

Implications of Rising Ocean Freight Rates for Agri-food Product Markets

Michael K. Adjemian, University of Georgia

Delmy L. Salin, USDA, Agricultural Marketing Service

William W. Wilson, North Dakota State University

Author contact: Michael.adjemian@uga.edu; 706-542-0756

USDA contact: Delmy.Salin@usda.gov

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Michael K. Adjemian is an associate professor in the Department of Agricultural and Applied Economics at the University of Georgia and a consultant to the Commodity Futures Trading Commission. No Commission resources were used in this work and its findings do not necessarily represent its views. Delmy L. Salin is a senior economist at the USDA's Agricultural Marketing Service. William W. Wilson is a professor in the Agribusiness and Applied Economics Department and CHS Chair in Risk Management and Trading at North Dakota State University. We thank Howard O'Neil and seminar participants at both the 2022 USDA Agricultural Outlook Forum and the 2022 meeting of the Transportation Research Forum for their helpful comments.

What Is the Issue?

Toward the end of 2020, as the global economy began to recover from COVID-19-related shutdowns, freight rates for ocean shipping (both container and bulk) increased rapidly. By February 2022, container rates reached their highest levels on record. Simultaneous with soaring rates, lockdowns and traffic increased congestion at U.S. ports. Agricultural stakeholders grew concerned that the rate jumps and traffic congestion could negatively impact U.S. agricultural exports. Because seaborne shipping is central to agricultural trade, a better understanding of the pandemic-era jumps in ocean freight rates is critical. More than 80 percent of the world trade in grains and oilseeds ships by sea—typically, by dry bulk carriers. Many other agricultural commodities are transported via container vessels.

The study's two main objectives are to describe the factors contributing to rising ocean freight rates and to quantify how rates can affect outcomes impacting producers of U.S. agricultural products—i.e., export market shares and commodity prices.

How Was the Study Conducted?

The researchers searched for and quantified causal relationships in the data (freight rates, ocean fleet size, global exports, crude oil prices, port congestion, and global bulk agricultural exports), to understand how ocean freight rates were determined and how they affected U.S. agricultural producers. In an auxiliary approach, the researchers built and estimated a cost-minimization model by Monte Carlo simulation to show how U.S. export market share was expected to change with a rise in ocean shipping costs. In addition, policies undertaken to address the congestion and associated export problems at U.S. ports were identified.

What Did the Study Find?

The researchers quantified the volumes and values of waterborne container shipments of U.S. agricultural exports, relative to other modes (i.e., bulk and air) as follows:

- Waterborne container shipments accounted for just around a quarter (averaging 24 percent monthly, over the last 5 years) of port-level U.S. agricultural exports by volume.
- Despite that modest share by volume, container shipments accounted for *over half of the value* of U.S. agricultural exports (54 percent over the last 5 years).

The researchers found that ocean freight rates for both bulk goods and containers increased with the demand for shipping services, fuel prices, and destination port congestion. Conversely, rates fell with increases in fleet capacity. According to the study's Monte Carlo simulation, the United States would actually gain global corn- and soybean-export market shares when ocean freight rates rise—at least in the short run. Those predictions were consistent with the actual increases in export market share of both U.S. corn and soybeans between marketing years 2019/20 and 2020/21. All of the study's findings were consistent with the USDA's forecast that the value of U.S. agricultural exports will set a record high in fiscal year 2022—even in the face of elevated ocean freight rates. Nonetheless, the research also showed how increases in ocean freight prices could potentially lead to negative consequences for U.S. exporters, including depressed export levels in the short run (although these findings were not statistically significant). The researchers note, however, that even if rising rates lower domestic export levels, the United States can still gain market share if its export competitors suffer an even larger reduction.

Because the analysis found port congestion raised freight rates, the researchers discuss related U.S. policies that are being implemented. These include (1) the development of a Federal portal to convey

detailed supply data, (2) provisions in the newly-passed Ocean Shipping Reform Act of 2022, and (3) targeted infrastructure investments in U.S. ports.

Introduction

Seaborne shipping is vital to international trade, accounting for 80-90 percent of its volume and 60-70 percent of its value (UNCTAD, 2018), and agricultural trade is no exception. For example, more than 80% of the world trade in grains and oilseeds occurs via maritime transport (IGC, 2021), which typically travel by dry bulk carriers (as opposed to the liquid bulk vessels used to move crude oil).² Many other agricultural commodities are generally transported via container vessels, which tend to call at different port terminals due to the need for specialized infrastructure. From the mid-20th century, containerization standardized the shipment of various goods,³ like refrigerated meats and cheeses. While bulk trade leads the worldwide modal shipment of commodities by volume, containerized vessels carry a significant share of their value (AMS, 2021a). For instance, figures 1 and 2 show that although waterborne container shipments account for just around a quarter (averaging 24 percent over the last five years, monthly) of port-level U.S. agricultural exports by volume, they transport over half of their value (54 percent over the same timeframe).⁴

With an abundance of land, a temperate climate, well-developed infrastructure, mature capital markets, and the best technological capacity on the planet, the United States has a natural comparative advantage in many facets of agricultural production. Indeed, despite running an overall merchandise trade

² Bulk goods are homogeneous, unpacked cargo (Kalouptsidi, 2014). Bulk carriers like Capesize vessels, which are too large to pass through the Suez or Panama Canal and must transit the Capes of Africa or South America to traverse the globe, also transport other dry bulk goods like ores and coal (MOL, 2021). Bulk agricultural commodities tend to transport via Panamax, Handymax, and Small Handy vessels.

³ Containerization improved the efficiency of ocean shipping, reducing its expense and increasing the speed of transport (Kutin et al. 2018).

⁴ Port-level shipments include those made by both sea and air. Figure 1 and 2 show that although airborne exports are fractionally small in volume terms (representing about a quarter of a percent of monthly exports over the last five-year period), they represent over 6.4 percent of their value.

deficit for decades, the United States has maintained a positive trade balance in agriculture (EOP, 2018). Yet, given that North America rests between the world's two largest oceans, seaborne transit dominates the export of American agricultural products, and a large share of the income generated by many commodity producers is derived from overseas markets. Export markets purchased nearly 80 percent of U.S. cotton production in 2019/2020;⁵ similarly large export levels prevail for walnuts (68%), almonds (63%), sorghum (60%), pistachios (56%), rice (51%), wheat (50%), and soybeans (47%).

Given that U.S. agriculture is so dependent on export markets and waterborne shipping, it is natural to wonder about the effect that rising ocean freight shipping prices have on the U.S. agricultural sector, specifically the welfare of U.S. producers. This topic is of strong interest to both industry participants and policymakers, as evidenced by the related hearings held by the U.S. House of Representatives Agriculture Committee in November 2021 (Tomson, 2021). As shown in figure 3, beginning in mid-2020, real freight rates for bulk (blue shades) and container (orange hues) shipments increased rapidly, peaked in September 2021, and declined so that inflation-adjusted prevailing rates today are more consistent with pre-pandemic levels. Market observers have tracked and published indices based on bulk shipping rates since the 1980s; historical container indices are available only from the 2000s. Recent spikes in bulk indices more closely resemble similar shocks that occurred as the world recovered from the financial crisis that the much more substantial rises experienced as global trade expanded rapidly in the early part of the 2000s following China's accession to the WTO.⁶ Recent rises in container rates are without precedent in the historical record but clearly correlate well to observed bulk rate shocks since late-2020, when the global economy began to emerge from the Covid-19 pandemic lockdowns.

⁵ These calculations are based on information available at USDA's Foreign Agricultural Service PS&D Database, available at <https://apps.fas.usda.gov/psdonline/app/index.html#/app/home>

⁶ Indeed, as we discuss below, the tight relationship between trade and shipping rates motivated economists to use these rates to infer the state of global economic output. Wall Street interests widely regard dry bulk shipping rates as leading indicators for performance in financial and commodity markets (Lin et al., 2019).

Our objective in this research paper is to describe the factors that contribute to rising ocean freight rates, and then quantify the impact that those rates have on outcomes that affect the producers of U.S. agricultural products. Throughout, we apply retrospective time series methods to estimate the historical relationship between variables we consider; that is, we search for and quantify causal relationships in the data in order to understand how U.S. agricultural producers are affected by ocean shipping costs.

We show that ocean freight rates (for both bulk goods and containers) rise with the demand for shipping services, fuel prices, and destination port congestion, and they fall with increases in fleet capacity. Although short-run median (i.e., most-likely) effects of freight rates on U.S. agricultural export levels and prices-received by producers are in the expected direction, the effects we estimate are not statistically significant. Using an ancillary approach, a Monte Carlo simulation of a cost-minimization model shows that the United States actually gains global corn and soybean export market share when ocean freight rates rise. Those predictions are consistent with the fact that the U.S. share of both commodity export markets increased between 2019/20 and 2020/21 (as well as 2021/22). All of our findings are consistent with the USDA's forecast that the value of U.S. agricultural exports—even in the face of elevated ocean freight rates—set a record in fiscal year 2022 (Kenner et al., 2022).

Determinants of Ocean Freight Rates

Oceans cover three-quarters of the earth's surface, and they separate its factories from its demand centers. Asia produced 53% of the world's manufactured goods (by value) in 2019, according to the United Nations (U.N. Stats, 2021). Residents of the Americas, Europe, Africa, and Australia purchase them, necessitating transport. Maritime shipping is the favored mode due to its relative affordability; Stopford (1997) notes that it is cheaper to import by sea from suppliers several thousand miles away than by land from competing suppliers even just a few hundred miles away. It is no coincidence that, as naval transport grew much cheaper over the last two centuries, world output grew exponentially (OWID, 2021).

Jacks and Stuermer (2021) document the 79% decline in real annual global shipping rates (for bulk goods) between 1850 and 2020; see figure 4. According to those authors, technological improvements in the form of improved naval architecture permitting larger ship capacities, more efficient power plants (from sail to steam and internal combustion), and infrastructure improvements to goods handling and storage drove the long run cost reduction. However, figure 4 also shows that these rates have, at times, spiked abruptly. As Jacks and Steurmer point out, before 1970 these positive shocks are all associated with global conflicts (e.g., World War 2); after 1970, notable rises in real shipping rates are associated with oil price shocks and unexpected increased in worldwide commodity demand.

Figure 4 plots commonly-cited bulk and container shipping rates since the 1980s, adjusted for inflation, at a monthly frequency. Like the annual rates in figure 4, the monthly rates in figure 5 exhibit several booms and busts that match well to commodity demand shocks. While rates spiked in the 2000s following China's WTO accession, the immediate recovery from the financial crisis, and again in late-2020 as the global economy began to emerge from the pandemic and associated lockdowns, their historical record also exhibits a sustained period of moderation and stagnation. This is likely due to the frequently-mentioned "overcapacity problem" in the shipping market (UNCTAD, 2019). Figure 5 shows a clear break in the trend observed in the ratio of global trade volume to the world's industrial production: a steep increase in the early-2000s, and a far less notable rise in the period following the financial crisis. Figure 6 shows that total deadweight tonnage (a measure of the maximum carrying capacity of vessels) in both the bulk and container fleets expanded steadily, to almost three times their size over the same period. Kaloupstidi (2014) notes that as the existing bulk fleet idled during 2008's economic slowdown, a further 70% of that fleet was scheduled for delivery in 2012, owing to the long lag between the order and delivery of new vessels. Together—the reduction in trade relative to production, and the expansion of the fleet—acted to drive and keep shipping rates down—until the recovery from the pandemic. As recently as January 2020 (Dupin), market analysts at shipping research and consulting firm Drewry were still

forecasting that overcapacity would continue to hold container shipping rates down, posing challenges to “battle-hardened” carriers.

Economic Literature on Ocean Freight Rates

Researchers have studied the relationship between the global economy and seaborne shipping since at least Isserlis (1938). Klovland (2002) and Michail (2020) demonstrate the relationship between the macroeconomy and freight rates and transported quantities, respectively. Kilian (2009) even introduces a well-known monthly index of worldwide real economic activity based on dry cargo ocean freight rates, explicitly to capture shifts in the demand for industrial commodities. Likewise, Kilian et al. (2021) construct a new index using container throughput at U.S. ports to identify shocks to U.S. and foreign aggregate demand, and use it to study the determinants of the Covid-19 recession and subsequent recovery.

Kalouptside (2014) explains that while the demand for sea transport is uncertain and subject to random shocks, its supply adjusts sluggishly due to the long time it takes to build vessels. He notes that in the short run the supply of shipping services is quite inelastic;⁷ therefore, fluctuations in shipping demand, in response to changes in economic output, leads to the observed volatility in freight rates.⁸ Kalouptside also points out the important role that vessel operating costs, like fuel, play in considering the evolution of freight rates.

Stopford (2009) models the demand for shipping services as a function of global economic activity and the supply as the size and performance of the global fleet. As in other markets, ocean freight rates ration this supply and demand. In proposing a new annual dry bulk freight index Jacks and Steurmer (2021)

⁷ Kalouptside (2014) recognizes that although capacity is somewhat flexible in that vessel operators can adjust the speed at which they travel, voyage costs are convex (i.e., they increase more than proportionally) in speed.

⁸ This is consistent with the rate volatility observed in figures 3 and 4.

follow this logic, and document and quantify the contribution of economic factors responsible for its fluctuation: global economic activity, fuel prices, and the world supply of shipping. To measure their influence, the authors combine these factors in a structural vector autoregression (SVAR) that uses sign restrictions for identification (i.e., distinguishing among the factors responsible for observed shocks). In relation to rates, they assume that unanticipated increases in (1) the global demand for shipping and (2) fuel prices raise them, and (2) unexpected expansions in the supply of shipping services lowers them. Following Rubio-Ramirez, Waggoner, and Zha (2010) and Arias, Rubio-Ramirez, and Waggoner (2018), Jacks and Steurmer use a Bayesian framework to generate a set of admissible models that are consistent with the data and the specified sign restrictions. They find that positive shipping demand and fuel shocks generally raise freight rates, but that shipping demand has larger and more persistent effects; they also show that negative shipping supply shocks raise freight rates.

Michail and Melas (2020) use a similar approach to model the response of a variety of indexed freight rates,⁹ at a monthly frequency. The authors order these variables in a manner similar to Jacks and Steurmer (2021), and like them find that freight rates rise with vessel loads (of iron but not necessarily grain) and Brent crude oil, and fall as the fleet expands. Michail and Melas also determine that the various rates tend to affect one another. In the container segment, Kutin et al. (2018) relate global economic activity, oil prices, fleet size, industry profitability, and the China Containerized Freight Composite Index (CCFI).¹⁰ Using a nonlinear vector autoregressive approach to account for business cycles in the liner shipping industry (which they base on freight rate growth), the authors find that economic activity raises freight rates during periods of high rate volatility, liner earnings raises rates when volatility is low, larger fleets reduce rates in both regimes, and crude oil tends to raise rates during stable periods.

⁹ Specifically, they study the Baltic Dry Index, the Baltic Clean tanker Index, and the Baltic Dirty Tanker Index.

¹⁰ The CCFI is generated by China's Shanghai Shipping Exchange based on data collected from 22 major international and Chinese shipping companies, for 11 of China's most important ports of departure (Kutin et al., 2018).

Other authors analyze factors that affect groups of individual freight rates—those that prevail between specific export and import locations. For example, Slack and Gouveral (2011) study thirty-five Northern European ports as destinations. Veenstra and Franses (1997) explore whether six different bulk freight rates are cointegrated (whether at least one linear combination of them exists that has a stable mean and variance). Because we are concerned with the impact of ocean freight on the producer side of the entire U.S. agricultural sector, we focus our modelling on U.S. economic aggregates: commodity prices and export levels.

Modeling Ocean Freight Rates

We follow the general approach of Stopford (2009) and Jacks and Steurmer (2021); ocean freight rates are set at the intersection of the supply and demand for freight services. The demand for freight services is determined by the importing and exporting firms that pay ocean shipping firms to move raw, intermediate, and finished goods around the world. The supply schedule of freight services is characterized by the available vessel capacity and the price of fuel.

Here we make one refinement of existing models: congestion at ports affects the available capacity of vessels. Recent articles in the popular press document the shipping backup at a variety of U.S. and international ports, (see, e.g., Burnett, 2021; and Milmo, 2021). Without accounting for this congestion, an understanding of the capacity of vessels to transport goods around the world is incomplete. Unfortunately, congestion data are even more difficult to gather than other types of shipping market data. Figures 7 and 8 plot the average waiting time (in days) for vessels at reporting U.S. ports, according to data maintained by the Refinitiv platform. Clearly, average waiting times increased following the pandemic onset—especially for containerized vessels along the U.S. West Coast. Figure 8 shows that post-pandemic waiting times are the highest on record since 2015, when a labor dispute by longshoremen seriously disrupted activities at thirty U.S. ports on the West Coast (Pinsker, 2015). Another, and perhaps more preferable, method to measure congestion is the capacity of vessels waiting to offload their cargo

at destination ports.¹¹ Figure 9 plots this indicator for containerships at U.S. ports and Panamax bulk carriers, the most commonly used vessels to convey grain from the United States to markets in Asia (AMS 2021b), at Chinese ports. Although the figure shows an increasing trend for both series from 2016-2020, port congestion in both cases is up markedly beginning in late-2020; this shock coincides with steep rises observed in both markets' ocean freight rates as the world economy began to recover from the pandemic-driven downturn.

We therefore develop a Bayesian structural vector autoregression (BSVAR) to study how unexpected shocks to each of these variables affects ocean rates. Vector autoregressions specify observations in each series as a function of its own lagged (i.e., past) values, the other variables in the series and their lags. A structural vector autoregression incorporates economic theory to identify how correlated observations among the variables in the system are generated by likely casual pathways. Ultimately, these types of models permit researchers to quantify the dynamic relationship between variables, stating how unexpected shocks to one of the variables leads to responses across the rest of the system. Because SVARs can incorporate a large number of parameters that increase the chance of overfitting the data researchers have used Bayesian methods to shrink the parameter space by imposing additional structure on the model (by including information about prior beliefs). Such methods have been shown to improve model precision and accommodate a variety of economic issues (Koop and Korobilis, 2010; Koop, 2013; and Gelman et al., 2013). Our approach imposes a “Minnesota” prior (Litterman, 1980)—the hypothesis that all variables in the model follow a random walk, a simple specification that is known to perform well in forecasting macroeconomic time series (Kilian and Lütkepohl, 2017).

¹¹ Unfortunately, the Refinitiv waiting-time data only stretch back to 2015, while the capacity-of-vessels-in-port data from Clarksons are only available as of 2016. This limits the sample period for our time series analysis. However, our impulse response results for the other freight rate determinants are virtually the same when using data that stretch back to 2005 for bulkers, and 2011 for container vessels.

