flows and relative logistical advantages and were included in the analysis. Results of these trade interventions were as follows:

- **EU import tariffs on U.S. corn.** The most dramatic trade intervention affecting corn trade is that of the EU import tariff on U.S. corn. Eliminating this duty would substantially reduce Ukraine market share to the EU, and most of those shipments would originate at the U.S. Gulf. As a result, some of Ukraine's exports were shifted to Japan and Indonesia, and U.S. Gulf shipments to China decreased. It is important to note that EU tariffs on US corn could be temporary and could be eliminated in the near future.

- **Increased Ukraine exports to 24 million metric tons (mmt) per year.** If Ukraine's exports increased to 24 mmt per year, Ukraine would gain market shares to Indonesia and Japan and U.S. PNW would lose shares to those destinations.

- **Removing genetically engineered (GE) corn restrictions by the EU.** If the EU removed restrictions on GE corn, Ukraine would lose the most EU market share, while Argentina would gain the most.

- **China tariff rate quotas (TRQ).** A key trade intervention in China is that of TRQs. As a result of a 65-percent over-quota tariff from all origins to China, Ukraine would gain the most, while U.S. Gulf would lose most. However, administration of TRQs was difficult to document and/or implement in the study's aggregated model.

- **Removing Chinese sanitary and phytosanitary (SPS) restrictions on Brazil and Argentina.** Removing the Chinese SPS restrictions on Brazilian and Argentine corn would have major impacts on corn flows. Specifically, Argentina would gain a sizable market share of China, while both the U.S. Gulf and PNW would lose share. For November, the results show that Brazil would gain the most, while the United States would lose most of the Chinese market.

- **China imports at 30 mmt per year.** One of the important shifts in global corn trade in the past year was the rapid increase in imports by China. In the baseline case (2015-19), the average imports were about 3.8 mmt per year, but in 2020-21, average annual imports appear to have increased to 30 mmt. The results from this study suggest that most of the increased exports would be from the United States and the frequency of hitting capacity restrictions increases.

Supply-Chain Disruptions Since 2019

Since the 2015-19 period, which was the base period for this study, major supply-chain disruptions in commodity trading have occurred. In part, these are driven by the pandemic and the post-pandemic recovery. Although the pandemic has affected all commodities—particularly, in international freight shipping—the U.S. grain-export industry has been resilient.[3] Notably, similar if not more drastic disruptions occurred in competitor countries.

In all countries, supply-chain disruptions have had major impacts on logistics in the grain and oilseeds trade. The most important effects have been increases in ocean shipping costs, interior basis, secondary rail market values, as well as escalated demand for corn by China. Both ocean shipping and demurrage costs more than doubled, which increased the advantage to origins that offered lower-cost ocean shipping—notably, PNW.

The impacts show that the U.S. Gulf and PNW gained market share for most destinations, and Ukraine increased its shares in the EU, North Africa, and Middle East. These changes have mostly been due to lower ocean shipping costs from the United States and a re-alignment of trade flows, which mainly favor U.S. exports.

How Was the Study Conducted?

The study assessed impacts of transportation and logistics functions in the U.S. and Ukraine on shares of the world corn-export market. An optimized Monte Carlo model was used to analyze spatial competition and to determine market shares and comparative logistical advantage. Interior and exterior shipping costs were included, as well as relevant trade interventions to reflect the competitive conditions for the base period. The total delivered cost included the origin's basis (Thomsen Reuters Eikon, AgriCensus), rail tariffs (BNSF, USDA-AMS), rail daily car values (Trade West Brokerage Co.) and fuel service charges (USDA-AMS), barge (USDA-AMS), and elevation costs (Industry sources) at the port to compute the cost parameter at the Freight on Board (FOB) port value. Trade flows from each of the origin to the destinations are collected from UN Comtrade and AgriCensus.

[3] This resilience owes to the importance of grains and oilseeds in producing foods, as well as to the fact export handling was declared an "essential work" function.

LOGISTICAL COMPETITION FOR CORN SHIPMENTS FROM THE UNITED STATES AND UKRAINE TO TARGETED INTERNATIONAL MARKETS

1. INTRODUCTION

The United States was the dominant exporter of corn during the 1970's and 1980's, but, since then, its market share has been declining. In contrast, the Ukraine is emerging as a large and fast-growing corn exporter into markets traditionally dominated by the United States. Figure 1.1 shows total corn exports from the United States and Ukraine. Corn exports from Ukraine have increased from 0.49 million metric tons (mmt) in 2002 to an all-time high to 32.34 mmt in 2019 and then slightly decreased to 27.94 mmt in 2020 (UN-Comtrade, 2021). During 2019-20, Ukraine is the dominant exporter of corn to China, and other countries previously dominated by the United States. Table 1.1. shows the total supply corn at major origins considered in this study. The most important markets in which this rivalry is evolving to be intense are China, and countries in the European Union (EU), North Africa, Middle East, among others. Over time, major factors impacting U.S. competitiveness in the world corn market include but not limited to supply, inland logistics and ocean shipping, quality and trade interventions.

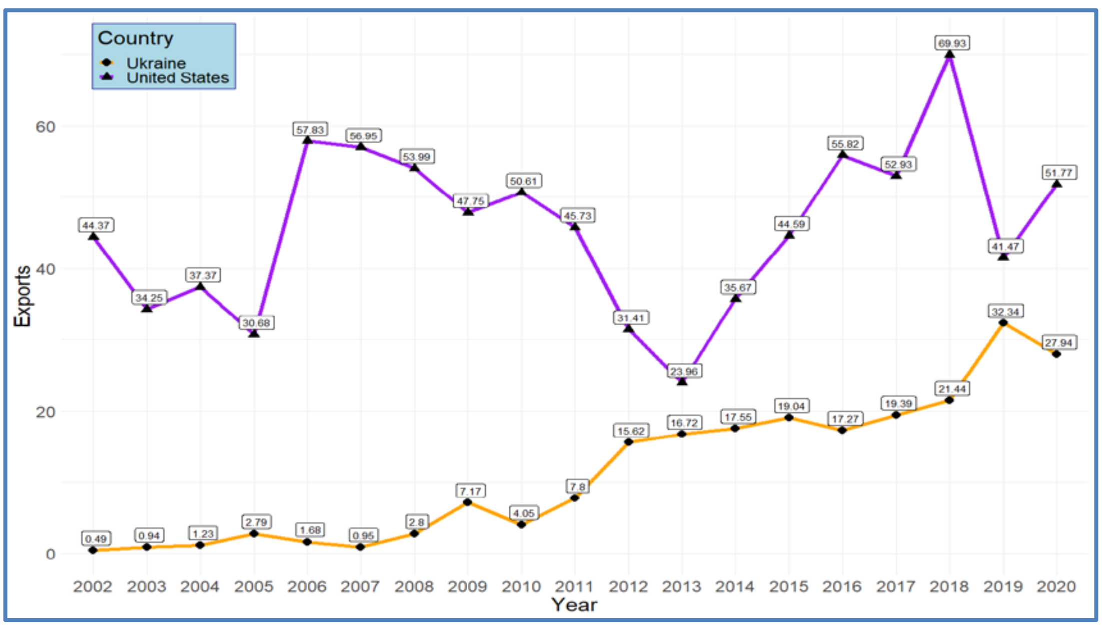

Figure 1.1. Corn Exports (Million Metric Tons) from the United States and Ukraine, 2002-2020

Table 1.1. Total Supply of Corn at Major Origins (Units: Million Metric Tons [mmt])

MY	Argentina	Brazil	Ukraine	US PNW	US Gulf
2013-14	27	90	32	48	111
2014-15	31	99	30	66	124
2015-16	32	78	25	75	119
2016-17	42	106	29	77	127
2017-18	37	97	26	81	130
2018-19	53	112	37	76	131
2019-20	53	109	37	68	123
2020-21	51	111	32	73	127
2021-22	53	125	38	78	130

Source: Compiled by authors from data collected from ProExporter Network and USDA Production, Supply and Demand.

Some of the important features of this competition include: spatially differentiated production across countries; multiple ports from each supplier; 2nd rail car values and barge rates that are volatile in the United States; ocean freight/shipping costs; and quality differentials. Also, heterogeneity in corn in terms of level of starch depending on the origins (Garcia and Shultz, 2021). While genetically engineered (GE) corn is dominant in the United States, it is not as pervasive or apparent in the Ukraine, though many recognize that GE traits are leaked into that country. Some buyers impute an advantage and value for that attribute/origin due to negative perceptions about GE products.

Over the past decade, the United States grain marketing system has a number of notable changes in its logistical system. These include expanded export handling capacity, adoption of forward shipping instruments (2nd rail car markets), shuttle rail shipping, and quite massive investments in the country handling and rail infrastructure all of which lower marketing costs (Wilson and Lakkakula, 2021; Wilson et al. 2020). It is also heavily dominated by the US river system which provides low cost and competitive barge shipping. However, costs of these shipments have substantial volatility (intra-year and inter-year), and the river system needs upgrading. Finally, US growers have significant on-farm storage.

In contrast, the changes in Ukraine agriculture (Lyddon, 2021; Pleasant, 2021) and its grain marketing system are evolving (Salin 2020; Sizov 2020; Wilson 2020). Over the past decade, there has been moderate increase in storage and country elevators and substantial expansion in export capacity. Interior rail shipping costs are extremely low by international standards and in comparison, to those in the United States. In recent years, Ukraine has partially adopted a form of shuttle shipments and increased use of private rail cars. However, interior rail shipping costs are under pressure to be increased (US Treasury Office, 2016). Through these competitive pressures, margins, particularly at the export port have been declining. Ukraine also has a river system (most prominent is the Dnieper river) which historically had been important.

But, in recent years, the Dnieper river has been under-developed and under-utilized, and needs upgradation (CTS, 2014).

In addition to the logistical differences between the United States and Ukraine, there is substantial trade intervention affecting competition in the global corn market. These interventions have emerged over time, and include EU's retaliatory tariffs on US corn imports, tariff rate quotas for imports into China, tariff rate quotas for Ukraine exports to the EU, and varying forms of quality restrictions related to phytosanitary and GE corn. In the recent years, China has become increasingly more dominant in this market. Finally, the Ukraine is continuing to evolve and now is confronting land reform that is expected to increase productivity and competitiveness (Day, 2021; Polityuk 2021; VanTrump 2021; Verbyany and DeSousa, 2021).

A combination of the changes in the logistical systems and trade interventions has resulted in intense rivalry between the United States and Ukraine, particularly in serving common corn importing countries. In coming years, this challenge will likely escalate.[4]

Traditionally, the United States was primarily the lowest cost supplier particularly relative to Brazil and Argentina (Meade et al. 2016). However, the Ukraine has gained an advantage in the recent years. In summary, two major challenges for the U.S. corn competitiveness include:

1) With expanded production in Ukraine and reduced costs for some functions, the US advantage for corn exports has lessened;

2) The competition between the United States and Ukraine has further exacerbated by the US-China Phase 1 agreement (ProFarmer, 2021).[5]

Overall, the changes in logistics as well as trade interventions confronting the United States and Ukraine suggest that there could be downward pressure on shipping costs in the United States (ports as well as interior shipping). Within the United States, the competition is both a public policy as well as private strategy that revolves around marketing, logistics, operational, and investment decisions.

1.1. Purpose and Scope

The purpose of this project is to analyze the impacts of transportation and logistics improvements on the global corn market shares focusing on two major exporters, the United States and Ukraine. We also consider other major exporters and importers to reflect the entire global corn

[4] The importance of logistics competition in marketing of Black Sea grains, particularly to the Middle East and North Africa, are evolving similarly.

[5] Important in the Phase One agreement is that China will expand its agriculture imports from the United States, but, these are subject to a number of conditions one of which is that purchases would have to be at "market competitive prices." It is not obvious the definition of this term. The results of this study provide some documentation of the relevant costs that would affect these competitive prices.

market conditions in our research results. A model is developed to determine and understand unique competitive conditions, equilibrium market shares and strategies.

Specific objectives include are to analyze logistical competitiveness of US origins relative to Ukraine for corn exports to selected competitive markets and address issues with respect to competitiveness between these countries. In addition, we provide an interpretation of the term "at market competitive prices" at which China would decide to buy U.S. corn. This is a key term in the Phase-I US-China agreement. Undoubtedly as the Phase I of the agreement ensues, it will be important to provide an interpretation of this term.

The first objective is significant given the US grain and shipping industry will have to assess the competitiveness of the marketing system with the evolving competitive market. Indeed, Ukraine is taking initiatives (expanding ports, lowering costs, reducing wait times) to make their marketing system increasingly competitive, which may have a direct impact on the U.S. corn market share.

Farm production costs are not part of the scope of this project. The scope of this project is primarily on transportation and logistics costs and consequently is shorter-term. Further research could expand the model framework to include production costs. Of course, this would require a set of production costs across the major supply regions and measured comparably. In addition, we include selected trade interventions that impact trade flows and therefore logistics demand.

1.2. Empirical Model:[6]

This study developed a stochastic optimization of corn flows from the United States and Ukraine (and other exporters) to selected importing countries. There are two features of the objective function. One is cost minimization (i.e., optimization), where the model determines the least cost (including costs defined below) origins for each month. These costs include: 1) origin basis at multiple interior locations; 2) U.S. interior shipping costs, including rail, 2nd market values, and barge rates and for Ukraine, these costs would include rail and truck; 3) elevation, and 4) ocean shipping costs. The model also imposes a number of restrictions to capture the effects of quality differentials and impacts of the trade interventions impacting competition in this market.

Second, the stochastic (or random) component of the model is important and accounts for risks in the marketing system. A number of the relevant variables are random (risky) and these would be represented as stochastic component in the model. The results allow us to derive the probability distributions of outputs (market shares, costs. etc.) and impacts of risk on relevant variables on the optimization solution.

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[6] We have recently analyzed international competition in the export basis market and are reported in Bullock and Wilson (2019). We have also analyzed competition in the United States soybean export market with an emphasis on logistics and quality, using similar methodologies (Skadberg et al. 2015).

A ‘base case’ representative of the most likely set of assumptions was specified to reflect the recent market conditions. Simulations and sensitivities were conducted on selected variables to evaluate their impacts on the resulting changes in the global corn market shares. Outputs from the base case include the identification of targeted origins (i.e., those that would be least cost), monthly shipments from each origin to targeted markets and estimated costs delivered to those markets.

The sensitivities were grouped based on the ocean shipping rates, other logistical costs, in addition to trade interventions. The structural variables include internal shipping cost and logistical capacity constraints. Random variables include 2nd market values, barge rates, basis distributions and correlations, and export levels.

1.3. Organization

The report is organized in 6 sections. Section 2 describes the data sources and Section 3 provides details on logistical functions and costs. The empirical model is specified in Section 4 and in Section 5 we discuss results in detail. Finally, Section 6 provides a summary and conclusions as well as implication for both private and public policy. More details about the empirical model and distributions are described in Appendix A and B. Appendix C discusses various trade interventions impacting competition in the international corn market.

2. DATA OVERVIEW

We analyze the logistics competition and trade interventions for corn shipments from major exporters to the major importers. Specifically, our focus is on the corn shipments originating from different sub-origins of the United States and Ukraine to various destinations. For the analysis, we collected data from different sources on variables of interest, including basis, daily car values, rail tariff, fuel service charge, barge, port elevation cost for inland sub-origins of the United States. Data from Ukraine also consist of basis, rail tariff and fuel service charge, port elevation cost. Data from Brazil and Argentina contains only the FOB port value plus ocean shipping costs. Also, we developed the data on trade flows and ocean shipping/freight rates from each origin-destination combination. Important variables and their sources are listed in Table 2.1.

Table 2.1. Variables and Data Sources

Variable	Source
US interior basis, prices, and futures price	Thomsen Reuters Eikon
US Rail tariff, and fuel service charge	BNSF Rail Tariffs and USDA-AMS Grain Transportation Tables
US Daily car values	Trade West Brokerage Co.
US Barge rates and tariffs	USDA-AMS Grain Transportation Tables
Ukraine farm prices and basis	USDA-AMS (2020)
Ocean freight cost for all origin-destination pairs	Thomsen Reuters Eikon
Ukraine elevator handling data at origin ports	Industry sources
Ukraine rail shipping cost	Industry sources
Brazil and Argentina FOB basis	AgriCensus (2021a)
Trade flows	UN Comtrade: Ukraine, Brazil, Argentina, and world. USDA (FAS, AMS, FGIS), and ProExporter Network: US ports (US Gulf and US PNW) export flows. The European Union: Europa.eu

Including inland and ocean shipping rates constitute a cost matrix for corn shipment delivered for each of the origin-destination combination for each month. For illustration, Table 2.2 shows the cost matrix for corn shipments delivered for each of the origin-destination flows used in this study, for May. For analysis, we then specified models for each month and compute the annual flows, market shares of all the origin-destination combinations in base case scenario.

For analyzing the sensitivities of change in various logistical variables and trade interventions between specific origin-destination combinations we only include results of May unless the results are drastically different from November in which case we include November results as well. For US and Ukraine, the cost includes interior basis, shipping and handling costs, and ocean shipping rates. For Brazil and Argentina, the delivered cost matrix includes FOB basis and ocean shipping rate. The delivered cost matrix from US Gulf (and the sub origins) to the EU includes an additional 25% tariff.

We report results for just May and November because November is representative of the fall harvest for the U.S. while May is representative of the peak spring shipping season for U.S. corn exports. Costs for US and Ukraine origins are comprised of origin basis, interior shipping and handling (including barge rail tariffs, daily car values, fuel service charge, elevation at the origin and exports ports, and ocean shipping. The delivered cost matrix from US Gulf to the EU includes the additional 25% import tariff applied to US corn imports by the EU (Table 2.2). For Brazil and Argentina, costs are the FOB basis and ocean shipping cost.

For simplicity and to avoid the zero values in trade flows, we categorize some country destinations into groups. The destination North Africa contains Algeria, Egypt, Libya, Morocco, Tunisia, Mauritania, and Sudan. Egypt, Morocco, and Algeria are the major regional countries in terms of corn imports. Similarly, the destination Middle-East group contains countries, including Iraq, Syria, Israel, Jordan, Kuwait, Lebanon, Oman, Qatar, Saudi Arabia, the United Arab Emirates, Yemen, and Bahrain. Saudi Arabia and Israel are the major regional contributors in terms of total corn imports.

Finally, total exports of corn from all the major origins considered in this study are shown in Table 2.3 between MY 2013/14 and MY 2021-22. To keep the consistency of the data across all the variables, we utilize the data of exports of corn for the period until MY 2019/20. For Ukraine, the data is quarterly and is available for only two quarters in 2019 and four quarters in 2020.

Table 2.2. Delivered Cost Matrix for Each of the Origin-Destination Combination for the Base Case Scenario for May (Units: US $/mt)

	US Gulf			US PNW			Ukraine			-	-
Destination	**Champaign, IL**	**Lincoln, NE**	**St. Louis, MO**	**Waite Park, MN**	**Jamestown, ND**	**Sioux Falls, SD**	**Western Ukraine**	**Eastern Ukraine**	**Central Ukraine**	**Brazil**	**Argentina**
China	70	63	53	59	51	65	55	43	64	48	56
Japan	79	71	62	64	57	70	58	45	66	64	68
Indonesia	75	68	58	62	54	68	53	41	61	60	61
The EU	109	100	88	-	-	-	46	34	54	36	38
South Korea	72	64	55	60	52	65	56	43	64	57	60
Vietnam	65	57	48	56	48	62	57	45	65	38	42
North Africa	55	48	38	-	-	-	31	19	39	36	33
Middle East	65	58	48	-	-	-	42	29	50	35	51

Notes: US PNW does not export to the European Union, Middle-East and North Africa. Therefore, the sub-origins (Waite Park, Jamestown, and Sioux Falls) of the United States that feed into the US PNW port constitute a very high cost in order to discourage exports from these locations to the EU, Middle-East, and North Africa to reflect the reality. For US and Ukraine, the cost includes interior basis, shipping and handling costs, and ocean shipping rates. For Brazil and Argentina,

Table 2.3. Total Exports of Corn at Major Origins (mmt)

MY	Argentina	Brazil	Ukraine	US PNW	US Gulf
2013-14	17	20	20	23	36
2014-15	19	34	20	15	43
2015-16	22	11	17	26	38
2016-17	26	31	21	31	33
2017-18	22	23	18	30	44
2018-19	37	38	30	26	41
2019-20	36	34	29	18	41
2020-21	34	32	23	26	45
2021-22	36	41	31	28	43

Source: Compiled by authors from data collected from ProExporter Network (US data) and UN Comtrade for all other countries.

Table 2.4 presents the Ukraine farm corn prices and associated corn basis using nearby futures price. Farm price of Ukraine is computed as the price at the elevator less the handling costs and farm to elevator transportation cost.

Table 2.4. Ukraine: Quarterly Farm Corn Prices and its Basis ($/mt)

	Year-Quarter	Western Ukraine	Eastern Ukraine	Central Ukraine
Farm Price	2019-Q3	156	143	162
	2019-Q4	152	140	155
	2020-Q1	172	164	175
	2020-Q2	170	163	173
	2020-Q3	180	170	184
	2020-Q4	238	233	243
Basis	2019-Q3	-2	-16	3
	2019-Q4	0	-12	4
	2020-Q1	24	26	28
	2020-Q2	39	32	42
	2020-Q3	45	35	49
	2020-Q4	79	74	83

Source: USDA-AMS (2020)

3. LOGISTICS OF CORN TRADE

A model is specified in Section 5 below to analyze the logistical competition among major corn exporters, with an emphasis on the United States and Ukraine. Data sources and the scope of the model were defined above, and in Section 5 below. This section provides an overview and description of logistical functions and behavior of the data. First the relevant origin and logistics costs are described for the United States and Ukraine. Then, ocean shipping costs are shown. In the final section a high-level summary of these costs is shown and discussed.

3.1. United States-Origination and Logistics Costs

Basis values for the US origins are shown in Figure 3.1. Results show that these values are highly variable and correlated. Further, there has been an upward trend in the values since about July 2019. Basis values for origins in North Dakota and Minnesota are the lowest. These results, though not apparent, have seasonal behavior.

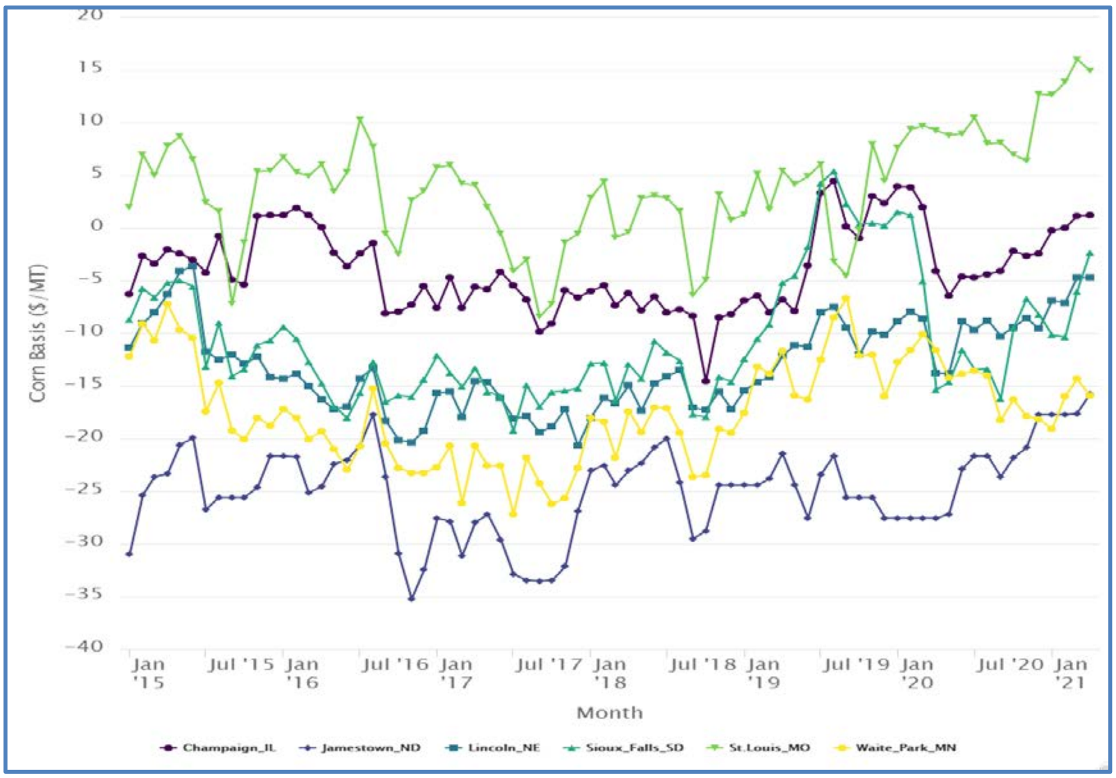

Figure 3.1. Basis of Corn at Various Inland Locations of the United States, January 2015-April 2020

The relevant interior shipping costs are comprised of elevation at origin and port, and rail costs, including tariffs, daily car values (DCV) and fuel service charges (FSC), and barge costs. Elevation costs were from industry sources and treated as distributions.

One of the important elements impacting shipping costs in the United States is the DCV.[7] These vary through time, apply to rail movements and as a result have a greater impact on shipments through the PNW. The DCV is shown in Figure 3.2. These results indicate the DCV is highly variable, risky and averaged $2.65 per mt.

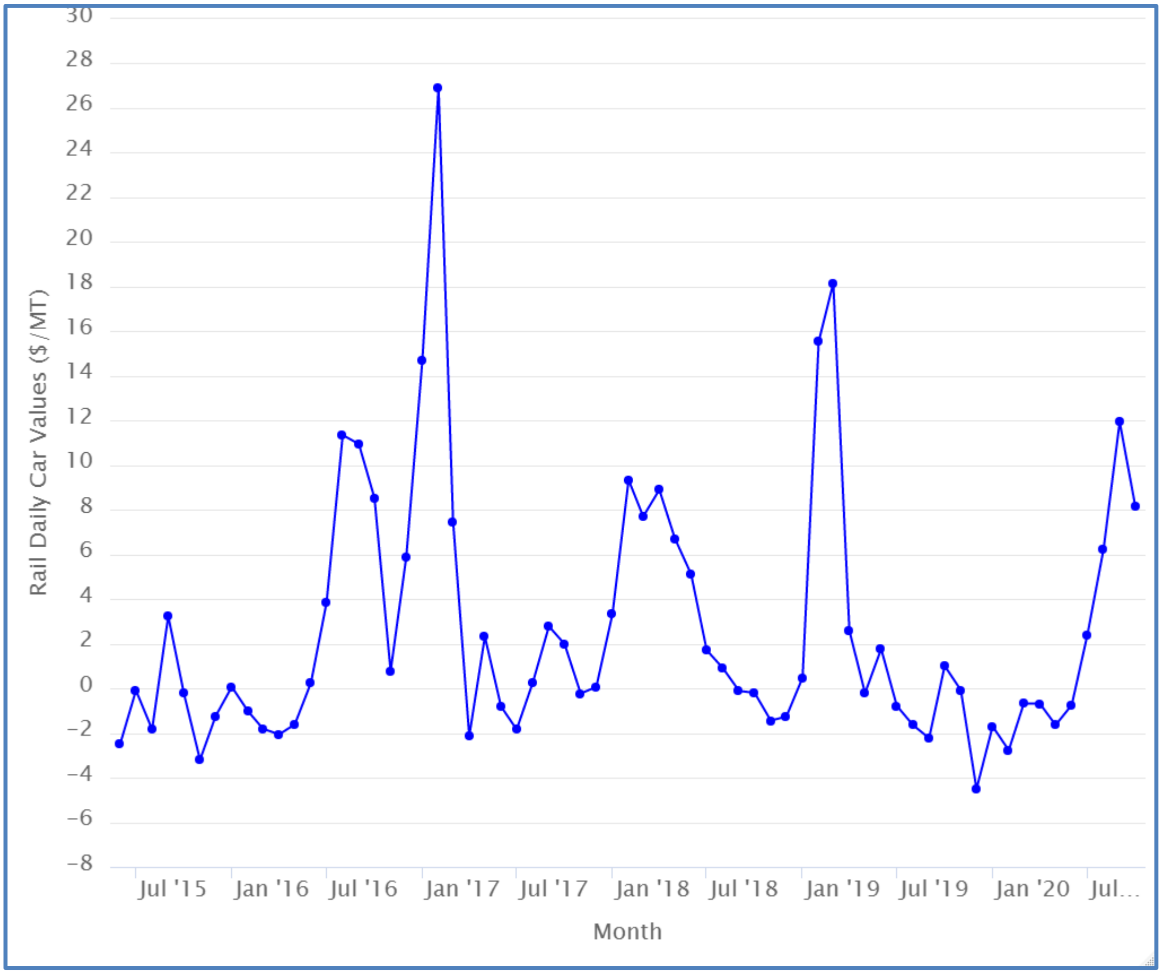

Figure 3.2. Rail Daily Car Values

The barge market, defined as the percent of published tariff is not regulated and used to derive the rate in $/mt. These values are also variable and are shown in Figure 3.3.

[7] Wilson et al. (2020) provides a detailed analysis of the evolution and operations of the rail car markets in the United States.

