CHOICES

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Theme Overview: Turmoil in Global Food, Agricultural, and Input Markets: Implications of Russia's Invasion of Ukraine

Jason Grant, Shawn Arita, and Wyatt Thompson

Keywords: Agricultural trade, Black Sea, Food security, Russia-Ukraine war

On February 24, 2022, Russian forces invaded Ukraine, sending shockwaves through global food, fertilizer, and energy markets. The Black Sea is considered a major "bread basket" region because Russia and Ukraine are key players in the world market for wheat, corn, sunflower and colza oil and seeds, barley, fertilizer, and energy. Historically, Russia and Ukraine have accounted for 28% of global wheat exports, nearly one-third of global barley exports, and a combined 73% and 81% of global sunflower oil and meal exports, respectively. Ukraine is also an important exporter of corn, representing 13% of global corn trade. Russia is also a key producer and exporter of fuel and all three nutrients that comprise fertilizer blends: nitrogen, phosphate, and potassium. Russia is the world's largest exporter of nitrogenous fertilizers and the third largest exporter of phosphate (behind China and Morocco) and potassium (potash) fertilizer (behind Canada and Belarus).

International institutions and world leaders quickly sounded the alarm (Food and Agriculture Organization of the United Nations, 2022). The International Monetary Fund (IMF) warned that the global economy faces its "biggest test" since the Second World War (Giles, 2022). The World Bank's Commodity Markets Outlook Report in April 2022 states, "The war in Ukraine has been a major shock to global commodity markets. The supply of several commodities has been disrupted, leading to sharply higher prices, particularly for energy, fertilizers, and some grains" (World Bank, 2022, p. 4). One of the more alarming calls came from World Food Programme executive director David Beasley, who warned, "Truly, failure to open those ports in Odesa region will be a declaration of war on global food security" (World Food Programme 2022). The conflict follows on the footsteps of a strong recovery in consumer spending on durable goods coming out of the global COVID-19 pandemic that left supply chains bottlenecked, created worker shortages in key logistics sectors, and sent inflation rates soaring to heights not seen since the early 1980s.

Articles in this Theme:

There are few certainties right now as to when and how this war ends and the longer-run implications for the global agri-food economy and food security. What we do know is that Ukraine and Russia are key sources of staple crops and crop inputs, so the repercussion of Russian troops marching toward Kyiv has been another shock to global crop output and higher production costs globally. The initial surge in commodity prices has subsequently softened, demonstrating that these effects alone are not the sole market drivers and that the scale of the impact cannot be known in advance by market agents.

In late July 2022, the UN and Turkey brokered a memorandum of understanding (the Black Sea Grain Initiative) that allows for the safe passage of vessels carrying Ukrainian grain from three ports around Odessa (Odessa, Yuzhny/Pivdenny, and Chernomorsk). This was the first diplomatic breakthrough since the start of the war and the first sign of relief for food insecure consumers residing in vulnerable net food importing countries. Although widely welcomed, the longevity of the deal remains uncertain.

This *Choices* theme issue provides a timely review and initial assessment of the impact of Russia's invasion of Ukraine on key agricultural commodity markets and trade, as well as implications for a potential conflict of longer duration. The changing conditions and surprises of the war reported almost daily in the news reflect the degree of uncertainty that exists in commodity markets today. The duration of the war, the extent of damage to agricultural facilities and Ukraine's infrastructure, and the on-and-off arrangement to allow Ukrainian crop exports are just some of the challenges and uncertainties decision makers face when they try to look ahead. The following articles look at immediate impacts of the war and sustained effects if this disruption extends into a prolonged conflict scenario. The results can be used to inform business planning, public policy, and international efforts to alleviate food security consequences of the war.

In the opening article, Elleby, Dominguez, Genovese, Thompson, Adenauer, and Gay employ the Aglink-Cosimo model to examine war-related supply and input price shocks. Their analysis includes the impacts on food security and potential implications if the European Union and United States were to implement policy efforts to rebalance markets.

Next, He, Carriquiry, Elobeid, Hayes, and Zhang use the CARD-IACM model to project impacts of the Russia-Ukraine conflict on global agricultural prices, production, and trade. Their analysis provides insights into shifts in production and acreage reallocation across crops and implications for comparative advantage in global agricultural markets.

Westhoff, Whistance, Cooper, and Meyer examine the impacts of the war's impact on U.S. agriculture. Using the modeling system maintained by the Food and Agricultural Policy Research Institute, they assess the impact of the war on U.S. commodity prices, exports, production expenses, farm income, and Consumer Price Index (CPI).

Bullock, Lakkakula, and Wilson address potential price effects associated with the reopening of Ukrainian ports to additional grain trade. They provide an assessment using two methods: an equilibrium displacement model (EDM) and by evaluating price distributions derived from futures and options markets.

Beckman and Ivanic provide a broader, economy-wide assessment using a computable general equilibrium (CGE) model to estimate the impacts of yield reductions (from higher energy and fertilizer prices) and export losses out of Russia and Ukraine as well as labor changes. The analysis offers insights into the impacts on commodity prices, agricultural production, trade, and GDP that occur under a set of general equilibrium adjustment scenarios.

Grant, Arita, Xie, and Sydow examine the war's impacts on global agricultural and fertilizer trade flows. Using a monthly, product line gravity model of bilateral trade, they provide a 10-month ex post empirical assessment as to how the war has altered agricultural commodity exports across regions dependent on Russia and Ukraine.

Finally, Smith places the current global commodity situation in context by providing a detailed overview of the war's initial impact on commodity prices and subsequent retreat of prices to preinvasion levels. He then evaluates the price response from the invasion on grains and fertilizers and reconciles these dynamics in the context of current and historical global supply and demand situations.

As of this writing, the Russia-Ukraine conflict continues to evolve. Much work and additional analyses by agricultural economists remains to be done to better understand actual economic impacts against other confounding influences that coincided or were in reaction to the war in Ukraine, including export restrictions on certain crop and crop inputs, economic sanctions, price transmission (or what consumers are actually paying to purchase staple food items in local markets), and an uncertain macroeconomic outlook. While this Choices theme issue cannot possibly address all of these factors, it does provide a comprehensive first look at the economic impacts of Russia's invasion of Ukraine.

For More Information

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How Did Russia's Invasion of Ukraine Affect Global Food Supplies?

Aaron Smith

JEL Classifications: Q11
Keywords: Agricultural supply, Commodity prices

On February 24, 2022, Russia invaded Ukraine, inflicting horrific violence on the Ukrainian people and capturing the attention of the world. The war has disrupted food supplies to people in Ukraine and to refugees who have fled to neighboring countries. In addition, because Russia and Ukraine are large producers and exporters of agricultural commodities, the war has disrupted global food supplies.

In this paper, I argue that the invasion's effects on global food commodity markets were large but not historic. Prices have been high since the invasion, but mostly because they had increased substantially in the 18 months before to the invasion.

I based this assessment on prices. Commodity prices reflect scarcity. If a supply disruption makes a commodity scarcer, then prices increase to incentivize consumers to cut back and producers to supply more. Supply and demand for agricultural commodities are quite inelastic, which means small supply disruptions cause large price increases (Roberts and Schlenker, 2013).

Major Crop Production in Russia and Ukraine

Russia produces 11% of the world's wheat and Ukraine produces 3% (see Figure 1). These countries make up a larger proportion of global exports. Russia accounts for 19% of the global wheat export market and Ukraine 9%. Ukraine is also a major corn exporter, accounting for 14% of exports. Neither country is a large player in rice or soybeans, the other two major agricultural commodities in the world.

Much of Ukraine's exports flow out through the Black Sea, where ports are currently closed and may stay closed for a long time. The potential withdrawal of some western commodity trading companies may reduce the market for its exports. China and India are the two largest consumers of wheat, but they already produce enough domestic wheat to satisfy their needs.

Has the world lost access to the 55 million metric tons of wheat and 30 million metric tons of corn exported annually from Ukraine and Russia? These quantities represent 7.3% of global wheat and 2.6% global corn production. To answer this question, we can analyze prices.

Price Response to the Invasion

For storable commodities, such as wheat, prices will increase in anticipation of an upcoming supply disruption. If traders expect that the next year's production will be low and they own the commodity, then they will hold onto it to sell in the future, which reduces available supply today and therefore raises prices today. This means that current prices reflect not just commodity scarcity today but also anticipated scarcity in the upcoming months and years.

Markets can be wrong. Commodity traders may have underestimated the impact of the invasion, but they also have more information about the movement and availability of grain than anyone else. Traders know, for example, that Russian and global agribusiness firms continue to operate in and export out of Russia.