Interpretation of the estimates generated by BSVARs and SVARs more broadly depend on proper identification of how the variables in the system react to structural shocks. Traditionally, SVARs were identified with exclusion restrictions, which in effect assign primacy to variables that are ordered earlier in the system when distinguishing structural shocks from contemporaneous correlations. Because that approach can be overly restrictive and difficult to justify, an increasingly popular identification method today is to use sign restrictions (Uhlig, 2005; Rubio-Ramirez, Waggoner, and Zha, 2010), which is more consistent with economic theory (that generally only offers predictions for the signs associated with certain shocks). Sign-restricted models are “set identified”, meaning that the researcher produces a set of models that are consistent with the data and the identifying restrictions.¹²

For our model of ocean freight rates, we specify our sign restrictions so that (1) the capacity of vessels increases in response to rises in the demand for freight services, and that ocean freight rates (2) rise with the demand for freight services, (3) fall as the supply of freight services increases, (3) rise with the prices of crude oil, and (4) increase as ports become more congested. Finally, we assume that (4) all the variables in the system rise in response to their own positive shocks, a logical and standard empirical assumption. In order to estimate how unexpected shocks to each of the variables in the system affect ocean freight rates, we transform all variables into natural logarithms, de-season and de-trend them. We draw our data for freight rates, fleet size, global TEU exports, and crude oil prices from Bloomberg, and for port congestion and global bulk agricultural exports from the Clarksons Shipping Intelligence platform and Trade Data Monitor. All data are recoded at a monthly frequency, and all prices and freight rates are adjusted for inflation according to the U.S. Consumer Price Index (CPI),¹³ so that all effects we measure are in real terms. All the effects we estimate in this report use available data up to October 2021—the

¹² Note that the null, i.e., empty, set is one potential outcome of sign identification. There may be no model consistent with both the data and the restrictions.

¹³ Jacks and Stuermer (2021) likewise convert their freight rates using a CPI deflator.

peak of freight rates during the post-pandemic period according to figure 3—to be sure to capture the most recent spikes in commodity prices.

We document our results in the form of impulse response functions (IRFs), which indicate how a modeled variable, on average, responds over time to unexpected shocks to other variables (we scaled the IRFs so they represent how each variable responds in percentage terms to a 1% rise in the shocked variable). Our IRFs are plotted over twenty-four month horizons, and display both the modal (most likely) structural model and the range including the 68% and 90% credible sets associated with the data and the imposed restrictions. We interpret these ranges as representing the likelihood that the true effect of a given shock is in the shaded areas portrayed in the IRFs.

The IRFs in figure 10 represent the effects of our four modeled factors on the Baltic Dry Bulk Index (BDI), the most prominent of the available dry bulk freight indices; the IRFs in figure 11 do the same for the price of container shipping, as represented by the CCFI.¹⁴ Figure 10 shows that the BDI rises for a period of several months in response to unexpected increases in global agricultural exports, energy prices, and congestion at destination ports, and falls with shocks to fleet capacity. Although the scales are somewhat different, the IRFs in figure 11 present similar findings for the CCFI. That is, in each case the IRFs in both figures align with *a priori* expectations consistent with economic theory. In relative terms, demand, supply, and congestion shocks make a larger impact on bulk rates than energy price changes; for containerized commodities, 1% shocks to demand and fleet supply have larger effects than do energy or congestion shocks.

Because historical congestion data are limited they reduce the timeframe over which we can estimate our bulk and container models; therefore, for robustness we also estimated them with only demand, supply, and energy factors (which permit a longer period of observation). Those results are

¹⁴ Our results maintain when we use alternate indices, e.g., the Baltic Panamax Index and the HARPEX. We showcase the results in this report because these series are well known benchmarks and easily accessed.

presented in figures 12 (for bulk) and 13 (for containers), adding eleven and five more years of monthly observations for each shipping method, respectively. Notice that the magnitude, direction, and statistical significance of our results is preserved, even in the longer sample.

Effects of Ocean Freight Rate Rises on U.S. Agricultural Prices and Seaborne Exports

Depending on the sensitivity of overseas buyers to transportation costs, rises in ocean freight rates may reduce the demand for U.S. agricultural exports. In theory, this may lead to lower export levels and domestic prices, both of which could harm U.S. producers. In this section, we specify a series of BSVARs similar to the ones we used above to estimate the observed empirical relationship between changes in ocean freight rates and outcomes important to the welfare of U.S. producers.

Visualizing the Data

Before specifying these models, however, we first explore how U.S. exports and price levels for major export commodities have changed since the beginning of the Covid-19 pandemic. USATrade maintains monthly port-level export data for U.S. commodities, by both weight and value; these data also indicate the vessel type used for export: containerized, other vessel, or airborne.¹⁵ As shown in figure 14, in general a single mode of seaborne transport tends to dominate port-level exports of individual U.S. commodities. For example, nearly 92% of U.S. beef (port) exports are transported via container vessel, while less than 7% are exported via bulk carrier—with the remaining 2% being exported by air (totals do not sum to 100% due to rounding). For wheat, the reverse is true: about 98% are exported via bulk vessel, 2% by container

¹⁵ We assume that bulk vessels transport the difference between total recorded oceangoing vessel exports and containerized exports.

ship, and a vanishingly small amount by air.¹⁶ We use the values in figure 14 to select the appropriate freight rate, whether BDI or CCFI, to apply in the models we estimate.

Figure 15a plots indices of the de-seasonalized seaborne export levels for major U.S. export commodities, with the level in January 2020 equal to 100.¹⁷ These indices present the change in the amount (in weight) of commodity exports over the last two years. Although every commodity (appears, but) is not labeled in the chart (for clarity), we point out certain commodities with notable increases or decreases. In addition, we plot the median index level by commodities according to their dominant export-vessel type. That is, the thicker and darker orange line in the chart represents the median index level each month across commodities that tend to export via bulk carrier; the thicker and darker blue line represents the median index level for commodities that tend to export by container vessel. Although the chart presents substantial variability across commodities, median export levels of commodities that travel by bulk or container vessel have increased since the beginning of the pandemic: rising by 9% in the case of predominantly-bulk-transported (i.e., from 100 to 109 in the chart), and by 52% in the case of containerized commodities. Commodities whose seaborne export levels increased notably include sorghum, corn, butter, and oats. Butter exports reached levels not observed for nearly a decade; oats achieved their highest level of waterborne exports since at least 2003, when the USATrade dataset begins. On the other hand, seaborne exports of barley, soybeans, and peanuts were somewhat lower than expected. Although, barley and peanut exports are still higher than they were historically in the period before the early-2010's, and soybean exports increased rapidly towards the end of the period of observation (as depicted in the chart), as the latest harvest began to ship out.

¹⁶ Eggs are a bit of an outlier in that the USATrade data indicate over 20% of their port-level export weight was transported by air from 2003-2021. Presumably those are some high-end eggs.

¹⁷ Purging the series in the chart for expected seasonal increases and decreases helps to identify periods of unexpected shocks.

The Bureau of Labor Statistics publishes producer price indices (PPIs) for a wide variety of goods and commodities. PPIs represent the selling prices that producers receive for their output, and the prices used to generate PPIs are generally the first commercial transaction for a product (BLS, 2021); because they are an index, they are unit free. Moreover, PPIs are available at the same monthly frequency as our exports data. As such, they are a suitable metric for the price that domestic agricultural producers are paid. Similar to figure 15a, figure 15b displays indices of the de-seasonalized PPIs for the commodities we analyze, with the PPI level in January 2020 equal to 100. Clearly, the price data are less variable than the exports data in the previous figure, although certain individual commodities display more distinct rises than others. And like the exports index chart, the median price level of both primarily bulk and containerized-vessel export commodities increased since Covid-19 onset, rising by 43% (for bulk) and 17% for containerized goods. Commodities whose prices increased notably over the period in the chart include beef, eggs, corn, and soybeans. Indeed, the beef PPI reached the its highest level since at least 2003, while corn and soybean prices approached levels not observed since the early-2010's. In contrast, the prices for walnuts, butter, and almonds fell post-January 2020; while PPIs for the latter two are easily within the historical range, walnut prices reached near recorded lows since the BLS data series for the commodity began publishing in 2008.

Measuring the Effect of Ocean Freight Rates on Seaborne Export Levels and Prices of U.S. Commodities

Although median export levels and producer prices for agricultural commodities increased from January 2020 to October 2021, that doesn't rule out a potential negative effect associated with the ocean freight spike. To the contrary, it's possible that either or both export levels and prices were lower than they should have been due to the spike. That is, a higher price of transportation may have placed a drag on outcomes that have direct welfare implications for U.S. producers. To study that, similar to the previous section we specify an empirical model of the historical relationship between ocean freight rates and (1) export levels and (2) domestic prices for U.S. commodities that are sensitive to seaborne trade. By

estimating the historical relationship, we can make inference on whether the large rises in the price of bulk and containerized shipping harmed U.S. producers in a measurable way.

As before, we develop a Bayesian structural vector autoregression (BSVAR) for each commodity market under study to observe how unexpected shocks to ocean rates affect seaborne export levels and producer prices. Recall that a structural vector autoregression uses economic theory to identify how correlated observations among the variables in the system are generated by likely casual pathways, permitting reliable identification. Variables that enter the BSVARs include (1) U.S. personal expenditures on food (from BLS), (2) global industrial production (based on the methodology of Baumeister and Hamilton, 2021), (3) U.S. maritime commodity export levels (in weight, from USATrade), (4) the producer price index (from BLS), and (5) the relevant measure of ocean freight—BDI or CCFI—depending on whether the commodity generally exports via bulk or containerized vessel (from Bloomberg). All models are estimated at the monthly frequency, and all expenditures, prices, and freight rates are adjusted for inflation according to the U.S. CPI.

We use sign restrictions (Uhlig, 2005; Rubio-Ramirez, Waggoner, and Zha, 2010) to impose theory as follows, all else equal: (a) all variables have positive own-effects, i.e., they rise in response to their own positive shocks; (b) exports respond positively to an unexpected rise in global industrial production; (c) prices rise with domestic food expenditures, increase with world industrial production, and rise with exports, and (d) ocean freight prices increase with world industrial production. We model the following U.S. commodities, each of which is sensitive to foreign exports: almonds, barley, beef, butter, cheese, chicken, corn, eggs, meat, milk, oats, peanuts, pork, rice, sorghum, walnuts, and wheat. Recall that we document our results in the form of IRFs that represent how each variable responds in percentage terms to a 1% rise in the shocked variable. These are plotted over twenty-four month horizons, and display both the modal (most likely) structural model and the range including the 68% and 90% credible sets associated with the data and the imposed restrictions; we interpret these ranges as representing the likelihood that

the true effect of a given shock resides in the shaded areas portrayed by the IRFs, with the sign of the modal model effect representing the weight of the likelihood. That is, a positive modal effect means that the data together with the economic theory used to estimate the model indicates a higher likelihood that the effect of the shocked variable on the outcome is positive than negative.

For illustration, we present selected IRFs for a single representative commodity—peanuts—in figure 16,¹⁸ and then an aggregation of the important results : the impacts of freight rates on seaborne export levels and commodity prices in the United States. As shown in panel A of the figure, a 1% rise in domestic food expenditures raises the price peanut producers are paid—at least for several months, while panel B likewise shows a similar boost (although smaller in the modal model) flowing from a rise in global industrial production; both effects are statistically significant (at the 90% credible level). In panel C, a positive shock to exports generates a likely rise in domestic prices, although the effect is smaller by an order of magnitude than the effects in the previous two panels. According to panel D, the modal model predicts that an unexpected rise in prices will reduce exports, although the effect is not statistically different from zero (since the horizontal axis is contained within both the 69% and 90% credible region), while panel E predicts the expected effect that a rise in global industrial production will raise freight rates (in this case the CCFI, since peanuts are primarily exported by container vessel). In panel F, a 1% positive shock in the CCFI lowers domestic commodity prices in the modal model, but the effect cannot be said to be statistically significant with a reliable level of confidence. That is, while the model results predict it is more likely than not that rising ocean freight rates will generate some downward pressure on peanut prices in the United States in the short run, there is a substantial likelihood that they won't. In the same way, panel G indicates that rising ocean freight rates may lower domestic prices (in the modal model) at least for a period of about six months, its likely that their effect will level out relatively quickly; again,

¹⁸ These IRFs are broadly representative of those obtained for the other 16 commodities in our analysis.

these effects cannot be used to rule out the claim that ocean freight has no credible impact on domestic peanut prices or maritime peanut exports.

Figure 17 summarizes our estimates of the average short-run (6-month) export effects generated by a 1% rise in ocean freight rates, by commodity; figure 18 does the same for price effects. The blue and yellow regions represent the average 68% and 90% credible ranges, respectively. The red lines in both figures represent the average modal model values, and the commodities are arranged in the chart from most to least negative modal effects in each case. In reviewing both charts, it is obvious that the expected export and price effects cannot be statistically distinguished from zero. In all cases the models award more likelihood to export losses than gains; in most cases, the modal price effect is likewise negative. And we plotted both figures against the same vertical axis values to demonstrate that uncertainty over price effects is far lower than export effects. To summarize these short-run effects graphically, figure 19 presents a scatter plot of the average modal price and export values for each commodity. The color of the dot (orange for bulk; blue for containerized) represents the dominant seaborne export mode for each commodity. As in figure 17, all commodities in figure 19 have negative modal export effects. Yet, outside of the chicken, beef, and meat, all the containerized commodities tend to have larger negative modal price effects associated with ocean freight rises. Bulk commodities, on the other hand, cluster around the horizontal axis, i.e., the null value. Although we caution that these effects are not statistically significant, our model awards a (slightly) higher likelihood to the possibility that ocean freight rises reduce the domestic price of agricultural commodities that tend to export via container, while having virtually no measurable effect on those that export via bulk vessel. Even so, that modal short-run price effect is less than -0.2%. In addition, while the modal effect of a 1% rise in the BDI on barley exports over is about -0.6% over the next six months, and oats is about -0.4%, the modal short-run effect of an ocean transport

price shock on exports of other important bulk commodities (sorghum, soybeans, corn, wheat, and rice) is less than half of that.¹⁹

Auxiliary Analysis: Effects of Ocean Freight Rises on Corn and Soybean Global Export Market Share

The analysis above illustrated the linkages among ocean freight rates and export prices for both containerized and bulk shipments from the United States. These represent the dynamic interdependencies using monthly data for key agricultural commodities. As illustrated, the impacts are important and vary substantially across commodities, and across containerized and bulk exports. To explore the effect of ocean shipping costs on export competitiveness, we analyzed the impact of ocean rate changes on two important export commodities, soybean and corn. One of the most important changes in the post-covid recovery for bulk commodities is the escalation in related ocean shipping costs. This contrasts somewhat from containerized exports which were also impacted by congestion and numerous other supply chain issues.

Building on models developed in recent studies of spatial competition in corn and soybeans (Scheresky, Wilson, and Bullock, 2022; Wilson, Lakkakula, and Bullock, 2022), this analysis estimates the effects of changes in the BDI and Brent crude oil prices on projected rates for route-specific dry bulk shipments using a partial least squares regression (PLS-R) approach.²⁰ After defining a base case and a ‘shock’, which is set equal to the rise in ocean bulk shipping rates during the post-COVID period (January-November 2021),²¹ the projected route-specific rates are then included in detailed spatial competitive

¹⁹ We note that, although not statistically significant, even these modal effects reverse in sign after six months or so. See panel G of figure 16 for the case of peanuts as a representative example.

²⁰ PLS is used due to multicollinearity in the rates over different routes. For more detail on how the analysis was accomplished and its findings, please see Wilson, Bullock, and Lakkula (2022).

²¹ Specifically, the simulated ocean rates were obtained from the coefficients of the individual PLS regression models with the individual ocean route rates as the dependent variable and three independent variables which included the spot Brent crude oil price, the Baltic Exchange Dry Index (BDI), and a calendar year variable to accommodate long-term trend in the relationship. For the 2021 monthly BDI values, the ‘base’ scenario utilized a time series fit of the historical data through the end of 2020 using the X13 ARIMA automated time series procedure. Forecasted values were derived from the model, along with standard errors, for each month in 2021 using the X13 ARIMA procedure. These were incorporated into a lognormal distribution for simulation of the

models of soybeans (origins: the United States and China; destination: China) and corn (origins: the United States, Brazil, Argentina, and Ukraine; destination: China, the European Union, Indonesia, Japan, the Middle East, North Africa, South Korea, and Vietnam). These scenarios are solved using stochastic spatial cost-minimization models based on Optimized Monte Carlo Simulation procedures. The results are used to determine how the modeled ocean freight shock affects export competition among key competitors. In the case of soybeans, the competitors are US Gulf and US PNW versus Brazil for shipments to China. For corn, the competitors include US Gulf, US PNW, Brazil, Ukraine and Argentina, for shipments to the major importing countries and regions. The difference in the scenario projections between the observed BDI and the counterfactual baseline represents the estimated impact of the shock. The models were simulated using base case ocean freight rates.

Figure 20 shows the estimated effect for both commodities, graphically. According to panel A, the impact of the observed BDI rise on ocean shipping rates increases the soybean export market share (in China) of the United States by 4% at the expense of Brazil. Panel B likewise shows that the United States gains corn export market share and so does Brazil, with reductions for Ukraine and Argentina. Overall, the simulation results illustrate that changes in ocean rates and their relationships cause a re-shuffling of optimal shipments; these increased shipping costs favor the United States as an origin, at least for soybeans and corn. Figure 21 displays the actual (and estimated, for the non-finalized crop years) global export market share for both commodities, by major exporter. For both the soybean (panel A) and corn (panel B) markets, U.S. export share increases before and after the sharp rise in ocean freight rates. Indeed, the U.S. share of exported soybeans and corn rises by 9.7% and 11.7% between 2019/20 and

conditional value given that the supply chain constraints had not occurred in 2021. For the 'shock' scenario, the actual monthly BDI values for 2021 were used to represent the actual impact of the supply chain issues. This value was non-stochastic as it was known with certainty at the time of the study. For the Brent crude price, the monthly value was simulated as a stationary lognormal random variable with a mean of \$70 and standard deviation of \$12 for both scenarios as no major shock was determined between the pre- and post-shock time periods but Monte Carlo simulation was retained so that the results could be determined across a variety of crude oil price scenarios. The calendar year variable was deterministic in both scenarios.

2020/21, respectively. These findings are consistent with the cost-minimization model predictions. They are also not inconsistent with our findings about the direction of the short-run effects of higher ocean freight rates on U.S. export levels; even if rising rates lower domestic exports, the United States can still gain market share if its competitors suffer an even larger reduction.