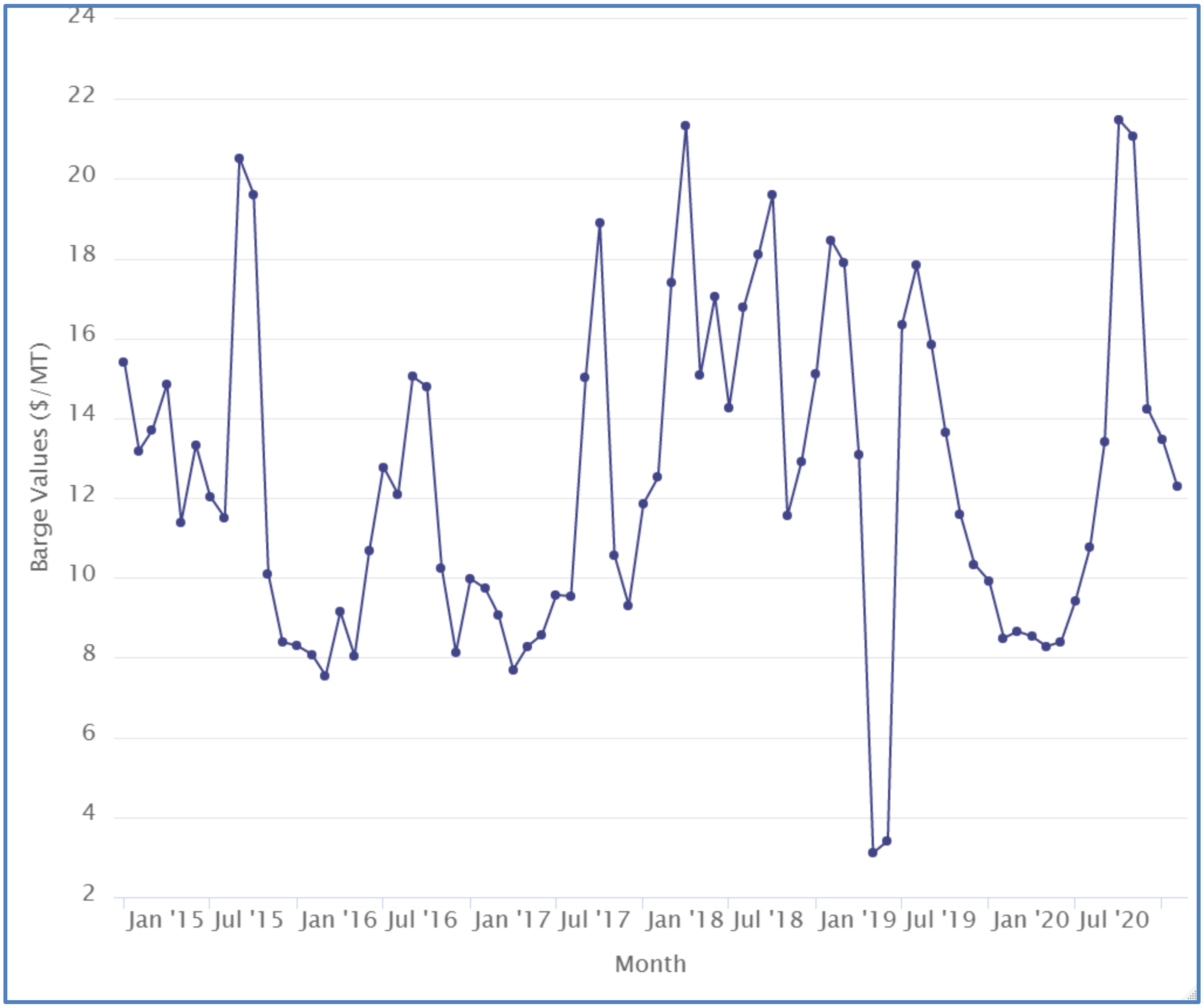

Figure 3.3. Barge Cost

The total shipping costs from the US interior locations to the ports are shown in Figure 3.4. St Louis is lowest cost. The highest cost is from the upper Midwest, including, North Dakota, South Dakota and Minnesota. The spikes in the figures are largely responsive to spikes in either the DCV or the barge.

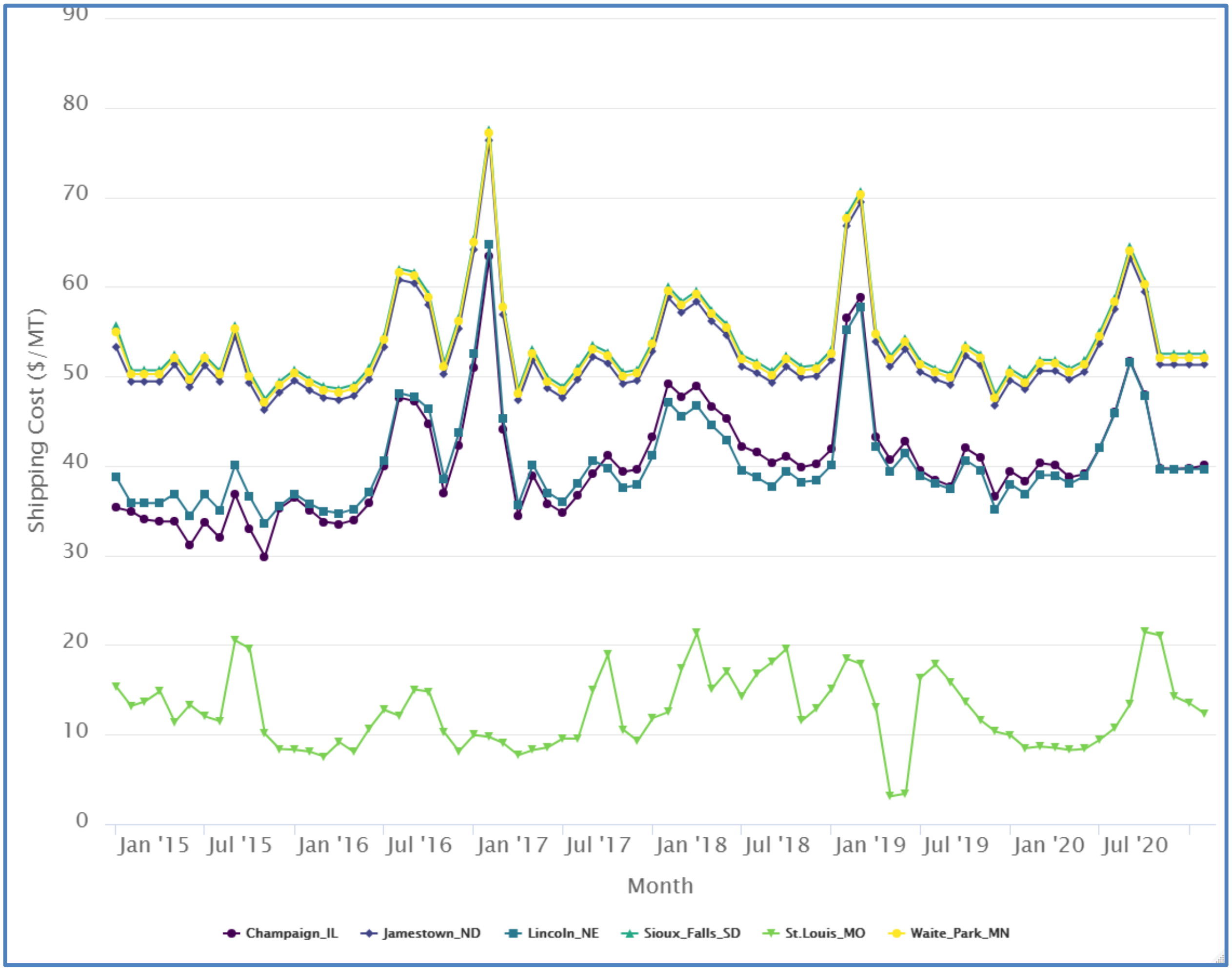

Figure 3.4. Shipping Cost from Various Inland US Locations, January 2015-February 2021

Shipping cost for all the locations were computed using the rail tariffs, DCV and FSC except St. Louis, whose cost is based on the barge. The shipping cost shown in Figure 3.4 show three levels of which the shipping cost based on barge from St. Louis, Missouri, is the lowest cost for shipping corn to the US Gulf. The next highest shipping cost is from Champaign, Illinois, and Lincoln, Nebraska via which the corn is shipped to US Gulf. Finally, the highest level of shipping cost from three locations from the upper Midwest, including Jamestown (North Dakota), Waite Park (Minnesota), and Sioux Falls (South Dakota) ships corn from their respective locations to US Pacific Northwest (US PNW).

3.2. Ukraine: Origination and Logistics Costs

Figure 3.5 shows the major corn production regions and two major export port locations for corn and other grains in Ukraine. Data on basis values for Ukraine is limited. As discussed in Section 2 (Table 2.4) we used the publicly available data from USDA-AMS (2020). To account for variability, we inferred distributions for these values as described in Section 5. Handling costs at export ports were from industry sources (Table 2.1). Rail shipping costs were from USDA-AMS (2020).

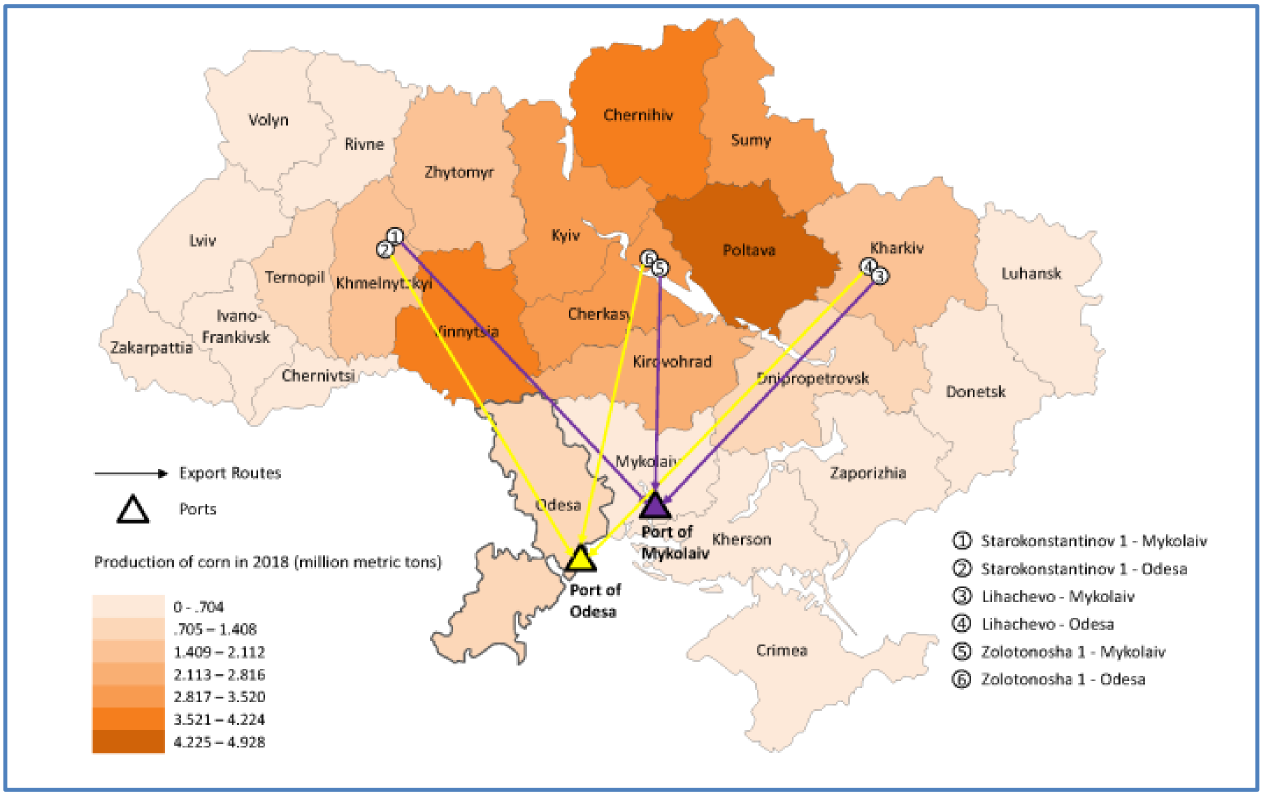

Figure 3.5. Ukraine Corn Production Regions and Major Export Ports
Source: Salin (2020)

3.3. Ocean Shipping

One of the most important functions that impacts trade is ocean shipping cost. These ocean shipping costs for the targeted origins to some of the key destinations in this study are shown in Figure 3.6.

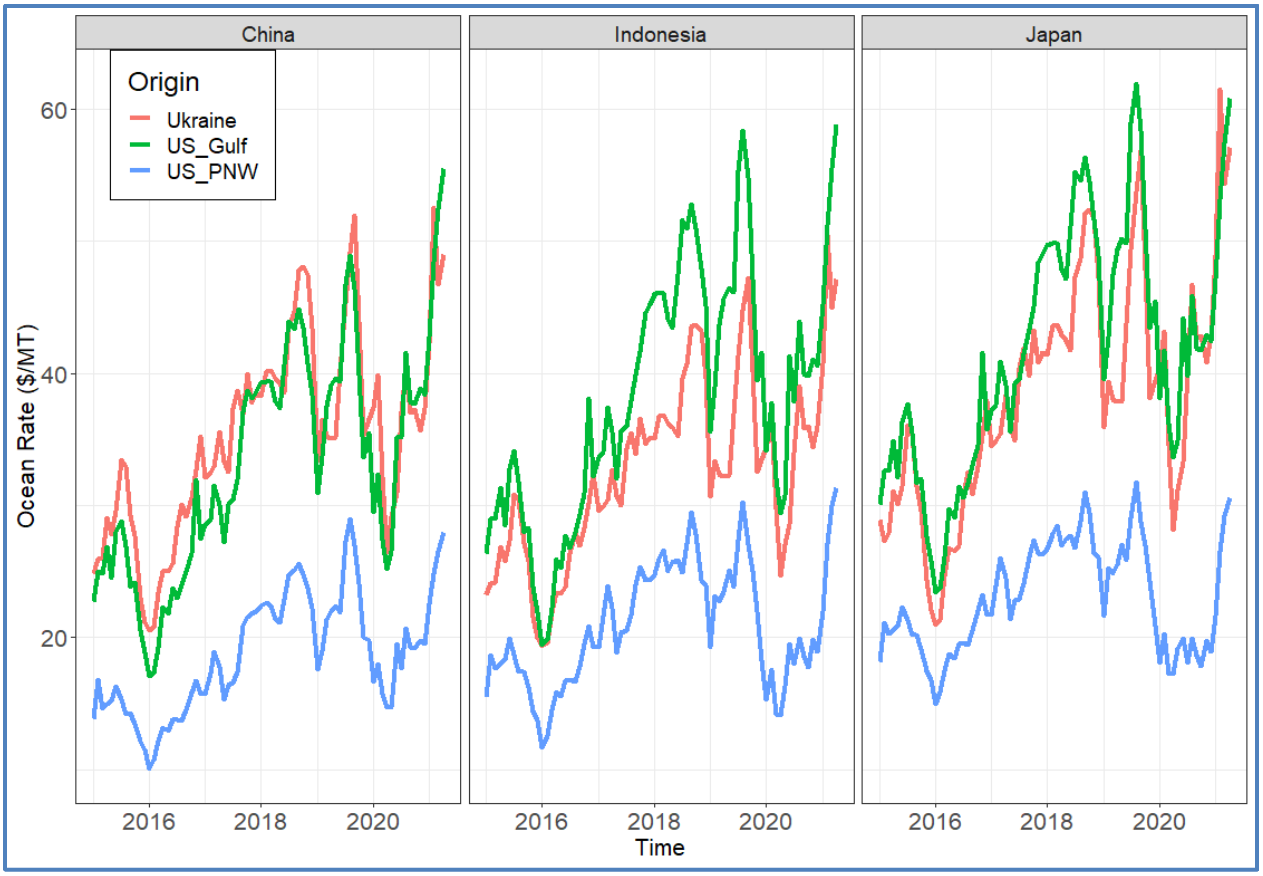

Figure 3.6. Selected Ocean Rates from US Gulf, US PNW, and Ukraine to China, Indonesia, and Japan

These are the ocean rates from the US and Ukraine origins to China, Indonesia, and Japan. There has been a general uptrend in all ocean shipping costs, but, a greater increase in those from the US Gulf and Ukraine. The US PNW has consistently lower ocean freight rates. Rates from the US Gulf and Ukraine are more comparable.

Ocean shipping rates are also shown in Figure 3.7 for shipments to the EU and the Middle East from the US Gulf and Ukraine origins. Overall, Ukraine had an advantage in the case of the Middle East in the period prior to about 2019. Since then, the United States has a slight advantage. In the case of the Netherlands, Ukraine's ocean rate is greater compared with the United States. However, as shown below (Table 3.3), the total cost (including origin basis, interior shipping and handling and import tariffs) for shipments to the EU are lesser for Ukraine versus the United States.

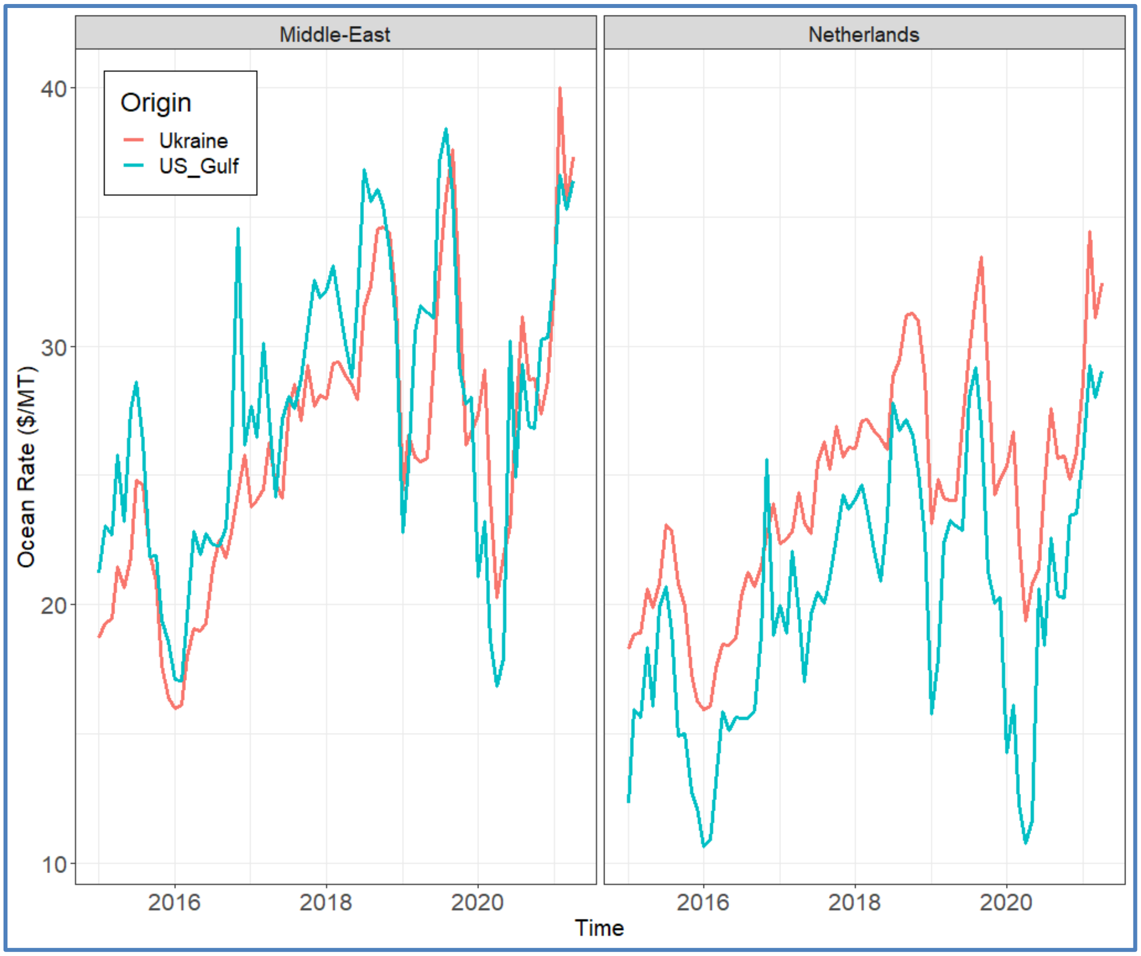

Figure 3.7. Ocean Rates of US Gulf and Ukraine to the Netherlands (the EU) and Middle-East

Several spreads between ocean shipping costs are important and impact shipping patterns. One of the frequently referenced spreads is the differential between US Gulf-Japan and US PNW-Japan as shown in Figure 3.8. This value is highly variable, ranging from $8/mt in 2016 to $30/mt in 2021. Since 2018, the spread has been above $20/mt for most of the periods, but, it has increased sharply after January 2021. This variable has an important impact on competition between the US Gulf and PNW for shipments to these destinations.

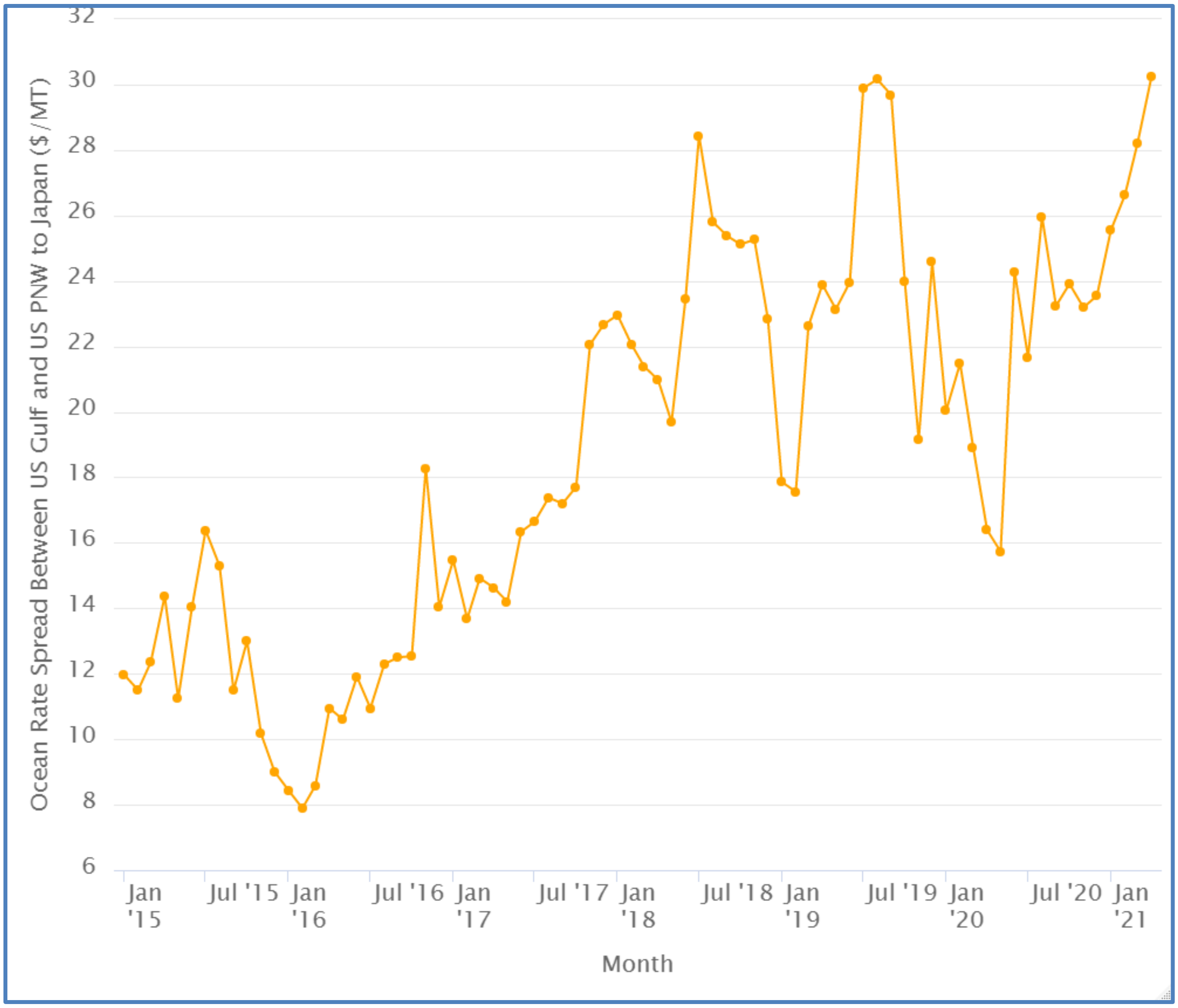

Figure 3.8. Ocean Rate Spread Between US Gulf and US PNW to Japan

Ocean rate spreads between US Gulf and Ukraine to various destinations, including China, the EU (Rotterdam, NL), and the Middle-East are shown in Figures 3.9, 3.10, and 3.11, respectively. The spread is the difference between US Gulf and Ukraine (US Gulf less Ukraine) ocean rate to China, Rotterdam, and the Middle East. The ocean rate spread between the US Gulf and Ukraine to China has been highly volatile and overall shows an increasing trend (Figure 3.9), increasing from -$2 to +$6 per mt. The spread between the US Gulf and Ukraine to Rotterdam, NL, is relatively stable (Figure 3.10) while the spread between the same countries/ports to the Middle-East show a decreasing trend (Figure 3.11).