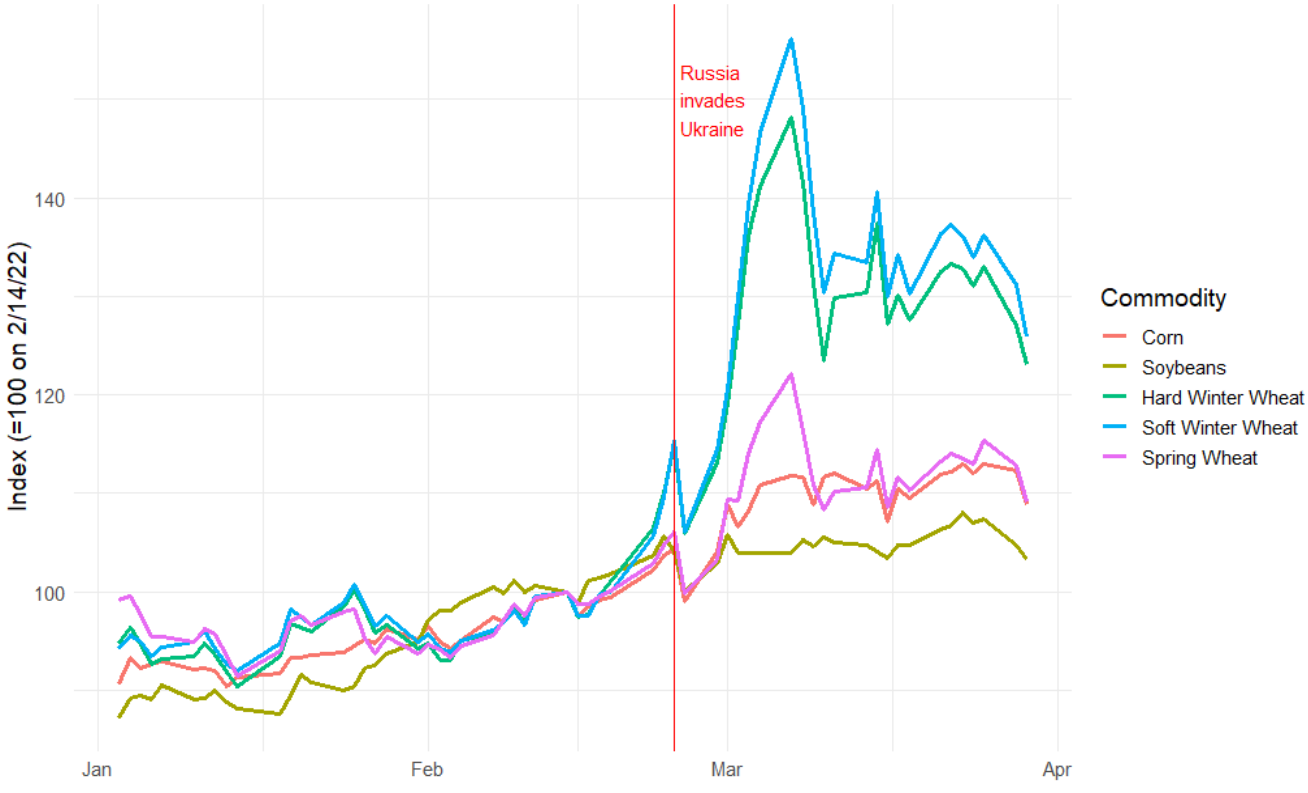
Winter wheat prices increased substantially in the days following the invasion (see Figure 2). The Chicago hard red winter wheat futures price for July 2022 delivery increased by almost 50% from February 14 to its peak on March 7. The soft wheat futures contract increased by a similar percentage. Corn, soybean, and spring wheat prices increased by much less following the invasion.

Winter wheat prices have increased by more than spring wheat prices because winter varieties make up about 95% of Ukrainian wheat and 70% of Russian wheat. Farmers planted their winter wheat several months before the invasion. It went dormant during the winter and resumed growth in the spring before harvest in the summer. The rest of Ukrainian and Russian wheat was planted in the spring for harvest in the late summer.

Figure 1. Global Production and Export of Major Commodities in 2020

Source: https://www.fao.org/faostat/en/#data/QCL

Figure 2: U.S. Futures Prices for Corn, Soybeans, and Wheat. July 2022 contracts



Source: Bloomberg

About two-thirds of U.S. wheat is winter wheat, mostly grown in the southern Great Plains. Bernard Warkentin originally brought hard winter wheat from Russia to Kansas in the 1870s[1]. U.S. spring wheat is grown mostly in the upper Great Plains states, which last year experienced a severe drought that reduced yield by 33%.

To put these price increases in perspective, Figure 3 shows spot prices since 2019 for the same three commodities. From mid-2020 through January 2022, prices approximately doubled as an array of shocks conspired to push food prices to high levels.

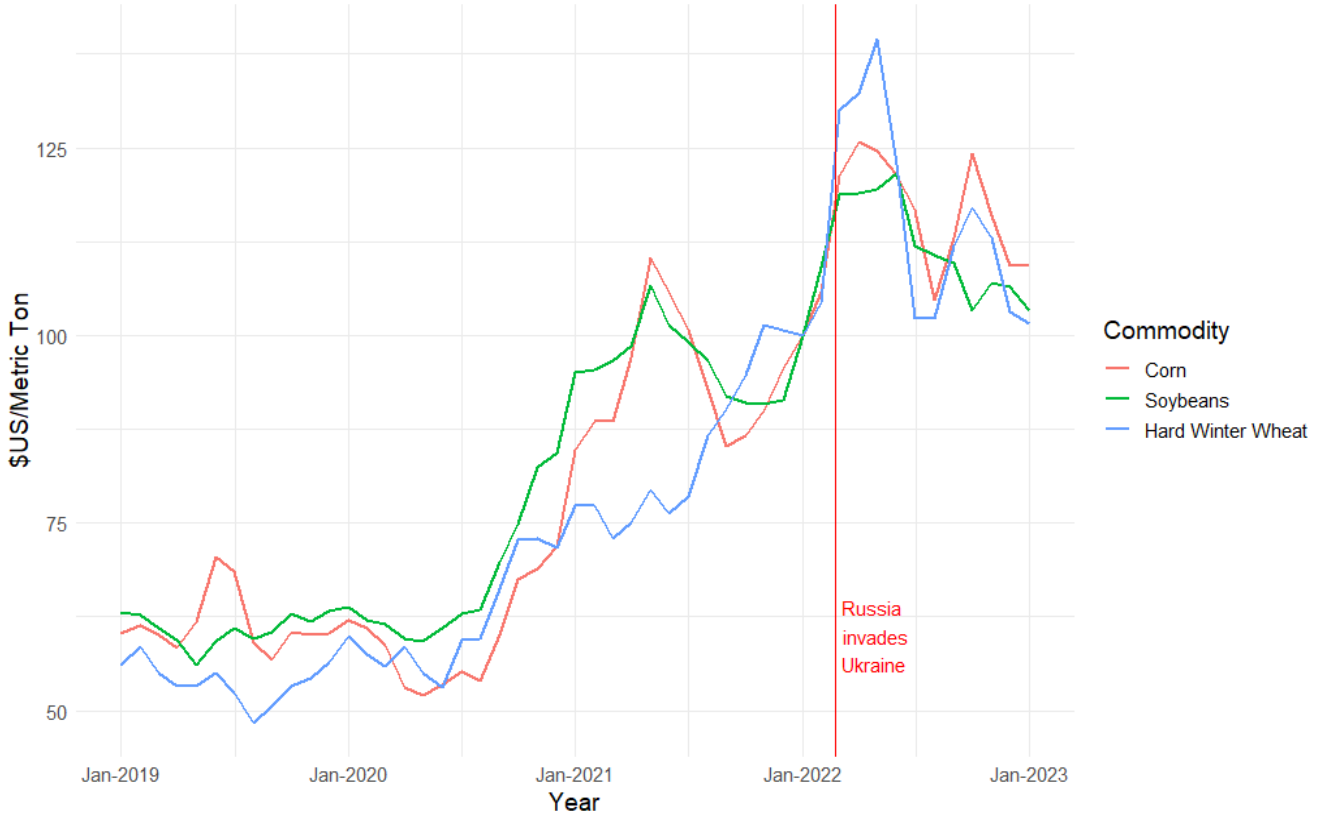
How Long Will the High Prices Last?

Futures prices for delivery at different future dates reveal how traders expect the market situation to change in the coming months. If the price for delivery this month is below the price for delivery next year, then it indicates that the commodity is relatively plentiful. Traders who store the commodity for future sale are compensated for their storage costs by the higher future price. However, if the price for delivery this month exceeds the price for delivery next year, then it indicates that the commodity is scarce right now but traders expect stocks to be replenished next year. The higher is the current price relative to the future price, the scarcer is the commodity at present.