Addressing the Impacts of Ocean Freight Shocks

We show that increases in ocean freight prices have the potential to lead to negative consequences for U.S. exporters, including depressed prices and export levels in the short run. Our research shows that these shocks can occur as a result of congestion at destination ports. Supply chain backup issues have clearly characterized the pandemic recession and ensuing economic recovery. In order to address associated problems, the U.S. policymakers are at various stages of developing several policy avenues. For example, on June 16th, 2022, President Biden signed into law the Ocean Shipping Reform Act of 2022 (OSRA). Below, we identify several related policy options that are being pursued to address congestion issues at ports in the United States, as well as some that may be considered going forward.

Reforming Regulations of Maritime Shipping Practices

According to our data and USDA forecasts (Kenner et al., 2022), export levels and values for many U.S. agricultural products increased throughout the pandemic, even as congestion at ports in the United States increased to historic levels. Yet, certain activities by ocean carriers raise concerns. For example, in 2021 ocean carriers suspended service at the Port of Oakland, requiring U.S. agricultural exporters to truck commodities and products to congested ports at the Ports of Los Angeles and Long Beach; likewise, agricultural shippers have reported that carriers denied them service and charged unfair fees while rushing the export of empty containers (USDA, 2021), presumably to take advantage of the very high rates they can earn on routes that terminate in the United States (Clayton, 2021). Ocean transport is concentrated among a small number of firms, and in theory firms in such a market can act together (whether expressly or tacitly) to restrict service and increase their profits. Three shipping alliances control

80 percent of global container shipping capacity, and industry profitability is sharply higher since the pandemic onset (The White House, Office of the Press Secretary, 2022).

To address these and related issues, the United States is reforming its maritime regulations. On June 16th, President Biden signed into law the Ocean Shipping Reform Act of 2022 (OSRA), revising the laws governing oceanborne international shipping in the United States, which is regulated by the Federal Maritime Commission (FMC). The new law includes a variety of provisions, including that it (i) requires that ocean carriers provide minimum service standards and certify that any late fees (detention and demurrage charges) comply with regulations, (ii) requires ocean carriers to justify any late fees, (iii) requires ocean carriers to report quarterly data on their shipping throughput, and (iv) forbids ocean carriers from unreasonably declining opportunities for U.S. exports. Moreover, the law (v) prohibits marine terminal operators (in addition to ocean carriers, who are already prohibited from doing so under current law) from retaliating against an exporter if that shipper has used another ocean carrier, filed a complaint against it, or “for any other reason”; the law likewise expands the counterparties protected from retaliation to, besides shippers, their agents and motor carriers. The precise implementation of these provisions will in most cases be done via FMC rulemaking.

Development of a Federal Portal with Detailed Supply Chain Information

The USDA Agricultural Marketing Service and the U.S. Surface Transportation Board have made important strides in developing public websites to provide transportation data.²² However, in collecting data for this study we notice that ocean shipping data are often unavailable or only available at a significant lag and must be aggregated across several expensive proprietary platforms. Commercial firms that engage in the export or import of agricultural goods depend on those data and would likely benefit from uniform, real-time access to a comprehensive transportation data portal because it will permit them to better anticipate

²² See, for instance, the AMS’ Agricultural Transportation Open Data Platform at <https://agtransport.usda.gov/>.

and manage supply chain developments and constraints. Ultimately, supply chain challenges must be resolved by private decision makers, who could make better decisions with more relevant information.

With the aim of strengthening goods supply chains, the Biden Administration announced in March, 2022, that it is facilitating the development of a proof-of-concept information exchange (called Freight Logistics Optimization Works, or FLOW) between a selected group of shippers, container liners, ports, terminal operators, and chassis firms (Johnson, 2022). Following its investigation into data constraints that reduce supply chain efficiencies, the FMC is pursuing the Maritime Transportation Data Initiative (MTDI). The MTDI (Leahy, 2022) is a coordinated effort to satisfy mandated data reporting obligations under the OSRA (see item iii in the subsection above), with real-time data sharing across stakeholders (including trucking, warehouse, chassis, rail, port, and shipping operators) as a means to improve supply chain coordination and efficiency. Other, similar efforts are also ongoing. For example, the Port of Long Beach—in an effort supported by the Port of Oakland and the Northwest Seaport Alliance—is developing a free-of-charge cargo visibility tool (dubbed the Supply Chain Information Highway) that can be integrated into end-user platforms and permits stakeholders like marine terminal operators, transportation providers, and cargo owners the ability to track cargo, plan resource allocation, and minimize delays (Biggar, 2022).

Targeted Infrastructure Investments

Shipping congestion and poor service to shippers may also be a function of less-than-ideal port and nodal infrastructure. Even before recent supply chain shocks revealed significant bottlenecks at American ports, the World Bank (2021) ranked the largest container ports in the United States, the Ports of Los Angeles and Long Beach, in the bottom 10% of over 350 ports worldwide in terms of overall performance; New York & New Jersey, the next largest U.S. port in terms of throughput, ranked at the outer edge of the top third.

Although their recent scale and duration are abnormal, congestion at U.S. ports is not a new or unique problem (figures 7 and 8). Many of the supply chain strategies employed by private decision makers in the United States have evolved in varying ways under current infrastructure constraints and therefore rely on just-in-time provision, with minimal capacity to account for surges in demands or supply interruptions. This is a problem at container port areas in particular.

In the face of record container import levels, storage areas at ports filled up quickly, raising congestion by reducing the space available for the movement of containers and the vehicles used to transport them (The White House, Office of the Press Secretary, 2021). To address that, the U.S. Department of Transportation (DOT) and USDA supported the development of inland pop-up sites at the Ports of Savannah and Oakland (as well as partially covering the cost of associated movement to these sites for agricultural cargo) (Savvides, 2022). These locations serve as overflow space for firms to load and unload containers. According to DOT (2022), after Savannah's pop-up sites were opened, container dwell times fell and fewer vessels anchored at the port. DOT is also planning to allocate \$450 million to improve port-level infrastructure investments. In addition, the OSRA contains a provision whereby the U.S. Comptroller General must submit to Congress a report on the technological capability at U.S. ports compared to foreign ports, and whether adopting better technology at U.S. ports will lower the cost of cargo handling, along with an assessment of any existing barriers to technological adoption.

References

Arias, J.E., J.F. Rubio-Ramirez, and D.F. Waggoner. 2018. "Inference Based on Structural Vector Autoregressions Identified With Sign and Zero Restrictions: Theory and Applications." *Econometrica*, 82(2): 685-720. <https://doi.org/10.3982/ECTA14468>

AMS (Agricultural Marketing Service). 2021a. USDA Agricultural Marketing Service Data on Waterborne Containerized Agricultural Trade. Accessed at: <https://agtransport.usda.gov/stories/s/5fu4-yi8t>

AMS (Agricultural Marketing Service). 2021a. USDA Agricultural Marketing Service Data on the Bulk Vessel Fleet. Accessed at: <https://agtransport.usda.gov/stories/s/bwaz-8sgs>

Baumeister and Hamilton. 2021. "Measuring Global Economic Activity." *Journal of Applied Econometrics*, 36(3):293-303. Accessed at: <https://onlinelibrary.wiley.com/doi/abs/10.1002/jae.2740>

Biggar, K. 2022. "Port of Long Beach data tool backed by Oakland, Northwest Seaport Alliance." *Splash247.com*, March 7th. Accessed at: <https://splash247.com/port-of-long-beach-data-tool-backed-by-oakland-northwest-seaport-alliance/>

Bureau of Labor Statistics (BLS). 2021. "Producer Price Indexes." Accessed at: <https://www.bls.gov/ppi/>

Burnett, J. 2021. "Waiting on That Holiday Gift from Your Online Cart? It Might be Stuck at a Seaport." *NPR*, Stuck in Transit series. November 5th. Accessed at: <https://www.npr.org/2021/11/05/1048678575/waiting-on-that-holiday-gift-from-your-online-cart-it-might-be-stuck-at-a-seapor>

Buzby, M.H. 2018. "The State of the U.S. Flag Maritime Industry." Statement of the Administrator of the U.S. Maritime Administration to the Committee on Transportation and Infrastructure, Subcommittee on Coast Guard and Maritime Transportation, U.S. House of Representatives. January 17th. Accessed at: <https://www.transportation.gov/testimony/state-us-flag-maritime-industry>

Congressional Research Service (CRS). 2020. "The U.S. Trade Deficit: An Overview." *In Focus*. December 9th. Accessed at: <https://sgp.fas.org/crs/row/IF10619.pdf>

Clayton, C. 2021. "U.S. Ag Exporters Come Up Empty." *Progressive Farmer (DTN)*. January 27th. Accessed at: <https://www.dtnpf.com/agriculture/web/ag/news/article/2021/01/26/shippers-sending-empty-containers-us>

Dupin, C. 2020. "Overcapacity Will Continue to Dog Container Shipping in 2020." *Freightwaves*. January 13th. Accessed at: <https://www.freightwaves.com/news/overcapacity-will-continue-to-dog-container-shipping-in-2020>

EOP (Executive Office of the President of the United States). 2018. Economic Report of the President: transmitted to the Congress together with the Annual Report of the Council of Economic Advisers. Washington, D.C.

Federal Maritime Commission (FMC). 2021. "FMC Effort Will Examine How Data Can Improve Ocean Cargo Velocity." Official website of the FMC. November. Accessed at: <https://www.fmc.gov/fmc-effort-will-examine-how-data-can-improve-ocean-cargo-velocity/>

Isserlis, L. 1938. "Tramp Shipping Cargoes, and Freights." *Journal of the Royal Statistical Society*, 101(1):53-146. <https://doi.org/10.2307/2980654>

Jacks, D.S. and M. Stuermer. 2021. "Dry Bulk Shipping and the Evolution of Maritime Transport Costs, 1850-2020." NBER Working Paper Series. Accessed at: <https://www.nber.org/papers/w28627>

Johnson, E. 2022. "White House taps supply chain stakeholders to build national data portal." *The Journal of Commerce online*. Accessed at: https://www.joc.com/technology/white-house-taps-supply-chain-stakeholders-build-national-data-portal-20220315.html?utm_campaign=CL_JOC%20Ports%203%2F16%2F22%20%20_PC00000_e-production_E-130555_TF_0316_0900&utm_medium=email&utm_source=Eloqua

- Kalouptsi, M. 2014. Time to Build and Fluctuations in Bulk Shipping. *American Economic Review*, 104: 564–608. <https://doi:10.1257/aer.104.2.564>
- Kenner, B., J. Hui, and D. Russell. 2022. *Outlook for U.S. Agricultural Trade: August 2022*. USDA Economic Research Service and Foreign Agricultural Service Situation and Outlook Report AES-118. August 30th. <https://www.ers.usda.gov/publications/pub-details/?pubid=104621>
- Kilian, L., 2009. Not All Oil Price Shocks are Alike: Disentangling Demand and Supply Shocks in the Crude Oil Market. *American Economic Review*, 99: 1053–1069. <https://doi.org/10.1257/aer.99.3.1053>
- Kilian L., and H. Lütkepohl. 2017. *Structural Vector Autoregressive Analysis*. Cambridge University Press. <https://doi:10.1017/9781108164818>.
- Kilian, L., N. Nomikos, and X. Zhou. 2021. “Container Trade and the U.S. Recovery.” Federal Reserve Bank Dallas Working Paper. Accessed at: <https://www.dallasfed.org/-/media/documents/research/papers/2021/wp2108.pdf>
- Klovland, J.T. 2002. *Business Cycles, Commodity Prices and Shipping Freight Rates: Some Evidence from the Pre-WWI period*. A Report for the Institute for Research in Economics and Business Administration. Bergen, Norway. Accessed at: <http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.195.557&rep=rep1&type=pdf>
- Koop, G.M. 2013. “Forecasting with Medium and Large Bayesian VARs.” *Journal of Applied Econometrics*, 28(2), 177–203. <https://doi:10.1002/jae.1270>.
- Koop, G.M., and D. Korobilis. 2010. “Bayesian Multivariate Time Series Methods for Empirical Macroeconomics.” *Foundations and Trends in Econometrics*, 3(4), 267–358. <https://doi:10.1561/0800000013>.
- Kutin, N., Z. Moussa, and T. Valee. 2018. “Factors Behind the Freight Rates in the Liner Shipping Industry.” Working Paper. halshs-01828633f. Accessed at: <https://halshs.archives-ouvertes.fr/halshs-01828633/document>
- Leahy, E. 2022. “A Look Inside the Maritime Transportation Data Initiative.” *Tideworks Technology Industry Insights*. Accessed at: <https://tideworks.com/what-is-maritime-transportation-data-initiative/>
- Lin, A.J., H.Y. Chang, and J.L. Hsiao. 2019. “Does the Baltic Dry Index drive volatility spillovers in the commodities, currency, or stock markets?” *Transportation Research Part E*, 127: 265–283. <https://doi.org/10.1016/j.tre.2019.05.013>
- Litterman, R.B. 1980. “A Bayesian Procedure for Forecasting with Vector Autoregressions.” MIT Working Paper, (275).
- Milmo, C. 2021. “Shipping Crisis ‘To Last Until Next Summer’ as Container Vessels Queue in the Channel for European Ports.” *inews.co.uk*. October 9th. Accessed at: <https://inews.co.uk/news/long-reads/shipping-crisis-last-next-summer-2022-container-ships-queue-channel-european-ports-1240039>
- Michail, N.A., and K.D. Melas. 2020. “Quantifying the Relationship Between Seaborne Trade and Shipping Freight Rates: A Bayesian Vector Autoregressive Approach.” *Maritime Transport Research*, 1(100001). <https://doi.org/10.1016/j.martra.2020.100001>

- MOL (Mitsui O.S.K. Lines). 2021. Dry Bulkship Transport. Accessed at: https://www.mol.co.jp/en/iroiro_fune_e/ships/01_bulk.html
- OWID (Our World In Data). 2021. World GDP Over the Last Two Millenia. Accessed at: <https://ourworldindata.org/grapher/world-gdp-over-the-last-two-millennia>
- Pinsker, J. 2015. "How 14,000 Workers Managed to Slow Down the Entire Economy." *The Atlantic*. February 24th. Accessed at: <https://www.theatlantic.com/business/archive/2015/02/how-only-14000-workers-briefly-slowed-down-the-entire-economy/385858/>
- Rubio-Ramirez, J.F., D.F. Waggoner, and T. Zha. 2010. "Structural Vector Autoregressions: Theory of Identification and Algorithms for Inference." *Review of Economic Studies*, 77(2): 665-696.
- Savvides, N. 2022. "USDA puts up cash for 'pop-up' port terminal at Oakland for agri-export drive." *The Loadstar*. February 2nd. Accessed at: <https://theloadstar.com/usda-puts-up-cash-for-pop-up-port-terminal-at-oakland-for-agri-export-drive/>
- Scheresky, G., W.W. Wilson, and D. Bullock. 2021. Spatial and Logistical Competition for Shipments to China from the United States and Brazil, Agribusiness and Applied Economics Report 812. Department of Agribusiness and Applied Economics, November 2021.
- Slack, B., and E. Gouvenal. 2011. "Container Freight Rates and the Role of Surcharges." *Journal of Transport Geography*, 19(6): 1482-1489.
- Stopford, M. 1997. *Maritime Economics*. Psychology Press, Routledge. New York, NY.
- The White House, Office of the Press Secretary. 2021. "Recent Progress and Actions on Port Congestion". February 28th. Accessed at: <https://www.whitehouse.gov/briefing-room/blog/2021/11/10/recent-progress-and-actions-on-port-congestion/>
- The White House, Office of the Press Secretary. 2022. "FACT SHEET: Lowering Prices and Leveling the Playing Field in Ocean Shipping". November 10th. Accessed at: <https://www.whitehouse.gov/briefing-room/statements-releases/2022/02/28/fact-sheet-lowering-prices-and-leveling-the-playing-field-in-ocean-shipping/>
- Tomson, B. 2021. "House Ag Tackles Crises in Trucking and at Ports". *Agri-Pulse*, November 3rd. Accessed at: <https://www.agri-pulse.com/articles/16748-house-ag-tackles-crises-in-trucking-and-at-ports>
- Uhlig, H. 2005. "What are the effects of monetary policy on output? Results from an agnostic identification procedure." *Journal of Monetary Economics*, 52(2):381-419. <https://doi.org/10.1016/j.jmoneco.2004.05.007>
- U.N. Stats (United Nations Department of Economics and Social Affairs, Statistics Division). 2021. National Accounts – Analysis of Main Aggregates (AMA) Data. Accessed at: <https://unstats.un.org/unsd/snaama/Index>
- UNCTAD (United Nations Conference on Trade and Development). 2018. 50 years of Review of Maritime Transport, 1968–2018: Reflecting on the past, exploring the future. *Transport and Trade Facilitation Series, No 11*. Accessed at: <https://unctad.org/webflyer/50-years-review-maritime-transport-1968-2018-reflecting-past-exploring-future>

United States Department of Agriculture (USDA). 2021. "Transportation and Agriculture Departments Urge End to Reduced and Poor Service for U.S. Grown Agricultural Commodities." Press release no. 0274.21. December 17th. Accessed at: <https://www.usda.gov/media/press-releases/2021/12/17/transportation-and-agriculture-departments-urge-end-reduced-and>

United States Department of Transportation (DOT). 2022. "DOT Lays Out Actions to Strengthen Supply Chains and Revitalize the Economy." Press release. February 24th. Accessed at: <https://www.transportation.gov/briefing-room/dot-lays-out-actions-strengthen-supply-chains-and-revitalize-economy>

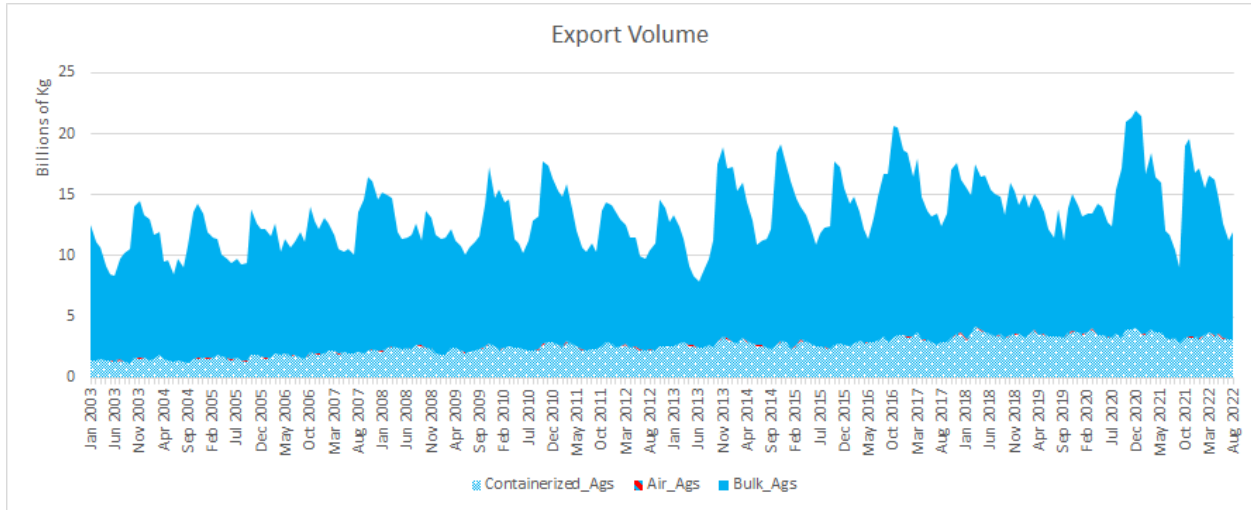
Veenstra, A.W., and P.H. Franses. 1997. "A Co-integration Approach to Forecasting Freight Rates in the Dry Bulk Shipping Sector." *Transport Research Part A: Policy and Practice*, 31(6): 447-458.