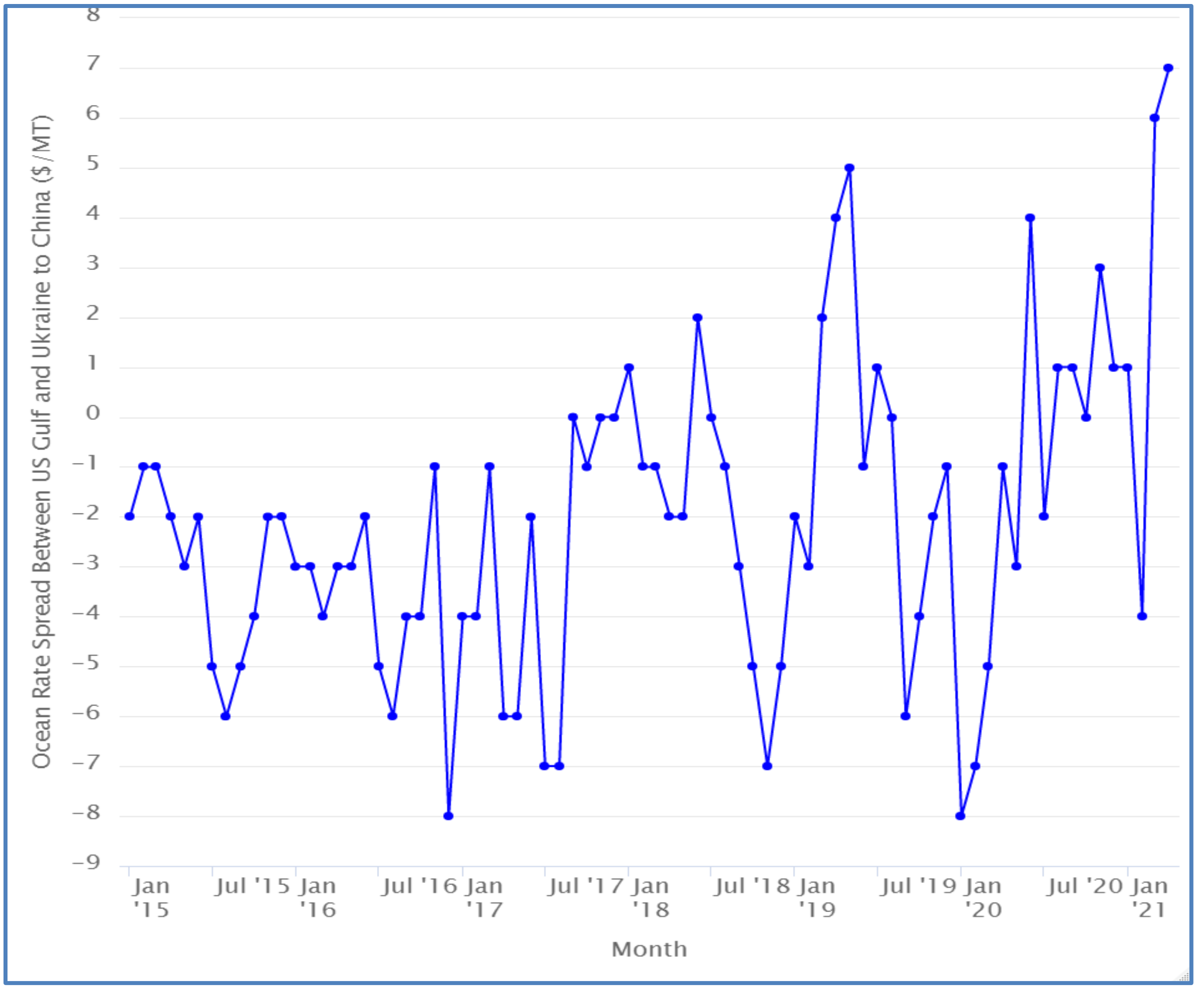

Figure 3.9. Ocean Rate Spread Between US Gulf and Ukraine to China

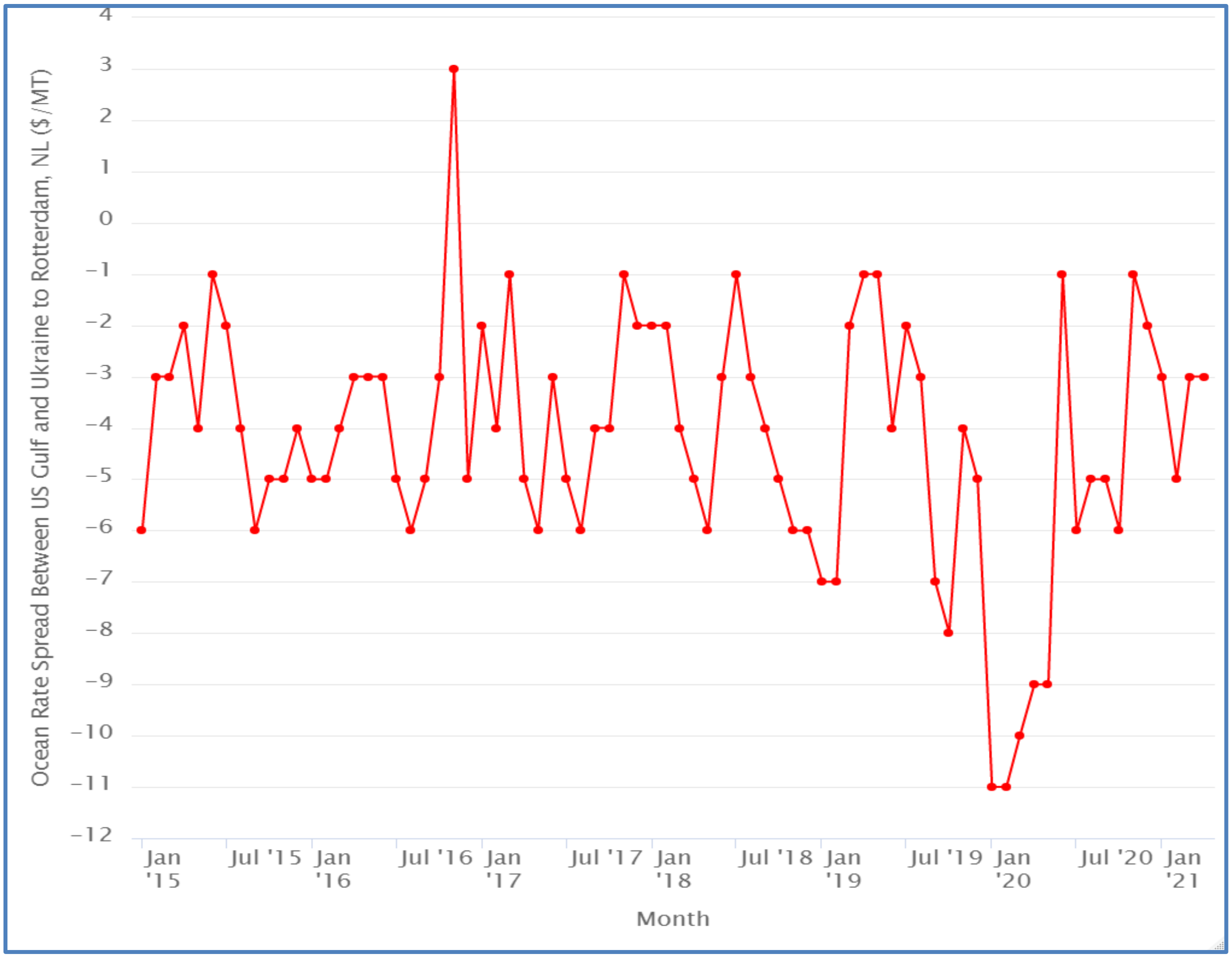

Figure 3.10. Ocean Rate Spread Between US Gulf and Ukraine to Rotterdam, NL

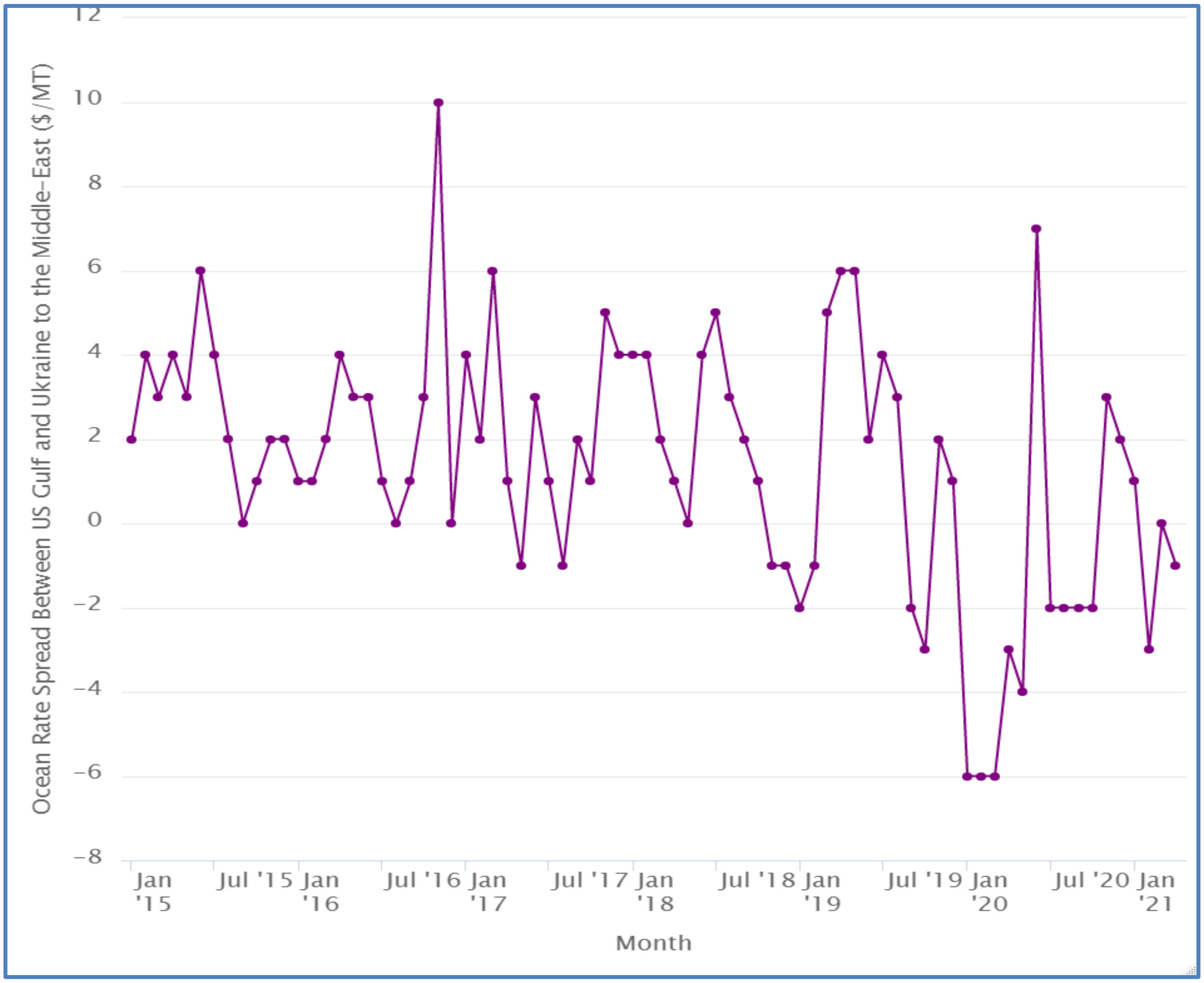

Figure 3.11. Ocean Rate Spread Between US Gulf and Ukraine to the Middle-East

These spreads have an important impact on the empirical results given their increase in volatility in the recent years. Notably are the spread of the US PNW vs the US Gulf, for which the changes are favoring the US PNW; and the changes in the spread between Ukraine and the US Gulf to China have been advantageous to the former.

3.4. Summary of Cost Matrix and Assumptions for Missing Values

All these costs are summarized in Tables 3.1-3.3.[8] Futures values are included in Table 3.1 in part that these are costs used to derive the import tariff for US corn shipments to the EU.

These costs are the elements of the total cost matrix used in the empirical model. These results show that the Ukraine has the lowest interior shipping costs, resulting in the lowest value

[8] Values in this section are shown for illustration purpose only. The actual empirical model uses probability distributions to account for the inherent variability in each value, and correlation among values. These are discussed in Section 6.

CIF Port. In fact, the Ukraine would have an advantage of $13 to $30/mt relative to US origins. This is mostly due to the lower interior rail shipping costs.

Table 3.1. Summary of Interior Prices and Logistics Costs by Origins ($/mt)

	U.S. Origins						Ukraine Origins			South America	
	Via U.S. Gulf			Via PNW			Via Odessa/Nikolyev			FOB Port Values	
	Champaign, IL	Lincoln, NE	St. Louis, MO	Waite Park, MN	Jametown, ND	Sioux Falls, SD	Western	Eastern	Central	Brazil	Argentina
Origin Price	140.68	133.11	151.12	129.00	122.12	134.30	147.50	135.28	159.14		
Tariff & FSC	36.80	37.02		49.75	48.96	50.13	12.85	12.82	9.63		
2nd Car Mkt	2.60	2.60		2.60	2.60	2.60					
Barge			12.13								
CIF Port	180.08	172.73	163.25	181.35	173.68	187.03	160.35	148.10	168.77		
Port Elevation	6.69	6.69	6.69	6.69	6.69	6.69	9.50	9.50	9.50		
FOB Port	186.77	179.42	169.94	188.04	180.37	193.72	169.85	157.60	178.27	169.62	170.22

A summary of ocean shipping costs is shown for illustration purposes in Table 3.2. Ocean routes from the US PNW to EU and North African destinations are not reported as they are not available.[9] Generally, the US PNW has lower shipping cost to the Asian markets. In contrast, Ukraine and US Gulf are highly competitive for shipments to the EU and North African destinations.

Table 3.2. Representative Ocean Shipping Cost by Origin-Destination Pair ($/mt)

	U.S. Origins						Ukraine Origins			South America	
	Via U.S. Gulf			Via PNW			Via Odessa/Nikolyev			FOB Port Values	
Destination	Champaign, IL	Lincoln, NE	St. Louis, MO	Waite Park, MN	Jametown, ND	Sioux Falls, SD	Western	Eastern	Central	Brazil	Argentina
China	29.52	29.52	29.52	16.95	16.95	16.95	31.63	31.63	31.63	24.29	32.34
Japan	38.17	38.17	38.17	22.41	22.41	22.41	34.03	34.03	34.03	40.26	43.50
Indonesia	34.40	34.40	34.40	19.97	19.97	19.97	29.18	29.18	29.18	36.90	36.90
The EU	17.30	17.30	17.30				22.14	22.14	22.14	12.20	14.07
South Korea	30.96	30.96	30.96	17.81	17.81	17.81	31.95	31.95	31.95	33.08	36.00
Vietnam	24.13	24.13	24.13	13.92	13.92	13.92	33.33	33.33	33.33	14.34	18.28
North Africa	14.28	14.28	14.28				7.15	7.15	7.15	12.35	8.80
Middle East	24.56	24.56	24.56				17.86	17.86	17.86	11.07	26.59

These are summarized in Table 3.3. These values include all costs, including US origin basis, interior shipping and handling for the US origins and Ukraine. For Brazil and Argentina, the FOB value was used. Also, the import duty for US shipments to the EU are included. Results are similar to above, but, the differentials are less.

Generally, the PNW and Ukraine are lowest cost for shipments to Asian destinations. However, the Ukraine has an advantage to the EU and most North African destinations.

[9] In the empirical model, these were replaced by $10,000 per mt to discourage the flows.

Table 3.3. Summary of Delivered Costs (C&F values) by Origin-Destination Pair ($/mt) for May

	U.S. Origins						Ukraine Origins			South America	
	Via U.S. Gulf			Via PNW			Via Odessa/Nikolyev			FOB Port Values	
Destination	Champaign, IL	Lincoln, NE	St. Louis, MO	Waite Park, MN	Jametown, ND	Sioux Falls, SD	Western	Eastern Ukr	Central Ukr	Brazil	Argentina
China	70.15	62.81	53.33	58.84	51.18	64.53	55.33	43.09	63.76	47.77	56.41
Japan	78.80	71.46	61.98	64.31	56.64	69.99	57.73	45.49	66.16	63.74	67.58
Indonesia	75.02	67.68	58.20	61.87	54.20	67.55	52.89	40.65	61.31	60.38	60.98
The EU	108.95	99.77	87.92				45.84	33.60	54.27	35.68	38.15
South Korea	71.59	64.25	54.76	59.71	52.04	65.39	55.66	43.42	64.08	56.56	60.08
Vietnam	64.76	57.42	47.93	55.82	48.15	61.50	57.04	44.80	65.46	37.83	42.36
North Africa	54.91	47.57	38.08				30.86	18.62	39.28	35.83	32.88
Middle East	65.19	57.84	48.36				41.56	29.32	49.99	34.55	50.67

3.5. FOB Export Basis

Market values for FOB export port are also published. Though not used in the empirical model below (except for Brazil and Argentina), these are shown for comparison. Figure 3.12 shows the FOB basis values for each of the origins in the model. These are highly correlated, high variable, and appear to be highly seasonal. Typically, Argentina has the lowest FOB basis, followed by Brazil. The greatest value is that of US PNW followed by US Gulf (AgriCensus, 2021a).

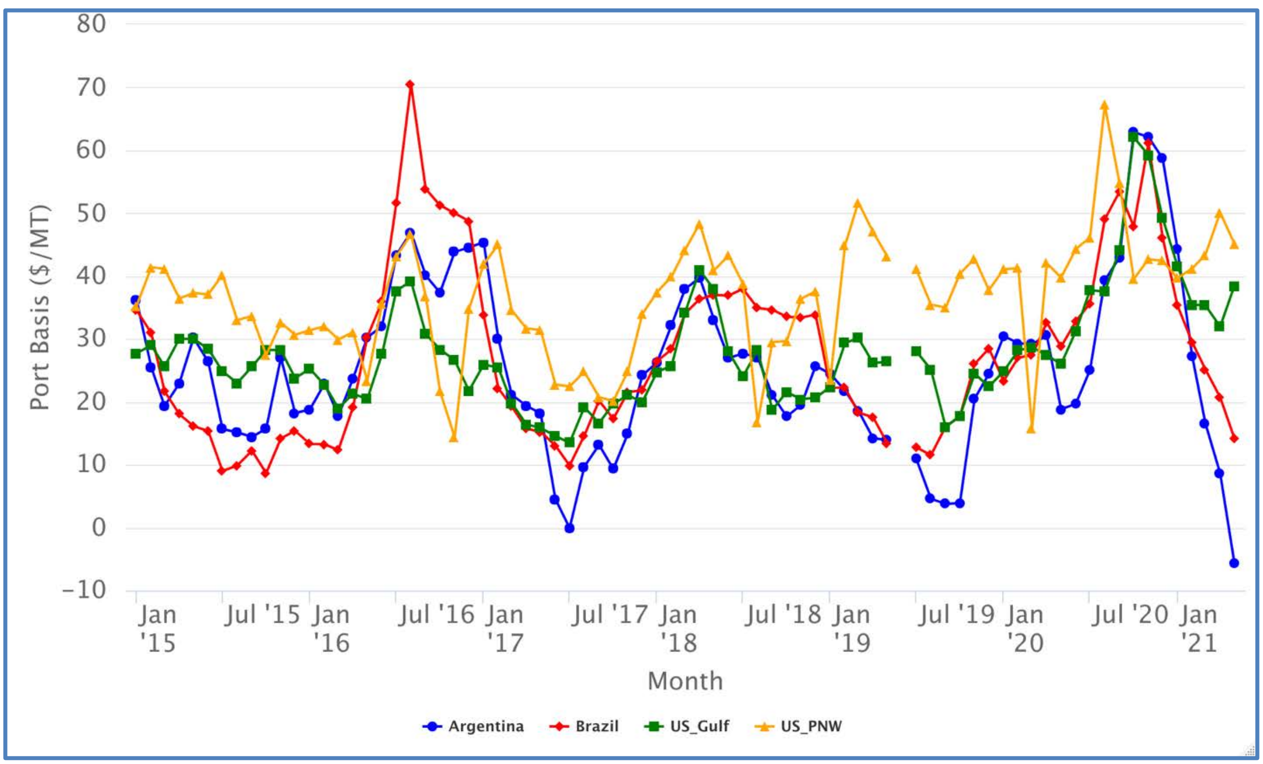

Figure 3.12. Basis at Various Ports/Countries, January 2015-May 2021

4. MODEL SPECIFICATION

The modeling methodology used in this study is referred to as *Optimized Monte Carlo Simulation* (OMCS). This differs from the traditional Monte Carlo optimization and risk programming approaches in that it is assumed that the relevant decision maker already knows the ex-post realized values of the random variables and then makes their optimized decisions accordingly. The procedure generates new values of the random variables at each iteration (a Monte Carlo iteration), makes the relevant calculations, and then determines the optimized decision based upon these observed values. The results of the optimized iterations are then summarized as a distribution of optimized choices.[10,11] The logic of this modeling framework is that the decision-maker chooses trade flows to optimally minimize the total logistics costs in the system given a plausible, simulated set of trade costs and market parameters that they observe with certainty. The model generates a set of historically plausible cost/market scenarios given what has been observed in past behavior.

The objective of the optimization in the OMCS model is to minimize the sum of the total delivered costs (basis, transportation, and handling) from a set of export origins to eight major export destinations (China, Japan, Indonesia, The European Union, South Korea, Vietnam, North Africa, and the Middle East). The delivered cost to an export destination is the sum of the products of the delivered costs ($US per metric ton) from each of the origin regions multiplied by the quantity (metric tons) that is sourced from the origin region.

The origins included three interior locations for each United States export port (Gulf and PNW), three interior locations for Ukraine (one export port), and one export port each for Brazil and Argentina. These are shown in Table 4.1 which shows an example iteration of the delivered costs with the origins and destinations considered in the model:

Table 4.1. Delivered Cost Matrix for One Sample Iteration of the Model

	Origins										
	U.S. Gulf			U.S. PNW			Ukraine				
Destinations	Champaign, IL	Lincoln, NE	St. Louis, MO	Waite Park, MN	Jametown, ND	Sioux Falls, SD	Western	Eastern	Central	Brazil	Argentina
China	$ 85.11	$ 84.05	$ 76.73	$ 73.99	$ 57.11	$ 64.26	$ 53.34	$ 96.51	$ 51.08	$ 36.10	$ 53.49
Japan	$ 61.82	$ 60.76	$ 53.43	$ 67.63	$ 50.76	$ 57.91	$ 38.61	$ 81.78	$ 36.35	$ 53.23	$ 88.70
Indonesia	$ 65.72	$ 64.66	$ 57.34	$ 65.62	$ 48.75	$ 55.90	$ 35.16	$ 78.33	$ 32.90	$ 56.38	$ 59.73
The EU	$ 99.18	$ 97.85	$ 88.69	$ 12,594.95	$ 12,573.85	$ 12,582.79	$ 34.80	$ 77.97	$ 32.54	$ 30.04	$ 35.79
South Korea	$ 67.26	$ 66.20	$ 58.87	$ 63.06	$ 46.19	$ 53.34	$ 43.95	$ 87.13	$ 41.70	$ 44.96	$ 62.92
Vietnam	$ 78.44	$ 77.38	$ 70.06	$ 69.01	$ 52.13	$ 59.28	$ 48.32	$ 91.49	$ 46.06	$ 26.35	$ 35.36
North Africa	$ 53.84	$ 52.78	$ 45.45	$ 10,048.50	$ 10,031.63	$ 10,038.78	$ 18.69	$ 61.86	$ 16.43	$ 30.80	$ 26.39
Middle East	$ 69.18	$ 68.12	$ 60.79	$ 10,048.50	$ 10,031.63	$ 10,038.78	$ 30.88	$ 74.05	$ 28.62	$ 29.44	$ 51.78

For all U.S. origins with the exception of St. Louis, the delivery price to a particular destination is calculated by the following formula (all in U.S. dollars per metric ton):

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[10] The OMCS methodology is somewhat novel in logistics and trade modeling. Details of the model are discussed in Figueira, and Almada-Lobo (2014) in which they referred to as *sequential simulation-optimization* (SSO) models.

[11] A detailed discussion of the steps employed in an OMCS are presented in Appendix A.

$$\tilde{c}_{ij} = \tilde{b}_i + \tilde{t}_i + \tilde{v} + \tilde{e}_i + \tilde{o}_{ij},$$

where i is the index for the origin location, j is the index for the destination, b is the nearby basis (cash minus CME futures), t is the railroad tariff and fuel surcharges from the origin to the export port, v is the rail secondary market railcar value, e is the export port elevation costs, and o is the ocean freight from the origin export port to the final destination. The tilde (~) character indicates that the variable is generated using Monte Carlo simulation to create a historically representable value. For shipments with no ocean freight cost (i.e., non-normal movements), a placeholder cost of $10,000 is applied which effectively constrains that flow to zero.

For the St. Louis origin, the above equation is modified by replacing the railroad costs (t_i + v) with the barge rate from St. Louis to the Gulf ports. For the Ukraine origins, the secondary railcar market value (v) is not included in the calculation. For the Brazil and Argentina origins, the p_{ij} values represent just the sum of the historical export port FOB basis values plus the ocean freight (o_{ij})to the destination. The sources for the data used in estimating these historical distributions was described in Section 2.

The objective is to minimize the total delivered cost across all trade flows from origins (i) to destinations (j) by selecting the optimal quantity for the trade flow (q_{ij}). [12] In addition to the eight major destination regions, other destinations are lumped together into a *rest of world* (*ROW*) category.

The model was solved subject to several constraints. The first constraint requires all of the trade flows be positive values (i.e., no negative backflows from destination to origins). The second constraint states that the sum of the trade flows from the origins cannot exceed the randomly generated capacity constraint value (Q_i) for each origin. The third constraint states that the sum of the flows to each of the 8 destinations must be greater than or equal to the randomly generated demand (D_j) for that destination. To assure convergence of this optimization model, the ROW is modeled as receiving any excess supply from each origin provided that the origin supply constraint is not binding. The model is set up such that the main priority is to fully meet the simulated demands from the 8 modeled destination regions with any excess supply allocated to the ROW region.

The following additional constraints have been applied to the model. For the EU tariff on all U.S. origin exports, a 25% additional surcharge has been added to the simulated $\tilde{c}_{ij}$ values from U.S. origins to the EU. To reflect current phytosanitary restrictions on South American exports to China, a maximum share of 1% (of all flows to China) has been applied to each origins' q_{ij} flow to China. For current phytosanitary restrictions on South American exports to

[12] The optimization problem that is solved for each iteration of the Monte Carlo simulation (with new randomly generated historical values) is mathematically illustrated in Appendix A.

the EU, a similar constraint with a maximum share of 18% (of all flows to EU) for Brazil and 2% for Argentina has been applied based on the historical data.

To reflect the historical seasonality of some random variables, the base optimization model was set up to simulate trade flows on a monthly basis. The user selects the particular month using a drop-down list and the simulation uses lookup tables to simulate the correct seasonal value for those variables displaying seasonality in their time series history.

The model treats prices as fixed and does not allow prices to adjust in reaction to supply and demand. Therefore, it should be interpreted as short run and is not a general equilibrium model. Simply, supplies and demands are represented by distributions and the model seeks to find a solution that minimizes expected costs. The results represent the optimal trade flows if – given historically plausible values for the random variables – a global benevolent power to minimize the total cost of the logistical system. The optimization results determine the optimal trade flows in a logistically efficient system given prices are fixed at a historically plausible value. The results won't exactly mimic historical trade flows for a number of reasons, but should approximate historical shipments. One of the main values of this type of model is for conducting *sensitivity analyses* to determine the critical cost components in the system and also to examine the impacts of various logistical costs and trade intervention changes upon the flows in the model.

4.1. Determination of Historical Distributions

This subsection provides a general discussion of the derivation of the historical distributions of the random cost, supply, and demand variables used in the model. The more technical information behind the estimations will be provided in Appendix B.

4.1.1. Origin Basis

The monthly average nearby origin basis (for all 11 origins in cents per bushel) were collected from January 2015 to April 2021. The basis for the U.S. and Ukraine were for interior origins while the basis for Brazil and Argentina represents FOB basis at the export ports. For each basis series and month, the mean and standard deviation were calculated. Additionally, across all origins for each month, a Spearman rank-order correlation matrix was calculated for the origin basis values. Therefore, for each origin-month combination, a mean and standard deviation was calculated (total of 108), and for each month, a rank-order correlation matrix was calculated (total of 12).

Figures B-1 and B-2 in Appendix B show the sample mean and standard deviation calculations for a subset of the basis data series including the complete Spearman rank-order correlation matrix for all of the basis series. These were calculated using the XLStats statistical add-in to Microsoft Excel.

The basis values are randomly generated using a correlated normal distribution using the historical sample means, standard deviations, and correlation matrices. Because basis can be either negative or positive, and represents the difference of two non-negative random variables (cash price and futures price), the correct distribution to use is one of the spherical distributions such as the normal.

4.1.2. Railroad Tariff and Fuel Surcharges (U.S. Rail Origins)

A similar procedure was used for railroad tariff and fuel surcharges. The monthly data included the sum of the tariff and fuel surcharge to the relevant export destination for each U.S. rail origin. For each month, the historical mean and standard deviation was estimated for each origin along with the Spearman rank-order correlation matrix for each month. The values (in $ per railcar) were simulated using a lognormal distribution. This distribution was used because it does not allow for negative values (cannot have negative tariffs nor fuel surcharges) and is commonly used for reflecting prices.

4.1.3. Secondary Railcar Market Values (U.S. Rail Origins)

These values are not specific to a particular origin. The historical dataset contained monthly average values ($ per railcar) from June 2015 through October 2020. A test for time series seasonality (HEGY test of seasonal unit roots) rejected the presence of seasonality in the historical data series; therefore, a single distribution was used to reflect the value for all origins and months. These values can be either at a discount (negative) or a premium (positive) and tend to exhibit positive skewness (i.e., long statistical tail to the upward side). The *Bestfit* procedure in Palisade @Risk was used to estimate the best-fitting statistical distribution based upon the Schwarz Bayesian Information Criterion (BIC).

The best-fitting distribution (along with other candidates considered) is illustrated in Figure B-3, and is the Pearson type 5 distribution with a negative shift of $662.81 in the location with shape parameter (alpha) equal to 4.15 and location parameter (beta) equal to 2,910.6. The shape of the historical distribution indicates that the majority (90%) of the values lie between a discount of $241 and a premium of $1,439 per railcar with the possibility of upward extreme values at or above $2,500 per railcar.

4.1.4. Barge Freight (St. Louis Origin Only)

The historical barge freight from St. Louis to the US Gulf is measured as a percentage of the base tariff of $3.99 per short ton, and the dataset includes monthly average values from January 2015 to February 2021. An application of the seasonality test (HEGY) also rejected seasonality in the barge rate data; therefore, a single distribution was estimated on the historical data using the *Bestfit* procedure and picking the distribution with the best BIC criterion value. The best fitting distribution (along with other candidates) is illustrated in Figure B-4 in Appendix B. The best-fitting distribution was the triangular distribution with minimum of 57.8%, maximum of 529.4%, and most likely (modal) value of 240.2%.

4.1.5. Ukraine Origin Basis

The available historical data on Ukrainian origin basis was extremely sparse – just quarterly average values for the last half of 2019 and all of 2020 and were taken from Salin (2020). These are the only data that are publicly accessible.

Due to the COVID-19 pandemic, the 2020 values were considered as more extreme with the 2019 values reflecting a more normal historical situation. Therefore, due to the paucity of the data, a subjective approach was utilized to derive the historical basis distributions. Based upon the authors' judgement, the values for the minimum, maximum, and selected percentiles (10^{th}, 50^{th}, 80^{th}, and 95^{th}) were selected based upon the observed data for the Western region. The 50^{th} percentile was set to the average of the two quarters for 2019 (-$1.20 per metric ton). The 95^{th} percentile was set at the mean of the four quarters from 2020 (+$46.57 per metric ton). The minimum was subjectively set at -$30, the maximum at +$55, the 10^{th} percentile at -$20, and the 80^{th} percentile at +$10 per metric ton respectively.

For the distributions for the remaining two regions, the parameters were adjusted by adding the difference in the mean value for 2019 (i.e., -$12.78 for the Eastern region and +$4.71 for the Central Region). For each of the regions, a Spearman rank-order correlation of 95% was assumed between each region pair. Figure B-5 in Appendix B shows the cumulative distribution results from a simulation of 5,000 observations (iterations) from each regional distribution with the sample statistical values.

4.1.6. Ukraine Rail Rates

The available historical data on Ukrainian rail rates was also extremely sparse with only quarterly rates for 2020 available (in $ per metric ton) and were from Salin (2020). The rates were available for one location in each origin with Khmelnitskii (Station Starokonstantinov 1) for Western, Kharkiv (station Lihachevo) for Eastern, and Cherkasy (station Zolotonosha 1) for Western regions. Each origin had rates to two different export destinations (Mykolaiv and Odessa). The sample mean and standard deviation for each origin – destination pair was estimated and a Spearman rank-order correlation of 95% was assumed across all pairs. The rail rate for each pair was then simulated using a lognormal distribution. For the particular origin, the minimum of the two export destinations was used for the simulated historical rail rate.

4.1.7. Ocean Shipping Rates

Monthly average ocean shipping rates ($/mt) were available on a total of 30 typical routes for the full study period from January 2015 to April 2021. Details for these routes are shown in Figure B-6. Partial (1 to 2 years) data was available on an additional 19 routes which are shown in

Figure B-7. In addition, a rough estimation was made for the PNW to Egypt route based upon similar calculations for the Ukraine origin (route 50 in list). Since there are no export flows from US PNW origin to the North Africa and Middle-East destinations and the base case delivered cost matrix between these origin-destination pairs are placed an exorbitant amount so that the flows were discouraged.

For routes with full information (Figure B-6), a seasonal monthly estimation approach that is equivalent to that for railroad tariffs / fuel surcharges was used. For each route – month pair, a historical mean and standard deviation is estimated. Then, for each month, a Spearman rank-order correlation matrix was estimated from the data. The route shipping rates were then generated using correlated, lognormal distributions using the estimated mean and standard deviation.

For routes with limited data availability (Figure B-7), a monthly spread was calculated between the specific series and the full series that had the highest correlation to the limited series. A *Bestfit* distribution was estimated from the spread data and used to simulate a spread to the full series. Then the simulated limited series was equal to the sum of the simulated related full series plus the simulated spread. For the approximated U.S. PNW to Egypt route, the Ukraine to Egypt (route 50) spread was added to the Longview to Damman, SA (route 33) simulated rate.

4.1.8. Export Port Outflows Constraint

A supply constraint was derived for each origin to restrict flows to their historical distribution. For each export port (US Gulf, US PNW, Ukraine, Argentina, and Brazil) monthly total corn exports (in mt) from January 2015 to December 2019 were calculated. Data from 2020 and 2021 were excluded due to the potential distortionary effects of the COVID-19 pandemic. The data was organized into a calendar year by month basis so that seasonal effects could be incorporated. For each port and month, the maximum, minimum, and Olympic average (drop max and min and average remaining three values) were calculated. Also, a Spearman rank-order correlation matrix was estimated for the full time series (all observations rather than by month) of values from Jan 2015 to Dec 2019. The monthly values for each port were simulated as triangular random variables with the estimated minimum, estimated maximum, and the Olympic average as the most likely (modal) parameter values. The distributions across ports were correlated using the estimated Spearman rank-order correlation matrix.