Prior to the invasion, futures prices for imminent delivery were quite similar to prices for delivery after the 2023 harvest. The hard winter wheat price for March 2022 delivery was $8.28 per bushel, compared to a price of $8.02 for delivery in December 2023 (see Figure 4). The spring wheat and corn price profiles were slightly steeper. Corn was $6.56 for March 2022 delivery and $5.61 for delivery in December 2023; spring wheat was $9.66 for March 2022 delivery and $8.98 for May 2023 delivery (most distant available). These price profiles indicate that the market for these commodities was tight (downward sloping curve), but not too tight (curve not steeply sloped).

Post-invasion, winter wheat futures prices for imminent delivery increased significantly, but prices for delivery after July 2023 barely increased. The same is true for corn. The spring wheat market was already tight because of the 2021 drought, and traders expect it to remain tight beyond 2023. This pattern indicates that, as of March 8, traders expected the impact of the invasion to affect markets only for a year. By the end of March, prices for imminent delivery had declined, but prices for 2023 delivery had increased, indicating that the near-term market effects were smaller than initially feared but the ongoing effects may be larger.

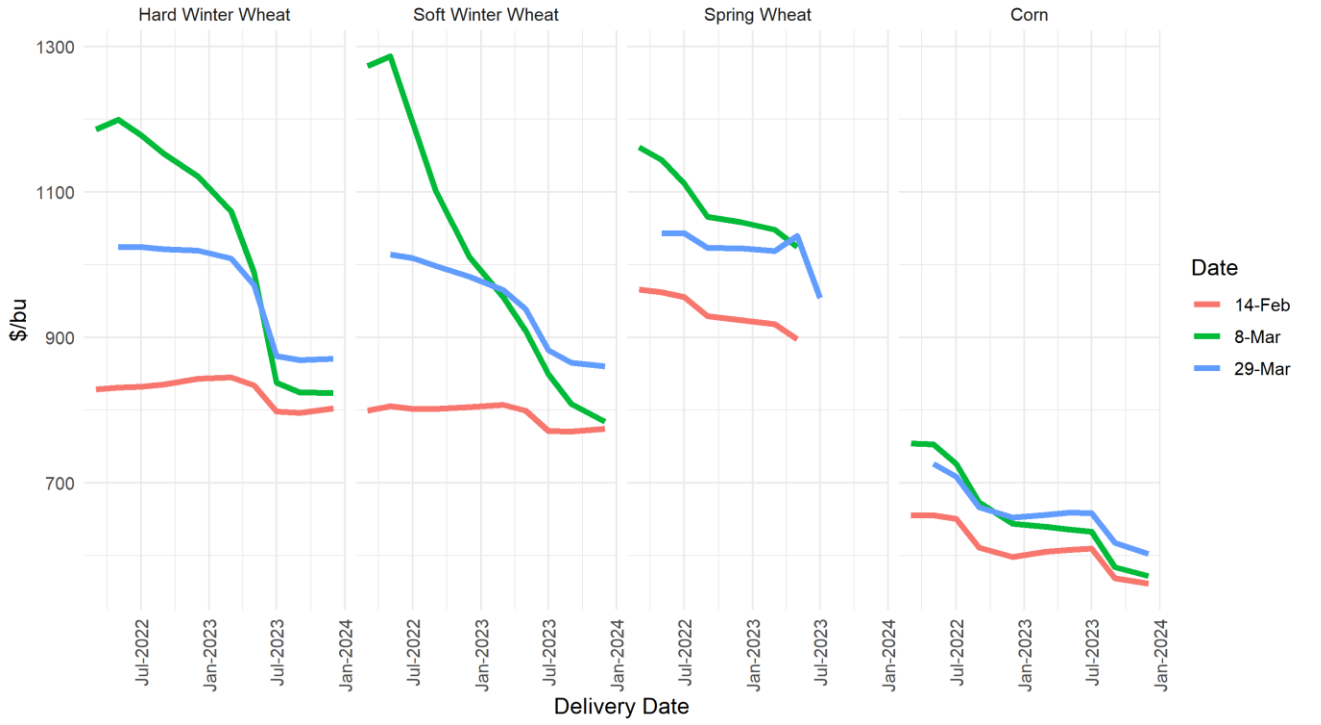
Figure 3: U.S. Corn, Soybean, and Wheat Spot Prices at the Louisiana Gulf



Source: https://www.worldbank.org/en/research/commodity-markets

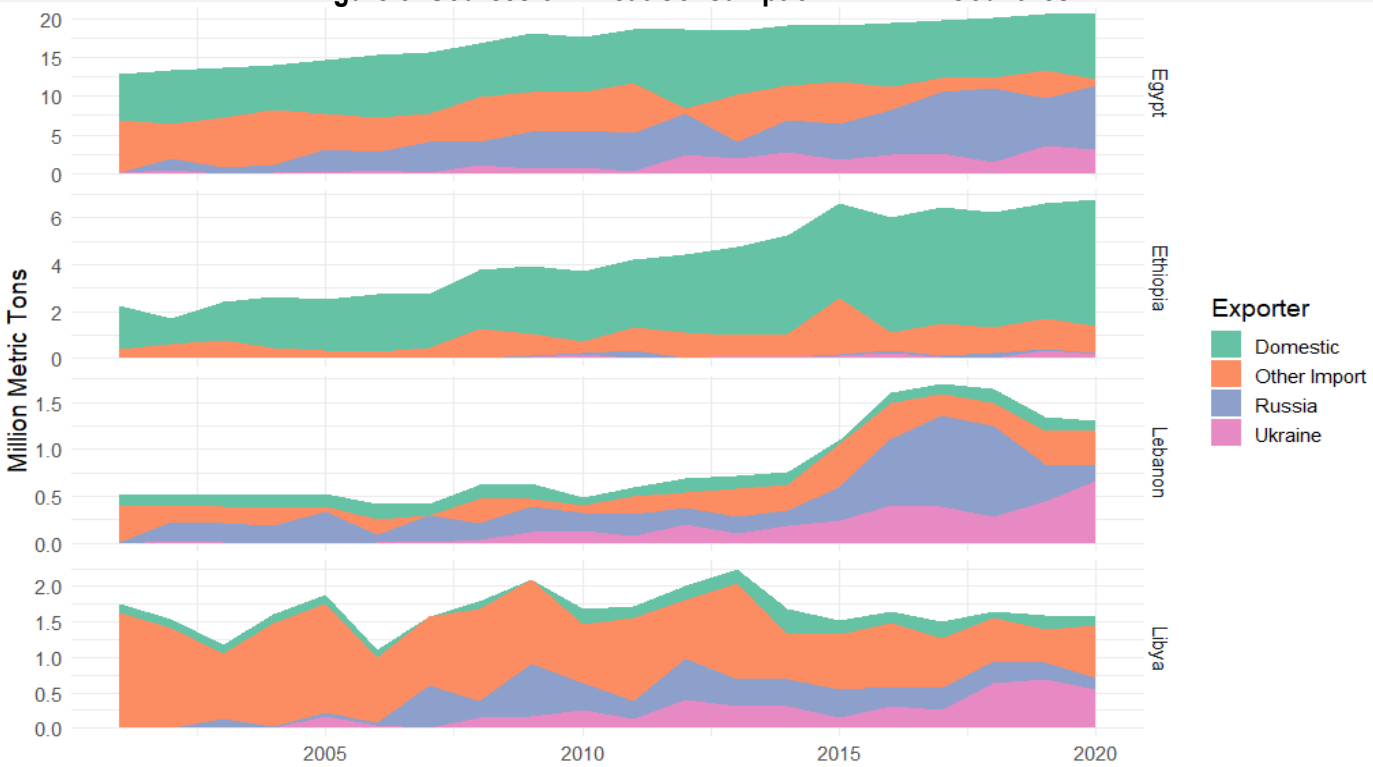
[1] https://www.kshs.org/kansapedia/bernard-warkentin/15595