Wilson, W. W., P. Lakkakula, and D. Bullock. 2022. *Logistical Competition for Corn Shipments from the United States and Ukraine to Targeted International Markets*. Agribusiness and Applied Economics Report 812. Department of Agribusiness and Applied Economics and USDA. February.

Wilson, W. W., P. Lakkakula, and D. Bullock. 2022. *Recent Surges in Ocean Transportation Rates and Their Effects on Grains and Selected Agri-food Product Markets*. Presented at the 2022 USDA Agricultural Outlook Forum. February.

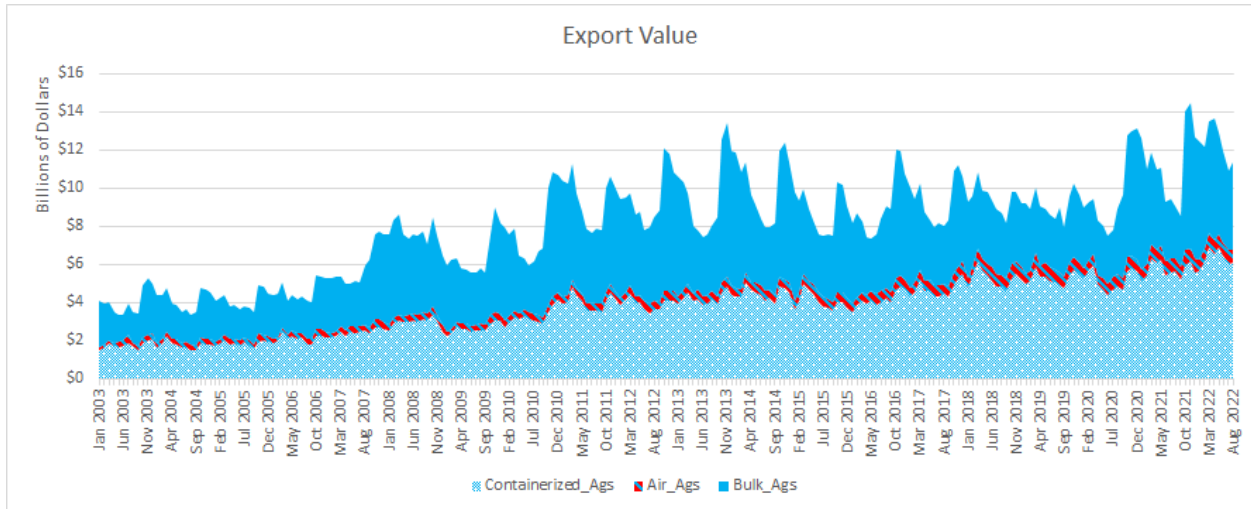
World Bank (International Bank for Reconstruction and Development). 2021. *The Container Port Performance Index*. Accessed at: https://www.maritimes.gr/images/PORTS/Container-Port-Performance_Index-WB-2021.pdf?t=1620669079

Figure 1. U.S. Maritime and Airborne Export Volume for Agricultural Products, by Month



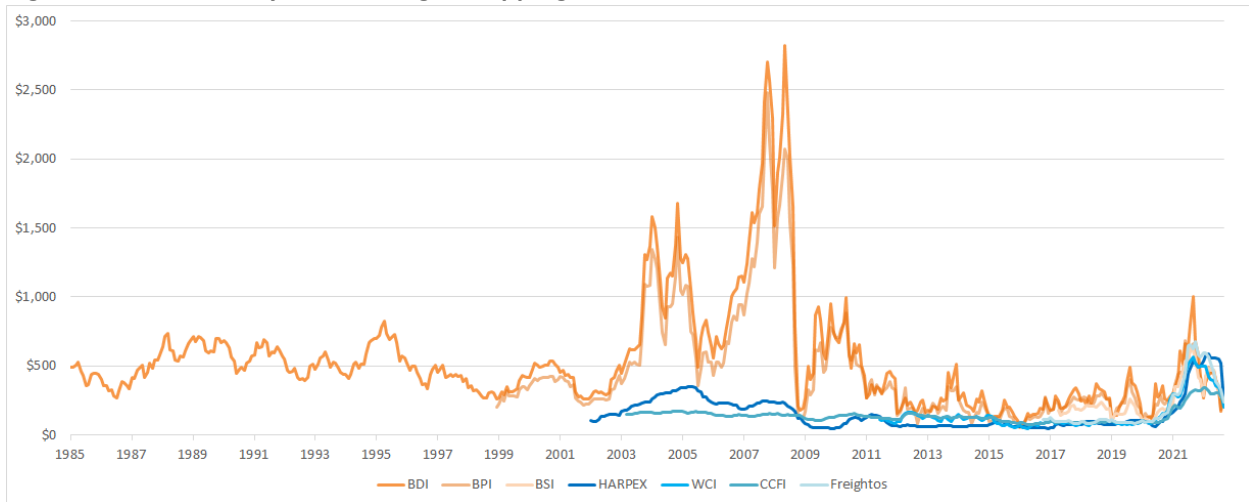
Source: USATrade and authors' calculations.

Figure 2. U.S. Maritime and Airborne Nominal Export Value for Agricultural Products, by Month



Source: USATrade and authors' calculations.

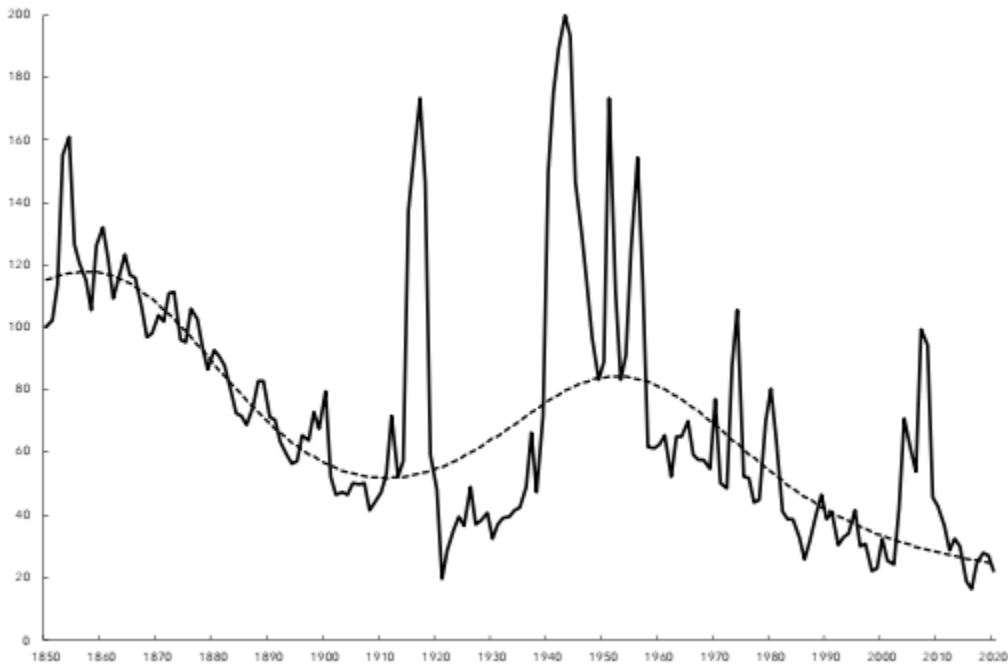
Figure 3. Real Monthly Ocean Freight Shipping Indices, 1985-2022



Sources: Clarksons Shipping Intelligence, Bloomberg, and authors' calculations.

Notes: BDI = Baltic Dry Index; BPI = Baltic Dry Panamax Index; BCI = Baltic Dry Capesize Index; BSI = Baltic Dry Supramax Index; HARPEX = HARPER PETERSEN Charter Rates Index; WCI = Drewry World Container Index; CCFI = China Containerized Freight Index; Freightos = Freightos Baltic Index for containers. All rates converted to real Jan 2021 dollars, and then indexed to a value of 100 in January 2020.

Figure 4. Jacks and Steurmer (2021) Annual Real Dry Bulk Index, 1850-2020 (1850=100)



Source: Jacks and Steurmer (2021)

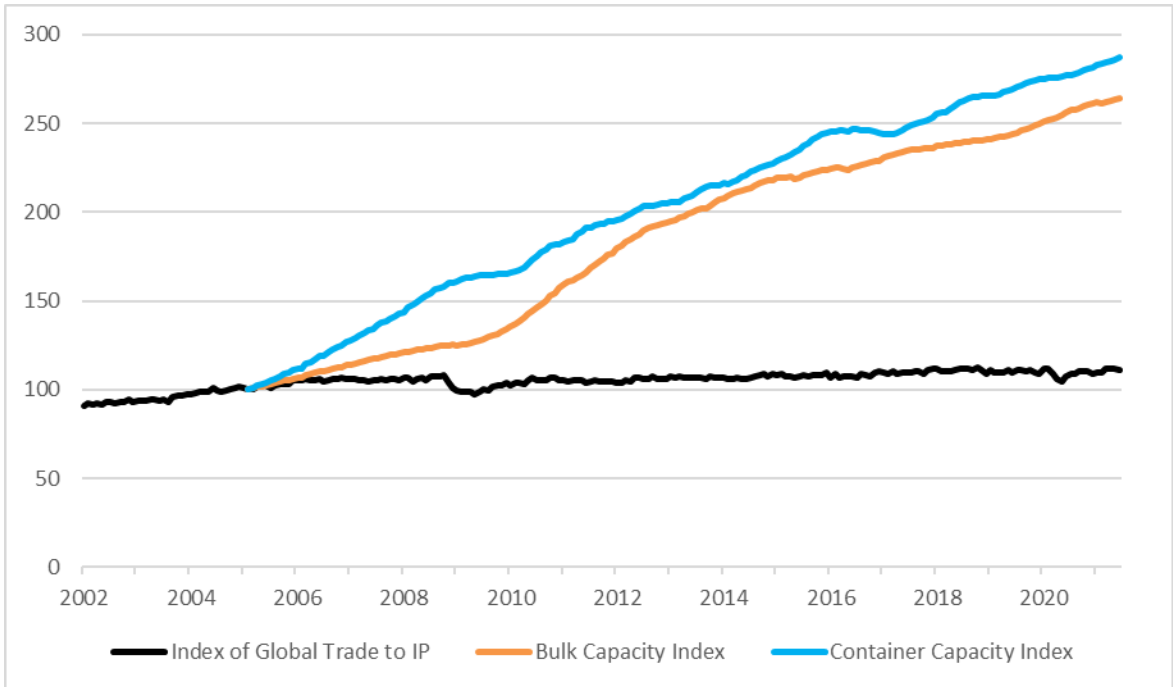
Notes: The solid black line represents the real dry bulk freight index. The dashed black line is an estimate of the long-run trend.

Figure 5. Index of Global Trade Volume to Industrial Production (Feb 2005 = 100)



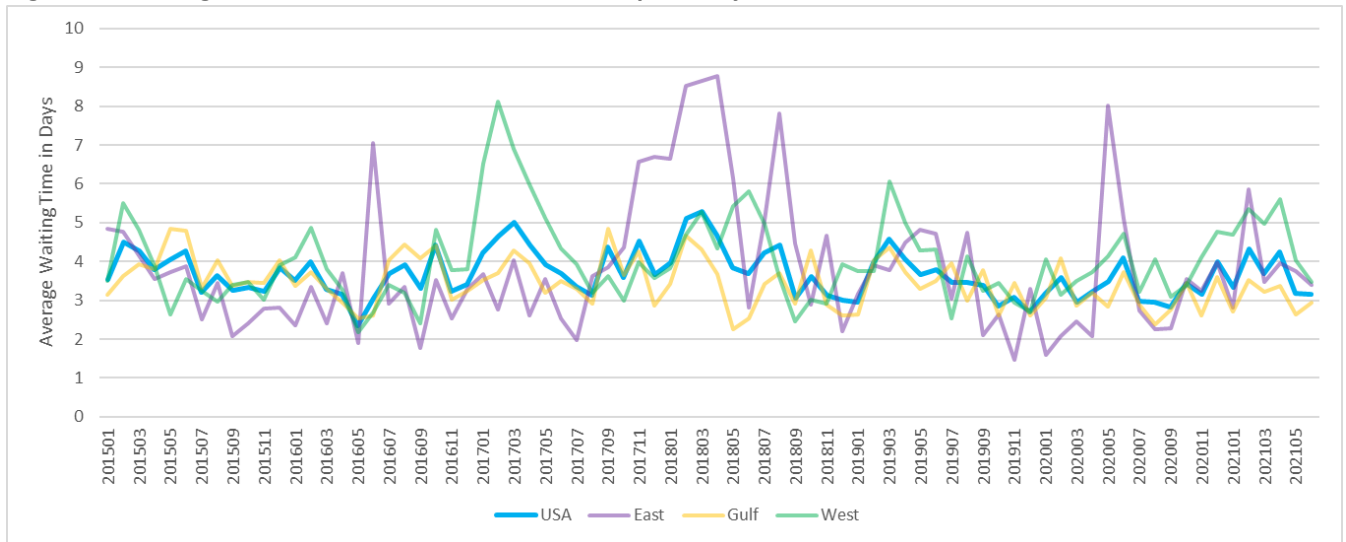
Sources: CPB Netherlands Bureau for Economic Analysis, Baumeister and Hamilton (2021), and authors' calculations.
 Notes: The index expresses the ratio of global trade volume to global industrial production.

Figure 6. Indices of Global Trade Volume to Industrial Production, and the Capacities of the Bulk and Container Fleets (Feb 2005 = 100)



Sources: CPB Netherlands Bureau for Economic Analysis, Baumeister and Hamilton (2021), Bloomberg, and authors' calculations.
 Notes: The index of global trade to industrial production expresses the ratio of global trade volume to Global GDP. The fleet indices are based on the aggregate deadweight tonnage.

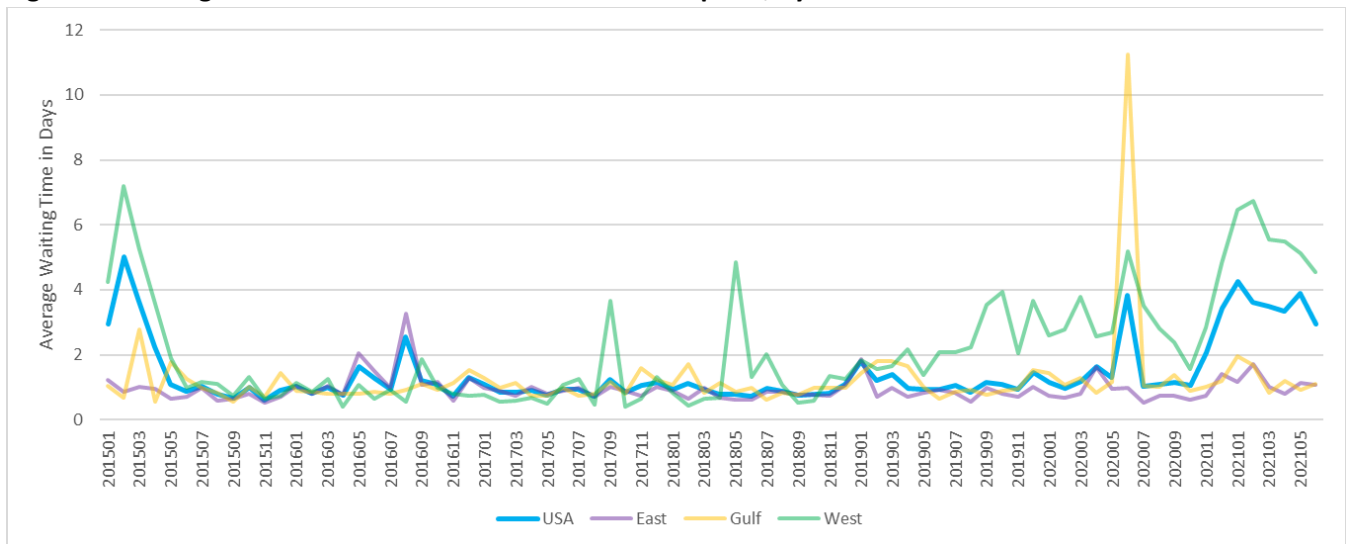
Figure 7. Waiting time for bulk vessels to enter U.S. ports, by month and coast



Sources: Refinitiv and authors' calculations.

Notes: These series represent the simple average of waiting times at reporting U.S. ports. Many ports do not report each month.

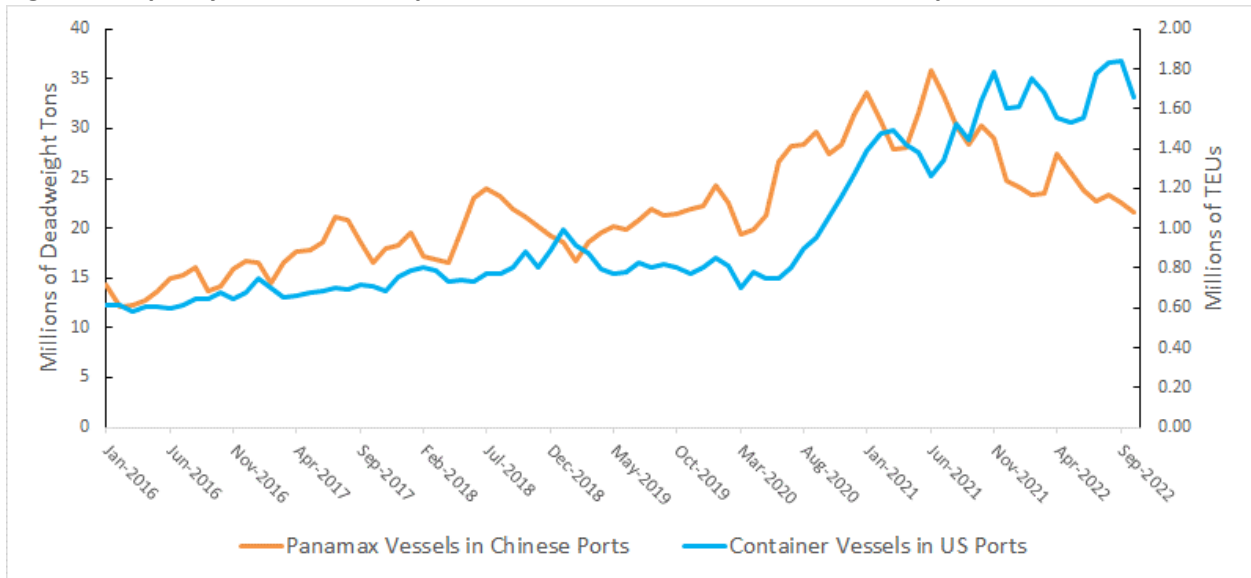
Figure 8. Waiting time for container vessels to enter U.S. ports, by month and coast



Sources: Refinitiv and authors' calculations.