For the U.S. port values, the simulated capacities were then allocated to the origin regions based upon historical production shares (using data from Proexporter Network) for those regions. Figure B-8 shows the values and calculations for the U.S. interior shares.

For the Ukraine, similar historical data was not available, so it was assumed that the total export capacity for the Ukraine was prorated in equal shares between the three regions (Eastern, Western, and Central).

4.1.9. Country and Regional Import Demands

For each importing country and region (China, Indonesia, The EU, North Africa, Middle East, Japan, South Korea, and Vietnam) an identical procedure to the export outflow estimations above was used to define the distribution of import demands. Monthly triangular distributions with the minimum, maximum, and Olympic average entered into correlated triangular distributions was used to simulate import demands (in metric tons). One Spearman rank-order correlation matrix (estimated on the entire continuous series of historical corn import flows) was estimated and applied to correlate the monthly values across each region.

4.2. Model Output

The linear programming solution for the optimal trade flows (q_{ij}^*) is solved for each of the 500 iterations of the model using the Simplex algorithm in the Excel Solver. A separate matrix calculates the mean of the optimal flows ($\bar{q}_{ij}^*$) which is used as the representative historical model solution. Table 4.2 is an illustration of one such solution:

Table 4.2. Illustration of an Optimal Solution from Optimized Monte Carlo Model

Monthly Trade (in mt)											
Destination	Champaign, IL	Lincoln, NE	St. Louis, MO	Waite Park, MN	Jametown, ND	Sioux Falls, SD	Western Ukr	Eastern Ukr	Central Ukr	Brazil	Argentina
China	31,161	182,793	144,746	65,049	53,048	11,767	2,634	4,298	5,337	1,145	2,990
Japan	13,078	26,968	13,487	570,694	124,436	83,131	165,648	146,420	120,650	4,733	88,041
Indonesia	729	3,517	1,318	3,918	852	811	11,021	10,682	8,678	0	27,195
The EU	0	56	2,923	0	0	0	177,703	240,271	130,998	68,079	68,718
South Korea	21,392	153,914	78,183	90,257	27,390	19,983	678	1,880	1,835	3,951	251,906
Vietnam	203	18,616	1,280	793	186	760	0	0	0	19,687	427,484
North Africa	3,423	10,395	2,375	0	0	0	58,362	49,853	56,469	691	913,697
Middle East	2,258	16,752	6,539	0	0	0	33,219	59,214	42,851	360,702	48,257
ROW	1,435,958	552,055	34,552	230,187	5,703	179,435	87,892	24,538	170,338	14,896	598,734

To illustrate the destination market share for each origin, a subsequent table calculates each origins' amount as a percent of the row total. This is illustrated for the above sample in Table 4.3.

Table 4.3. Illustration of Origin Shares for each Destination Market from Above Example

Monthly Trade (% of Total Imports by Destination)											
Destination	Champaign, IL	Lincoln, NE	St. Louis, MO	Waite Park, MN	Jametown, ND	Sioux Falls, SD	Western Ukr	Eastern Ukr	Central Ukr	Brazil	Argentina
China	6.2%	36.2%	28.7%	12.9%	10.5%	2.3%	0.5%	0.9%	1.1%	0.2%	0.6%
Japan	1.0%	2.0%	1.0%	42.0%	9.2%	6.1%	12.2%	10.8%	8.9%	0.3%	6.5%
Indonesia	1.1%	5.1%	1.9%	5.7%	1.2%	1.2%	16.0%	15.5%	12.6%	0.0%	39.6%
The EU	0.0%	0.0%	0.4%	0.0%	0.0%	0.0%	25.8%	34.9%	19.0%	9.9%	10.0%
South Korea	3.3%	23.6%	12.0%	13.9%	4.2%	3.1%	0.1%	0.3%	0.3%	0.6%	38.7%
Vietnam	0.0%	4.0%	0.3%	0.2%	0.0%	0.2%	0.0%	0.0%	0.0%	4.2%	91.1%
North Africa	0.3%	0.9%	0.2%	0.0%	0.0%	0.0%	5.3%	4.6%	5.2%	0.1%	83.4%
Middle East	0.4%	2.9%	1.1%	0.0%	0.0%	0.0%	5.8%	10.4%	7.5%	63.3%	8.5%
ROW	43.1%	16.6%	1.0%	6.9%	0.2%	5.4%	2.6%	0.7%	5.1%	0.4%	18.0%

This is further broken down to show the percent origin shares by country of origin in Table 4.4. In addition, a "port binding" calculation is included to indicate the percent of the iterations where the total amount from the origin was allocated to the 8 primary export destinations (i.e., no residual amount to the ROW). In this example, the U.S. Gulf was only fully committed to the 8 destination markets for 0.6% of the simulation iterations while Brazil was fully committed (i.e., no ROW flows) for 92% of the iterations. In other words, for US Gulf, 0.6% of the iterations were shipments were binding and demands would be diverted to other routes. In contrast, Brazil was supply-constrained for 92% of the iterations.

Table 4.4. Illustration of Destination Shares by Origin Country and Port Binding Value

Destination	U.S. Gulf	U.S. PNW	U.S. Total	Ukraine	Brazil	Argentina
China	71.0%	25.7%	96.8%	2.4%	0.2%	0.6%
Japan	3.9%	57.3%	61.3%	31.9%	0.3%	6.5%
Indonesia	8.1%	8.1%	16.2%	44.2%	0.0%	39.6%
The EU	0.4%	0.0%	0.4%	79.7%	9.9%	10.0%
South Korea	38.9%	21.1%	60.0%	0.7%	0.6%	38.7%
Vietnam	4.3%	0.4%	4.7%	0.0%	4.2%	91.1%
North Africa	1.5%	0.0%	1.5%	15.0%	0.1%	83.4%
Middle East	4.5%	0.0%	4.5%	23.7%	63.3%	8.5%
ROW	60.7%	12.5%	73.1%	8.5%	0.4%	18.0%
Port Binding?	0.6%	30.0%	0.0%	62.4%	92.0%	41.2%

4.3. Model Sensitivity Analysis

The value of the model is the ability to conduct sensitivity analyses to determine how various logistics costs and trade interventions would impact the optimal trade flows and costs (from a cost minimization basis). The Palisade @Risk Monte Carlo software was used to conduct a wide range of sensitivity and stress analyses on the model. Within a single simulation run, the key random variables impacting any model output can be summarized using a *tornado diagram*.

5. RESULTS AND SENSITIVITIES

The Optimized Monte Carlo Simulation model analyzed included all the major trade flows for corn, supply side restrictions, import demands, interior logistical costs, and ocean shipping. The model is seasonal (monthly) to account for the nature of underlying seasonal variables and trade flows. Many of the variables are stochastic and are treated as random. The results are also represented as distributions and interpreted as risk. In addition, corn trade is subjected to several trade interventions which impact trade flows and thereby market shares.

The results of the base case scenario are presented in the first sub-section shown below. Trade flows, market shares for selected months (May and November; for sensitivity analyses only May results are shown, unless noted otherwise) are shown in addition to the effects of export capacity as well as cost and distribution of trade flows. These results are of interest as they represent the logistical competitive advantage of trade flows. Finally, some of the variables are represented as random, and the effect of randomness are illustrated in terms of risks of model outputs.

Sensitivities are presented for all the relevant random variables as well as restrictions and trade interventions. First, we illustrate the impact of increasing ocean shipping rates, and then, the impact of change in the key interior logistic variables including the barge rate, rail rate, and secondary market values. We also illustrate the impact of critical trade interventions or their relaxation between various origin-destination combination on that specific origin-destination trade flows/shares in addition to its impact on the entire global corn trade flows/shares.

The model was solved for each individual month. The results in the base case are shown for the entire crop year, as well as separately for May and November which are months representative of peak and off-peak flows. Finally, the focus of the sensitivities is on the variables that are important.

5.1. Base Case Results

We specified the base case scenario to approximately reflect spatial competitive conditions and market shares of major players in the global corn market during the base period, 2015 to 2019. In the base case, the total cost matrix includes origin basis, shipping and handling costs, and ocean shipping rates between each of the origin-destination combination, daily car values/barge depending on the mode of transportation for shipping corn to major ports within the United States, port elevation cost for the United States and Ukraine origins. The total cost is minimized subject to the constraints as part of the base case scenario. These constraints include the 1) non-negative monthly trade value, 2) total exports from each of the origins are less than or equal to supply capacity, 3) Brazil and Argentina's exports to China are constrained to less than or equal to 1% of total imports by China each month, and 4) Brazil and Argentina's exports to the EU are constrained to less than or equal to 18% and 2% of total imports by the EU each month, respectively.

We imposed respective constraints on Brazil and Argentina's exports to China and the EU in order to reflect the sanitary and phytosanitary standards restrictions imposed by China and the restriction on genetically engineered corn imports by the EU on these origins. Although greater than 90% of total US corn is genetically engineered, we did not place the constraint on US corn exports entering the EU because of the *Abatimento* agreement by Spain and Portugal to which most of the US corn is delivered to the EU as part of the agreement (European Commission, 2007). At the same time, it is important that as part of the *Abatimento* agreement Spain and Portugal import up to 2 mmt and 0.5 mmt corn from any country without import tariffs. But, given historical nature of the agreement most of the US corn exports to the EU goes to Spain and Portugal.

The data were developed using the 2015-2019 period from which the means, distributions, and correlations were drawn in addition to demand, supply, as well as trade interventions that existed during this period. Also, demand and supply conditions were seemingly representative. During this period, the logistics costs and distributions were representative. For these reasons, the results should be interpreted as representative of this base case period.

There is a large volume of results. Therefore, we show only selected and important results that are relevant to the objective of the study. Trade flows, and market shares are shown, and then distributions of total cost are evaluated. Total cost and market share distributions are shown for selected routes, including China and Japan as measures of risk and interdependence.

Table 5.1 shows the annual trade and Table 5.2 the market shares of trade flows between each of the origin-destination combination for the base case. Table 5.3 shows the port-area shares by aggregating the inland origins for the United States and Ukraine. The shares indicate that US Gulf would dominate the Chinese and South Korean corn markets while the US PNW dominates Japanese corn import market. Ukraine dominates the EU, North Africa, Japan, and Indonesian markets. Finally, Brazil dominates Vietnam and the Middle-East corn markets while Argentina dominates Vietnam as well as North African markets.

The results in Table 5.3 can also be used to infer the likelihood that a specific flow is the lowest cost flow. Though these are shown and interpreted as least cost market shares, they can also be interpreted as the probability that a specific origin is the least cost origin. This provides a critical interpretation. In this context, the probability that the US Gulf is the least cost origin for China is 0.65, and for South Korea is 0.35 during the base period. US PNW would be the least cost origin for Japan. Ukraine would by far be the least cost origin for the EU and Indonesia. Brazil would be the least cost origin to the Middle-East, and the most likely least cost origin for Vietnam would be Brazil and Argentina.

Table 5.1. Base Case Scenario: Annual Trade Flows Between Origin-Destination Combination Estimated Using Optimized Model (in `000 mt)

	US Gulf			US PNW			Ukraine			Brazil	Argentina
Destination	**Champaign, IL**	**Lincoln, NE**	**St. Louis, MO**	**Waite Park, MN**	**Jamestown, ND**	**Sioux Falls, SD**	**Western Ukraine**	**Eastern Ukraine**	**Central Ukraine**	-	-
China	211	964	1028	410	304	75	69	101	164	19	19
Japan	537	889	317	4588	1059	866	1012	1294	1145	2796	725
Indonesia	40	92	57	71	37	18	210	248	176	107	433
The EU	2	164	269	0	0	0	3439	3863	1895	2101	228
South Korea	583	1645	720	762	259	108	146	80	73	2151	1956
Vietnam	42	117	23	20	9	5	3	0	0	4163	4331
North Africa	175	249	43	0	0	0	972	1011	993	2332	8810
Middle East	69	69	22	0	0	0	232	391	306	5666	295
ROW	13858	5740	458	2188	103	1404	1218	314	2550	12790	7956

Notes: Base case scenario included all the current logistical and trade interventions placed as the constraints in the optimization model. Few examples include the EU' s genetically engineered restrictions as well as Chinese sanitary and phytosanitary standards placed on Brazil and Argentina corn.

Table 5.2. Base Case Scenario: Annual Market Shares Between Origin-Destination Combination (in %)

	US Gulf			**US PNW**			**Ukraine**			**Brazil**	Argentina
Destination	**Champaign, IL**	**Lincoln, NE**	**St. Louis, MO**	**Waite Park, MN**	**Jamestown, ND**	**Sioux Falls, SD**	**Western Ukraine**	**Eastern Ukraine**	**Central Ukraine**	-	-
China	6.3	28.7	30.6	12.2	9.0	2.2	2.1	3.0	4.9	0.6	0.6
Japan	3.5	5.8	2.1	30.1	7.0	5.7	6.6	8.5	7.5	18.4	4.8
Indonesia	2.7	6.2	3.9	4.7	2.5	1.2	14.1	16.7	11.8	7.2	29.1
The EU	0.0	1.4	2.2	0.0	0.0	0.0	28.8	32.3	15.8	17.6	1.9
South Korea	6.9	19.4	8.5	9.0	3.1	1.3	1.7	0.9	0.9	25.4	23.1
Vietnam	0.5	1.3	0.3	0.2	0.1	0.1	0.0	0.0	0.0	47.8	49.7
North Africa	1.2	1.7	0.3	0.0	0.0	0.0	6.7	6.9	6.8	16.0	60.4
Middle East	1.0	1.0	0.3	0.0	0..0	0.0	3.3	5.5	4.3	80.4	4.2
ROW	28.5	11.8	0.9	4.5	0.2	2.9	2.5	0.6	5.2	26.3	16.4

Notes: Base case scenario included all the current logistical and trade interventions placed as the constraints in the optimization model. Few examples include the EU’ s genetically engineered restrictions as well as Chinese sanitary and phytosanitary standards placed on Brazil and Argentina corn.

Tables 5.4 and 5.5 are the shares of the base case scenario for the months of May and November, respectively. For May, the results reflect the annual market shares presented in Table 5.3 except that Brazil is not dominated in Vietnam like it does when the entire annual market considered. Table 5.5 shows the November shares.

Table 5.3. Base Case Scenario: Annual Market Shares (in %) by Origin Port Area and Destination

Destination	U.S. Gulf	U.S. PNW	U.S. Total	Ukraine	Brazil	Argentina
China	65.5	23.4	89.0	9.9	0.6	0.6
Japan	11.4	42.8	54.2	22.7	18.4	4.8
Indonesia	12.7	8.4	21.1	42.6	7.2	29.1
The EU	3.6	0.0	3.6	76.9	17.6	1.9
South Korea	34.7	13.3	48.1	3.5	25.4	23.1
Vietnam	2.1	0.4	2.5	0.0	47.8	49.7
North Africa	3.2	0.0	3.2	20.4	16.0	60.4
Middle East	2.3	0.0	2.3	13.2	80.4	4.2
ROW	41.3	7.6	48.9	8.4	26.3	16.4

Table 5.4. Base Case Scenario: Market Shares (in %) by Origin Port and Destination for May

Destination	U.S. Gulf	U.S. PNW	U.S. Total	Ukraine	Brazil	Argentina
China	71.5	25.4	96.9	2.4	0.2	0.6
Japan	4.0	58.0	62.0	31.1	0.2	6.7
Indonesia	7.6	8.5	16.1	42.5	0.0	41.4
The EU	0.4	0.0	0.4	79.9	17.7	2.0
South Korea	38.8	20.5	59.2	0.6	0.4	39.7
Vietnam	4.2	0.4	4.5	0.0	3.1	92.3
North Africa	1.4	0.0	1.4	14.1	0.0	84.5
Middle East	5.2	0.0	5.2	27.8	55.7	11.3
ROW	60.5	12.4	72.9	8.5	0.4	18.3

Table 5.5. Base Case Scenario: Market Shares (in %) by Origin Port and Destination for November

Destination	U.S. Gulf	U.S. PNW	U.S. Total	Ukraine	Brazil	Argentina
China	65.2	19.1	84.3	14.4	0.8	0.5
Japan	14.1	29.8	43.9	25.2	24.4	6.6
Indonesia	10.7	13.4	24.1	40.6	11.3	24.0
The EU	1.2	0.0	1.2	79.9	17.2	1.8
South Korea	34.4	12.0	46.3	2.8	38.5	12.4
Vietnam	3.1	0.1	3.1	0.0	62.7	34.1
North Africa	2.0	0.0	2.0	31.6	18.5	48.0
Middle East	1.4	0.0	1.4	10.2	88.0	0.4
ROW	26.7	2.7	29.3	8.6	42.2	19.8

Supply-capacity available for exports is an important constraint in the model. We refer to it as a port-binding constraint and is an indication of shipments diverted due to this restriction. This was imposed on the model. Technically it is not an export capacity constraint. Rather, the constraint imposed is the maximum amount of corn exports shipped during a given month. This differs from export capacity due to not counting other crops exported, as well as the physical limits of the export infrastructure. Nevertheless, the results do provide a high-level interpretation of capacity utilization for corn.

Table 5.6 shows the results in percentages of port-binding constraints for the stochastic optimization model based on the selected monthly models and annual computations. The port-binding constraints indicates the percentage of iterations that hit the capacity limit imposed on the model. For May, US Gulf hits only 0.6% of iterations for their export capacity in order to meet the global corn demand while US PNW hits about 30.2% of iterations for their export capacity. Taken together, these results suggest prospective supply-capacity limits notably in Ukraine and Brazil in May, and US PNW and Ukraine in November.

Table 5.6. Base Case Scenario: Port Binding Constraints of Their Export Capacity

Model	U.S. Gulf	U.S. PNW	U.S. Total	Ukraine	Brazil	Argentina
May	0.6	30.2	0.2	62.4	92.4	41.2
November	18.6	57.3	17.2	66.3	20.2	42.3
Annual	7.9	42.1	7.4	61.5	44.9	42.6

Figure 5.1 shows the contribution of different variables on the total cost. The variables of interest in rank order of importance are the ocean rate from Brazil to Japan, central Ukraine basis, Argentina FOB basis, ocean rate from Brazil to South Korea, ocean rate from Argentina and to North Africa, daily car values, east Ukraine basis, North Dakota basis, and St. Louis barge. Beyond selected ocean rates and origin basis, the rail daily car value also contributes to

the variance of the total cost. While numerous variables impact the total cost, two logistical costs within the United States, DCV, and St. Louis barge are important.

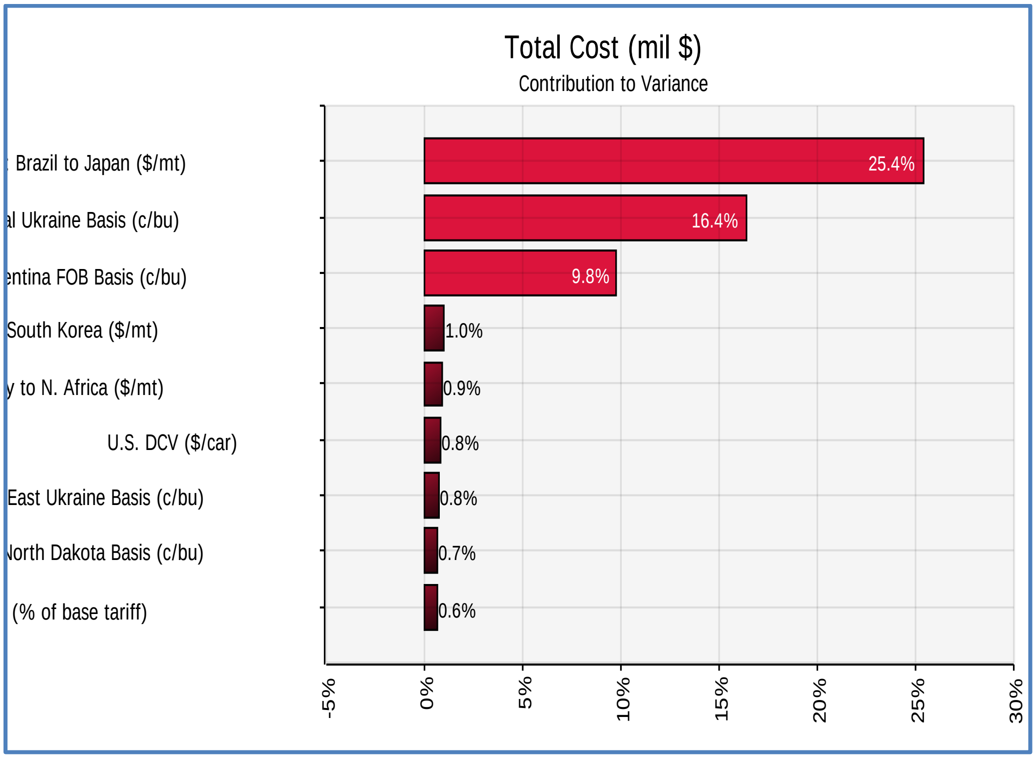

Figure 5.1. Contribution of Variables to the Variance of Total Cost

Figures 5.2 and 5.3 shows the probability distribution of the total cost of the Optimized Monte Carlo Simulation model from all the origins to China and Japan destination, respectively. On average, the US Gulf is high cost origin for shipments to China. However, the standard deviation of the cost for each of Ukraine, Brazil, and Argentina are greater than those at the US Gulf and US PNW (those with the lowest variability in costs). The same is generally true for shipments to Japan (Figure 5.3).

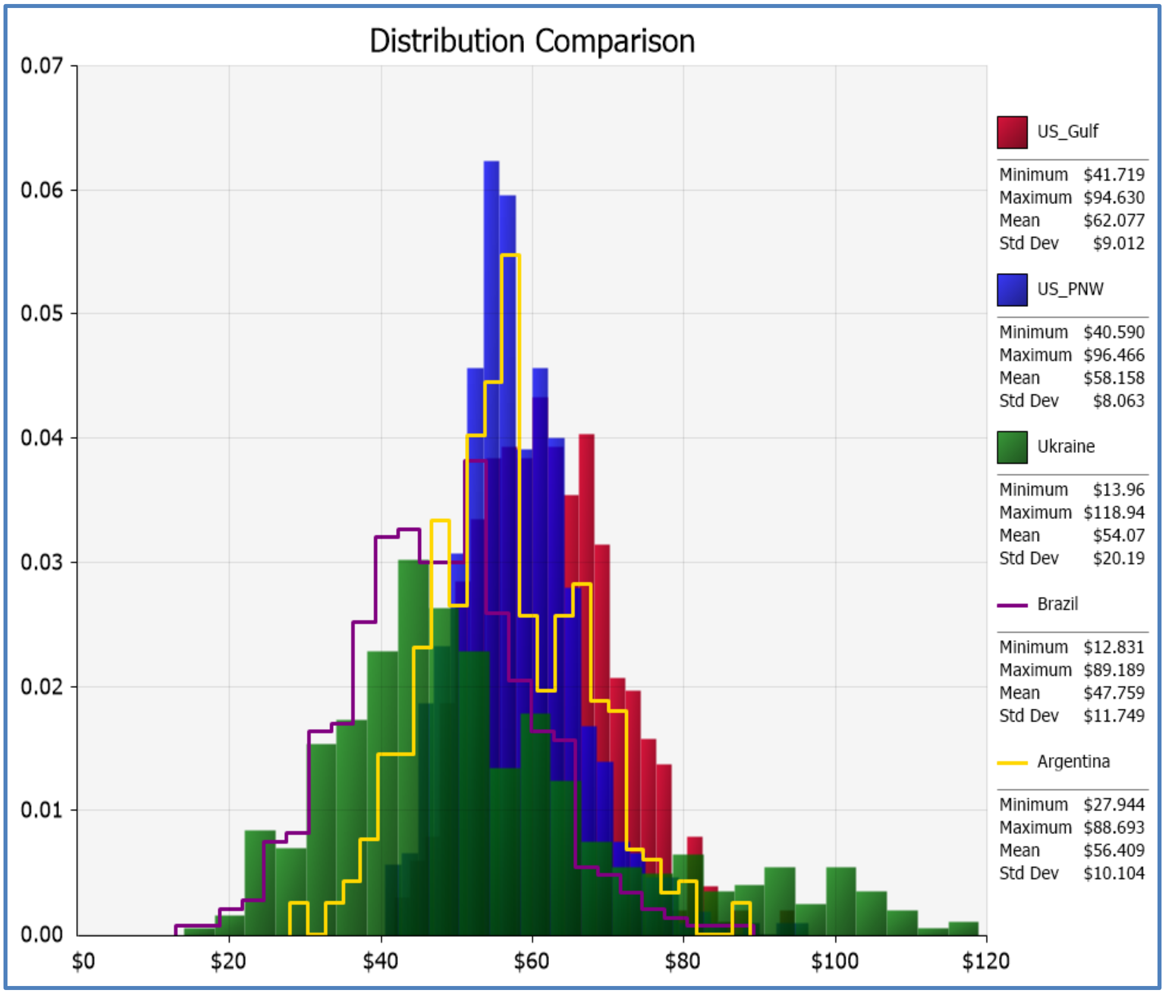

Figure 5.2. Probability Distribution of Total Cost from Different Origins to China

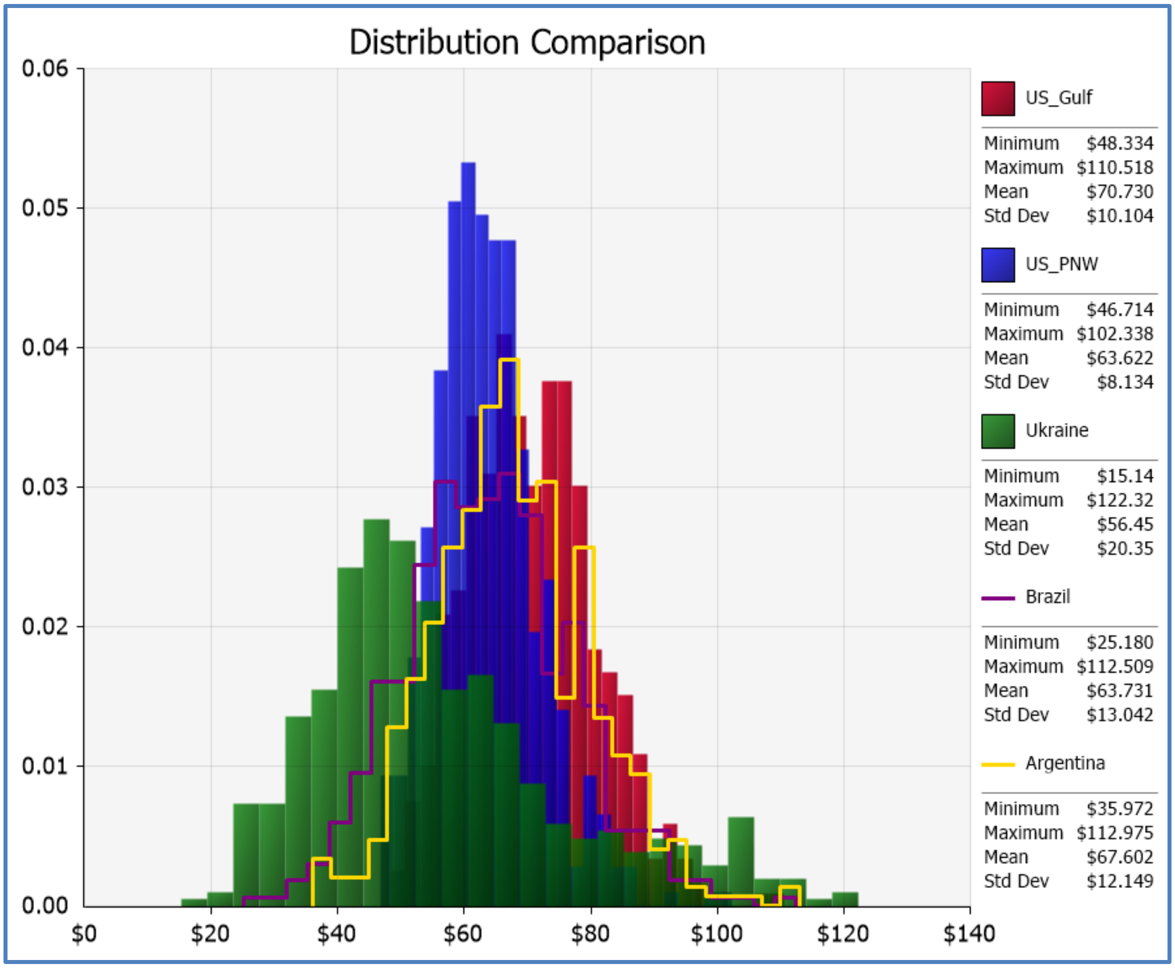

Figure 5.3. Probability Distribution of Total Cost from Different Origins to Japan

5.2. Sensitivity Analysis and Results: Logistical and Transportation Competition

We performed sensitivities analyses by relaxing some or assuming alternative distributions to the base case in order to analyze the effect of these variables on market shares for each trade flow. Specifically, we performed two sensitivities, including the ones related to logistic and transportation competition variables as well as relaxing or assuming specific trade interventions.

First, we conduct sensitivities by increases in ocean rates, changes in daily car values (DCV) and barge rates. In addition, we analyze the effects of dredging in the Mississippi river and increase in Ukraine rail cost by 19% on the change in market shares of all the exporters or origins to each of the destinations (Industry sources).

5.2.1. Increase in Ocean Rates

An important factor impacting cost and trade flows are ocean shipping costs. To illustrate this effect, we compared the base case scenario to an alternate scenario in which all the ocean freight rates increased in 25% increments. That is, we increase ocean freight rates by 25%, 50%, 75%, and 100% to compare with the base case (0%). This is in line with the recent increase in ocean rates since 2020 (Thukral and Maguire, 2021; Ren, 2021).