Figure 4: U.S. Futures Prices by Delivery Date



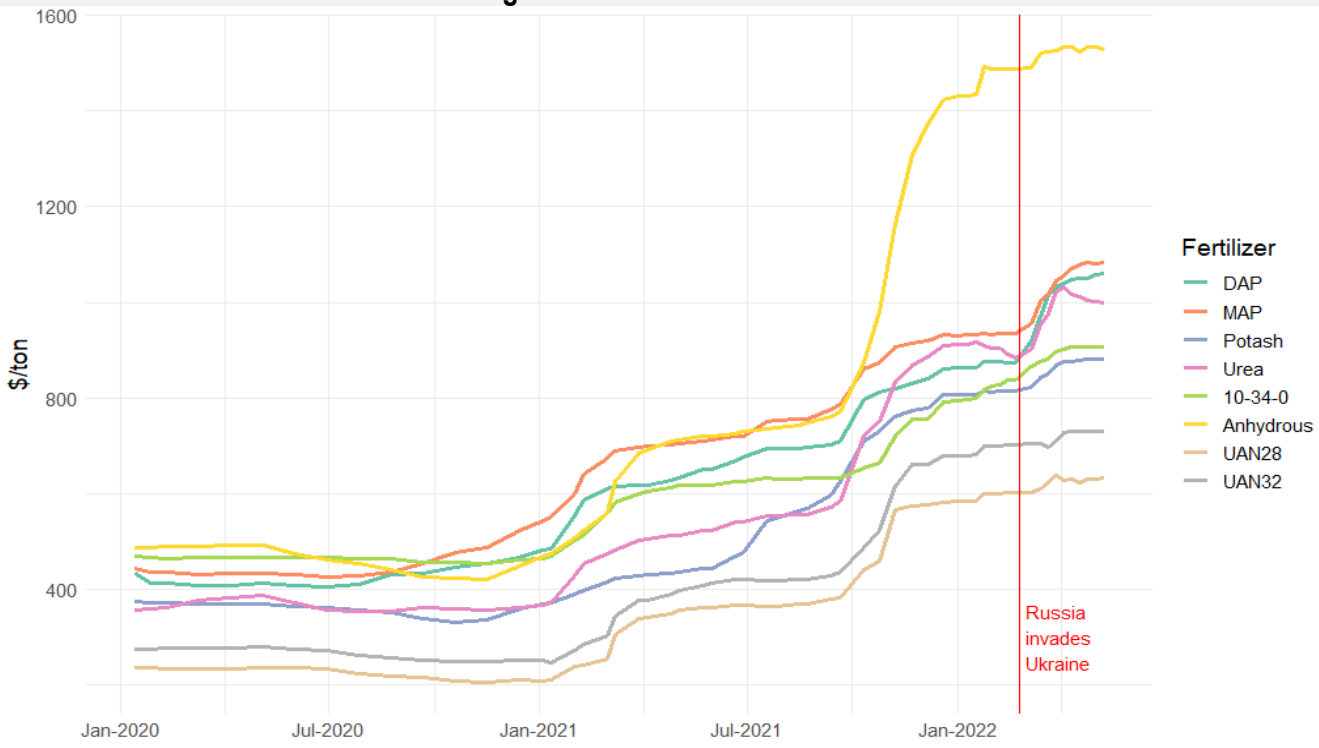
Source: Bloomberg.

Figure 5: Sources of Wheat Consumption in MENA Countries



Data Source: USDA PSD, UN Comtrade

Figure 6: U.S. Fertilizer Prices



Source: The excellent weekly blogs by Russ Quinn at DTN, e.g., https://www.dtnpf.com/agriculture/web/ag/crops/article/2022/03/16/dap-10-34-0-lead-fertilizer-prices

How Much Lost Grain Is Implied by the Observed Price Increases?

Based on the observed price increases, we can infer how much grain that traders think the rest of the world has lost. In doing so, it is important to account for any substitutions across crops. For example, a reduction in wheat exports from Russia and Ukraine may lead farmers in other countries to plant more wheat and less corn, and it may cause consumers to eat more rice and less wheat. One way to do this is to aggregate across commodities, which requires measuring quantities in comparable units (e.g., dollars or calories) because a ton of rice is a very different food product than a ton of corn. Roberts and Schlenker (2013) studied supply and demand for total calories from corn, rice, soybeans, and wheat combined. They found that, for every 1% decrease in calories from these commodities, the average price increases by 7%.[2]

On February 14, the average price of the four commodities was 15.1 cents per 1000 calories. By March 8, it had risen to 17.4 cents, an increase of 15.2%. Using the Roberts and Schlenker factor of 7, this implies a 2.2% decrease in available supply of calories. Removing 55 million metric tons of wheat and 30 million metric tons of corn entails a 2.7% reduction in available supply of calories from the big four commodities[3].

So, it seems that soon after the invasion, traders were banking on the world losing about three-quarters of Ukrainian and Russian grain exports (2.2/2.7). Given the large increase in winter wheat prices relative to the other commodities, most of the loss would be from wheat. Prices have decreased since March 8, which suggests that these estimated effects have been revised downwards. However, the more time that passes since the invasion, the less certain we can be that price changes are due to the invasion rather than other factors that have arisen in the interim, such as revised production expectations in other countries and possible demand reduction due to a global economic slowdown.

How common are market shocks of this magnitude? Russian and Ukrainian wheat exports were 7.3% of global production in 2020. Wheat production declined 6.3% in 2010, in part due to a drought that reduced Russian production by 20 million metric tons. Similarly large declines also occurred in 1991, 1994, 2003, and 2018. From the analysis above, the observed price increases are consistent with a 2.2% decrease in available supply of calories from corn, rice, soybeans, and wheat. Similar declines occurred

[2] As a class assignment, graduate students at UC Davis have re-estimated this relationship using more recent data, and using price weights rather than calorie weights, and obtained similar results.

[3] Here (https://files.asmith.ucdavis.edu/Russia_Ukraine_quantity_effects.xls) is an Excel file containing these computations.

in 2018, in part due to drought in Argentina and lower wheat acreage in Russia, and in 2012, in part due to drought in the United States.

What about Countries that Rely on Ukraine and Russia for Food Imports?

Numerous countries, notably those in the Middle East and North Africa (MENA), import a high percentage of their calories from Russia and Ukraine. For example, wheat contributes more than a third of calories consumed in Egypt, and half of this wheat comes from Russia and Ukraine (see Figure 5).[4] Lebanon imports about 90% of its wheat and gets most of its imports from Russia and Ukraine. These countries will need to find new suppliers this year.

These are serious issues that can be easily overlooked by a focus on aggregate supply and demand. Low-income consumers in these and other countries can be severely affected by relatively small increases in food commodity prices, especially given that wheat prices were already relatively high before the invasion. Wealthy governments and donors can help bridge the gap by providing aid according to best practices (Lentz et al. 2013).

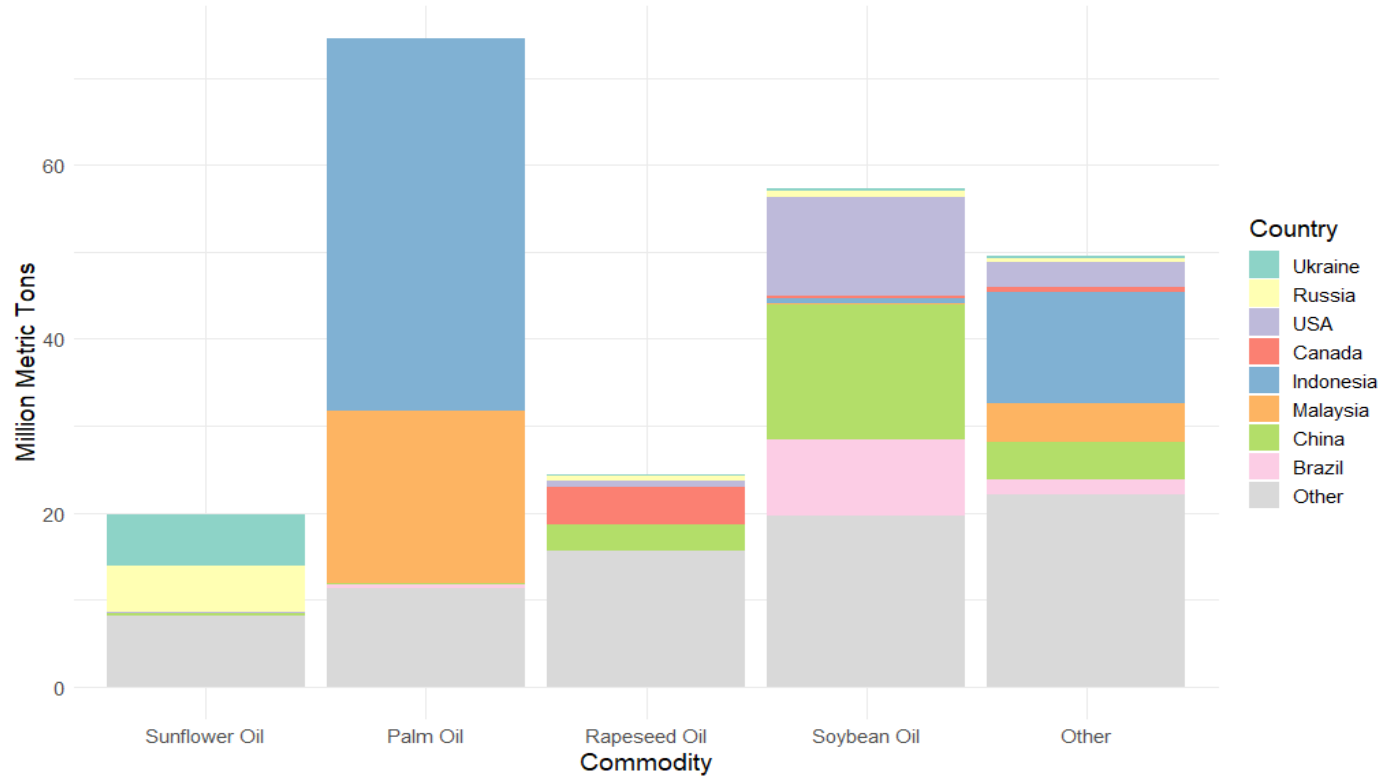
What about Fertilizer?