Notes: These series represent the simple average of waiting times at reporting U.S. ports. Many ports do not report each month.

Figure 9. Capacity of Containership and Panamax bulk vessels in destination ports



Sources: Clarksons shipping intelligence network and authors' calculations.

Figure 10. Impulse response functions for the determinants of dry bulk cargo ocean freight rates, 2016-2021

Figure 10a. Impact of a 1% increase in worldwide seaborne agricultural exports on the Baltic Dry Index

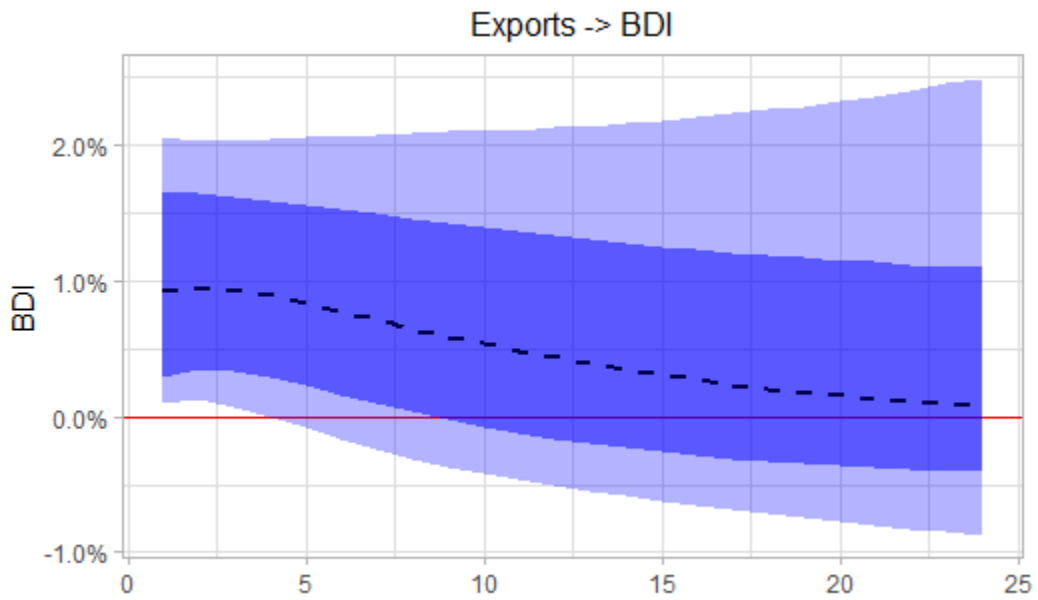


Figure 10b. Impact of a 1% increase in bulk vessel fleet (in deadweight tonnage) on the Baltic Dry Index

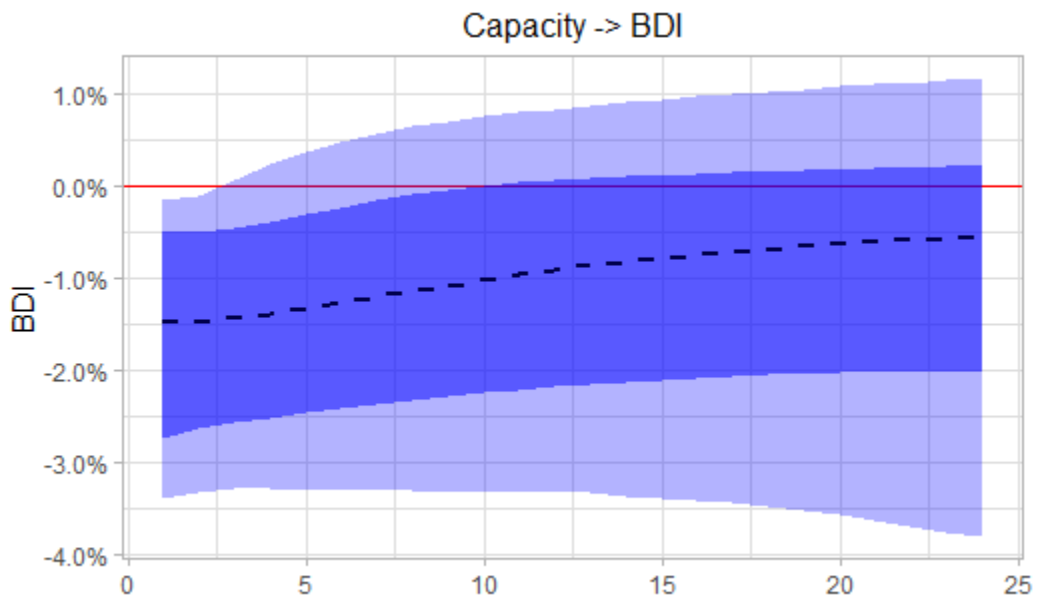


Figure 10c. Impact of a 1% increase in the price of crude oil on the Baltic Dry Index

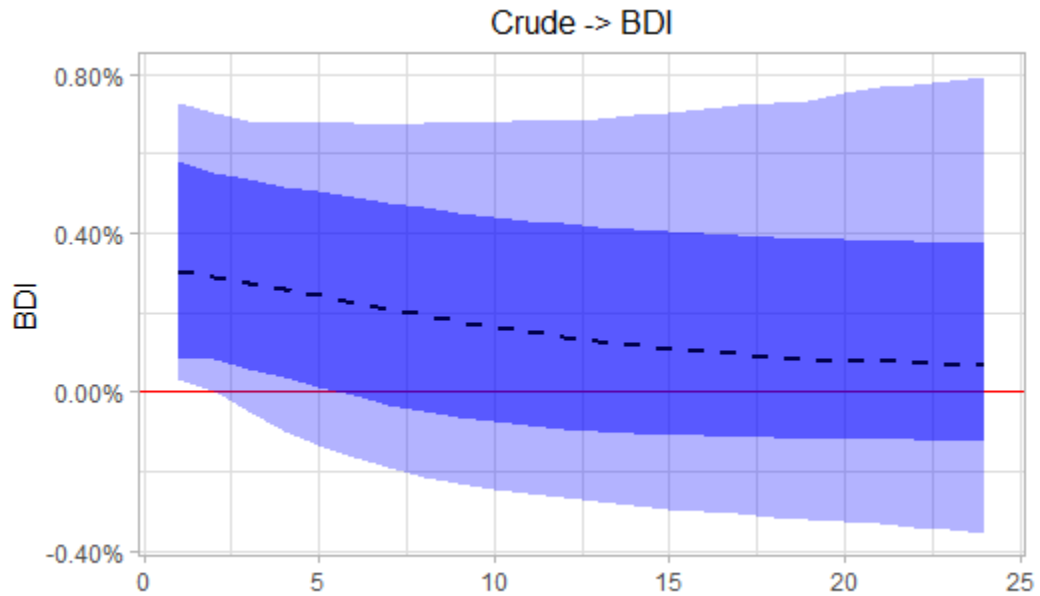
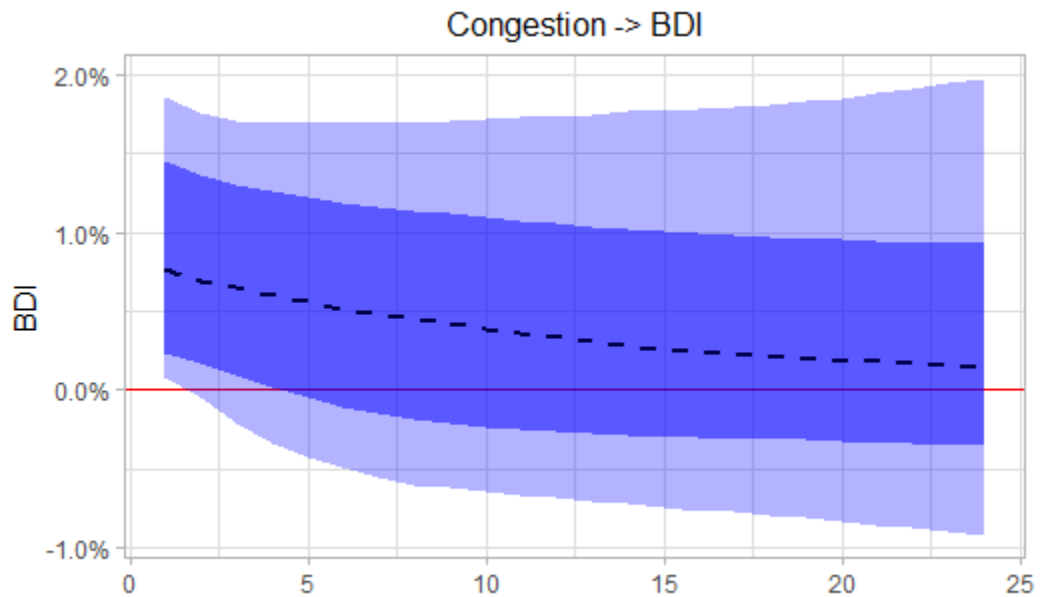


Figure 10d. Impact of a 1% increase in destination-port bulk vessel congestion (capacity in deadweight tonnage at Chinese ports) on the Baltic Dry Index



Sources: Bloomberg, Clarksons shipping intelligence network, Trade Data Monitor and authors' calculations.

Notes: The impulse response functions in this figure are estimated via a sign-identified BSVAR. The dashed line represents the modal model, the dark blue region is the range of the 68% credible set, and the light blue region is the 90% credible set.

Figure 11. Impulse response functions for the determinants of containerized ocean freight rates, 2016-2021

Figure 11a. Impact of a 1% increase in global seaborne exports (in TEUs) on the CCFI

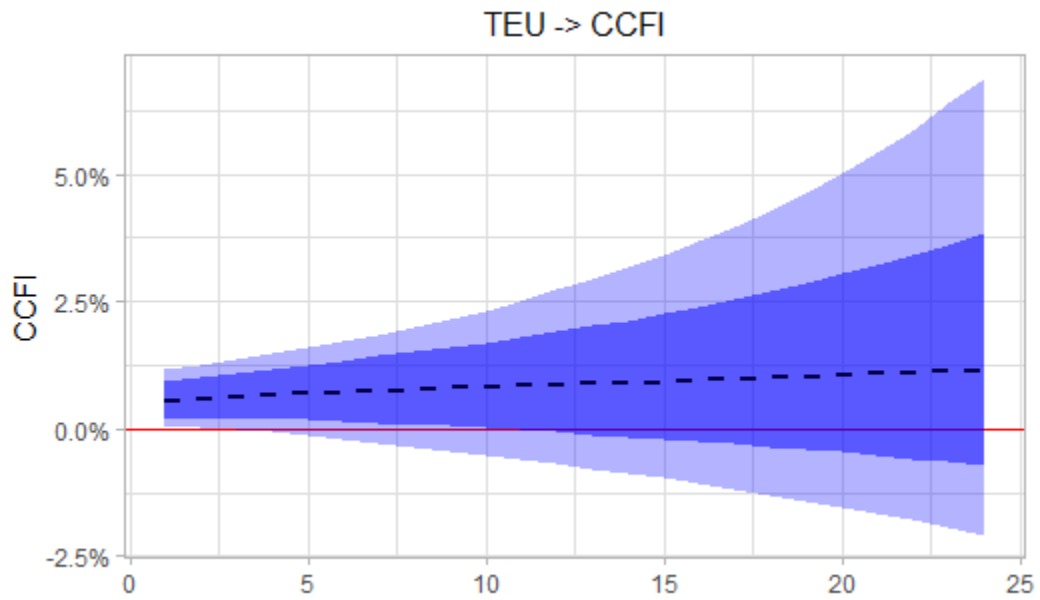


Figure 11b. Impact of a 1% increase in container vessel fleet capacity (in deadweight tonnage) on the CCFI

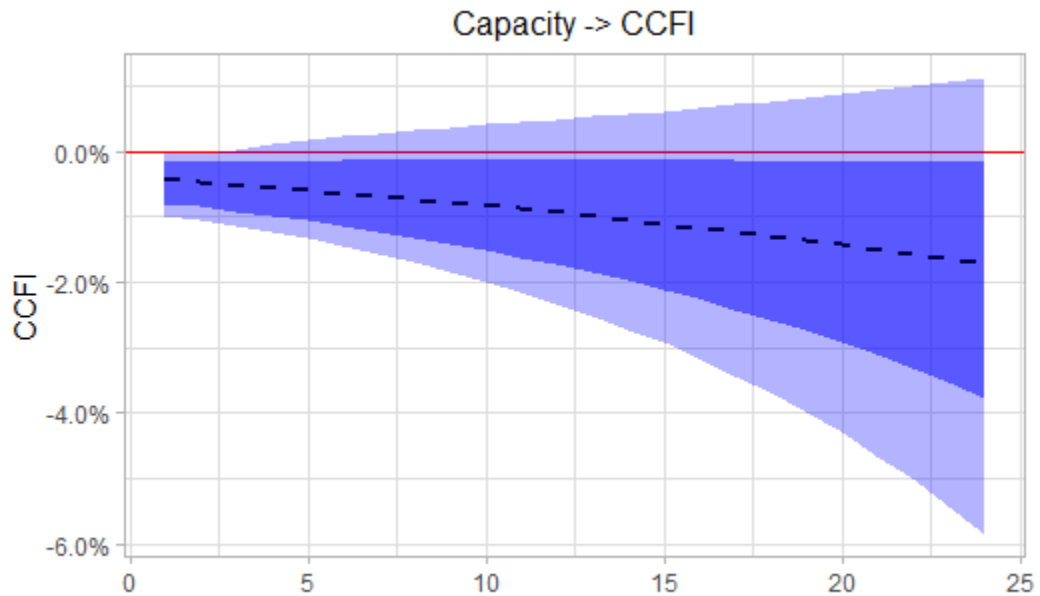


Figure 11c. Impact of a 1% increase in the price of crude oil on the CCFI

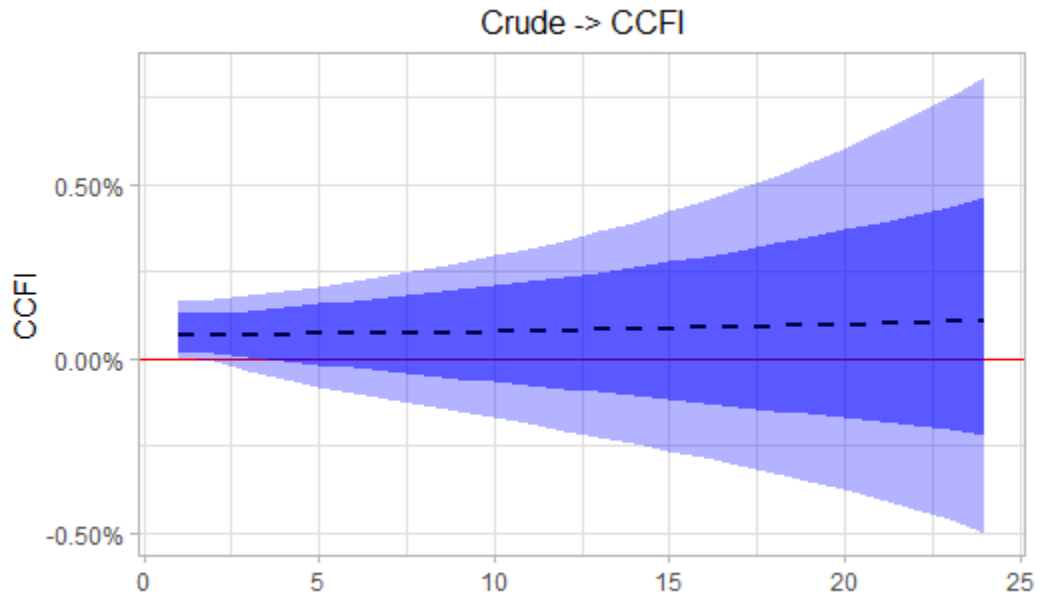
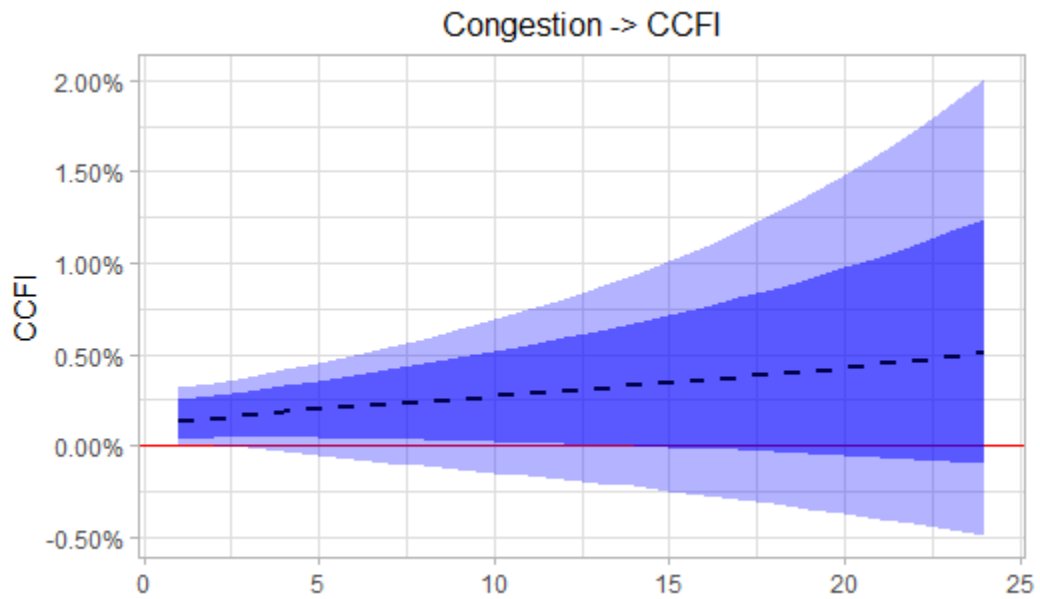


Figure 11d. Impact of a 1% increase in destination-port container vessel congestion (capacity in deadweight tonnage at U.S. ports) on the CCFI



Sources: Bloomberg, Clarksons shipping intelligence network, and authors' calculations.