Figure 5.4[13] shows the results of the sensitivity analysis of increasing the ocean freight rates on the market shares. The results show that Ukraine and US PNW gain market shares while Argentina and US Gulf lose market shares for various destinations with the increase of ocean freight rates. Ukraine gains market share in Indonesia while US PNW gains to China, Japan, and South Korea. Argentina loses market shares to South Korea, Indonesia, and North Africa while US Gulf loses market share to China. One of the reasons is that the US PNW and Ukraine are origins with relatively lower ocean shipping costs, and hence, increases in percentage terms gives that origin a greater advantage (as reflected in the inter-spatial spreads in ocean rates in Figures 3.5 and 3.6).

5.2.2. Sensitivity to Changing Daily Car Values and Barge Rate

One of the important U.S. interior logistical functions is that of the DCV and barge rates. The impacts of both are similar in that they are volatile through time, and impact export costs. To evaluate the increase in inland transportation costs of the United States, we compare the top 10% values of historical distribution of daily car and barge values with the base case scenario, and also a specified decrease in the respective values.

Figures 5.5 and 5.6 show the results of the sensitivity analysis of increasing DCV and barge rates to represent top 10% values of their historical distribution. The results regarding daily car values indicates the United States loses the most. The US Gulf loses its market share to China and South Korea while the US PNW loses Indonesia and Japan market shares but gains a minor share of the Chinese market. Argentina gains market shares to South Korea, Indonesia, and North Africa with the increase in daily car values in the United States.

We also conducted sensitivity analysis of decreasing the rail daily car values by $2/mt and barge rates by $4/mt. The results of decreasing rail daily car values are shown in Table 5.7, which show that the US gains market shares with highest gains in South Korea, and Japan. The results shown in Table 5.8 are similar to the results of Table 5.7 but with higher magnitude. The results of decreasing barge rates by $4/mt show a significant increase in market share of US Gulf to China and South Korea while decreasing the shares of US PNW for the same destinations. Each of the other exporters would lose, but the re-allocation would shift more Ukraine corn exports to North Africa.

[13] Figures for the remainder of this section are at the end.

Table 5.7. Changes in Market Shares (in %) of Decreasing DCV by $2/mt (or $200/car), May Results

Destination	U.S. Gulf	U.S. PNW	U.S. Total	Ukraine	Brazil	Argentina
China	1.6	-1.0	0.6	-0.5	-0.0	-0.1
Japan	0.2	7.9	8.2	-5.9	-0.0	-2.2
Indonesia	3.8	3.1	6.9	2.2	0.0	-9.1
The EU	0.2	0.0	0.2	-0.1	-0.1	-0.0
South Korea	9.7	0.3	10.0	-0.3	-0.0	-9.7
Vietnam	1.7	-0.2	1.5	0.0	0.5	-2.0
North Africa	0.5	0.0	0.5	4.5	0.0	-5.0
Middle East	1.6	0.0	1.6	0.9	-1.3	-1.2

Table 5.8. Changes in Market Shares (in %) of Decreasing DCV by $4/mt (or $400/car), May Results

Destination	U.S. Gulf	U.S. PNW	U.S. Total	Ukraine	Brazil	Argentina
China	3.0	-1.8	1.2	-1.0	-0.1	-0.1
Japan	0.4	10.6	11.0	-7.9	-0.1	-3.0
Indonesia	6.6	4.6	11.1	1.2	0.0	-12.3
The EU	0.4	0.0	0.4	-0.2	-0.1	-0.0
South Korea	14.7	1.3	16.0	-0.3	-0.2	-15.6
Vietnam	3.0	0.2	3.2	0.0	0.9	-4.1
North Africa	1.0	0.0	1.0	5.8	0.0	-6.7
Middle East	3.3	0.0	3.3	1.2	-2.0	-2.4

The sensitivity results show that increasing barge rates do not affect market shares of any of the origin-destination combination as cost of barge is comparatively low. However, reducing barge shipping costs by $4/mt (for illustration) has fairly significant increases in US market shares (Figure 5.9). With this change, the US Gulf market share increases substantially in China, South Korea, and minor gains in other markets. The US PNW loses, as does Ukraine and Argentina.

Table 5.9. Change in Market Shares (in %) of Decreasing Barge by $4/mt, May Results

Destination	U.S. Gulf	U.S. PNW	U.S. Total	Ukraine	Brazil	Argentina
China	12.6	-11.9	0.7	-0.6	0.0	-0.1
Japan	4.5	-1.8	2.6	-1.8	0.0	-0.9
Indonesia	4.2	-0.5	3.7	-2.3	0.0	-1.4
The EU	0.2	0.0	0.2	-0.2	0.0	0.0
South Korea	10.2	-4.9	5.3	-0.1	-0.1	-5.0
Vietnam	2.2	-0.1	2.1	0.0	0.2	-2.3
North Africa	1.3	0.0	1.3	1.1	0.0	-2.4
Middle East	1.6	0.0	1.6	0.0	-0.7	-1.0

5.2.3. Effect of Dredging in the Mississippi River

The United States recently initiated a dredging project in the Mississippi river (particularly the lower Mississippi) to increase the depth of the river (Informa Economics, 2018). With the increase in the depth of the river, vessel capacity increases and thereby the cost of shipping grain per unit from the US Gulf decreases. The reason for this is that ships can increase their loading capacity and/or larger vessels can be used for these flows. It is not exactly clear how much shipping rates would decrease. For illustration, we conduct the sensitivity analysis of decreasing the cost of transporting grain via Mississippi river by $2, $4, and $5 per mt to compare with the base case scenario (Informa Economics, 2018).

Figure 5.7 shows the results of the sensitivity analysis of increasing the depth of the Mississippi river as part of the ongoing dredging project. The results show that the effect of dredging on change in the market shares indicate that most of the direct impact is on the US Gulf. Specifically, the US Gulf shares to China and South Korea increase while the US PNW to the same destinations decrease along with the share to Japan. All other origins have a relatively minor effect on their shares with dredging in the Mississippi river. These results are of interest in that most of the shift is from shipments through other competing US ports, the PNW, in contrast to being captured from other export origins.

5.2.4. Increase in Ukraine's Rail Cost by 19%

Rail shipping costs in Ukraine are highly regimented and change infrequently. Due to a multitude of reasons, it is expected that during 2021, Ukraine's rail shipping cost would increase by 19% (Wilson, 2021). To evaluate the increase in rail cost within Ukraine and its effect on the market shares, we performed a sensitivity analysis comparing with the base case scenario (Figure 5.8).

The results of the sensitivity analysis do not show any effect on either Ukraine's or other origins' market shares. Partly, this is due to the fact that Ukraine internal rail cost is relatively lower to begin with and an increase of 19% did not show any effect on the global corn market shares. Further, their more advantageous logistical partition to the EU, and North African markets is sufficient that this cost can be absorbed.

5.3. Sensitivity Analysis and Results: Supply Chain Disruption

There are many factors impacting the post-COVID (Corona Virus Disease) induced supply chain disruption. While most of these have impacted the container shipping business, there have been a number of impacts on the bulk shipping supply chain. These include, as example, dramatic increase in ocean shipping rates, increased wait times, and resulting increased demurrage costs, increased COVID-testing at the import ports (notably China), labor shortages, and other constraints. These are in addition to changes in interior basis values, DCVs and shipping times. Further, these effects have occurred at most export ports, and to some extent at the import ports. Hence, in spatial competition, their effects are compounding.[14]

We extrapolated this model to capture some of these effects to illustrate the prospective impacts of these effects. Specifically, we conducted a sensitivity to capture the impacts of 1) increasing ocean rates by 75% and 2) an increase in FOB basis values by 22% in case of both Argentina and Brazil, simultaneously. These are approximately the change that occurred during the post-COVID period, versus our base case.

Results of the sensitivity analyses are shown in Table 5.10. For May, the results show that the US Gulf and US PNW gain market shares for most of destinations compared to the base case. However, US PNW loses about 10% of Chinese market share compared to the base case. Brazil and Argentina lose market shares for all destinations. It is interesting that Brazil loses Indonesia (-10.5%), South Korea (-31.5%) and Vietnam (-12.4%) in November while Argentina loses Indonesia (-43.6%), South Korea (-40.7%), and Vietnam (-68%) in May. One of the main reasons driving the above results is that the US PNW and Ukraine being the lower shipping costs would become favorable origins for shipments given a percentage increase of these origins results in lesser increases in the absolute value of the ocean shipping rates compared with the other origins.

[14] There has been extensive media coverage on the supply chain disruption, but, most are focused on container shipping.

Table 5.10. Change in Market Shares Due to Supply Chain Disruption (All figures are in percentages)

Destinations	Origins					
	US Gulf	US PNW	US Total	Ukraine	Brazil	Argentina
China	12.7; 20.8	-9.6; -9.8	3.1; 11	-2.3; -10.3	-0.2; -0.3	-0.6; -0.3
Japan	2.3; 13.7	29.2; 11.9	31.5; 25.7	-24.3; -3.2	-0.2; 17.9	-7.1; -4.5
Indonesia	24.8; 16.1	26.7; 12.8	51.5; 29	-7.8; -2.7	0; -10.5	-43.6; -15.8
The EU	-0.1; -0.3	0; 0	-0.1; -0.3	3.2; 1.6	-2.7; -1.2	-0.5; -0.2
South Korea	38.3; 41.4	3.1; 1.8	41.4; 43.2	-0.3; -1.5	-0.4; -31.5	-40.7; -10.2
Vietnam	53.6; 11.5	3.9; 0.7	57.4; 12.2	0; 0.4	4.1; -12.4	-61.5; -0.1
North Africa	29.6; 2.5	0; 0	29.6; 2.5	38.4; 21.2	-0.1; -9.0	-68; -14.7
Middle East	23.1; 3.9	0; 0	23.1; 3.9	9.8; 14.1	-21.7; -17.3	-11.2; -0.7

Notes: The first number in each cell represents May results while the second one in each cell represents November result.

5.4. Sensitivity Analysis and Results: Trade Interventions

There are numerous trade interventions that impact corn flows, as discussed in Appendix C of this report. In this subsection, we conduct sensitivities to analyze the effect of different trade interventions on corn market shares for each of the origin-destination combination by either relaxing the restrictions and the compare to the base case.

5.4.1. The Effect of Chinese 65% Over-quota Tariff on Global Corn Market Shares

An important trade intervention impacting corn is the tariff-rate-quota policy for Chinese corn imports. These are implemented on exports from all origins with 1% in-quota tariff applied on Chinese corn imports less than 7.2 mmt per year. If the Chinese corn imports exceed more than 7.2 mmt, then an additional over-quota tariff of 65% is subjected to the corn imports exceeding 7.2 mmt for that year.

However, in contrast to the above stated official TRQ policy, China has quietly imported close to 11.2 mmt in 2020 and it is predicted to import a similar (higher than normal) corn imports in 2021 as well. Industry sources indicate that the Chinese government has increased their in-quota amount but there has been no official confirmation.

We analyzed an alternate scenario where the exports from all the origins are subjected to an additional 65% tariff to compute its effect on the change in global corn market shares. Figure

5.9 shows the dot plots comparing the base case and the scenario with 65% tariff placed on all the exporters to China and the difference of market shares for both the scenarios. The results indicate that Ukraine benefits the most in gaining the Chinese market by 52% while US Gulf loses the equivalent market share (–43%) to China. One of the reasons for this is that Ukraine is lower cost origin and hence, a percentage point increase in cost is less when compared with the increase in other origins. Ukraine loses the market shares for other countries such as Indonesia (-13%), Japan (-13%), among others in order to gain the Chinese market share. Similarly, in the case of US Gulf, the corn market shares have increased to countries, including South Korea (12%) to compensate the loss of Chinese market share.

5.4.2. The Impact of Increase in Chinese Total Imports to 30 Million Metric Tons (mmt) Year on Global Corn Market Shares

In calendar year 2020, China imported close to 11.2 mmt and it is projected to import similarly high levels of corn due to increase in Chinese corn demand as a result of recovery of their hog industry from African Swine Fever compared with previous years (USDA-FAS, 2017b). More recently, China has imported about 30 mmt (USDA-FAS, 2021).

This would represent a major change in Chinese imports in contrast to our base model, which had Chinese imports at an average of 3.29 mmt/year. To illustrate the impacts of this change, we compared the base case scenario to an alternate scenario that increased total Chinese corn imports to 30 mmt. Since our models are monthly, we used monthly (Olympic) import shares of China to distribute 30 mmt per year to monthly quantities.

Results show that most of the increase in Chinese imports are captured by the United States taking away almost all its exports from other destinations, including the rest of the world. As Brazilian and Argentine corn is restricted to less than 1% to China, exports from these countries are directed to the destinations other than China. Further, the frequency of hitting capacity constraints increases at the US PNW, Ukraine, and Argentina.

5.4.3. The Effect of Increasing Ukraine's Total Exports to 24 mmt Per Year Due to Eliminating Export Restrictions

Corn exports from Ukraine have been increasing substantially in the past decade. In our base case, Ukraine exports were the equivalent of 19 mmt/year. Other recent studies suggest that over time, Ukraine exports would continue to increase, and potentially could increase to 24 mmt/year.

We specified an alternate scenario of increasing 5 mmt/year so that the total exports from Ukraine increase to 24 mmt/year. Figure 5.10 shows the sensitivity results of incorporating an increase in 24 mmt per year of corn exports from Ukraine and its effect on the global corn market shares. The result is that Ukraine captures increased market shares to Indonesia (11%), Japan (11%) while Argentina and US PNW lose market shares of Indonesia (–8%) and Japan (–9%), respectively.

5.4.4. Impacts of Eliminating the Current 25% Tariff on US Corn by the European Union

After the United States imposed tariffs based on the sections 232 and 301, the EU retaliated with an additional 25% tariff on US corn, among other products. This was maintained assumption in our base case model. As an alternative, we a scenario by eliminating the EU's 25% tariff on US corn to analyze the effect on the global market shares.

Figure 5.11 shows the results of the sensitivity of elimination the EU's current 25% tariff on US corn and its effect on global corn market shares. The results indicate that Ukraine suffers the greatest loss with its market share to EU declined by 75%, however, this lose has compensated to some extent with its increase in market share to Japan (31%) and Indonesia (18%). Predictably, the United States has the biggest gain with US Gulf share to the EU increasing as high as 81% while decreasing share with China by 38%. Eliminating the EU's 25% tariff on the US corn has indirect effect of increasing US PNW market share to China (36%), and South Korea (20%) while also declining US PNW market share to Japan by 28%.

5.4.5. Impacts of Removing the EU's Restriction on Importing Genetically Engineered (GE) Corn from Brazil and Argentina

Another important set of interventions that restrict global corn trade is related to the impacts of EU restrictions on the importation of GE corn. This was discussed in detail in Section 4. To capture this in our base case model, we specified a constraint in the stochastic optimization model restricting the exports of Brazil and Argentina to the EU to less than or equal to 18% and 2% of the EU's total imports, respectively. As an alternative, we relax this constraint of the base case scenario to analyze the effect on the global corn market shares.

The results are shown in Figure 5.12. The results suggest that Ukraine is the biggest loser with its market share to the EU decreasing by 79% while Argentina is the biggest beneficiary with its market share to the EU increased by 97%. Ukraine incurs a loss in its share to the EU market by capturing increased shipments to North Africa (20%), Indonesia (21%), and Japan (15%) market shares. Although Argentina gains the EU market share significantly, it loses North Africa (-21%), Indonesia (-21%), and South Korea (-16%) market shares.

5.4.6. The Effect of Removing the Chinese Restriction on Importing Brazil and Argentina Corn Due to Sanitary and Phytosanitary Standards Issues.

Another intervention in the international corn market is related to the Chinese phytosanitary requirements for corn shipments from Brazil and Argentina. To capture these in the base case, we imposed restrictions to reflect the historical flows from these origins, which were less than 1% of the total Chinese imports.

As an alternative, we relaxed the constraints of Brazil and Argentina corn exports restricting to less than or equal to 1% of total corn imports to China. The sensitivity results are different for May and November. Figures 5.13 and 5.14 shows the results for the months of May and November. In the case of May results, the removal of Chinese sanitary and phytosanitary standards (SPS) restrictions on Brazil and Argentina show that Argentina's corn market share to China has increased by 46% while the shares to South Korea (-16%), Indonesia (-9%) have decreased. The United States loses the Chinese market at both of its US Gulf (-30%) and US PNW (-17%) ports. It is important to note that the Brazil corn shares to China has little effect (4%) in the case of May results.

For the month of November, the results differ. Brazil's market share to China has significantly increased by 71% while the Argentina's share to China show little effect (6%) with the removal of Chinese SPS restrictions on Brazil and Argentina corn. Similarly, the May results, United States seem to lose the corn market shares to China at both of its major ports in the November as well.

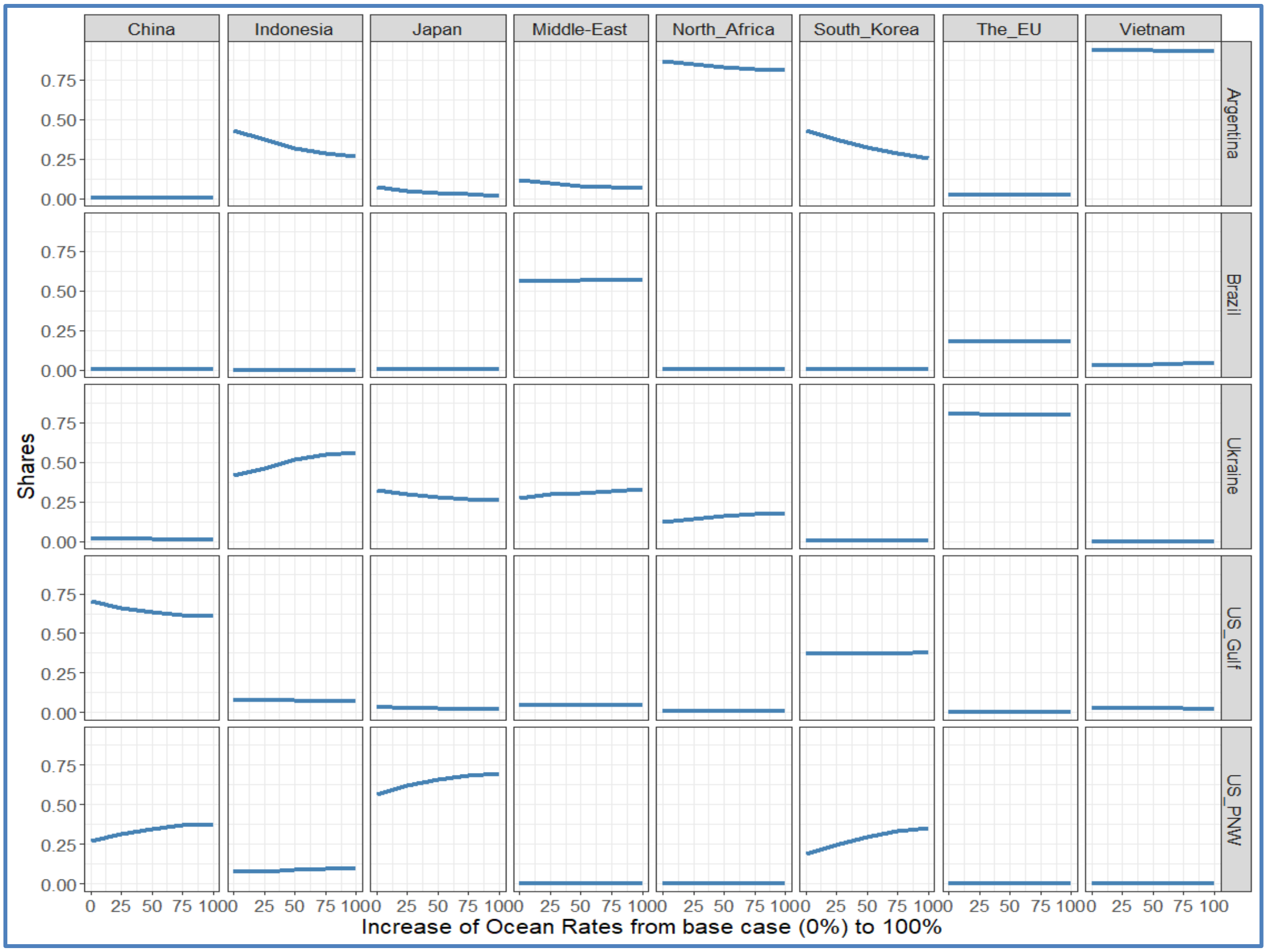

Figure 5.4. Logistical Competition: Sensitivity to Increase of Ocean Rates from Base Case (0%) to 100%

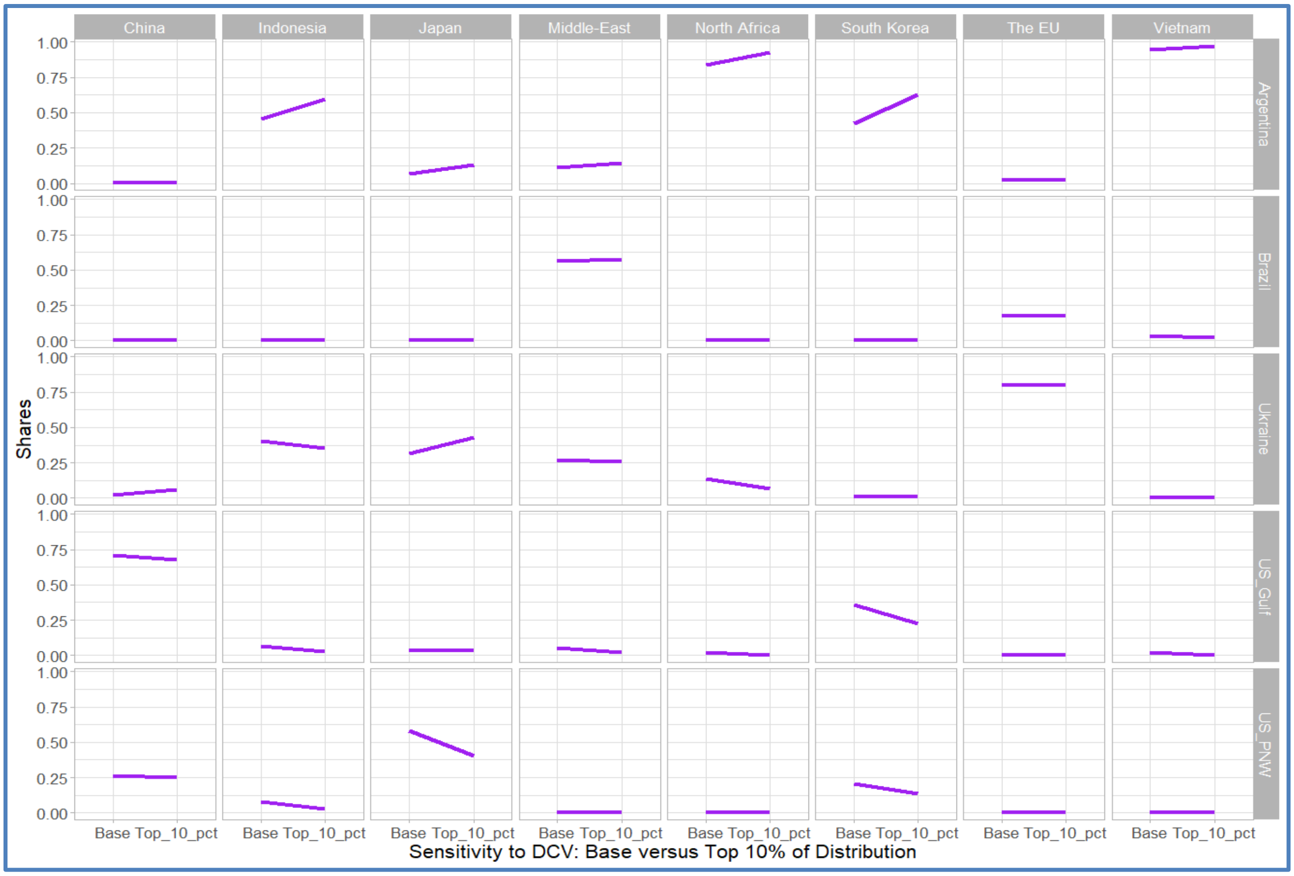

Figure 5.5. Logistical Competition: Sensitivity to Increase in Daily Car Values: Base Case Versus Top 10% of DCV Distribution Values

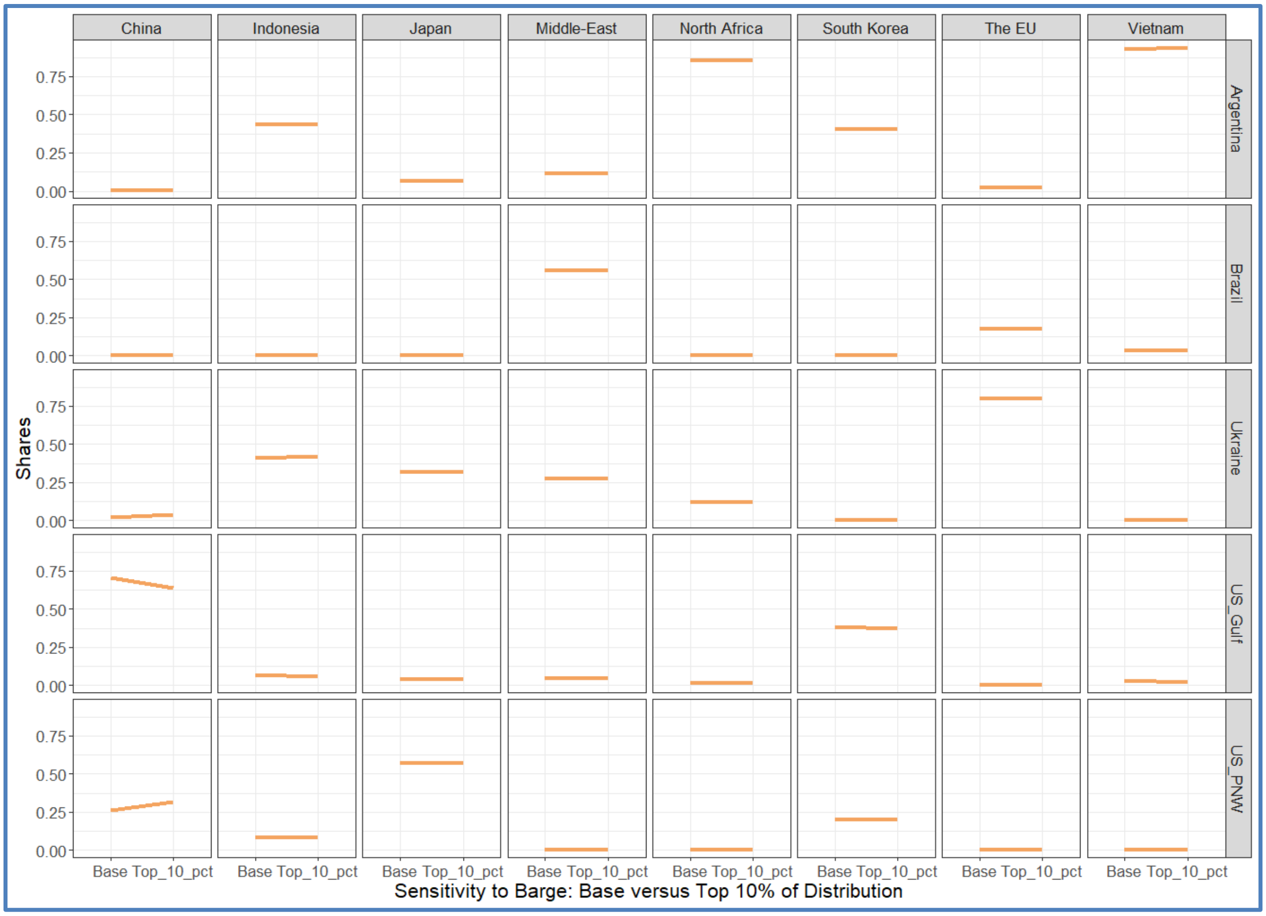

Figure 5.6. Logistical Competition: Sensitivity to Barge: Base Case Versus Top 10% of Barge Distribution Values