Fertilizers are produced throughout the world and traded heavily between countries. Russia produces 9% of global nitrogen fertilizer, 10% of global phosphate fertilizer, and 20% of global potash fertilizer. It exports more than two-thirds of its production of each product. Belarus produces an additional 17% of global potash and exports almost all of it. Ukraine produces only a small amount of fertilizer.[5]

Fertilizer prices in spring 2022 were approximately double their levels in mid-2020 (see Figure 6). However, as with agricultural commodities, most of the price increase occurred prior to the invasion; they have not increased much since Russia invaded Ukraine.

If the war cuts Russia and Belarus off from world markets, then it will leave a hole that other producers will need to fill. China produces almost all of the nitrogen and phosphate it uses, so it will not absorb Russia's exports. However, the apparent lack of a post-invasion price spike suggests that traders are not worrying about a global shortage of fertilizer. Moreover, wheat and corn traders account for fertilizer prices when they make trading decisions. If the invasion had caused a substantial reduction in global fertilizer availability, then this would have been reflected in an increase grain and oilseed prices following the invasion.

Figure 7: Global Vegetable Oil Production (2019)



Source: http://www.fao.org/faostat/en/#data/FBS

[4] For Figure 5, I used data on consumption and total imports from USDA's PSD database and data from UN's Comtrade database on exports from Russia and Ukraine to the four countries. I used data reported by the exporters rather than by the importers because there are some missing data in the latter (e.g., for Egypt in 2013 and Tunisia before 2007 and after 2018). Total imports data from USDA's PSD also differs somewhat from that reported in FAOSTAT (https://www.fao.org/faostat/en/#data/).

[5] https://www.fertilizer.org/public/resources/publication_detail.aspx?SEQN=6198&PUBKEY=C5D3054A-4F40-4FFD-8F1A-24AD36D4087D

What about Sunflower Oil?

The sunflower originated in North America and was domesticated by Native Americans. Spanish explorers carried the plant back to Europe around 1500, where it became a popular ornamental flower. It was first commercialized for oil production in Russia and Ukraine in the nineteenth century. Many now consider it a national symbol of Ukraine.

Together, Russia and Ukraine now produce more than half of the world's sunflowers. These two countries account for most of the increase in sunflower production since 2000. This market dominance has caused many to worry that Russia's invasion of Ukraine will seriously affect the global vegetable oil supply.

The world produced 225 million metric tons of vegetable oils in 2019, contributing about 10% of total calories consumed by humans.[6] In the United States, vegetable oils make up 19% of calories consumed. Figure 7 shows that sunflower oil makes up less than 10% of vegetable oils. Palm oil, produced mostly in Indonesia and Malaysia, is the largest category, followed by oil from soybean and rapeseed (which includes canola and mustard). The largest category in "Other" is palm kernel oil, which is produced from the palm kernel rather than the palm fruit.

The prices of the major vegetable oils tend to move up and down together, which indicates that most consumers view them as substitutable. The prices of all oils have increased substantially since early 2020 but have not seen large increases since the invasion. This is because a large disruption to sunflower oil production has a small effect on the global vegetable oil market.

All vegetable oil users are seeing higher prices, but mostly not because of the invasion. Only users that relied on sunflower oil from Ukraine or Russia and cannot easily switch to other oils may be facing locally high prices because of the invasion.

Conclusion

Grain and oilseed prices approximately doubled from mid-2020 through January 2022. When Russia invaded Ukraine, winter wheat prices increased another 50%, whereas corn, soybeans, and spring wheat prices increased only moderately. I estimate that these price increases imply world markets would lose about three-quarters of Ukrainian and Russian grain exports in 2022, or about 2.2% of the available supply of calories from corn, rice, soybeans, and wheat. Most of the losses would be from wheat. These shocks are similar in size to several other global shocks in the past decade, including in 2012 and 2018.

Futures prices for 2023 delivery changed little after the invasion, suggesting traders did not expect the market disruption to last more than a year. For winter wheat, the most affected crop, there was little opportunity for supply increases to mitigate the initial shock because the 2022 northern hemisphere crop was already in the ground at the time of the invasion. The market was expecting supplies to be replenished with the new crop harvest in earlier summer 2023. After the initial shock, corn and wheat spot prices decreased somewhat, and futures prices for 2023 delivery increased. These developments indicate that the near-term market effects may be smaller than initially feared, but the ongoing effects may be larger.

By itself, Russia's invasion of Ukraine was not a historic shock to food commodity prices, and markets and trade patterns will adjust to absorb it. Yet the shock has worsened food security in some countries, especially Ukraine. Moreover, this shock came at a time when food prices were already high. The FAO real food price index had exceeded its 2008 and 2010 highs before the invasion. It rose by 44% between June 2020 and February 2022, and it increased another 15% after the invasion. Smart food and financial aid for those most affected by high food prices is an important focus for policy responses.

[6] https://www.nationalgeographic.com/what-the-world-eats/

For More Information

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A Perfect or Persistent Storm for Global Agricultural Markets: High Energy Prices and the Russia-Ukraine War

Christian Elleby, Ignacio Pérez Dominguez, Giampiero Genovese, Wyatt Thompson, Marcel Adenauer, and Hubertus Gay

JEL Classifications: Q11, Q17, Q18
Keywords: Food security, Ukraine conflict, Ukraine-Russia war

A Globally Disrupted Market Environment

Russian soldiers marching on Kyiv, Ukraine, in early 2022 pushed already-rising agricultural commodity prices higher. Whereas much of the discussion has focused on the immediate effects as the two crop-producing countries experienced reductions in area and exports, there are also uncertainties about what will happen if these circumstances persist, stocks are drawn down, and crop area in other crop-producing regions is reallocated or even expanded.

In fact, the war in Ukraine has brought to the forefront, and to a certain degree accentuated, significant uncertainties that have characterized agricultural markets since the previous price boom and bust in the aftermath of the financial crisis of the late 2000s, namely the transformation of food systems, the transition to more sustainable forms of energy, and the international ruling of trade relationships. While these uncertainties cover known areas and topics, and had already been identified as a result of asymmetry in post-COVID recovery, the Russian invasion added a dramatic new twist to every one of these issues.

High Inflation and Post-COVID Economic Growth

Commodity prices have been increasing since the second quarter of 2020 and are now at a level close to previous peaks in the 2008/09 and 2011/12 marketing years. Food commodity prices, represented by the FAO Food Price Index, reached an all-time high in February 2022. After Ukraine and Russia agricultural potential was partly removed from the market, cereal, meat, and sugar prices surged, with vegetable oils rising even faster.
Sustained general food price increase (also referred to as "food inflation") can be explained by market fundamentals. Global demand was supported by the rapid post-COVID recovery, and supply-chain bottlenecks persisted in many sectors, especially shipping. The global economic rebound also pushed up the price of energy and raw materials, which was passed on to the costs of the agricultural and food sector. A negative shock to Ukrainian and Russian commodity exports added to the inflationary supply-side pressures in global markets.

Energy and Fertilizer Price Spikes

International energy prices in general, represented by the IMF Energy Index, were rising from their pandemic lows to mid-2022 yet still not as high as they had been in 2008. The Brent crude oil price increased from around USD 40 per barrel (b) in 2020 to approximately USD 100/b in February–March 2022. The price of coal and gas, which are used to produce nitrogen fertilizer and electricity, also spiked; the World Bank's Natural Gas Index for February 2022 was more than four times higher than the 2020 average.

Impacts of the War on Ukraine's Agricultural Food System

Ukraine is a global agricultural powerhouse, accounting for a significant share of the world's exports of wheat (10%), maize (16%), other coarse grains (10%), oilseeds (3%), and vegetable oils (7%) (OECD/FAO, 2022b, using 2018–2020 averages). As long as military combat persists, at least some farmers will be prevented from planting, growing, harvesting, or exporting crops due to population and labor-force displacement, damage to infrastructure (e.g., ports, farmland, storage facilities), and missed fertilizer and pesticide applications.