Notes: The impulse response functions in this figure are estimated via a sign-identified BSVAR. The dashed line represents the modal model, the dark blue region is the range of the 68% credible set, and the light blue region is the 90% credible set.

Figure 12. Impulse response functions for the determinants of dry bulk cargo ocean freight rates (without accounting for congestion), 2005-2021

Figure 12a. Impact of a 1% increase in worldwide seaborne agricultural exports on the Baltic Dry Index

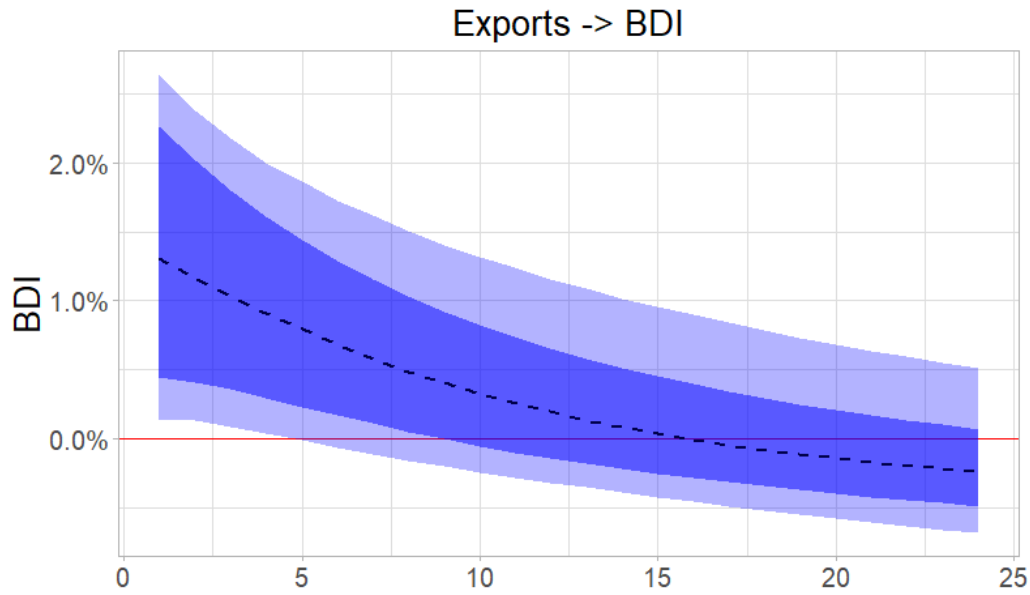


Figure 12b. Impact of a 1% increase in bulk vessel fleet (in deadweight tonnage) on the Baltic Dry Index

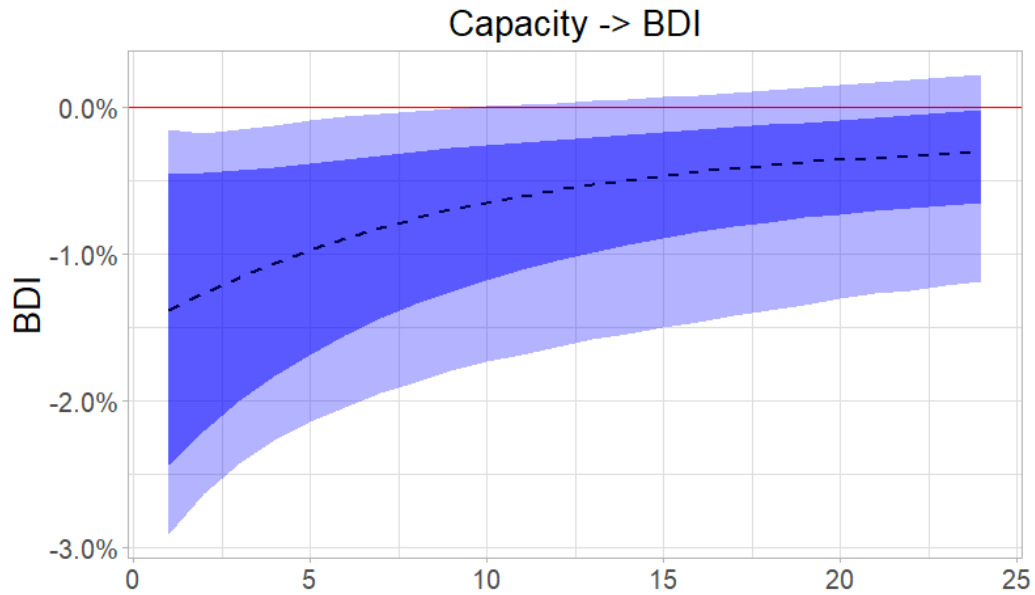
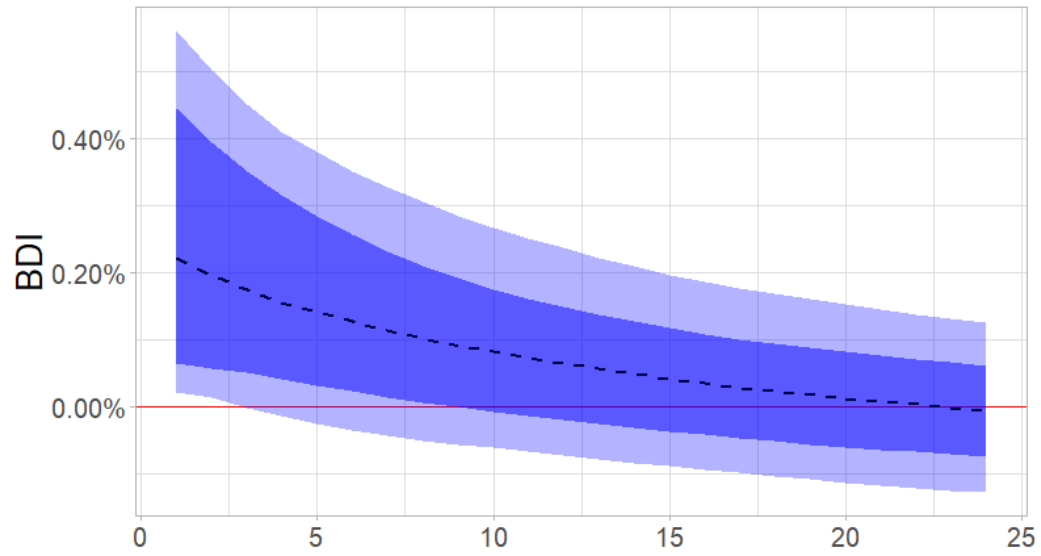


Figure 12c. Impact of a 1% increase in the price of crude oil on the Baltic Dry Index
Crude -> BDI



Sources: Bloomberg, Clarksons shipping intelligence network, Trade Data Monitor and authors' calculations.

Notes: The impulse response functions in this figure are estimated via a sign-identified BSVAR. The dashed line represents the modal model, the dark blue region is the range of the 68% credible set, and the light blue region is the 90% credible set.

Figure 13. Impulse response functions for the determinants of containerized ocean freight rates, 2011-2021

Figure 13a. Impact of a 1% increase in global seaborne exports (in TEUs) on the CCFI

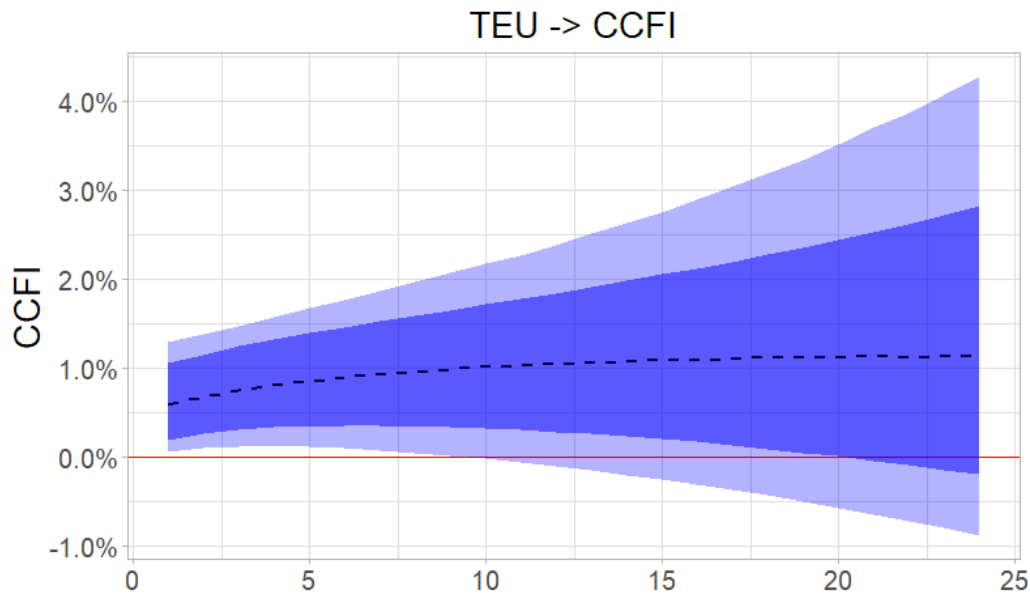


Figure 13b. Impact of a 1% increase in container vessel fleet capacity (in deadweight tonnage) on the CCFI

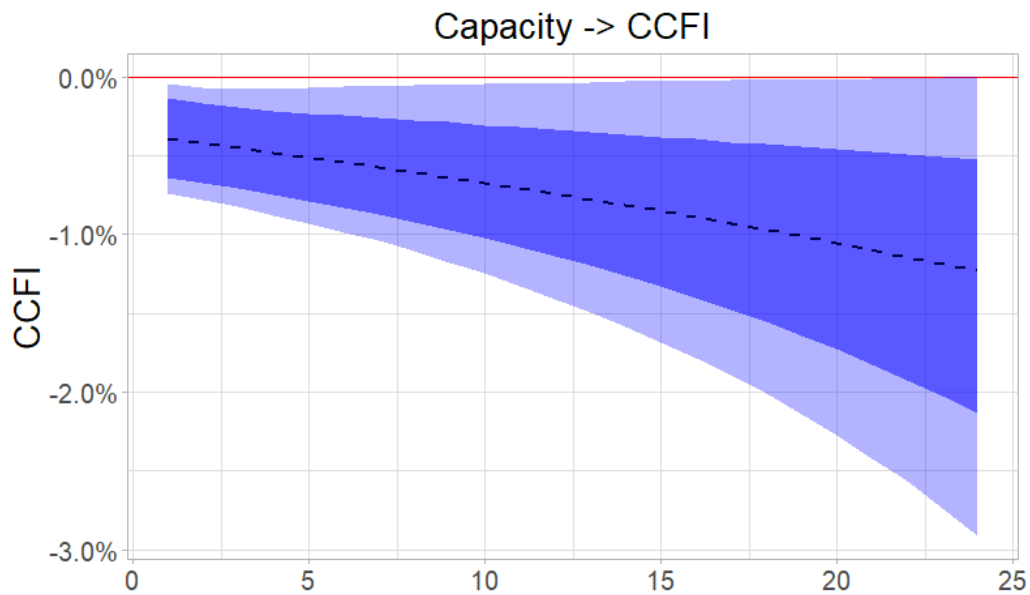
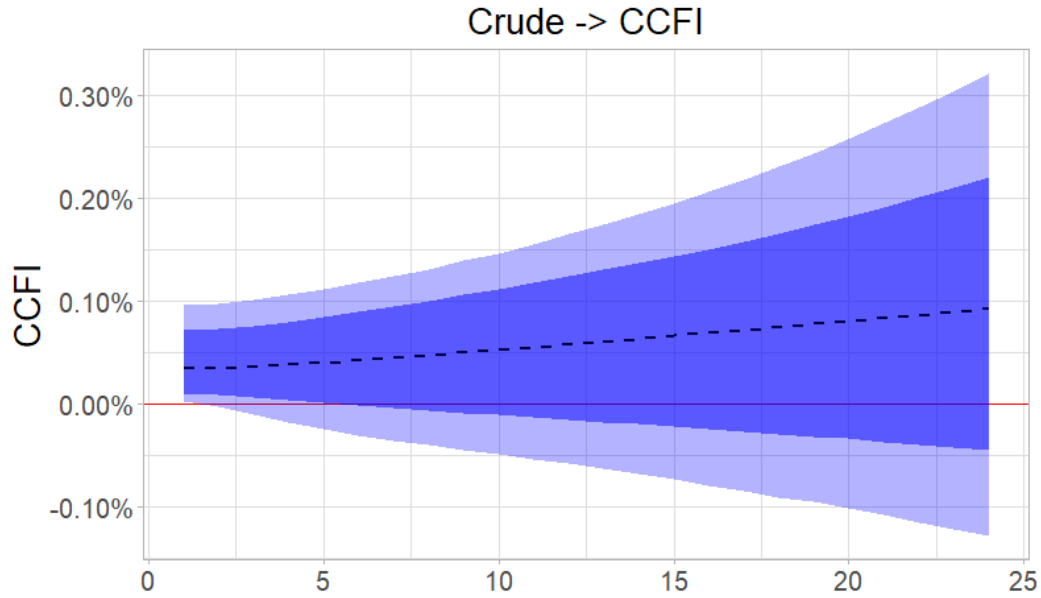


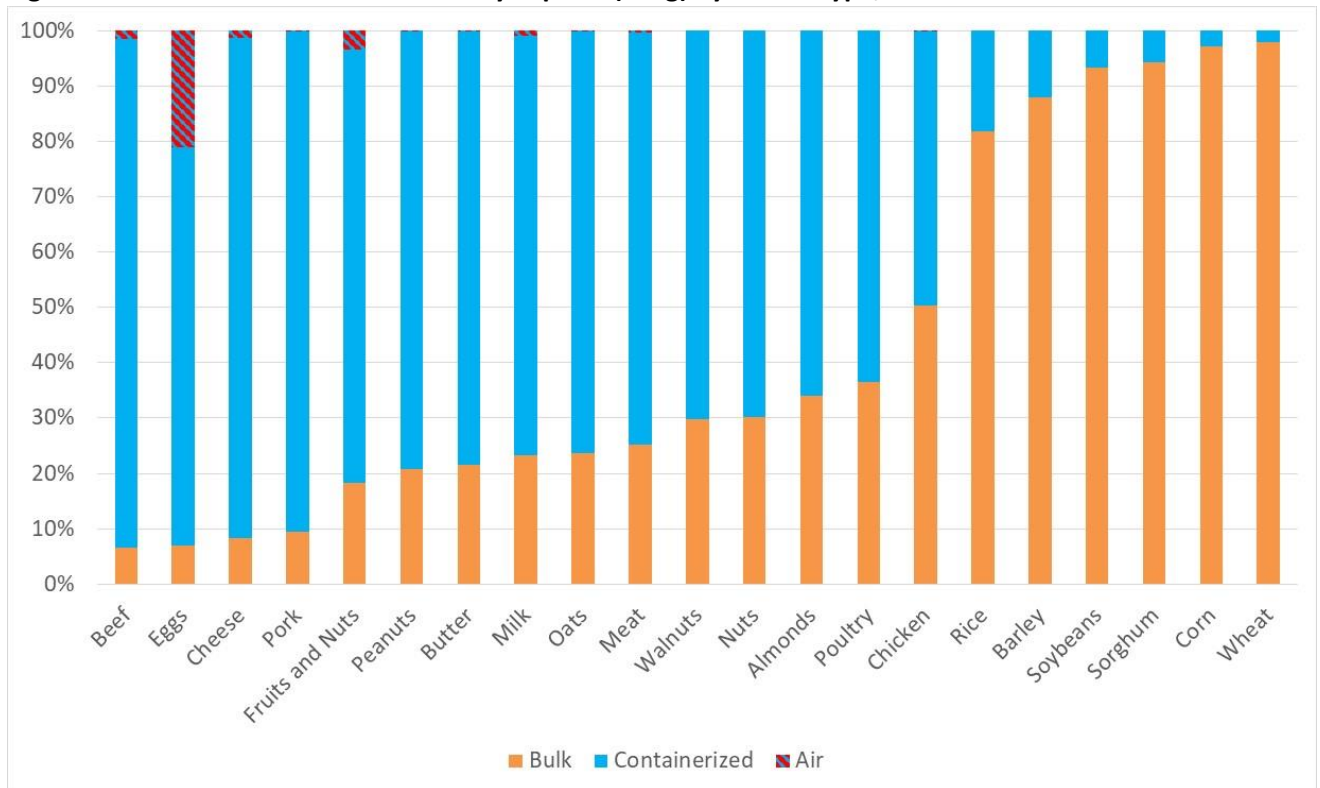
Figure 13c. Impact of a 1% increase in the price of crude oil on the CCFI



Sources: Bloomberg, Clarkson's shipping intelligence network, and authors' calculations.

Notes: The impulse response functions in this figure are estimated via a sign-identified BSVAR. The dashed line represents the modal model, the dark blue region is the range of the 68% credible set, and the light blue region is the 90% credible set.

Figure 14. Share of Port-level Commodity Exports (in kg) by Vessel Type, 2003-2021



Source: USATrade.

Notes: The period of observation runs from January 2003 to October 2021.