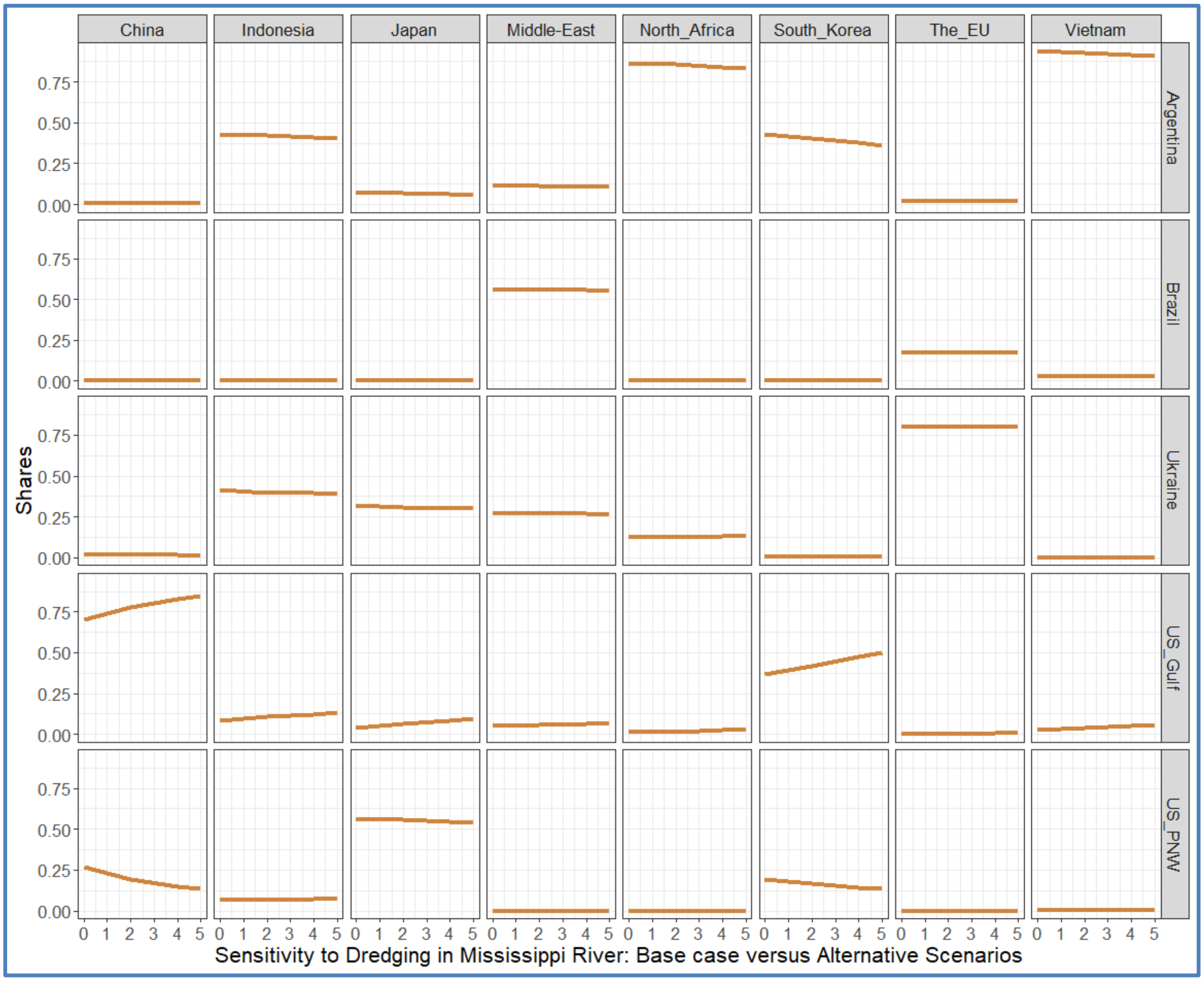

Figure 5.7. Logistical Competition: Sensitivity to Dredging: Base Case Versus Addition Depth (in feet) in the Mississippi River

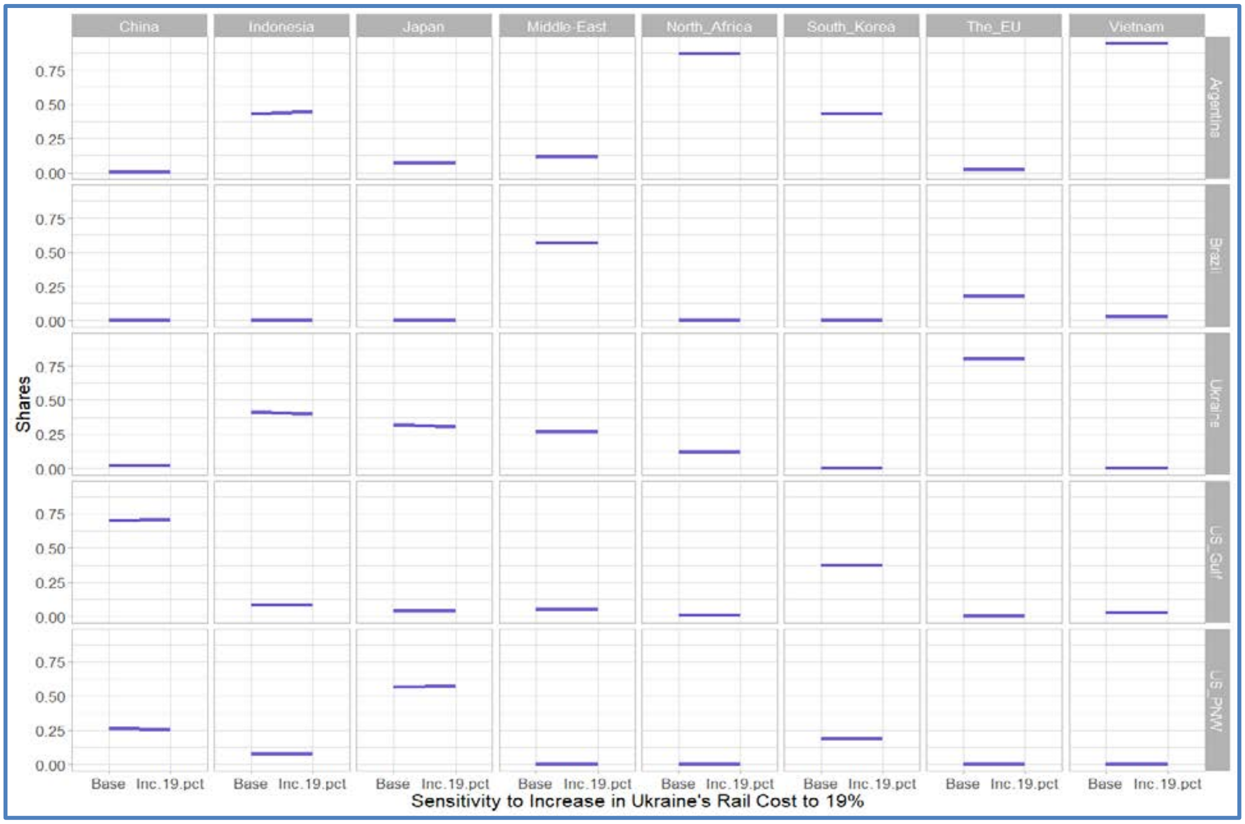

Figure 5.8. Logistical Competition: Sensitivity to Increase in Ukraine's Rail Cost to 19%

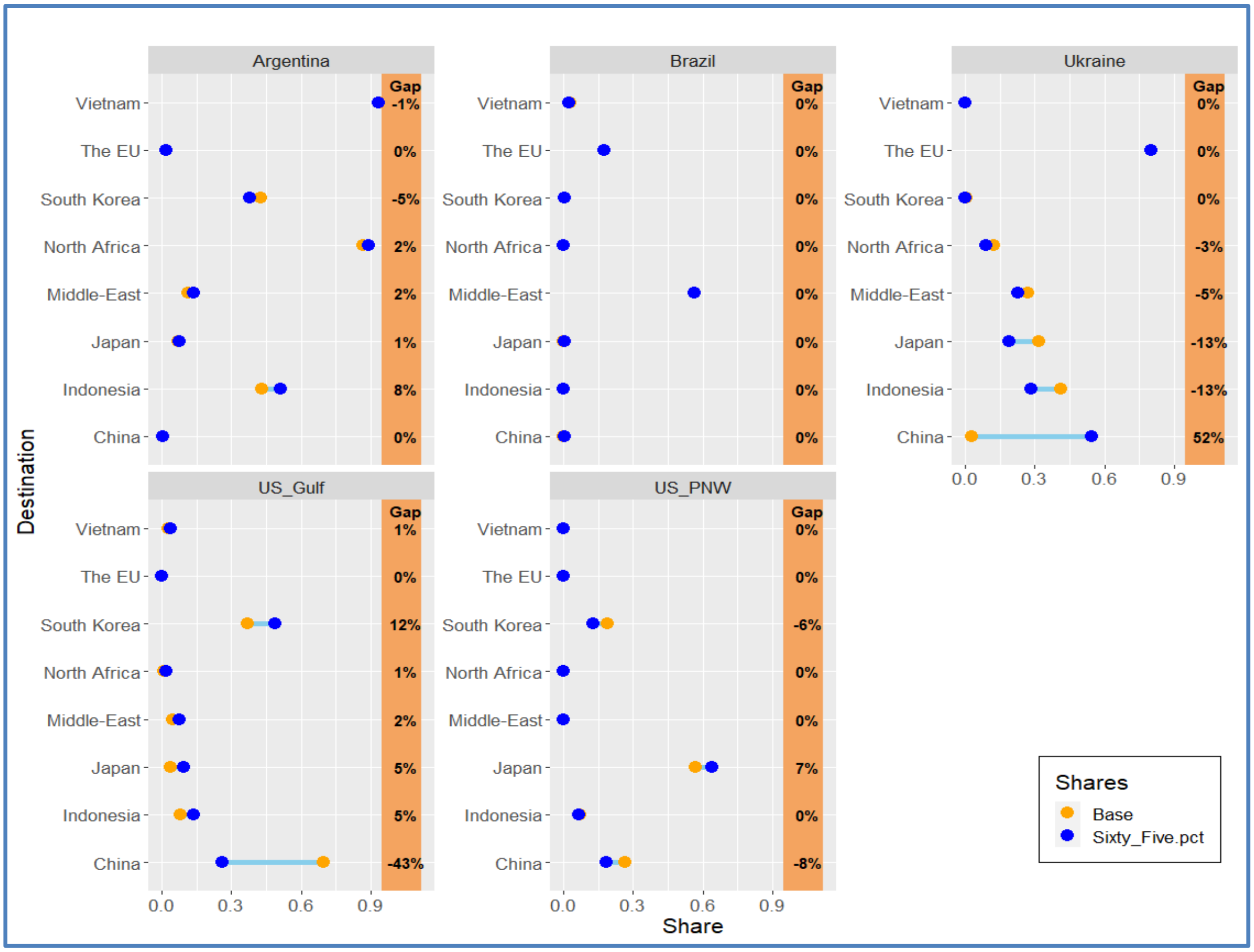

Figure 5.9. Trade Policy: Sensitivity to Increase in 65% Over-Quota Tariff to Corn Shipments to China from All Origins

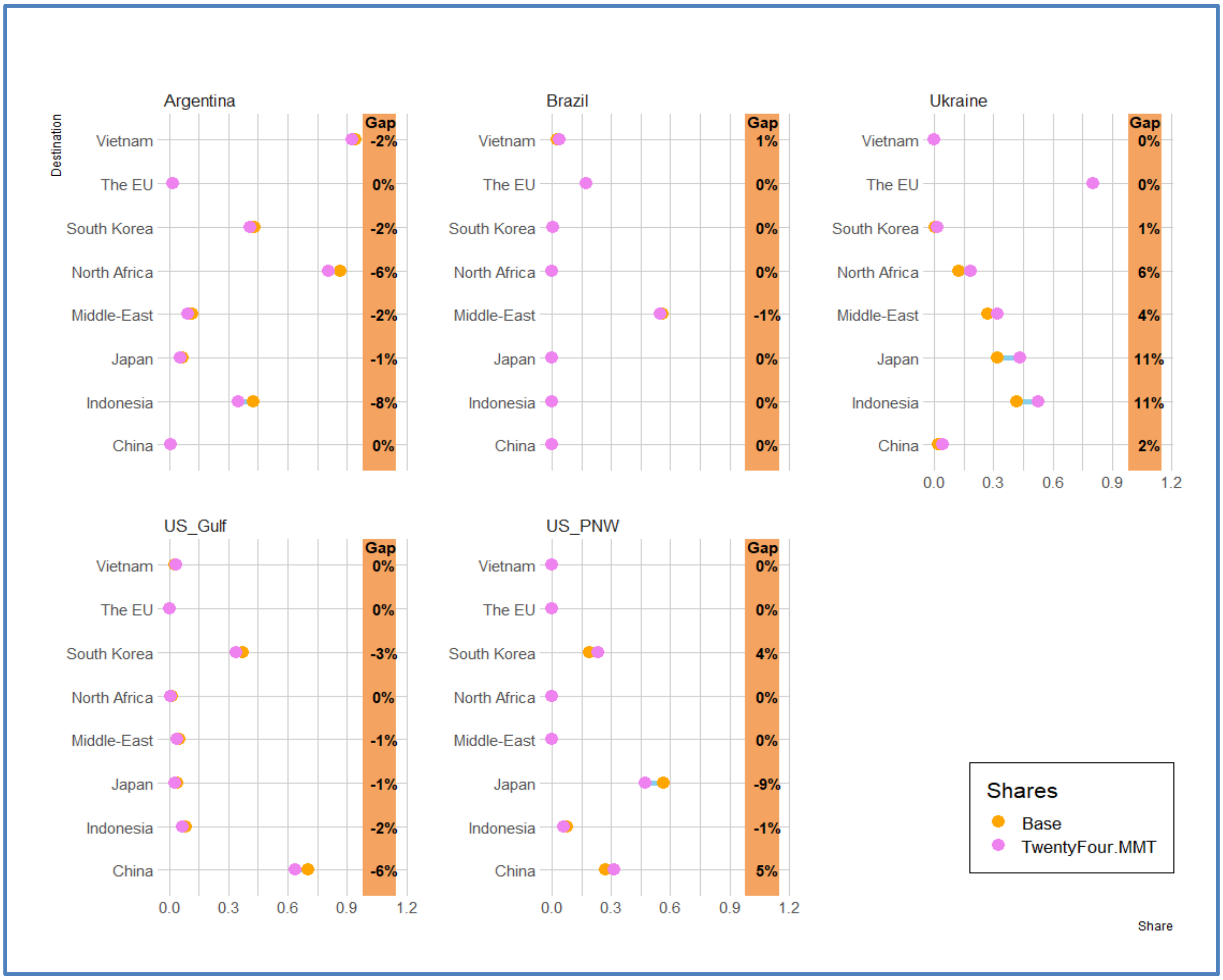

Figure 5.10. Trade Policy: Sensitivity to Increase in Ukraine's Total Exports to 24 mmt per Year

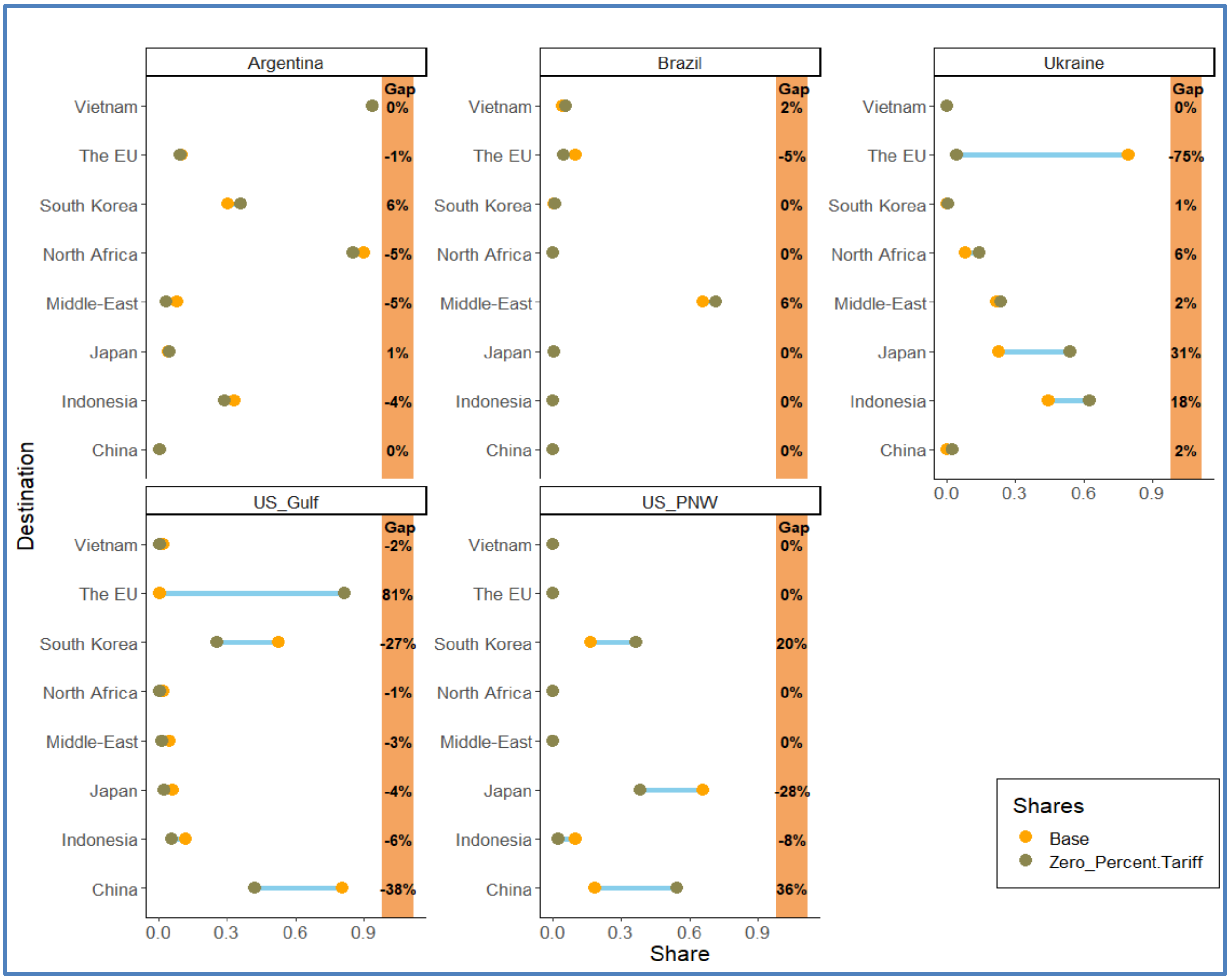

Figure 5.11. Trade Policy: Sensitivity to Removing the Current 25% Tariff on US corn by the EU

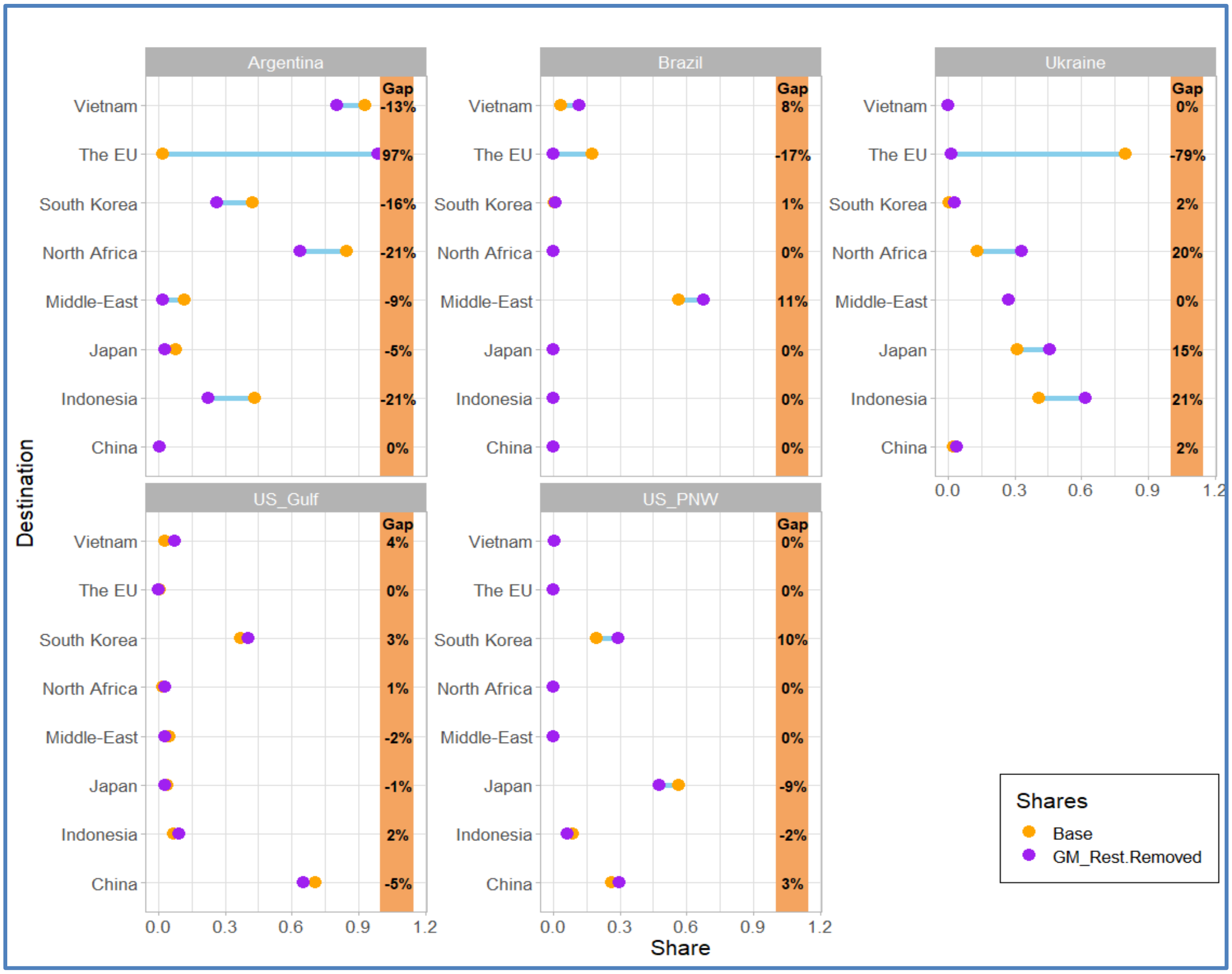

Figure 5.12. Trade Policy: Sensitivity to Removing Restriction on Importing Genetically Engineered Corn from Brazil and Argentina

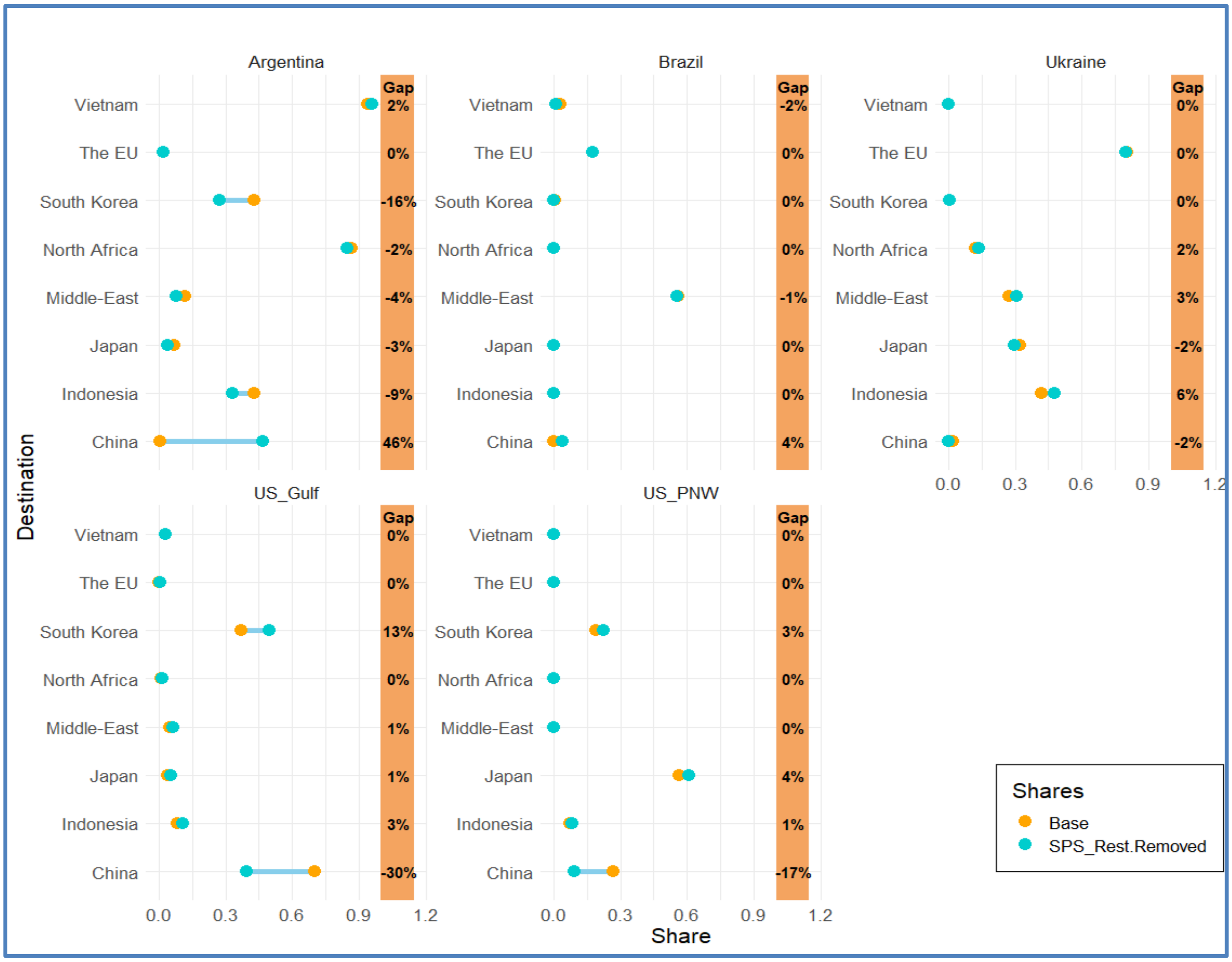

Figure 5.13. Trade Policy: Sensitivity to Removing Chinese Sanitary and Phytosanitary Standards (SPS) on Brazil and Argentina's Corn (May results)

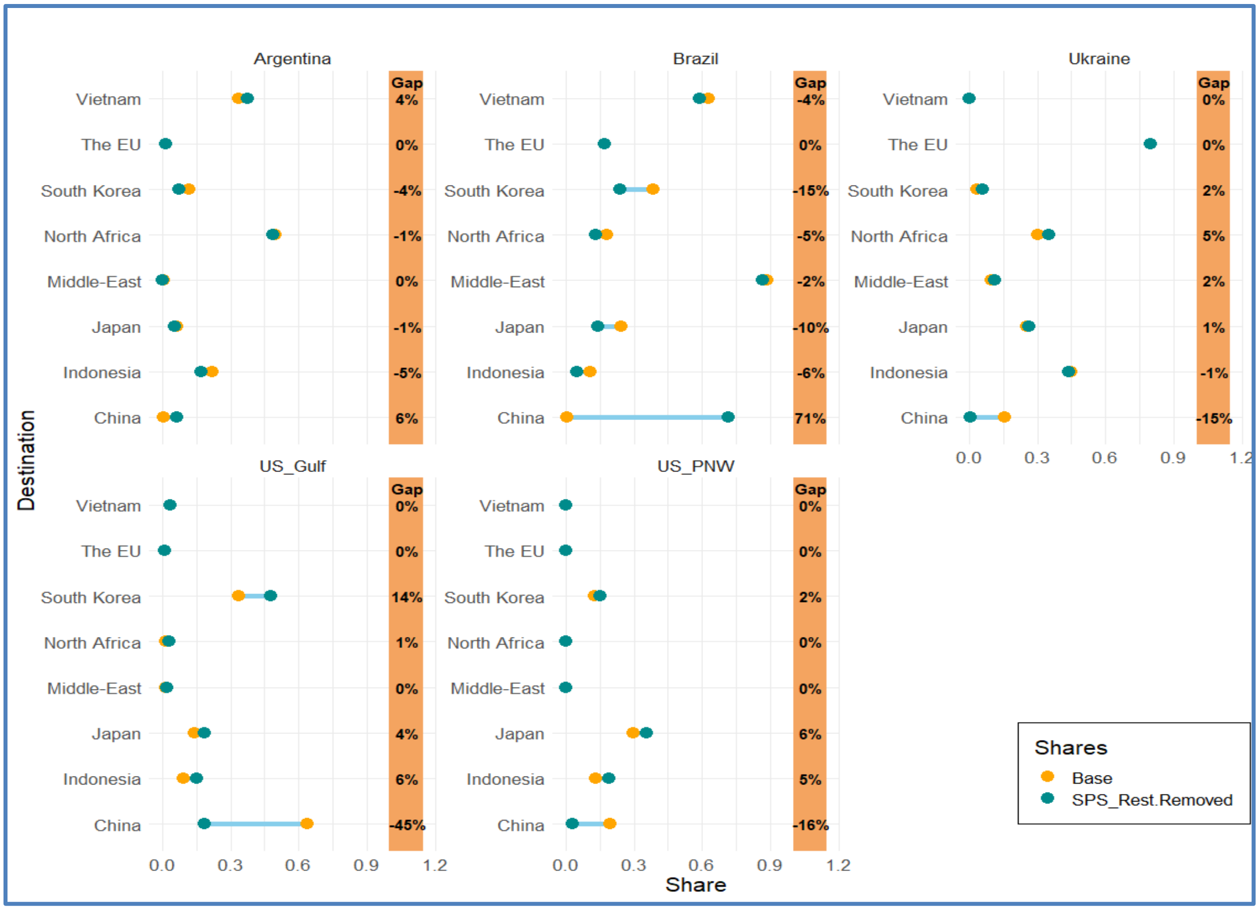

Figure 5.14. Trade Policy: Sensitivity to Removing Chinese Sanitary and Phytosanitary Standards (SPS) on Brazil and Argentina's Corn (November results)

6. SUMMARY AND IMPLICATIONS

The United States was the dominant exporter of corn during the 1970's and 1980's, but its market share has declined. In contrast, Ukraine has emerged as a fast-growing corn exporter into markets traditionally dominated by the United States. Ukraine is currently the dominant supplier of corn to China and other important markets previously dominated by the United States. There are numerous factors impacting this competition including supplies and capacity, ocean shipping costs, and numerous logistical functions and differences, in addition to many recently introduced trade interventions.

The purpose of this project is to analyze impacts of transportation and logistics functions on the United States and Ukraine world corn market shares. We developed an optimized Monte Carlo model to analyze spatial competition and determine market shares, and comparative logistical advantage. Our focus was on corn flows from the United States and Ukraine to selected importing countries and regions. We included other exporters to build a global model.

The empirical model was specified to allow many of the input variables to be random to reflect the historical distribution of their values over time. Given a Monte Carlo realization (iteration) of these variables, a historically plausible random scenario is created. The model uses linear programming to determine the optimal (i.e., cost minimizing) trade flows. The optimized trade flows for each iteration are then summarized as output distributions with the mean of each distribution utilized as the most likely trade flow over time. We include interior and exterior shipping costs as well as relevant trade interventions to reflect the competitive conditions for the base period. The total delivered cost matrix includes the origin's basis, rail tariffs, daily car values and fuel service charges, barge, and elevation costs at the port/origin to compute the cost parameter at the Freight on Board (FOB) port value. Ocean shipping costs are added to these values to derive the total cost of shipping corn from each origin to the each of the destinations.