Perspectives for Global Agricultural Markets: Scenario Analysis

Scenario Assumptions

To assess the potential impact on global agricultural markets if the war persists, a simulation scenario was undertaken based on two blocks of assumptions:

• Crude oil and fertilizer prices: The world petroleum price average stays at $100/b and fertilizer prices are pressured higher still, to average about 65% higher than in the baseline.
• Agricultural supply: Ukrainian exports are reduced for wheat (-50%), coarse grains (-40%), and soybeans (-30%). Assuming sanctions persist, Russian exports are off for wheat (-15%). The sizes of the scenario shocks are based on the difference between the 2021 and 2022 OECD/FAO agricultural outlook baselines. Exports of all other crops from these two countries are assumed to be at their 2021 baseline level. Harvested areas in Ukraine are reduced in proportion to exports.

These shocks clearly have a negative impact on agricultural supply levels. In the discussion, we therefore also consider the potential of certain land use policies in the European Union and United States, intended to increase the agricultural area temporarily, to mitigate the market impacts of the negative supply shocks.

The model we use is a large-scale, dynamic partial-equilibrium model called Aglink-Cosimo (OECD/FAO, 2022a; Pieralli et al., 2022), which has been used to study other market and policy shocks (Araujo-Enciso and Fellmann, 2020; Elleby et al. 2020; Chatzopoulos et al., 2021). Below, in the discussion of the scenario results, we focus on 2025/26 marketing year results for crops and 2025 calendar year outcomes for livestock product markets, assuming the same supply and input price shocks in each of the years 2022–2025. Our focus is on the outcomes if the shock persists; the long-lasting price pressure depletes stocks but also induces supply response elsewhere.

Global market impacts

World market impacts are summarized in terms of their impacts on global export supply (Table 1) and indicator prices (Figure 1). World trade falls, but other producing regions increase their export supply in response to the sustained high crop prices. Wheat trade falls the most, and it is also the crop that experiences the largest price increase (29% compared to the baseline). Canada, Australia, and the European Union increase their wheat exports considerably in response to the higher prices. The reallocation of area in some countries to wheat, lower Ukrainian exports of coarse grains, and higher fertilizer prices cause coarse grains prices to increase by 17%, enough to cause increased exports from other suppliers to offset the loss of supply from Ukraine. Oilseeds, protein meal, and vegetable oil prices increase by 8%–14%, with the sign of the total export impact depending on the commodity. The exact trade response varies among exporting and importing countries according to local price impacts, their comparative advantages, the role fertilizers play in production of different crops, and demand the domestic response.

Livestock product supplies respond, too, if the conflict is sustained, but more time also allows time for livestock herds to contract. The higher crop prices put pressure on livestock supplies, resulting in mostly lower output and higher prices of meats, poultry, and dairy products (Figure 1). Pork, in particular, experiences the largest price increase on the world markets (14%), followed by butter (11%) and poultry (10%). Skim milk powder experiences the smallest price increases (2%) in the scenario.

The higher price of crude oil in the scenario also has an important effect on the biofuel market. Higher crude prices, on the one hand, translates directly into higher fuel prices, which lowers the demand for fuel in general but increases the demand for biofuel as a substitute for fossil fuels. On the other hand, higher energy and fertilizer prices increase the production costs of the main biofuel feedstocks (maize, sugar cane, and oilseeds), which leads to lower supply and, in turn, higher prices. Finally, the loss of biofuel feedstock supply (especially maize) from Ukraine adds to price pressure. Together, these effects cause the biodiesel and ethanol prices to increase by 21% and 15%, respectively, on the world market, relative to the baseline.

Increasing Food Prices and Security Concerns

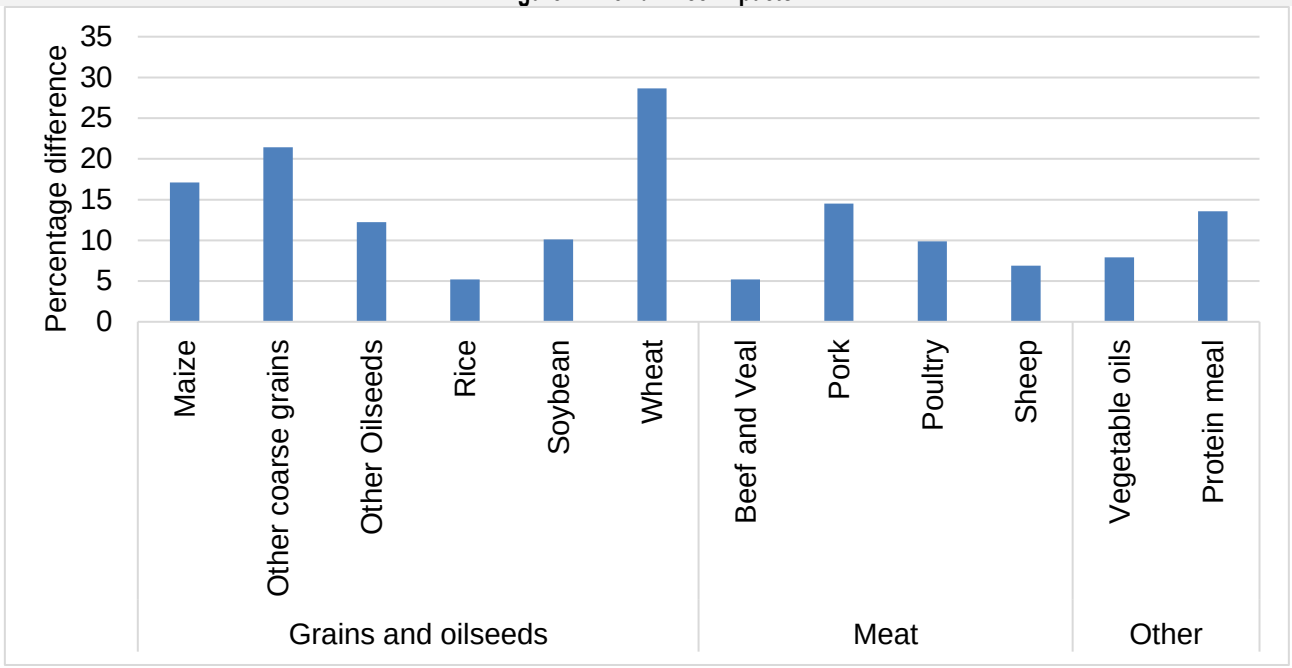
The sharply lower crop supplies caused by the conflict raised concerns about food prices throughout the world. It seems mistaken to attribute strong consumer food price inflation to this one factor alone, but the impact of a persistent conflict on food prices warrants consideration given that it does affect food security at least to some extent. Consumer price impacts vary widely (Table 2), even though producer price impacts are often more similar among countries. EU and U.S. producer and consumer prices rise,

Table 1. Scenario Impacts on Exports of Crops, Meals, and Oils: Major Exporters and World Trade

	Ukraine	Russia	Australia	Brazil	Canada	EU	USA	World
Maize	-13.49	0.00	0.02	2.04	-0.13	0.21	7.37	-0.31
Other coarse grains	-2.20	0.00	1.34	0.00	-0.88	1.72	1.15	0.85
Wheat	-11.65	-6.67	2.12	0.00	7.07	6.31	-1.28	-2.89
Soybean	-0.63	0.00	0.00	0.29	-0.16	0.00	1.18	0.45
Other Oilseeds	0.00	0.00	0.06	0.00	-0.89	0.01	0.01	-0.70
Protein Meal	0.00	0.00	0.00	0.71	-0.18	-0.02	0.45	0.52
Vegetable oils	0.00	0.00	0.00	-0.26	-0.20	-0.07	0.01	-0.51

Note: Impacts in million metric tons. Difference between scenario and baseline after three years of conflict.

Figure 1. World Price Impacts



Note: Impacts in percentage difference between scenario and baseline after three years of conflict.

but consumer price changes are often a third of the producer price changes or less in relative terms reflecting the role that large marketing margins play in dampening the impacts on final goods' prices. In other countries—such as Egypt, Nigeria, and Pakistan—the producer price impacts are sometimes muted by policy or other barriers to trade, yet the consumer price impact can be closer to half as large as the producer price change in relative terms.