Figure 15. Maritime Export-level and Price Indices for Major U.S. Export Commodities Since the Onset of the Covid-19 Pandemic, by Dominant Export Vessel Type (Jan 2020 = 100)

Figure 15a. Maritime Export Indices for Major U.S. Export Commodities (Median Values by Vessel Type are darker)

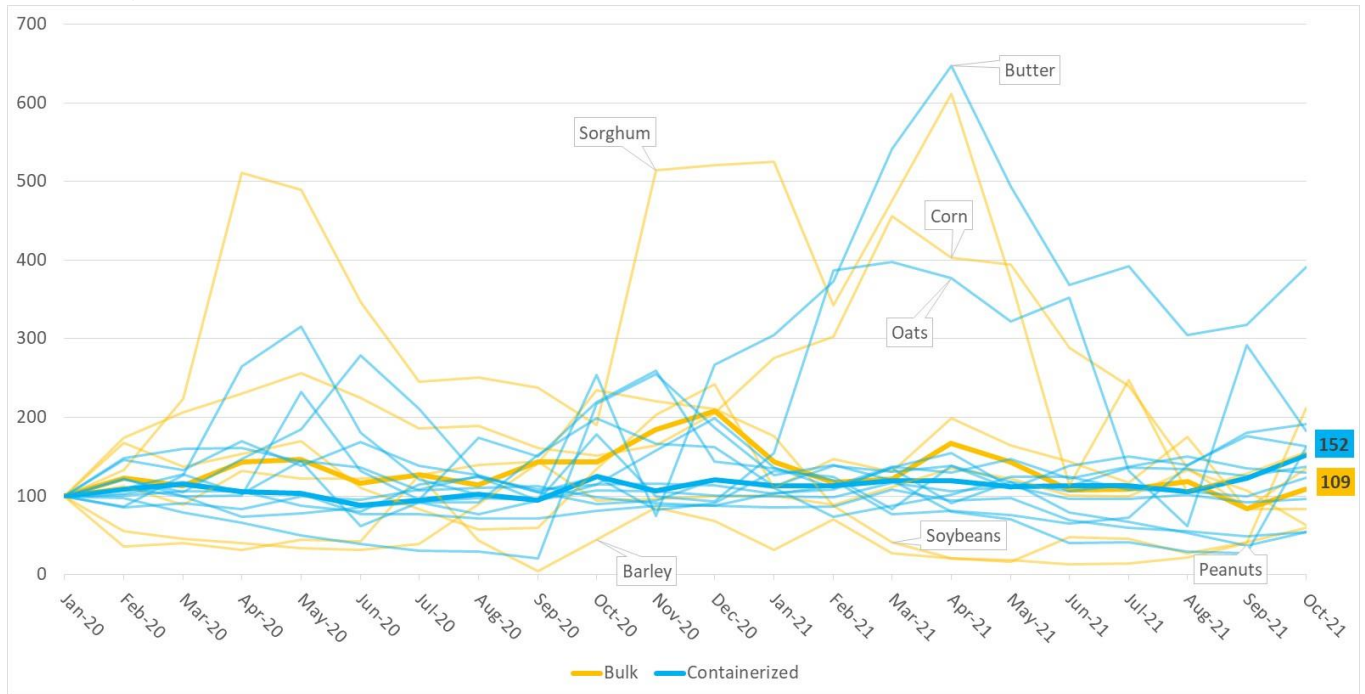
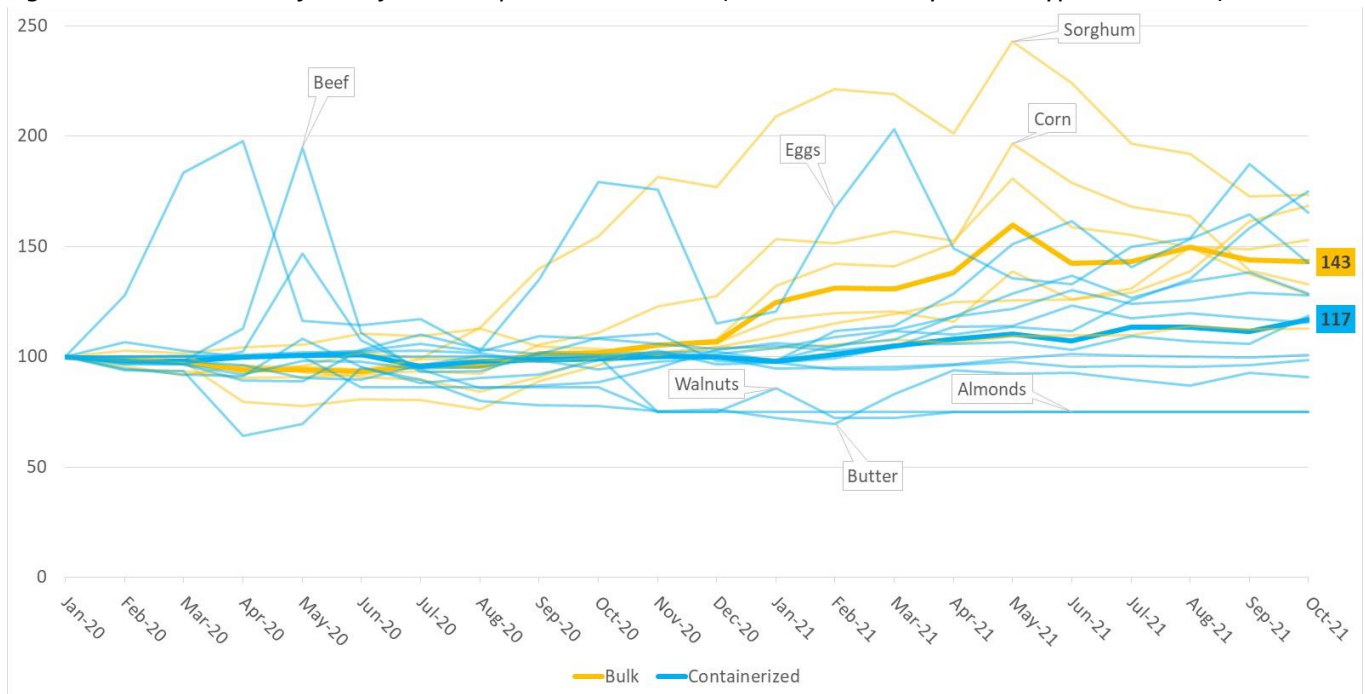


Figure 15b. Price Indices for Major U.S. Export Commodities (Median Values by Vessel Type are darker)



Sources: USATrade, BLS, and authors' calculations.

Notes: For clarity of exposition, we plot the series for each commodity but do not include all names, although certain commodities with notable swings in exports or prices are indicated. Median values are calculated across commodities based on the dominant vessel export mode.

Figure 16. Impulse response functions for the Export and Price of U.S. Peanuts, 2003-2021

Figure 16a. Impact of a 1% increase in domestic personal food expenditures on U.S. peanut prices

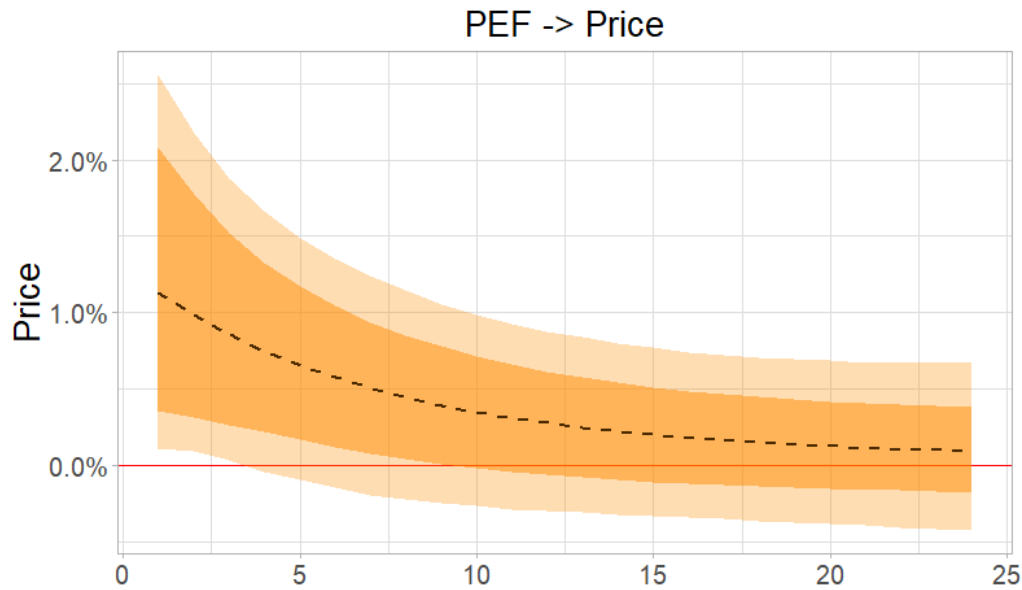


Figure 16b. Impact of a 1% increase in global industrial production on U.S. peanut prices

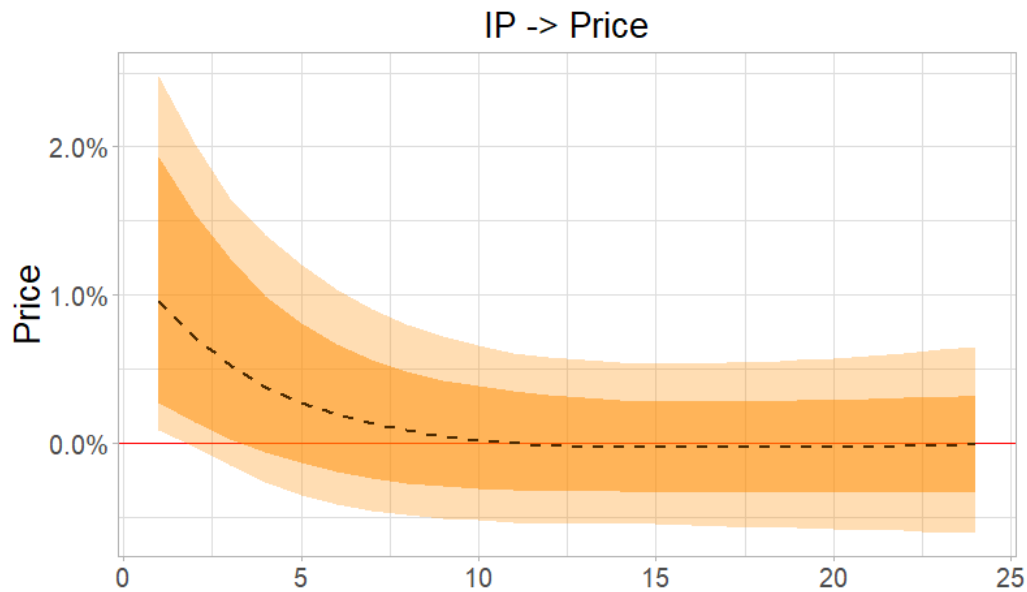


Figure 16c. Impact of a 1% increase in domestic peanut exports on U.S. peanut prices

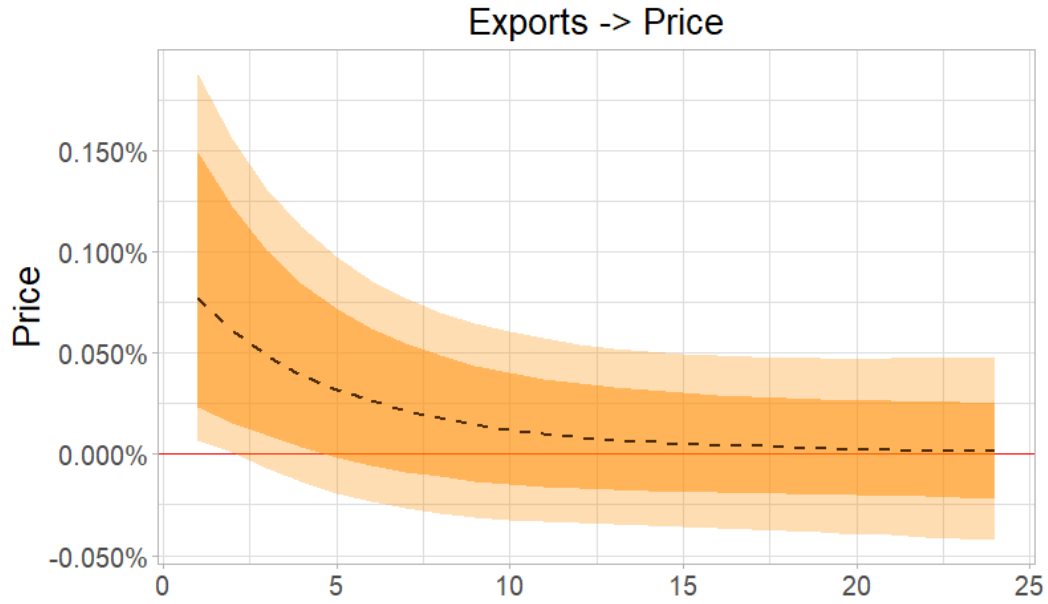


Figure 16d. Impact of a 1% increase in U.S. peanut prices on domestic peanut exports

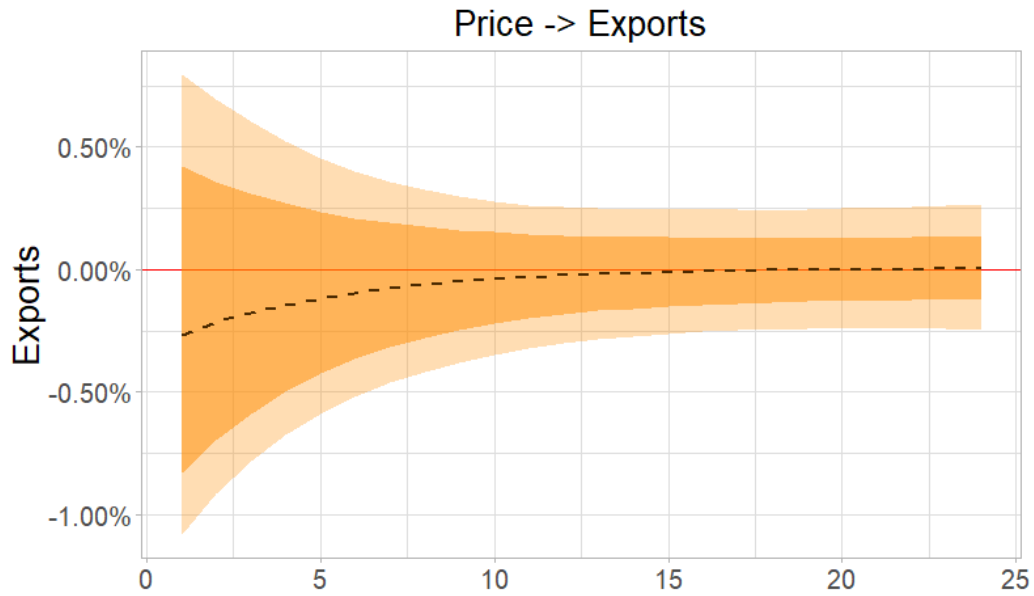


Figure 16e. Impact of a 1% increase in global industrial production on containerized ocean freight prices (CCFI)

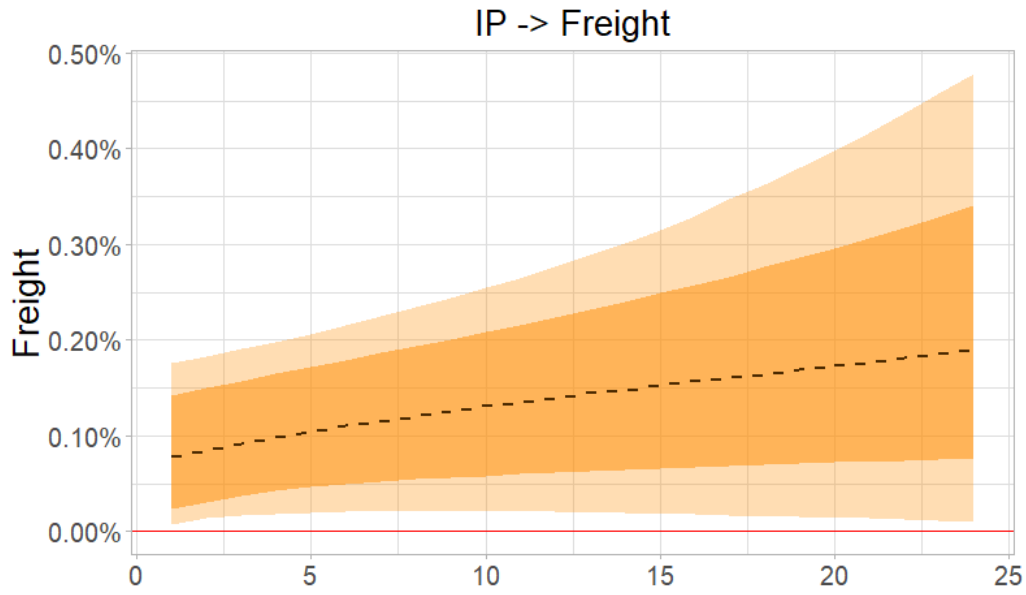


Figure 16f. Impact of a 1% increase in containerized ocean freight prices on U.S. peanut exports

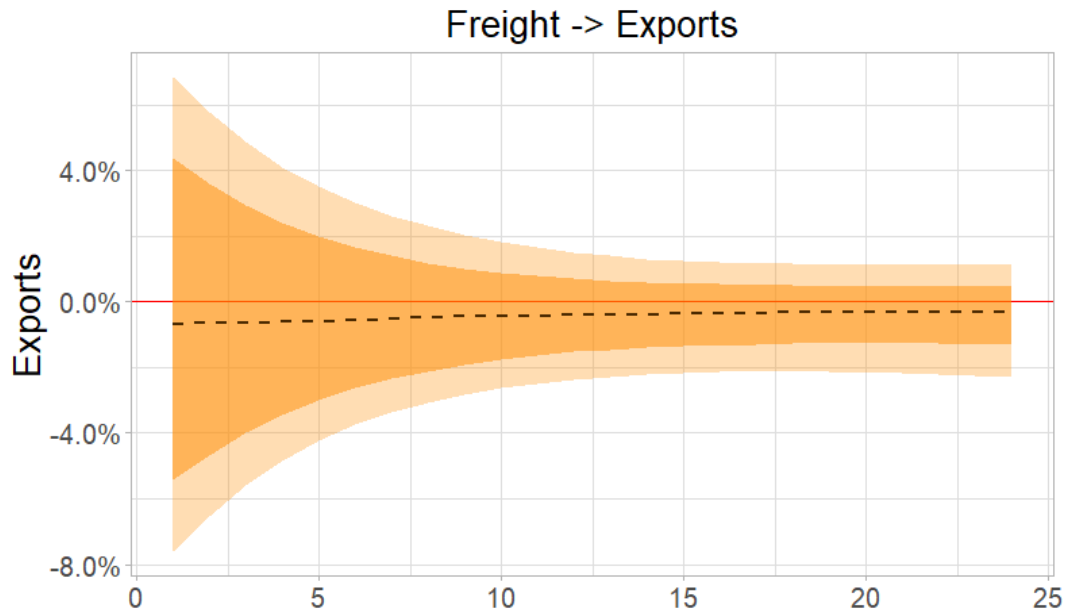
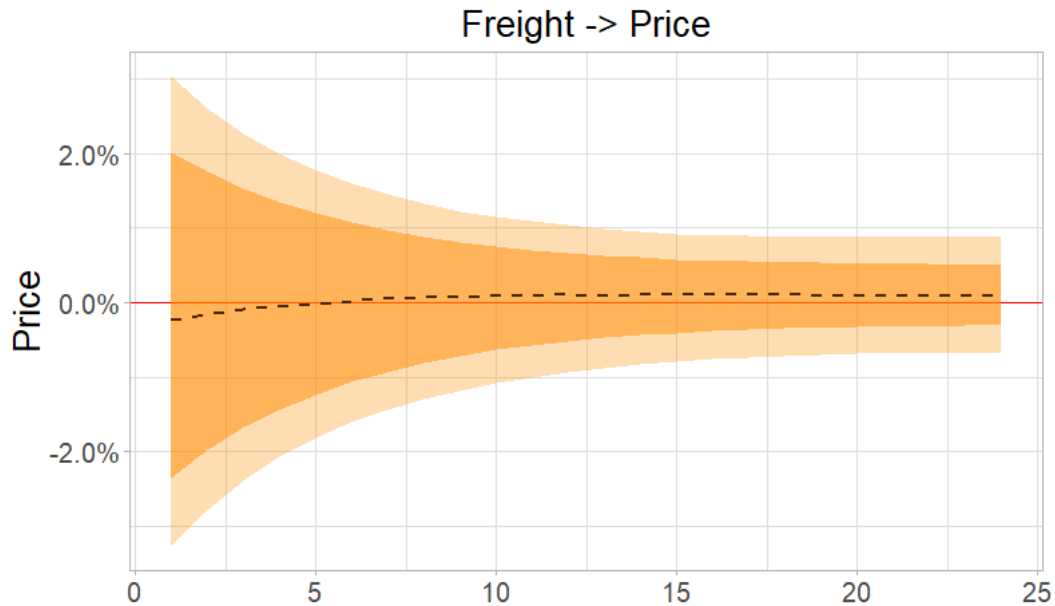