The model minimizes cost subject to several constraints as part of base case scenario. The constraints are detailed and reflect logistical restrictions and the effect of trade interventions.

6.1. Base Case Results

The model was simulated using monthly data between 2015 and 2019. The model reflects the distribution of market shares during this period.

The base case results indicate:

1) While there are many logistical costs throughout the marketing system, it is important that the Ukraine has a substantial interior rail shipping cost advantage relative to the United States.

2) The United States has a logistical comparative advantage in serving China, Japan, and South Korea. The US Gulf is the dominant port for export shipments to China and South Korea. The US PNW has an advantage for shipments to Japan.

3) The Ukraine has a logistical comparative advantage for the EU and Indonesia; however, the advantage in the EU is partly due to the import tariff applied to corn imports from the United States.

4) Brazil and Argentina have reduced market shares due to Sanitary and Phytosanitary Standards imposed by China as well as the import restrictions on GE corn by the EU.

5) Barge shipping costs and ocean rates are some of the most important variables leading to variability in market shares.

6) The results can be used to infer the likelihood of the US being the lowest cost suppliers. The probability of the US Gulf being the lowest cost supplier for China is 0.80; but 0.13 for Indonesia during the base period. The US PNW would be the least cost supplier to Japan with a probability of 0.67. The Ukraine would be the lowest cost supplier in serving the EU with a probability of 0.80.

7) The distribution of costs indicate that the volatility of costs is less from the US origins meaning these are less risky, but, slightly greater mean values.

8) The results illustrate the importance of diversification for both exporting firms, as well as importing countries. Other than China, all the other import countries would optimally buy from a diversified set of origins.

   In the case of China, the US Gulf, and PNW should be the dominant origins for corn shipments to China. This differs somewhat from observed shipments during the base period, where the Ukraine was the dominant supplier. While there are many reasons for this distinction, important likely include 1) China's goal of diversification; 2) non-price preference[15] for non-US origin corn, among others; and 3) the apparent non-transparency of the Ukraine export marketing.[16]

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[15] Non-price preference refers to the willingness to pay a premium for non-US origin corn. There a number of potential reasons for this and typically related to perceptions of quality and/or GM content.

[16] A recent trade story suggested that China preferred purchases from Ukraine due to it being less transparent than the United States in its export sale reporting (Polityuk and Hogan, 2021). This story pointed specifically to Chinese purchases during October 2021 in which sales were made from Ukraine, instead of the United States, even though the latter were lower cost. The allegation is that China preferred Ukraine as it was less transparent in sales reporting.

Upon further investigation, this allegation is more complicated and involves sales to public versus private firms, and the availability of quotas for purchases from the United States (personal communication).

9) Numerous trade interventions impact world corn trade and the demand for shipments. Those of particular importance and impacting the United States are the EU's 25% additional import tariffs on US corn, phytosanitary restriction on Brazilian and Argentine corn exports to China, GE restrictions on EU imports, and Chinese TRQ restriction and over-quota tariffs.

6.2. Logistical Sensitivities

We conducted several sensitivity analyses for both logistical competition and trade interventions to analyze the change in the market shares.

1) Ocean Rate Sensitivities: The US PNW has a substantial ocean rate advantage to the Asian destinations. Given that ocean shipping costs are volatile, correlated and have increased in recent years, one sensitivity evaluated the impacts of increased ocean shipping costs.

   The results indicated that increases in ocean rates increases market shares for the US PNW and Ukraine while US Gulf and Argentina lose the market shares;

2) Mississippi River Dredging: The US has a project underway to dredge the Mississippi river to 50 feet. This has the impact of allowing ships or vessels to be loaded to a greater depth, and prospectively lowering shipping costs on a per metric ton basis. Results of an increase in the depth of Mississippi river and thereby lower the cost of carrying grain has a greatest impact on US Gulf shares increasing to China and South Korea. This increase in shares are taken primarily from the US PNW which is negatively impacted;

3) Barge Rates: Increased barge rates do now show any effect in market shares. However, reductions in barge rates have significant increases in US market shares;

4) Daily Car Values (DCV): Increasing daily car values lowers the US market share. In contrast, reductions in DCV result in larger increases in US market shares;

5) Export Capacity: The model did not include export handling capacity explicitly, but, rather a distribution of export supply capacity for each origin region. The results suggest that if/as exports increase, there will be greater frequency of shipments being diverted from the least cost origin due to this constraint binding. The greatest demand would be for more supply capacity at the US PNW, Ukraine and Brazil.

6.3. Trade Intervention Sensitivities

While the focus of this study is on logistical costs and the comparative advantage created by these functions, it became apparent that there are many trade interventions that impact trade flows in this sector, and therefore impacts relative advantage and logistical demand. The model analyzed the impacts of these interventions on equilibrium trade flows. Results of these trade interventions are shown below:

1) EU Import Tariffs on US Corn: The most dramatic trade intervention impacting corn trade is that of the EU import tariff on US corn. Eliminating this duty has the impact of reducing Ukraine market share to the EU substantially. Some of their exports are shifted to Japan and Indonesia. The US Gulf share to the EU increases the most, and US Gulf shipments to China decrease;

2) China TRQ: An important trade intervention in China is that of TRQs. The effect of 65% over-quota tariff from all origins to China indicates that Ukraine gains the most while US Gulf loses most of the Chinese market. However, the administration of TRQ's is difficult to document and/or implement in an aggregated model as here.

3) Increased Ukraine Exports to 24 mmt per year: If Ukraine exports increase to 24 mmt per year, the Ukraine gains market shares to Indonesia and Japan and US PNW shares decreased to some extent to those destinations.

4) Removing GE corn restrictions by the EU: Removing the GE corn restrictions by the EU indicate that Ukraine would be the biggest loser while Argentina gains most of the EU import market.

5) Removing Chinese SPS restrictions on Brazil and Argentina: The effect of removing the Chinese SPS restrictions on Brazilian and Argentine corn suggest major impacts on corn flows. Specifically, results for May indicate that Argentina gains a sizable market share of China while both the US Gulf and US PNW lose. For November, the results show that Brazil gains the most while the United States loses most of the Chinese market.

6) China imports at 30 mmt per year: One of the important shifts in global corn trade in the past year has been the rapid increase in imports by China. In the base case, the average imports were about 3.8 mmt per year between 2015 and 2019; but, in 2020/21, the level of imports appears to be increasing to 30 mmt, on an annual basis.

For illustration purposes (recognizing that the base case distributions did not account for these level of Chinese imports), we simulated the impacts of this level of increased imports. The results indicated almost all the United States exports are directed to China taking its exports to away from other destinations, including the rest of world.

Of course, this is dramatic and likely would not prevail due to the numerous other repercussions on trade flows. Nevertheless, the comparative static results suggest that these unprecedented corn imports by China would have a drastic impact on trade flows, and suggest the pressures instilled on the world logistical system.

6.4. Supply-Chain Disruption

There have been major supply-chain disruptions in commodity trading since the base case period of this study. These are driven in part due to the pandemic, and the post-pandemic recovery. While the pandemic has disrupted the supply chain of all commodities, and particularly international freight shipping (Saul et al. 2021; Khasawneh, and Xu, 2021; AgriCensus, 2021b; Varley and Niu, 2021), the US grain exporting industry has been fairly resilient. In part, this is due to the importance of grains and oilseeds in foods, but also that export handling was declared an 'essential work' function. It is important that similar if not more drastic disruptions occurred in competitor countries.

There are important impacts of changes in logistic on supply-chain disruption in grain and oilseeds trade. Most important are increases in ocean shipping costs, interior basis, secondary rail market values, in addition to the escalated demand for corn by China. The change in ocean shipping costs are very dramatic. Specifically, ocean shipping costs more than doubled, which had an impact on increasing the advantage to origins that had lower cost ocean shipping, notably the PNW. Additionally, demurrage costs were more than doubled.

To explore these impacts, we specified the spatial competitive model to the extent appropriate to illustrate the prospective and tentative impacts on world trade flows and market shares. The results indicated that US Gulf and PNW gain in market share for most destinations, and Ukraine increases its shares in the EU, North Africa and Middle East. The reasons for this are mostly due to the lower ocean shipping costs from the United States and a re-alignment of trade flows. But, in general, while these are dramatic changes, the effects favor US exports.

6.5. Implications

There are both private and public implications of these results. Each are discussed below:

Private: Many of the functions in the world grain trade are funded by and performed by private firms. These include traders, importers, shippers, exporters, handlers, among others. These results suggest a number of implications for this group.

The results indicate that the international corn trade is extremely competitive, now with multiple origins capable of supplying most import markets. As a result, the importance of diversification as a strategy for both exporting firms as well as importers. Clearly, the base case results (Table 5.3) indicate that for every importing region/country, no single origin would be a single dominant source (i.e., as would be the case in a non-stochastic model). For most countries/regions, it would be optimal to plan a share of purchases spread across the five origins in this study. Some importing countries/regions would concentrate more purchases from some export origins, than others. China, Japan and South Korea would optimally buy most of their imports from the United States. In contrast, Ukraine would be the dominant supplier to the EU. For all others, the optimal purchases, over time would be shared across origins.

Further, as any one of the many distributions of logistical costs change, or any of the trade constraints change, these optimal shares for trade flows would change.

The implications of these for traders is the advantage of being able to supply corn from all origins. Indeed, this is a virtue of multiple-origination capability. In addition, given these optimal routes change in response to the critical variables in the model, traders need the ability to be anticipating changes.

The results have similar implications for importers. Important is that no one origin would always be the least cost origin. Hence, the ability to purchase from multiple origins is important. This of course, is more important for some importers than others. Last, a common term and strategy executed in trading is referred to as a switching option, or, simply the ability to change origins.

A second set of private implications relates specifically to logistics. These results illustrate the importance of interior logistics costs relative to competing regions. Indeed, the Ukraine has an advantage in terms of lower interior shipping costs, relative to those in the United States. Further, some of the functions in the United States are variable through time, and have important strategic roles. These notably refer to barge shipping costs, and the rail daily car values (i.e., the secondary market). Managing these costs strategically can provide advantages in the international market. These results clearly show that increasing costs of these functions impact export costs, and therefore competitiveness. Reducing either of these have significant impacts on US market shares.

Additionally, in most countries the export capacity and supply-chains are controlled by private trading and handling firms. These results indicate that a number of the supply-regions are periodically constrained. Further, as exports grow, there would be a greater frequency of supply-capacity being restricted. There is pressure for expanded capacity. Indeed, since the inception of this project, expansion initiatives have been announced at each of the US Gulf, Brazil and Ukraine.

Public: There are several implications for the public sector. First, while a previous study (Meade et.al. 2016) indicated that the US had an advantage relative to Brazil, these results are probably dated. Much has changed since then. Further, the results in this study show that Ukraine has a logistical cost advantage relative to the United States. No doubt this facilitates their growing market share.

A second public implication relates to logistical infrastructure. The United States has recently initiated a project to dredge the Mississippi. Results from this study illustrate that this will have an impact on corn flows which are favorable to the United States.

However, no doubt there are other infrastructure opportunities in the grain marketing system. One is improving the river-barge system. Another would be to facilitate expanded capacity to relax the supply-constraints identified in this section. These results show that reducing these costs and/or improving the constraints, improves US exports.

In identifying these public implications, it is important that improvements in export capacity is occurring in at least a number of major competitor countries. Notable is that in Brazil there have been substantial investments in international handling and export infrastructure. There have also been increased exporting infrastructure in Ukraine. This illustrates the rivalrous nature of inter-country competition fostered in terms of institutional and infrastructure projects, all of which impact export competitiveness.

These results show that there are numerous trade interventions that have a drastic impact on trade flows, and demand for logistical infrastructure more than others. Some of these are long-lived, while others are fairly recent and may be short-lived or transient. Most important are the EU import tariff on corn, phytosanitary and GE restrictions. As and if these changes, there would be significant impact on change in trade flows and demand for infrastructure.

Of course, one of the most important impacts relates to China. With respect to this study, China impacts trade in a number of aspects, including: 1) imposing phytosanitary restrictions on US competitors; 2) their TRQ, 3) the recent drastic increase in corn imports and 4) interpretation of the execution of the Phase I. These results show that all of these have a drastic impact on trade flows, with many of the changes favoring imports from the United States. These results also show that during our base period, the United States was predominantly the lowest cost supplier. This is important in that the Phase I agreement has a term related to imports being made so long as the United States is "competitively priced." These results suggest that though the relative delivered costs to China would vary, most of the time the US would be competitively priced. Thus, that China is under-purchasing relative to its Phase I commitments, should not be attributed to the United States not being competitively priced.

6.6. Further Studies/Extensions

There are four areas worthy of further study to further refine these results. These include:

1) <u>Origin basis at Ukraine</u>: While the United States and some other countries have fairly sophisticated and transparent mechanisms for reporting prices, this is not true in Ukraine. This is probably due to that the Ukraine market is still maturing. Nevertheless, there is scant public information on origin basis like in other countries. The data used in this

study was from USDA. However, if this could be improved, it would improve the empirical analysis.

2) Supply response: The model in this study should be interpreted as very short-run. As such, it does not allow a supply response. The model represents supply as a distribution of historical data, and the iterations choose values within that distribution. This differs from a supply-response. Normally, in annual models of aggregate origins (i.e., as countries), a study could capture this by using a supply function. However, this would be challenging as more disaggregated origins are used, and as there are multiple functions (e.g. supply of the commodity, storage and supply of logistical capacity) performed.

   An alternative would be to capture the impact of changes in the basis in response to changes in exports (i.e., $\Delta B/\Delta E$). This could be estimated and is significant in other studies, and can accommodate less aggregated data and relationships. Such a relation could be included in a model as specified here and capture how the basis changes when exports change.

3) Capacity: The model did not explicitly include export capacity, for varying reasons. Nevertheless, the results are suggestive that come routes confront restrictions on shipments due to what we define as supply-constraint. These are further exacerbated as exports increase, in this case for China.

   The effect of capacity constraints should be re-assessed.

4) Production Costs: The model could be expanded to include farm level production costs. This would provide a better view of the comparative advantage of particular origins. However, to do so would require a comparable cost derivation across origins.

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APPENDIX A: OPTIMIZED MONTE CARLO MODELING METHODOLOGY

The optimization problem that is solved for each iteration of the Monte Carlo simulation (with new randomly generated historical values) is as follows:

$$\min_{q_{ij}} C = \sum_{i=1}^{11} \sum_{j=1}^{8} \tilde{c}_{ij} q_{ij},$$

subject to:

$q_{ij} \geq 0,$

$\sum_{j=1}^{8} q_{ij} \leq \tilde{Q}_i$ for all $i = 1, \ldots, 11$ origins,

$\sum_{i=1}^{11} q_{ij} \geq \widetilde{D}_j$ for all $j = 1, \ldots, 8$ destinations.

The objective (first equation) is to minimize the total delivered cost across all trade flows from origins (i) to destinations (j) by selecting the optimal quantity for the trade flow (q_{ij}). In addition to the eight major destination regions, the other remaining destinations are lumped together into a *rest of world* (*ROW*) category.

The first constraint requires all of the trade flows be positive values (i.e., no negative backflows from destination to origins). The second constraint states that the sum of the trade flows from the origins cannot exceed the randomly generated capacity constraint value (Q_i) for each origin. The third constraint states that the sum of the flows to each of the 8 destinations must be greater than or equal to the randomly generated demand (D_j) for that destination. To assure convergence of this optimization model, the ROW is modeled as receiving any excess origin supply from each origin provided that the origin supply constraint is not binding. Therefore, the model is set up such that the main priority is to fully meet the simulated demands from the 8 modeled destination regions with any excess supply allocated to the ROW region.

For the base simulation model, the following additional constraints have been applied to the model. For the EU tariff on all U.S. origin exports, a 25% additional surcharge has been added to the simulated p_{ij} values from U.S. origins to the EU. To reflect current phytosanitary restrictions on South American exports to China, a maximum share of 1% (of all flows to China) has been applied to each origins' q_{ij} flow to China. For current phytosanitary restrictions on South American exports to the EU, a similar constraint with a maximum share of 18% (of all flows to EU) for Brazil and 2% for Argentina has been applied.

To reflect the historical seasonality of some random variables, the base optimization model has been set up to simulate trade flows on a monthly basis. The user selects the particular month using a drop-down list and the simulation uses lookup tables to simulate the correct seasonal value for those variables displaying seasonality in their time series history.

The modeling methodology utilized in this study is known as *optimized Monte Carlo simulation* which differs from traditional *Monte Carlo optimization* or *risk programming*. The important difference is that the values of the random variables are known with certainty by the decision-maker before they solve the optimization problem. Therefore, the results of the analysis provide a statistical summary of optimal decisions across a wide range of possible scenarios that are presented by the Monte Carlo simulation rather than an optimal decision made by the decision maker under risk. Consequently, the output results from each iteration can be summarized as a probability distribution. This distinction is important when interpreting the presented results from the model.

The process for running the optimized Monte Carlo simulation procedure is as follows:

- **Step 1.** Generate, using the @Risk Monte Carlo add-in to Excel, a stochastically simulated value for each of the random variables in the model and then calculate the destination net delivery costs using the random values.

- **Step 2.** Using the random delivery cost values from Step 1, run the linear programming optimization problem using the Excel Solver add-in to determine the optimal trade flows for each origin-destination pair. This is done individually for each iteration.

- **Step 3.** Collect the optimal flows for later statistical summarization and analysis.

- **Step 4.** Return to Step 1 and repeat until the required number of iterations has been conducted to assure statistical convergence of the results (our analysis indicated 500 iterations was sufficient for convergence).

- **Step 5.** Conduct required statistical analysis upon values collected in the data register.

APPENDIX B: TECHNICAL INFORMATION ON STATISTICAL ESTIMATIONS AND FITTING

Statistic	Mean	Standard deviation (n-1)
futures_price | Month-1	392.0434	56.0075
futures_price | Month-2	398.3595	66.8490
futures_price | Month-3	396.5426	66.8735
futures_price | Month-4	391.9219	75.0010
futures_price | Month-5	371.2114	29.2033
futures_price | Month-6	380.4804	38.2192
futures_price | Month-7	384.3231	38.0158
futures_price | Month-8	362.5909	21.8345
futures_price | Month-9	359.9392	15.5462
futures_price | Month-10	373.1255	20.9138
futures_price | Month-11	369.9283	26.5114
futures_price | Month-12	379.4925	31.2034
basis_ChampagneIL | Month-1	-7.9227	11.8154
basis_ChampagneIL | Month-2	-4.8656	10.0294
basis_ChampagneIL | Month-3	-8.0167	11.5501
basis_ChampagneIL | Month-4	-8.5546	7.9840
basis_ChampagneIL | Month-5	-13.8735	6.3281
basis_ChampagneIL | Month-6	-10.8089	3.1647
basis_ChampagneIL | Month-7	-9.1231	9.7535
basis_ChampagneIL | Month-8	-7.0405	11.4313
basis_ChampagneIL | Month-9	-14.8993	9.3172
basis_ChampagneIL | Month-10	-17.0143	12.6484
basis_ChampagneIL | Month-11	-8.5347	11.9166
basis_ChampagneIL | Month-12	-8.0959	10.8920

Figure B-1. Sample mean and standard deviation estimates for nearby futures and Champaign, IL basis (cents per bushel).

Correlation matrix (Spearman) / Group 1:

Variables	futures_price	basis_ChampagneIL	basis_NE	basis_StLouis	basis_kensalND	basis_hudsonSD	basis_waitepark	basis_BrazilFOB	basis_ArgyFOB
futures_price	**1**	0.2857	0.9286	0.3214	-0.0180	0.6071	0.3571	0.4643	0.2857
basis_ChampagneIL	0.2857	**1**	0.5714	0.6786	0.3604	0.5714	0.4286	-0.2500	-0.3571
basis_NE	0.9286	0.5714	**1**	0.6071	0.1081	0.7500	0.3571	0.3214	0.2143
basis_StLouis	0.3214	0.6786	0.6071	**1**	0.4685	0.4286	-0.2143	0.2143	0.2857
basis_kensalND	-0.0180	0.3604	0.1081	0.4685	**1**	-0.3604	-0.4505	-0.1081	-0.3063
basis_hudsonSD	0.6071	0.5714	0.7500	0.4286	-0.3604	**1**	0.6786	0.0357	0.1071
basis_waitepark	0.3571	0.4286	0.3571	-0.2143	-0.4505	0.6786	**1**	-0.2857	-0.4286
basis_BrazilFOB	0.4643	-0.2500	0.3214	0.2143	-0.1081	0.0357	-0.2857	**1**	0.8571
basis_ArgyFOB	0.2857	-0.3571	0.2143	0.2857	-0.3063	0.1071	-0.4286	0.8571	**1**

Figure B-2. Spearman rank-order correlation matrix for month of January.

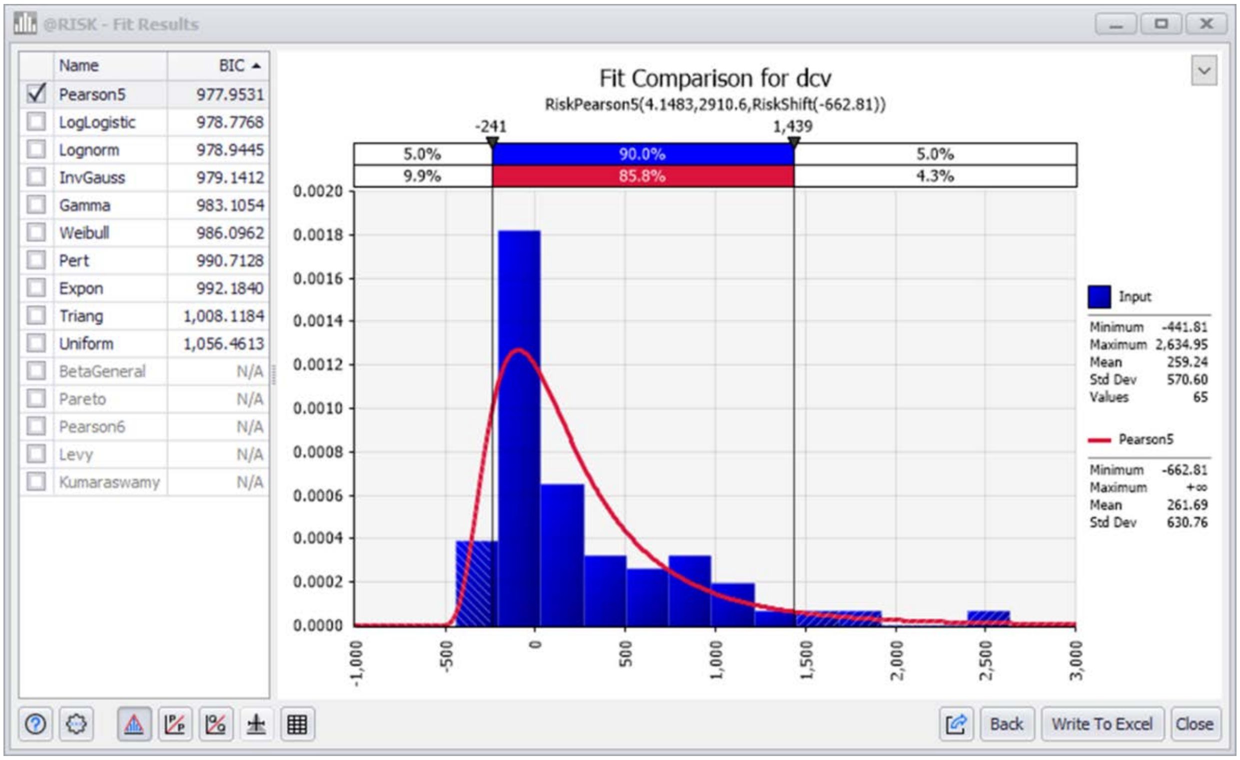

Figure B-3. Palisade *Bestfit* applied to historical secondary railcar market values ($ per car).

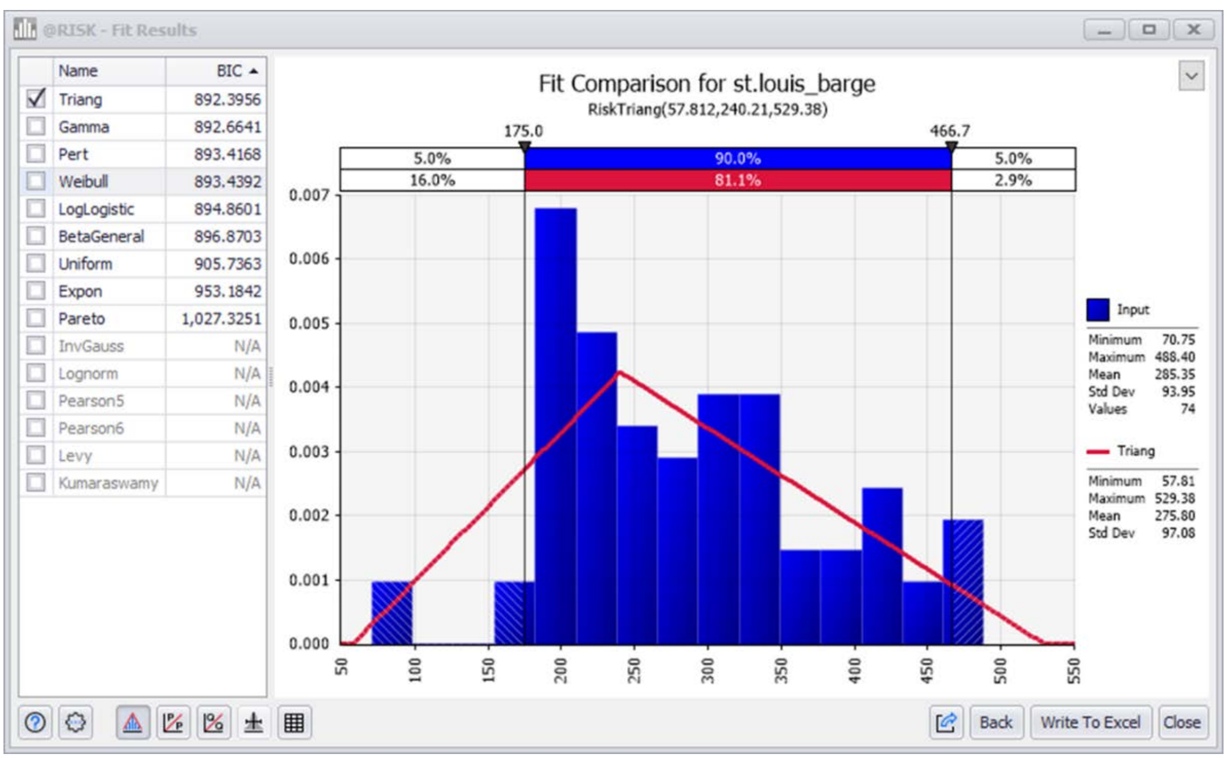

Figure B-4. Palisade *Bestfit* applied to historical St. Louis barge rate (% of base tariff).

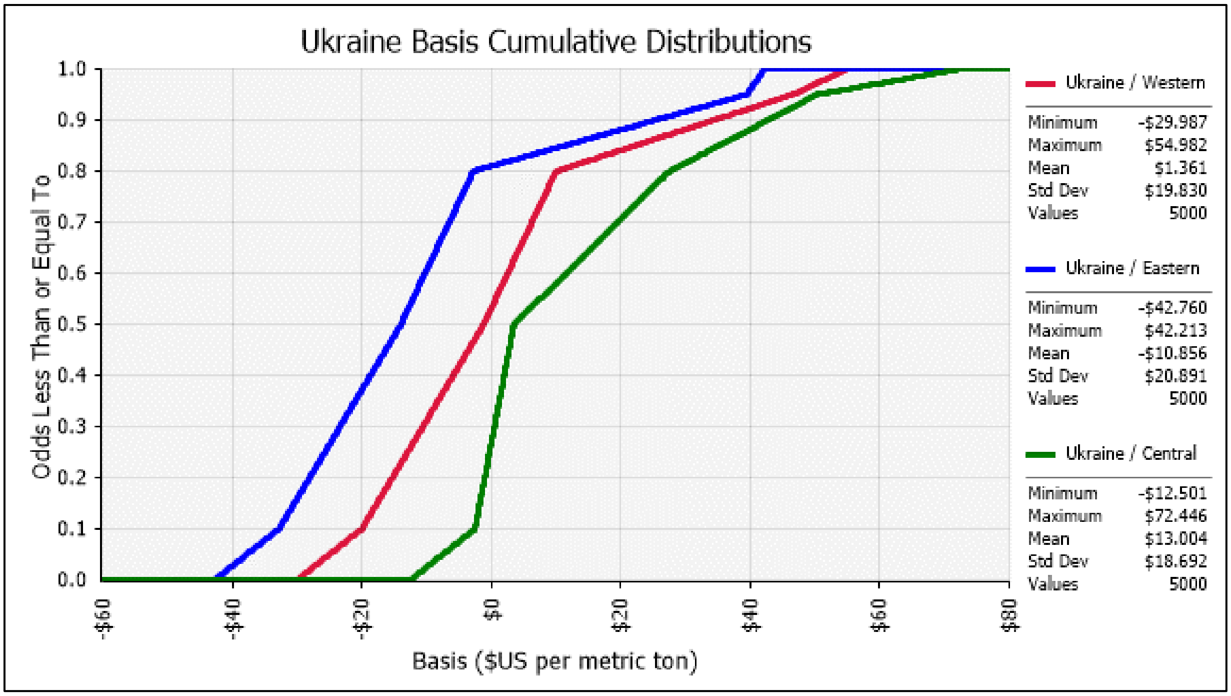

Figure B-5. Representative cumulative basis distributions for Ukraine origin basis (by region).