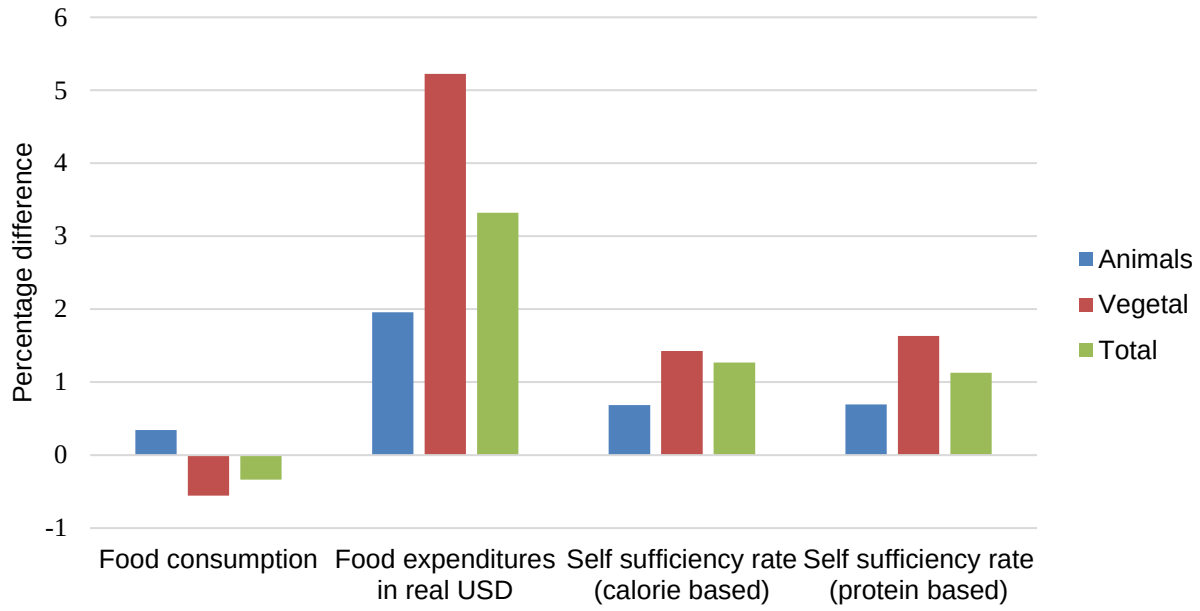
Wheat prices relate to a food staple and are sensitive to disruptions caused by events in Ukraine. An enduring conflict raises producer prices of wheat by 26%–29% in the European Union and United States, but EU and U.S. wheat product consumer prices rise by 1%–5%. In Egypt and Nigeria, the wheat producer price rises by a similar amount, yet the consumer price impacts are 10%–11%. Less of the world market impact is transmitted to the commodity price in

Table 2. Domestic Price Impacts in Selected Countries

	EU		USA		Egypt		Nigeria		Pakistan	
	PP	CP	PP	CP	PP	CP	PP	CP	PP	CP
Meat										
Sheep	7.1	2.5	7.0	2.8	2.0	1.1	0.5	0.3	0.9	0.5
Beef and Veal	7.4	2.6	7.0	2.3	3.4	1.8	1.8	0.9	0.7	0.3
Pork	16.2	3.3	14.8	2.6	14.2	4.2	4.7	1.1		
Poultry	8.8	3.8	12.4	2.4	3.1	1.6	3.3	1.6	0.6	0.3
Dairy										
Cheese	5.8	1.8	7.8	2.3	6.4	3.0	4.7	2.0	7.0	2.9
Skim milk powder	1.5	0.3	2.5	1.0	2.6	1.2	2.4	1.0	2.5	1.0
Whole milk powder	4.7	1.1	5.1	1.8	6.0	2.6	5.9	2.3		
Butter	9.2	3.9	11.4	4.5	10.8	5.2	10.6	4.5	5.9	2.4
Grains										
Wheat	26.1	5.2	29.3	1.2	28.1	11.0	28.4	9.6	17.6	6.6
Maize	14.7	13.9	15.7	1.2	17.4	3.6	14.8	3.0	10.7	2.2
Other coarse grains	18.0	1.1	20.2	1.6	21.3	5.4	5.3	1.0	20.6	4.6
Rice	5.3	1.3	5.7	0.9	5.5	3.1	5.0	2.1	5.3	2.3
Other processed products										
Sugar	9.4	0.0	8.5	3.9	10.0	5.1	8.7	3.9	9.1	3.9
Vegetable oils	9.2	2.6	7.9	2.2	7.7	2.9	7.5	2.5	7.8	2.6
Biofuels										
Biodiesel	21.4	13.1	20.2	11.8						
Ethanol	13.4	7.5	17.6	11.6						

Note: Price impacts in percentage difference between scenario and baseline after three years of conflict. PP: Producer prices. CP: Consumer prices.

Figure 2. Food Security Impacts in the MENA Region



Note: Impacts in percentage difference between scenario and baseline after three years of conflict.

Pakistan, but the wheat product consumer price nevertheless rises more than the prices of such goods in the European Union and United States.

Food security indicators outline the implications of a sustained conflict on people in the Middle East and North Africa (Figure 2). Food consumption falls with losses of crop products, including staples, induced by rising world prices more than offsetting modest cross-effects on livestock products. But food consumption must be maintained despite rising prices; food expenditures rise by over 3% in this region, with crop product costs rising over 5%. Self-sufficiency rises as global market disruption reduces these countries' import opportunities. The higher share of domestic production in food consumption among these countries could offer some protection against further international market shocks yet at the same time increase vulnerability to domestic shocks. Extrapolating from this case, the global food security impacts of sustained conflict are negative if measured by food consumption quantities or costs.

High Uncertainties Prevail

The scenario represents the case of a sustained conflict. This perspective seems necessary for setting the context of any policy response that goes beyond alleviating short-term stress, including policies relating to crop area, research, or new mechanisms that will take time to implement. Impacts are based on observed events, but there is uncertainty about measured planting and exports during such a conflict, and extrapolating into the future is fraught with uncertainty. Moreover, future pressures on natural gas markets and fertilizer prices, which have varied widely among regions in the short run, are unknown. Fertilizer supply response might curtail price impacts over time and fertilizer trade might equalize price shocks spatially. Nevertheless, the experiment is intended to help policy makers and market agents consider the possible context for their decisions if the conflict is sustained.

EU and U.S. Policy Effort to Rebalance Markets

Persistent disruption in crop and crop product supplies from Ukraine and Russia could lead to more discussion about changing the balance between environmental and other policy goals. In particular, some proposed in the early weeks of the crisis that U.S. and EU crop areas set-aside for conservation purposes be reduced to support greater production. Moreover, an increase in consumer prices might lead to unrestricted grain exports from Russia even if the crisis continues. We undertake some admittedly speculative scenarios to explore possible outcomes.

We simulate the evolution of markets and prices during an extended crisis in the case that U.S. Conservation Reserve Program (CRP) and EU set-aside (as ecological focus areas) are reduced below levels implied by existing targets or baseline levels. Just over 1.5 million acres (0.6 million ha) are expected to exit CRP (AgWeb, 2022); we reduce EU set-aside by 1.7 million ha. We assume the yield on this area is the same as the average yield on land already in crop production, whereas the actual yield from the converted land could be quite different.

The price impacts of EU and U.S. policy changes that shift land set aside for environmental objectives into agricultural commodity production offset a portion of the price impacts of a sustained Ukraine crisis (Table 3). In this case, the world

Table 3. Comparison of World Price Impacts			
	Scen1	Scen2	Scen3
Maize	17.1	16.0	16.1
Other coarse grains	21.4	18.6	18.2
Soybean	10.1	9.1	9.6
Wheat	28.6	26.3	22.1
Other Oilseeds	12.3	11.2	10.9
Protein Meal	13.6	12.2	12.8
Vegetable oils	7.9	7.4	7.6

Note: Impacts in percentage difference between scenario and baseline after three years of conflict. Scen1: same as the tables above. Scen2: Scen1 + additional farmland in the European Union and United States. Scen3: Scen1 + endogenous export response in Russia. No additional trade costs.

wheat price is 26% higher than it would have been without the Ukraine crisis, compared to a 29% increase without the reduction in set-aside area. The world corn price change is 16%, compared to 17% without the set-aside change. Other changes in price outcomes are of a similar magnitude. We do not estimate the environmental impacts of the set-aside reduction, which would presumably be negative by design. We also do not test the implications of this policy after the Ukraine crisis is concluded, but we recognize that this analysis would be sensitive to assumptions about whether the policy change would be reversed and total set-aside area restored at some point.

There is also the possibility that the world price impacts brought about by sustained conflict lead to greater exports from Russia. In the initial scenarios, we implicitly constrained Russia export supply response; we assumed that Russian crop exporters and producers could not take advantage of rising world prices. If the higher prices do lead to greater Russian production and exports, then this response mitigates some of the price impact (Table 3). The wheat price impact of sustained conflict is 22%, compared to 29% without Russian export expansion, and other crop price impacts are also moderated in this case.