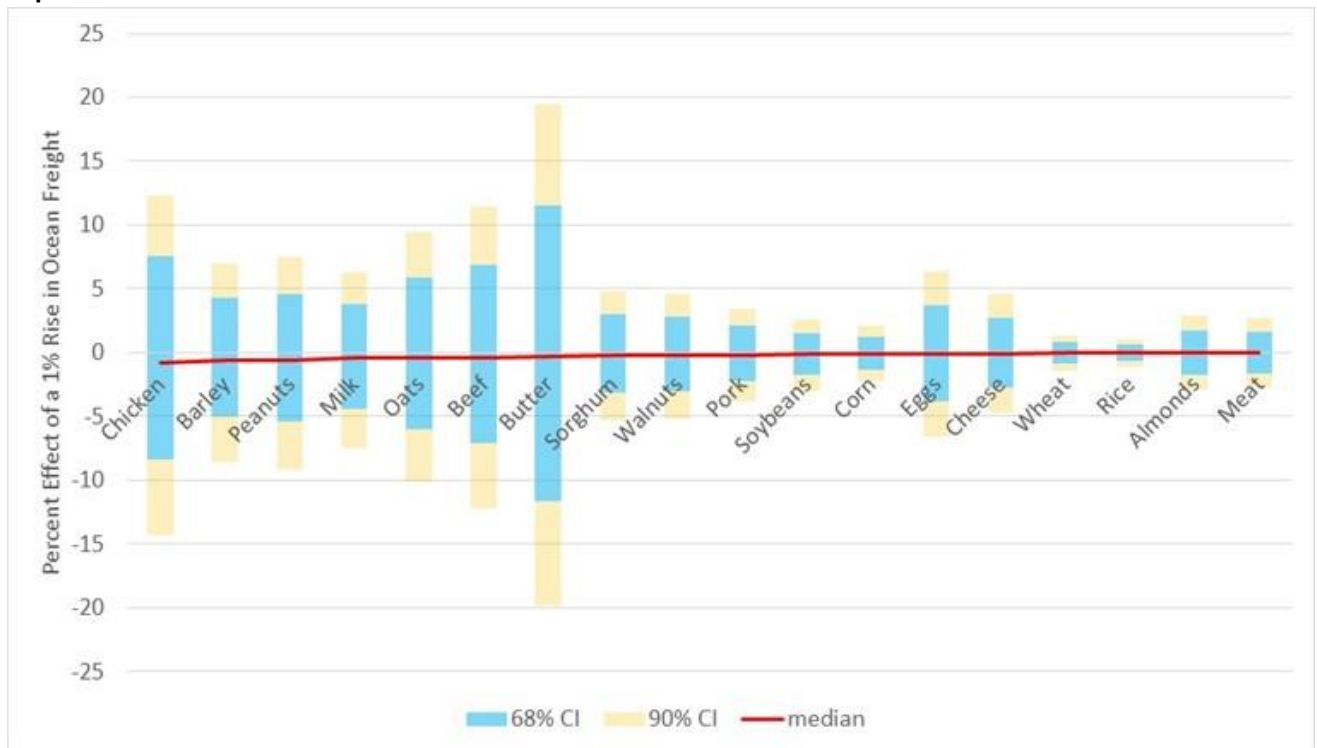
Figure 16g. Impact of a 1% increase in containerized ocean freight prices on U.S. peanut prices



Sources: Bloomberg, BLS, USATrade, and authors' calculations.

Notes: The impulse response functions in this figure are estimated via a sign-identified BSVAR. The dashed line represents the modal model, the dark orange region is the range of the 68% credible set, and the light orange region is the 90% credible set.

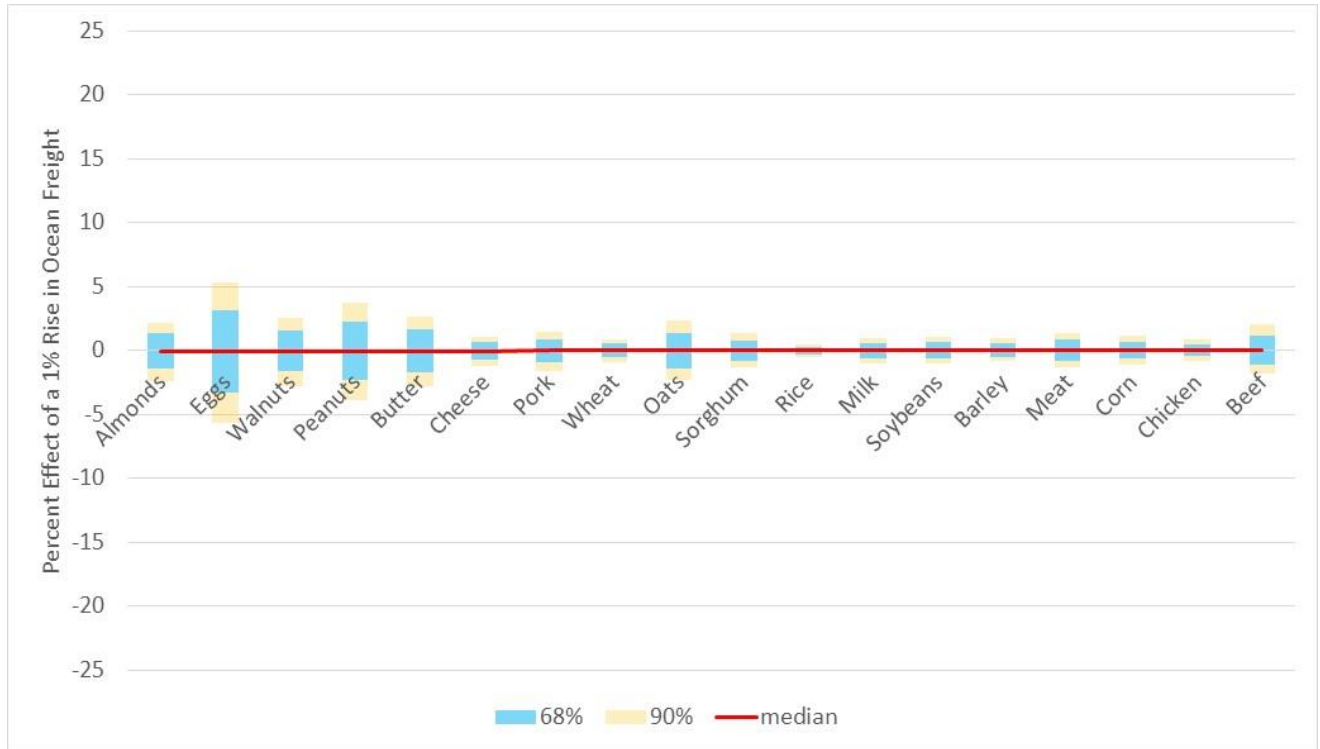
Figure 17. Short-run Effect of a 1% Rise in the Commodity's Dominant Ocean Freight Rate on U.S. Exports



Sources: Bloomberg, BLS, USATrade, and authors' calculations.

Notes: The colored bars represent the average credible range for the percent effect of a 1% rise in ocean freight rates for the commodity's dominant mode (containerized or bulk) method of maritime export, over the first six months following the shock; the red line represents the average value of the modal model.

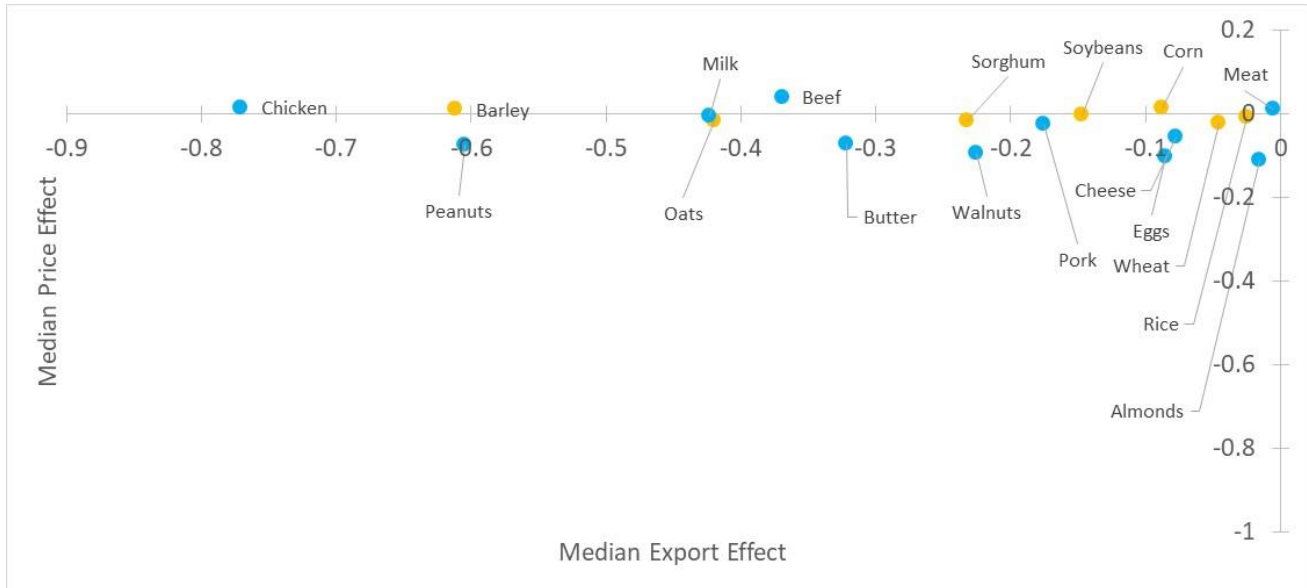
Figure 18. Short-run Effect of a 1% Rise in the Commodity's Dominant Ocean Freight Rate on U.S. Prices



Sources: Bloomberg, BLS, USATrade, and authors' calculations.

Notes: The colored bars represent the average credible range for the percent effect of a 1% rise in ocean freight rates for the commodity's dominant mode (containerized or bulk) method of maritime export, over the first six months following the shock; the red line represents the average value of the modal model.

Figure 19. Short-run Modal Effects (in Percent Terms) of a 1% Rise in the Commodity's Dominant Ocean Freight Rate on U.S. Seaborne Exports and Producer Prices



Sources: Bloomberg, BLS, USATrade, and authors' calculations.

Notes: The colored dots represent the average modal value for the percent effect of a 1% rise in ocean freight rates for the commodity's dominant mode (containerized or bulk) method of maritime export, over the first six months following the shock. Blue dots represent commodities whose dominant method of seaborne export is containerized vessel, while orange dots represent those commodities who generally transport via bulk carrier.

Figure 20. Estimated Effect of the Observed Ocean Freight Rise in 2021 on Global Export Market Share
 Figure 20a. Impact on Soybean Markets

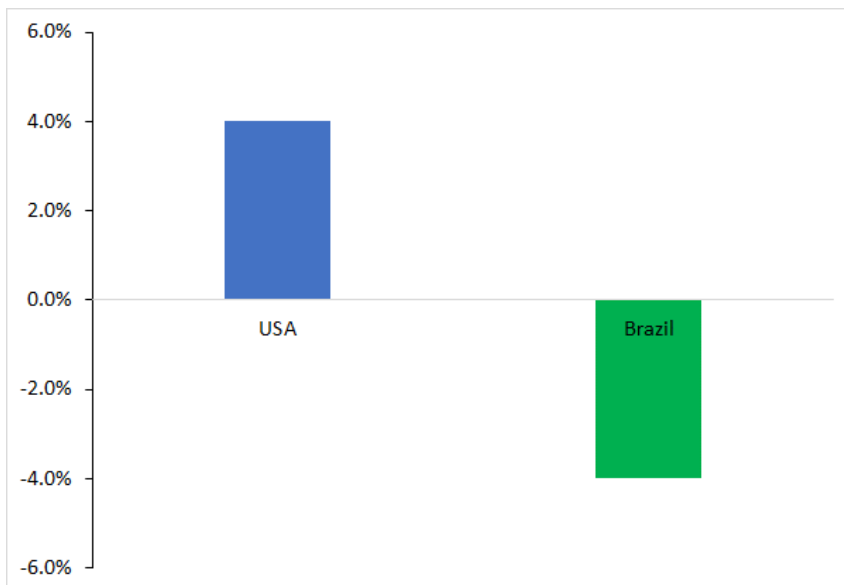
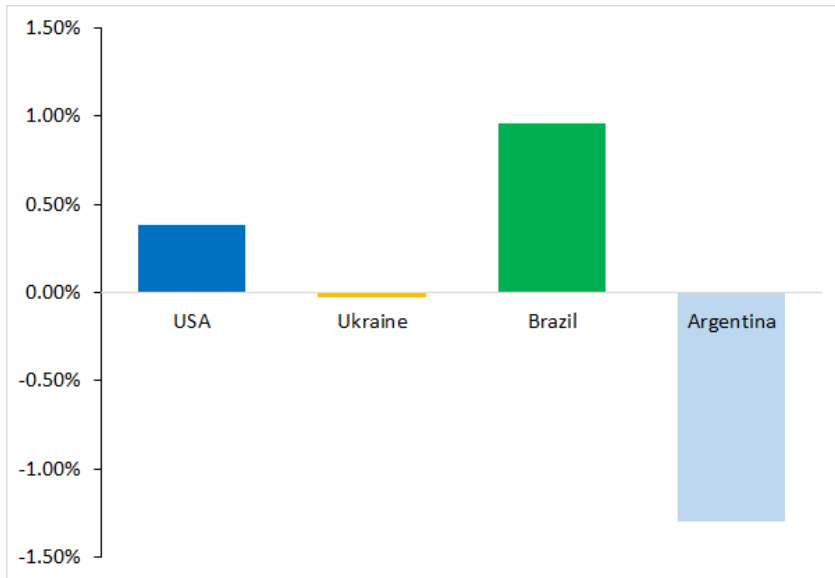


Figure 20b. Impact on Corn Markets



Sources: Wilson, Bullock, and Lakkula (2022).

Figure 21. Global Export Market Share, by Major Exporter

Figure 21a. Global Share of Soybean Export Market

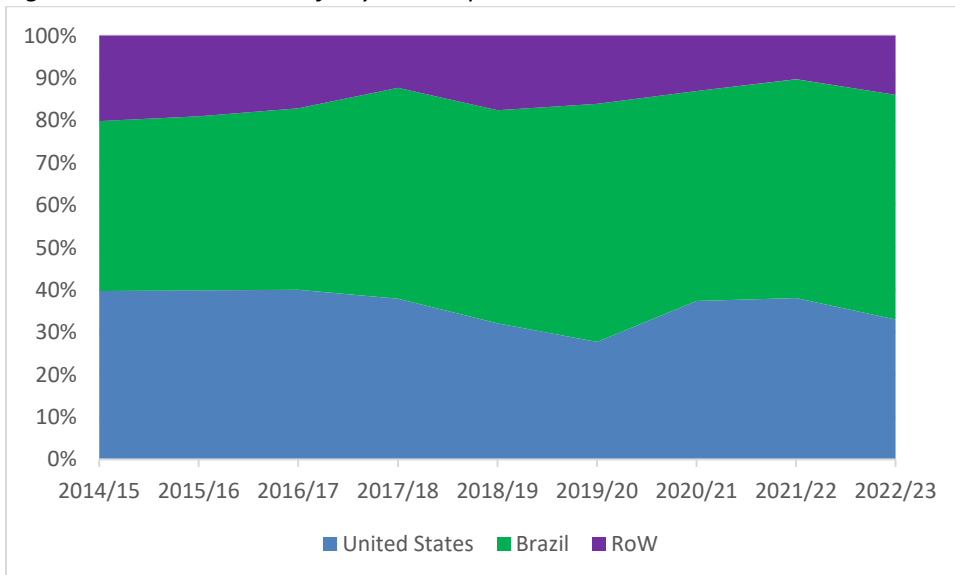
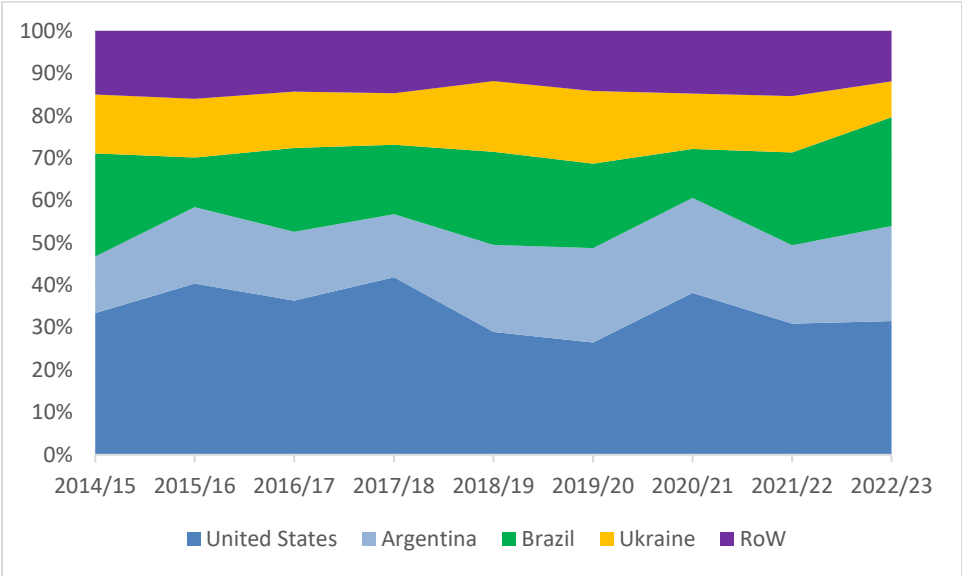


Figure 21b. Global Share of Corn Export Market



Sources: USDA and authors' calculations.
 Note: The 2021/22 and 2022/23 marketing year values are USDA projections.