	Index	Route	Reuters Name
Routes with Full Data	2	Davant, US --> Dalian, China	DRYP-DVTDLC-GRA
	3	Davant, US --> Damietta, Egypt	DRYP-DVTDAT-GRA
	4	Davant, US --> Jakarta, Indo	DRYP-DVTJKT-GRA
	5	USG Miss Riv --> Rotterdam, Netherlands	DRYP-MISRDM-GRA
	6	NOLA, US --> Jeddah, Saudi Arabia	DRYP-MSYJED-GRA
	7	Davant, US --> Tokyo, Japan	DRYP-DVTTYO-GRA
	8	Davant, US--> Ulsan, Korea	DRYP-DVTUSN-GRA
	9	Portland ==> Dalian, CH	DRYP-PDXDLC-GRA
	10	Portland ==> Jakarta, Indonesia	DRYP-PDXJKT-GRA
	11	Portland ==> Tokyo, Japan	DRYP-PDXTYO-GRA
	12	Portland ==> Inchon, South Korea	DRYP-PDXINC-GRA
	13	River Platte ==> Dalian, CH	DRYP-RVPDLC-GRA
	14	River Platte ==> Jakarta, ID	DRYP-RVPJKT-GRA
	15	River Platte ==>Rotterdam, NE	DRYP-RVPRDM-GRA
	16	Bahia Blanca ==> Jeddah, SA	DRYP-BHIJED-GRA
	17	River Platte ==> Tokyo, Japan	DRYP-RVPTYO-GRA
	18	River Platte ==>Ulsan, S.Korea	DRYP-RVPUSN-GRA
	19	Paranagua, Brazil --> Dalian, China	DRYP-PNGDLC2-GRA
	20	Paranagua, Brazil --> Jakarta, Indonesia	DRYP-PNGJKT-GRA
	21	Maceio, Brazil ==> Rotterdam, NL	DRYP-MCZRDM-GRA
	22	Paranagua, Brazil --> Tokyo, Japan	DRYP-PNGTYO-GRA
	23	Paranagua, Brazil --> Ulsan, Korea	DRYP-PNGUSN-GRA
	24	Odessa, Ukraine --> Qingdao, China	DRYP-ODSTAO-GRA
	25	Odessa, Ukraine --> Balikpapan, Indonesia	DRYP-ODSBPN-GRA
	26	Odessa, Ukraine --> Rotterdam, Netherlands	DRYP-ODSRDM-GRA
	27	Odessa, Ukraine --> Jeddah, Saudi Arabia	DRYP-ODSJED-GRA
	28	Odessa, Ukraine --> Chiba, Japan	DRYP-ODSCHI-GRA
	29	Odessa, Ukraine --> Busan, Korea	DRYP-ODSPUS-GRA
	30	Odessa, Ukraine --> HoChiMinhCity, Vietnam	DRYP-ODSSGN-GRA
	31	Odessa, Ukraine --> Jebel Ali Port, Dubai	DRYP-ODSJEA-GRA

Figure B-6. List of routes with full monthly data from Jan 2015 to Apr 2021.

Routes with Partial Data		Route	Reuters Name
	32	NOLA, USA --> Cai Mep, Vietnam	DRYP-MSYTOT-GRA
	33	Longview ==> Dammam, SA	DRYP-LOGDMM-GRA
	34	Longview ==> Cai Lan, VN	DRYP-LOGCLN-GRA
	35	Longview ==> Cai Mep, VN	DRYP-LOGTOT-GRA
	36	Arroyo-Seco ==> El Dekheila, EG	DRYP-ASOEDK-GRA
	37	San Martin ==> Cai Mep, VN	DRYP-SMATOT-GRA
	38	San Martin ==> Cai Lan, VN	DRYP-SMACLN-GRA
	39	Arroyo-Seco ==> Cai Mep, VN	DRYP-ASOTOT-GRA
	40	Puerto Galvan ==> Cai Mep, VN	DRYP-PGVTOT-GRA
	41	Rosario --> Izmir, Turkey	DRYP-ROSIZM-GRA
	42	Rosario ==> Mercin, Turkey	DRYP-ROSMER-GRA
	43	Santos, Brazil --> Damietta, Egypt	DRYP-SSZDAT-GRA
	44	Santos, Brazil --> Cai Mep, Vietnam	DRYP-SSZTOT-GRA
	45	Santos, Brazil --> Cai Lan, Vietnam	DRYP-SSZCLN-GRA
	46	Santos, Brazil --> Hai Lan, VN	DRYP-SSZHLG-GRA
	47	brazil --> Cai Mep, VN	DRYP-IARTOT-GRA
	48	Paranagua --> Izmir, TR	DRYP-PNGIZM-GRA
	49	Paranagua --> Mercin, TR	DRYP-PNGMER-GRA
	50	Nikolaev, Ukraine --> El Dekheila, Egypt	DRYP-NLVEDK-GRA
	51	PNW --> Egypt (Estimated)	None

Figure B-7. List of routes with partial information or rough estimation.

Marketing Year	Million MT					
	PNW Pacific			Gulf - South Atlantic		
	ND (Kensal)	SD (Sioux Falls)	MN (Waite Park)	Lincoln (NE)	MO (St. Louis)	IL (Champaign)
2015-16	2.84	7.87	15.29	10.64	4.27	22.99
2016-17	4.72	8.26	17.78	10.90	5.94	15.95
2017-18	4.93	6.12	18.62	14.86	5.84	22.91
2018-19	4.67	5.84	15.34	15.70	2.90	22.61
2019-20	3.68	0.36	13.56	16.69	1.32	23.34
2020-21	1.19	4.85	20.12	16.26	4.09	24.74

Marketing Year	Percent of Total					
	PNW Pacific			Gulf - South Atlantic		
	ND (Kensal)	SD (Sioux Falls)	MN (Waite Park)	Lincoln (NE)	MO (St. Louis)	IL (Champaign)
2015-16	10.9%	30.3%	58.8%	28.1%	11.3%	60.7%
2016-17	15.4%	26.8%	57.8%	33.2%	18.1%	48.6%
2017-18	16.6%	20.6%	62.8%	34.1%	13.4%	52.5%
2018-19	18.1%	22.6%	59.3%	38.1%	7.0%	54.9%
2019-20	20.9%	2.0%	77.1%	40.4%	3.2%	56.4%
2020-21	4.6%	18.5%	76.9%	36.1%	9.1%	54.9%
Rate	***14.4%***	***20.2%***	***65.4%***	***35.0%***	***10.3%***	***54.7%***

Figure B-8. Amounts and prorating calculation for interior shares by export port.

APPENDIX C: REVIEW OF GLOBAL CORN TRADE INTERVENTIONS

Global corn trade overview: The global corn market has evolved in the last decade. Major importers/destinations of corn include China, Indonesia, Japan, Middle-East, North Africa, South Korea, the European Union, and Vietnam. Similarly, major exporters/origins include the United States (both from US Gulf and US Pacific Northwest), Ukraine, Argentina, Mexico, and Brazil.[17] However, for the purpose of this study, our focus is on the United States and Ukraine as major exporters, and China, the EU, and the North Africa as major importers.

Figure C-1 shows the import shares of corn by destination's total imports from each of the origin between 2012 and 2019. Historically, China imported a majority of its corn from Ukraine (although it was volatile) followed by US PNW and Brazil. Brazil and Argentina dominated Indonesia, the Middle-East, and Vietnam corn markets. United States and Brazil dominated the Japan and the rest of world (ROW) corn imports while Argentina and US Gulf are the major exporters of corn to the Middle-East. South Korea imports most of its corn from US PNW and Brazil followed by Argentina between 2012 and 2019. Ukraine is the major sources for the EU corn imports along with Brazil.

[17] Mexico is also one of the major importers of corn. We exclude Mexico in this study because our main focus is on the logistical competition between the United States and Ukraine to Asian, European, North African, and Middle-East import markets

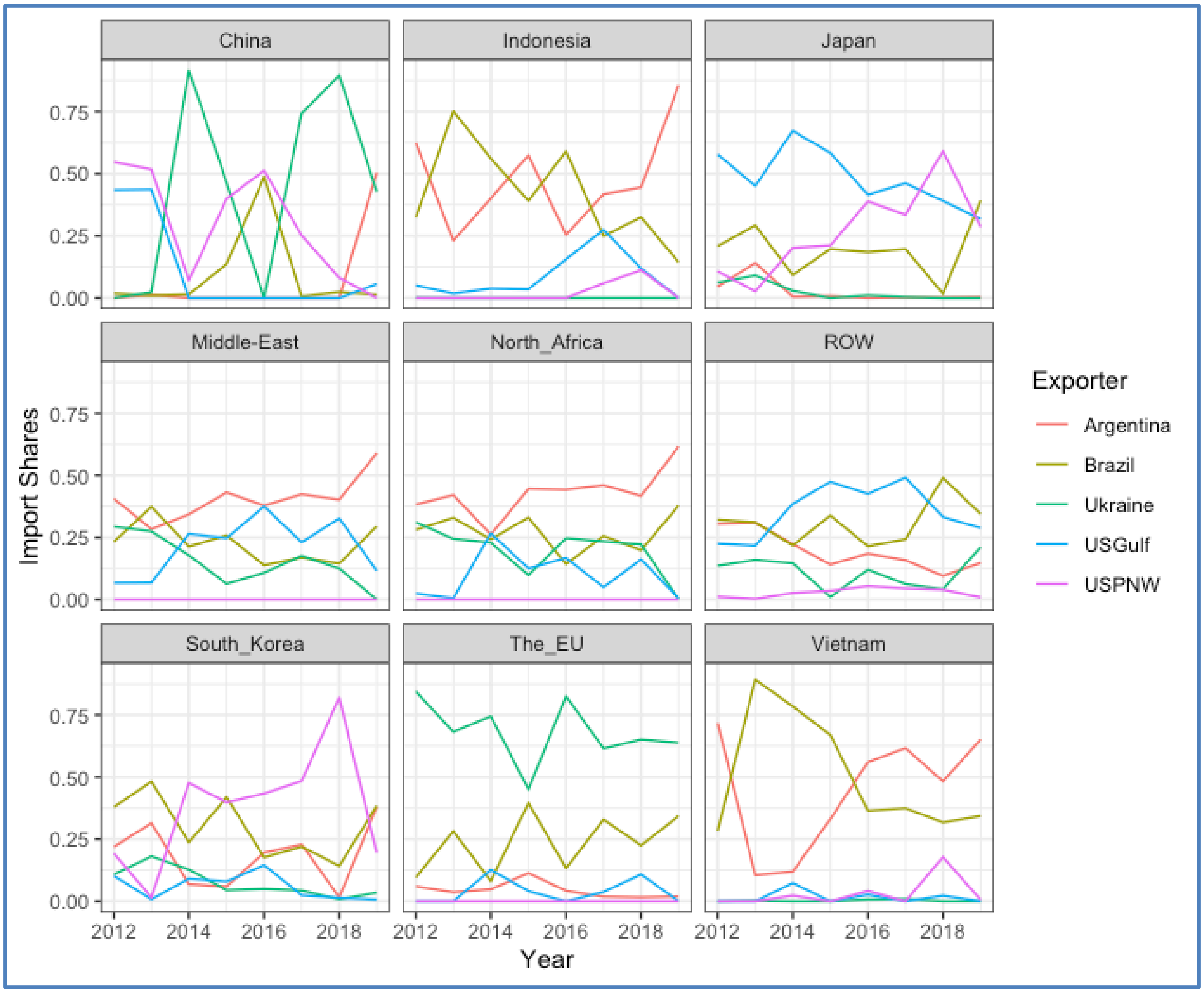

Figure C-1. Corn Import Shares by Destination from Major Exporters, 2012—2019.

Figures C-2—C-4 show the export shares from the US Gulf, US PNW, and Ukraine, respectively. A major share of corn from the US Gulf is exported to the rest of world category. One of the major destinations of the rest of the world category includes Mexico, which we did not include in this study. During the 2012-2019 period, the share of corn exports from the US Gulf to Japan has shown a decreasing trend. Finally, the US Gulf also exports to China and North African countries.

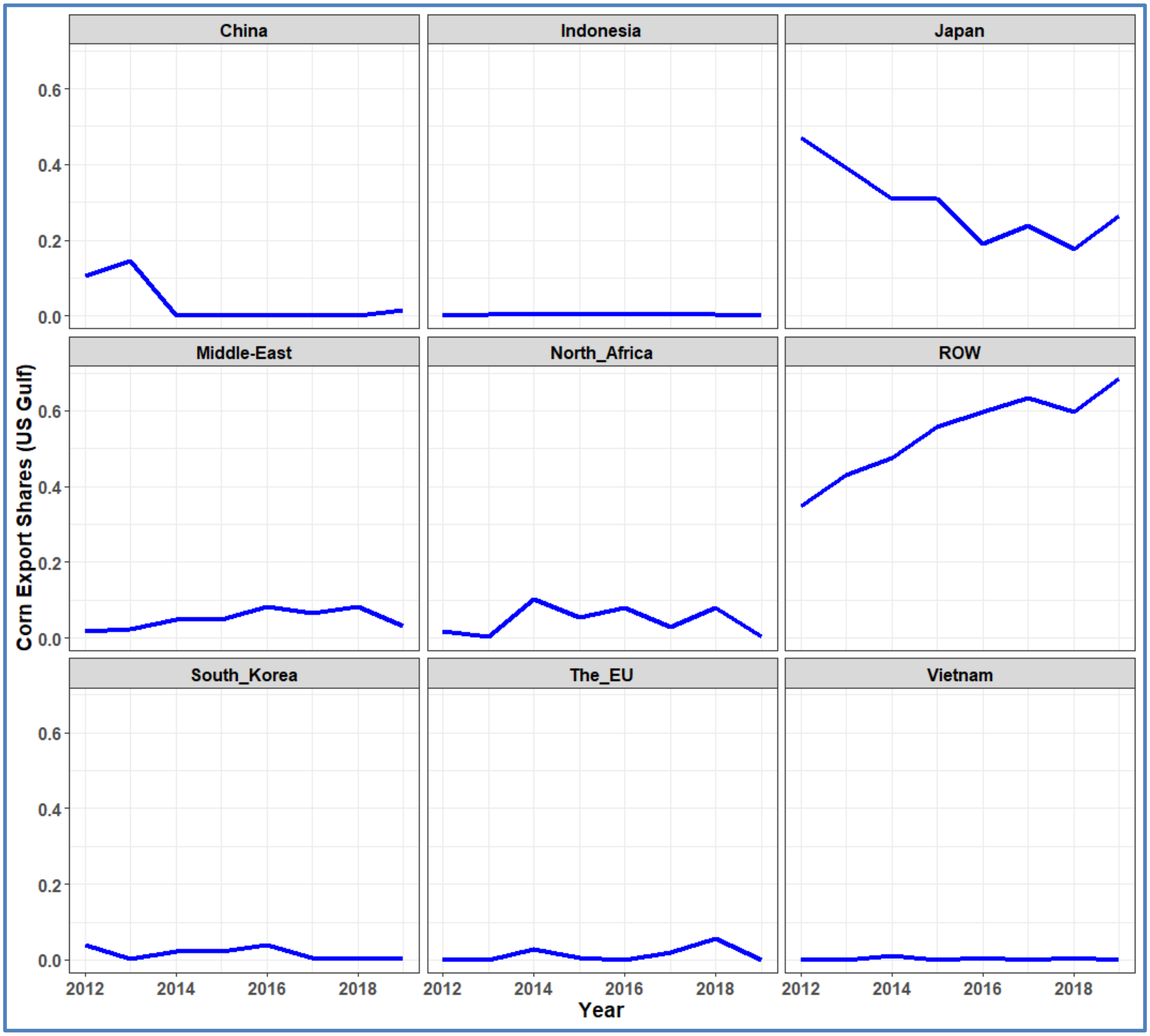

Figure C-2. US Gulf: Corn export shares, 2012—2019

Corn export shares of US PNW are shown in Figure C-3. Japan, South Korea, and China are the key destinations for the corn originating from US PNW. Specifically, the share of corn exports from US PNW to Japan has more than doubled between 2012 and 2019.

Figure C-3. US Pacific Northwest: Corn export shares, 2012—2019

Ukraine is one of the important players in the global corn export market along with the United States, Brazil, Argentina. The European Union market is the dominant market for Ukraine corn exports. Other important destinations for the Ukraine corn include, China, North Africa, and the rest of world.

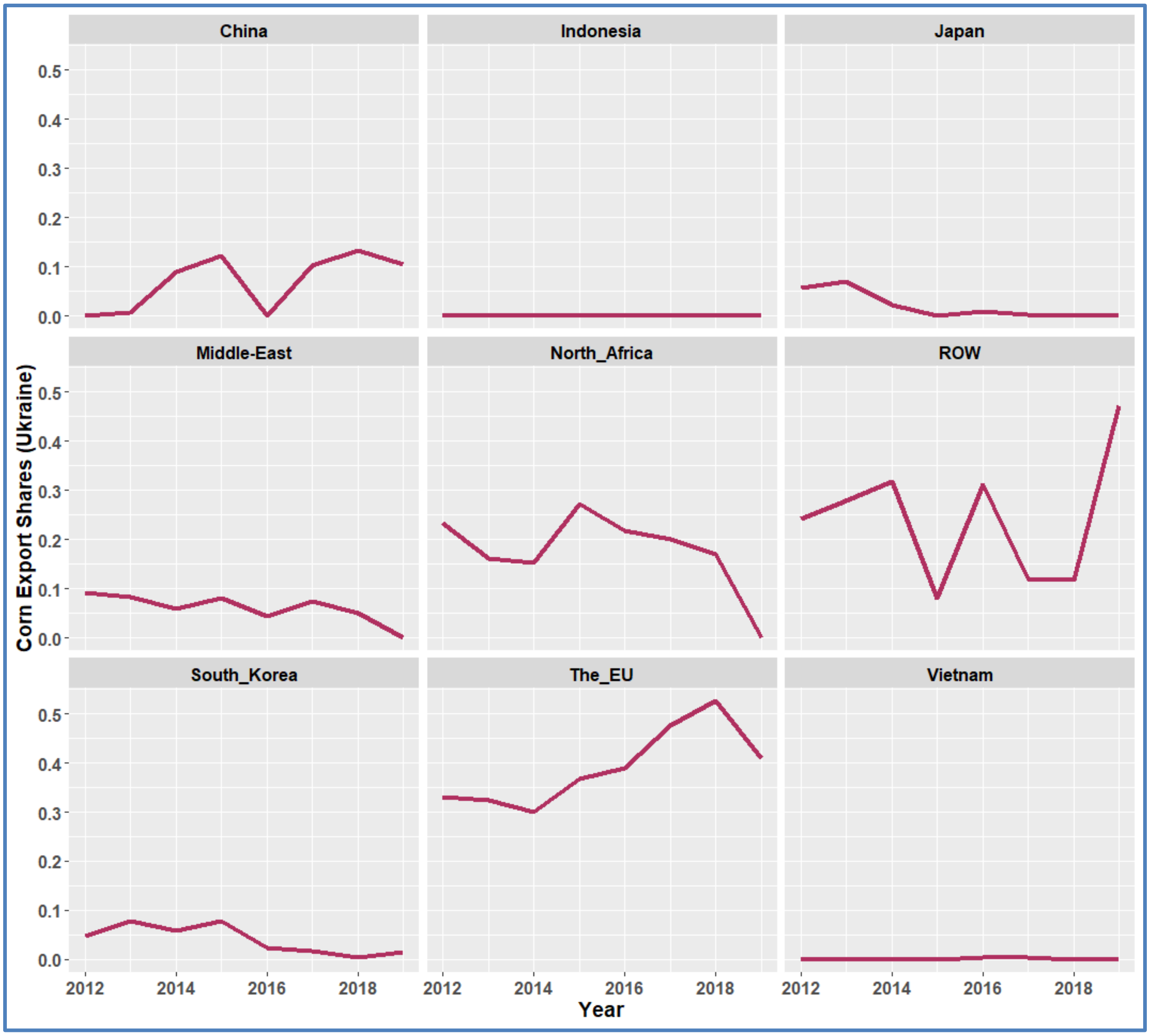

Figure C-4. Ukraine: Corn export shares, 2012—2019

Previous Studies

There are only a few recent studies analyzing competitiveness among corn exporters. Meade et al. (2016) analyzed the export competitiveness of corn (and soybean) from three countries, including Argentina, Brazil and the United States. Their report compared three important parameters, including farm-level production costs, the cost of internal transportation and handling, and the cost of shipping the grain a common destination, across three origins. At a national average level, they find that the United States accounts for the lowest farm-level products costs per bushel of corn compared with Argentina and Brazil. Also, the United States has an advantage in transportation costs especially the inland transportation costs that includes lowest cost barge and rail transportation methods compared with Argentina and Brazil (Meade et al. 2016). However, as shown in this study, this is not true for Ukraine.

Recently, Mallory (2021) analyzed the patters of commodity exports from the United States and Brazil during the first wave of COVID-19 pandemic in the United States between April, 2020 and May, 2020. The study finds that the exports of grain and oilseeds were not affected by the COVID pandemic in 2020.

Trade Interventions

Many changes resulted in the grain and oilseed sector since 2020. Few examples include the increase in transportation costs, especially the ocean shipping rates which affect not only grain and oilseeds export costs but also other commodities, and a significant increase in Chinese corn imports to 30 mmt in 2020-21 that exceeded its 7.2 mmt per year TRQ levels (USDA-FAS, 2021). In this report, we account for these developments with sensitivities to analyze the effect on the market shares of major global corn exporters.

Global corn trade interventions have impacted trade flows and the demand for logistics. There are a few key policies important in this study, including 1) the European Union's 25% tariff on US corn, 2) the European Union's import restrictions on genetically engineered (GM) corn, 3) Chinese tariff rate quota (TRQ) of 7.2 mmt per year and over-quota additional tariff of 65%, 4) sanitary and phytosanitary standards (SPS) of China on corn originating from Brazil and Argentina. Although the Chinese stated policy of 7.2 mmt of TRQ per year is still in place, China imported about 23 mmt in 2020, which was not considered in our analysis.

Though the focus of this study is on domestic and international logistics impacting exporter competition, there are a number of trade interventions that have overriding impacts on the spatial distribution of corn flows. Those that impact corn are summarized in this section.

<u>Chinese Tariff Rate Quotas and Phase I Trade Agreement</u>

China allows a majority of its corn imports from few selected countries that includes the United States, Ukraine, Laos, Bulgaria, Brazil, Argentina, Peru, Thailand, Chile, Germany, and Myanmar. However, periodically, few other countries were added to this list based on the need.

Since 2004, China has been implementing the tariff rate quotas (TRQs) of 7.2 million metric tons (mmt) for its total corn imports for each calendar year (CY) (USDA-FAS, 2015). However, it is only after 2010 that China has become a net importer of corn. Of this 7.2 mmt TRQ, about 40% (3 mmt) is allocated to private sector while the remaining 60% (4.2 mmt) is allocated to Chinese state-owned enterprises, including the SinoGrain and the China Oil and Foodstuffs Corporation (COFCO) (USDA-FAS, 2017a).

Since CY 2020, the unofficial estimates of the total corn imports have risen to exceed the original TRQ quota. In CY 2020 the total Chinese corn imports were estimated to be at about 11.2 mmt (UN-Comtrade, 2021). For CY 2020, unofficial sources indicate that an additional TRQ of 5 mmt has been extended without public announcement to accommodate the Chinese need for corn (USDA-FAS, 2019). There are three main reasons for the change in the TRQ, including 1) increase in Chinese demand for feed caused due to the recovery of the African Swine Fever, 2) Phase 1 trade agreement with the United States allowed China to import more of corn as part of an overall increase in the total agricultural products by China in the agreement, and 3) the Chinese government removal of the price supports for corn in 2016 and the displacement of corn acres into rice and other crops have led to decrease ending stocks of corn in China (USDA-FAS, 2017b).

China has both in-quota and over-quota tariffs imposed based on the 7.2 mmt per CY quota on all of its corn imports irrespective of the exporting country. Specifically, one percent in-quota tariff is implemented for the corn imports less than 7.2 mmt while a 65% over-quota tariff applies to the corn imports that are greater than 7.2 mmt. However, due to a trade war between the United States and China an additional 25% tariff (in response to US Section 301-tariffs on China) has been applied to US corn exports to China since July 2018 (USDA-FAS, 2018; USTR, 2020a). As a result, the tariffs on US corn has increased to 26% (in-quota) and 90% (out-of-quota) between the July 2018 and December 2019.

In 2018, after the United States announced and implemented the Section 301 tariffs on Chinese goods, China retaliated with its own tariffs on several US commodities, including agricultural commodities such as soybeans and corn. This period of tariffs on each other's goods went till December 2019. However, on January 15, 2020, the United States and China signed an economic and trade agreement (Phase One agreement) in which China agreed to purchase $40 billion of U.S. food, agricultural, and seafood products per year for a total of $80 billion for two years between January 2020 and December 2021 (USTR, 2020a). However, the Chinese purchases of U.S. food, agricultural, and seafood products have been short of the targets under the agreement (Bown, 2021)

A critical term in Chapter 6 (pp. 6-1) of the Phase One document, indicated that "*the parties recognize that the United States produces and can supply high-quality, competitively priced goods and services, while China needs to increase the importation of quality and affordable goods and services to satisfy the increasing demand from Chinese consumers*" (USTR, 2020b). However, it was unclear what the term "competitively priced goods and services" means in this specific case.

European Union Interventions

The European Union (including all 28 countries) corn imports have increased from 3.84 mmt in 2010 to a maximum of 23.74 mmt in 2019 and then decreased to 15.82 mmt in 2020 (UN-Comtrade, 2021). Since 2014, the Ukraine's share of the total EU corn imports has increased significantly in part due to signing of the EU-Ukraine Association agreement by both the parties. For example, since 2012, Ukraine has consistently maintained its market share between 50% and 70% of total EU imports (UN-Comtrade, 2021; USDA-FAS, 2016).

The European Union implements two main interventions to regulate its corn imports. First, the EU does not allow GE corn imports for human consumption except for its use for feed and biogas production. Second, tariff rate quotas for Ukraine as well as other corn exporting countries as part of the *Abatimento* agreement (European Commission, 2007).

i) Restriction on GE Corn Imports: Restricting GE corn imports is one of the important trade interventions affecting the flow of corn from major global corn exporting countries into the European Union. Before 2016, there was only one approved genetically engineered (GE) corn variety (MON810) for cultivation in the EU (USDA-FAS, 2016). However, on September 16, 2016, the European Commission approved eleven other GE trait varieties, which are BT resistant to the European corn borer. It is important that the GE corn produced locally is used for animal feed as well as biogas production (USDA-FAS, 2016).

Although the EU restricts GE corn imports, it has a policy of "low level presence" (0.1% limit) of unapproved GE corn in its feed shipment imports (USDA-FAS, 2016). Due to restrictions on imports of GE corn, the United States and Argentina lost a majority of the EU corn market. Table C-1 shows the share of the GE corn in total corn production in each of the exporting country. The percentage of the GE corn shown in Table C1 in part explains why the United States' and Argentina's exports to the EU are minimal while Brazil still maintains a significant share of the EU import market apart from Ukraine.

Table C-1. Share of GE corn in total corn production, 2015

Country	Percentage
Argentina	95%
Brazil	83%
Canada	86%
Russia	0%
Serbia	0%
Ukraine	30%-35%
United States	93%

Source: USDA-FAS, 2016

ii) Tariff rate quotas: As part of the EU intervention on corn imports, Ukraine is allowed to export up to 650,000 mt of corn duty-free, each year (industry experts). If Ukraine's exports exceed 650,000 mt, then those additional exports are subjected to a floating import tariff. Also, as part of the *Abatimento* agreement all the exporting countries are allowed to export up to 2 mmt of corn to Spain and 0.5 mmt of corn to Portugal, duty free.[18] Any additional exports are subjected to a floating import tariff. Although about 93% of the total corn cultivated in the

[18] *Abatimento* agreement signed between the United States and the EU in 1986 allows both Spain and Portugal to import corn (and sorghum) from the United States and other exporters (USDA-FAS, 2020a).

United States is genetically engineered, Spain and Portugal, together constitute a majority of the US exports to the EU largely due to the historical nature of the *Abatimento* agreement.

iii) Floating import tariff and Section 301 tariffs: In general, the EU Commission computes tariff as per the Commission Regulation 642/2010 (USDA-FAS, 2020b). The tariff is computed based on the difference between the European and world references prices of corn each year, or the cost net freight (CNF) price of corn delivered at the port of Rotterdam, Netherlands (USDA-FAS, 2020b). Depending on the year, historically, this tariff has been between 0.26 and 15 Euros/mt based on the market prices (USDA-FAS, 2020b). Finally, on June 22, 2018, the EU has imposed 25% tariff on US corn in response to Section 301 tariffs implemented by the United States on certain imports originating from the EU (European Commission, 2018).

Sanitary and Phytosanitary Standards (SPS)

Some countries have specific sanitary and phytosanitary standards to be complied with for its corn imports. China mandates the relevant phytosanitary laws on its corn imports originating from Argentina (and Brazil) to be free from live insects and quarantine pests. National Food Safety and Quality Service (SENASA) of Argentina is responsible for regulating and certifying the products of both animal and plant origin to prevent, eradicate, and control of spread of diseases (SPS-Protocol, 2012; Industry experts). Regarding the SPS standards, China requires the SENASA and Argentine enterprises to undertake *sifting*, which is a cleaning procedure to significantly reduce soil, plant debris, impurities, weed seeds, and other grain seeds in its corn shipment to China (SPS-Protocol, 2012).

In order to comply with Chinese SPS protocol, two requirements have to be met for the corn trade. First, the Argentine enterprise must possess phytosanitary certificate issued by the SENASA, including the declaration that the corn imports from Argentina is free from the quarantine pests concerned by China (SPS-Protocol, 2012; Industry experts). Second, the Chinese importers must possess an import permit issued by the General Administration of Quality Supervision, Inspection, and Quarantine (AQSIQ) of China (SPS-Protocol, 2012; Industry experts). If pests are detected in the shipment after arrival at the port of destination in China, the shipment will be cleared at the customs and then allowed into China only after the recommended treatment.