We do not trace the export response of Russia to any specific factor, allowing that it might be explained by policy responses or disruptions associated with the conflict.

Summary

Stories of mined crop land, blocked ports, and lost grain stocks seized the attention of everyone involved in global commodity trade at the start of 2022. Prices jumped and people looked to satellite images and food price indicators to assess the impacts. Yet the focus on immediate impacts betrays the potential that the risks might change if the conflict endures and does not inform policy makers about the context for those options that have delayed impacts, such as those relating to area, research, or slowly developing food support.

We apply a widely used structural economic model to estimate the impacts of a three-year conflict on key world market and food security indicators. Even taking into account supply response in other crop producing regions, there is potential for food grain price impacts of nearly 30%. Moreover, the effects spill over into livestock markets over time. The implications for consumers in developing countries could be sustained pressure on food security.

For More Information

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Impacts of the Russian-Ukraine Conflict on Global Agriculture Commodity Prices, Trade, and Cropland Reallocation

JEL Classifications: Q17, Q18
Keywords: Agricultural exports, Fertilizer prices, Modeling of agricultural markets, Russia-Ukraine conflict

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The Russia-Ukraine conflict that started in February 2022 has caused significant disruptions in the already volatile global food and fertilizer markets (Benton et al., 2022; Food and Agriculture Organization of the United Nations, 2022). These disruptions have pushed agricultural commodity and fertilizer prices to record highs (Cowley, Rodziewicz, and Cook, 2022), as Russia and Ukraine accounted for 26%, 15%, 28%, and 75% of global exports of barley, corn, wheat, and sunflower oil, respectively, in the 2020/21 marketing year (Figure 1). Additionally, in 2020, Russia was the world's largest exporter of fertilizers. Brazil (21%), China (10%), the United States (9%), and India (4%), all critical players in global agricultural markets, were the primary destinations of Russian fertilizers (Colussi, Schnitkey, and Zulauf, 2022).

In this article, we use the Center for Agricultural and Rural Development International Agricultural Commodity Market (CARD-IACM) model to project impacts of the Russia-Ukraine conflict on global agricultural prices, production, and trade. We measure the impacts against a baseline that reflects the expected trajectory of these markets in absence of the conflict. We focus on major grain and meat products, including corn, wheat, soybeans, rice, sunflower oil, beef, broiler, and pork. While it is uncertain how long the conflict will last, we assume that its impacts on the markets will last about five years. We focus on three important questions:

a) Do Ukraine's export reductions incentivize the production of those crops in countries other than Russia and Ukraine?

b) Do higher fertilizer prices shift production from crops that rely more on fertilizers, such as corn, to crops that rely less on fertilizers, such as soybeans?

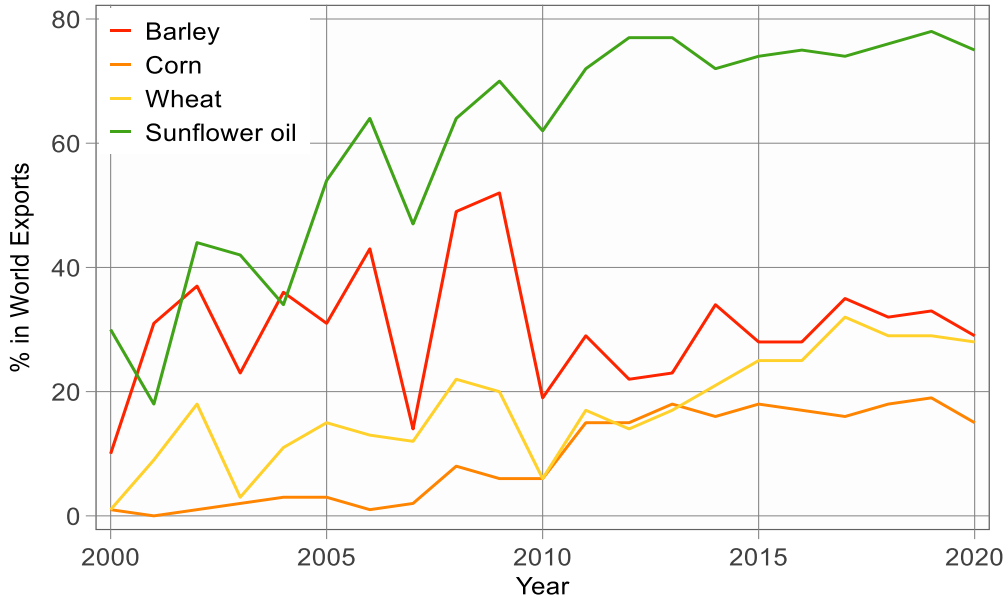
c) Do Ukraine's export reductions and higher fertilizer prices change major agricultural exporters' comparative advantage?

Policy Scenarios and Modeling Framework

Ideally, we would use actual changes in Ukrainian exports and fertilizer prices as shocks to the baseline model. However, at the time of writing, the actual changes in Ukraine's agricultural production and exports remain uncertain. World Bank (2022) documents that imports of Ukraine corn into China, the European Union (EU), Japan, and the United States dropped by 30% and their imports of Ukraine sunflower oil fell by 50%. Fertilizer prices have risen nearly 30% since the start of 2022, following last year's 80% surge (Baffes and Koh, 2022). Therefore, we assume reasonable shocks to both Ukraine's exports of its major agricultural commodities and global fertilizer prices.

Table 1 lists our four simulation scenarios. In the baseline (i.e., the preconflict status quo scenario), Ukraine's exports of barley, corn, wheat, and sunflower oil and the prices of the three major nutrients in commercial fertilizers (nitrogen, phosphorus, and potassium) are not affected. In Scenario 1, we assume that Ukraine's barley, corn, wheat, and sunflower oil exports fall by 25%, while the prices of nitrogen, phosphorus, and potassium increase by 100%. In Scenario 2, we assume a 25% reduction in Ukraine's exports of the impacted products and a fertilizer price increase of 150%. In Scenarios 3 and 4, we assume a 50% reduction in Ukraine's exports of barley, corn, wheat, and sunflower oil and a 100% and 150% increase in fertilizer prices, respectively. Note that in the 2021/22 marketing year, Ukraine exported 22.8%, 26.3%, 1.6%, and 43.9% of its barley, corn, sunflower oil, and wheat production, respectively. We assume no shocks to Russia's agricultural exports because the conflict has not significantly impacted Russia's exports. Fertilizer prices are exogenous to the model. We assume that the shocks will remain for five years and focus on the projected outcomes in the 2025/26 marketing year.

Figure 1. Russia And Ukraine's Shares in Global Exports of Barley, Corn, Wheat, and Sunflower Oil



Source: U.S. Department of Agriculture (2022).

These scenarios allow us to compare prices, production, and trade flows of major agricultural products, especially grains, oilseeds, and meat products across a series of plausible "what if" scenarios. They also allow us to investigate the substitution patterns across commodities as well as trade creation and diversion effects across countries under different scenarios.

The CARD-IACM model is an agricultural modeling system that can quantify the impact of market changes and policies on global land allocation, production, consumption, and trade of a broad set of agricultural and biofuel commodities (Dumortier, Carriquiry, and Elobeid, 2021). The model is comprised of 22 countries/regions with all agricultural sectors (commodities) contained within each country or region. The model places each sector's land use within a hierarchical land-use structure within each country or region. The model assumes that per capita demand for food increases with income at a decreasing rate on the demand side. This model solves for a set of successive annual commodity prices to equate global supply and demand for agricultural products. To generate yearly projections from 2021/22 to 2025/26, we first calibrate the model using data until the 2020/21 crop marketing year to establish five-year baseline projections for supply, utilization, and prices from 2021/22 to 2025/26. We then run the model to project agricultural prices, production, and trade under the four simulation scenarios outlined in Table 1.

Higher World Prices for Major Commodities

Figure 2 shows the percentage changes in prices for each scenario relative to the baseline for several major commodities in the analysis for the last year of the projection (2025/26). (The full numerical results are available upon request.) In Scenario 1 (25% export reduction/100% fertilizer price increase), the prices of corn, barley, wheat, sunflower oil, rice, and soybeans increase by 24.9%, 22.4%, 18.3%, 22.5%, 11.7%, and 7.1%, respectively, in 2025/26. The prices of meat products are also higher but to a lesser extent: pork, broiler, and beef prices rise by 11.7%, 10.0%, and 8.6%, respectively. In Scenario 2 (25% export reduction/150% fertilizer price increase), the prices of crops and meat products increase by a larger magnitude than in Scenario 1.

Table 1. Simulation Scenarios

	Reductions in Ukraine's Exports of Barley, Wheat, Corn, and Sunflower Oil	Increase in Global Prices of Nitrogen, Phosphorus, and Potassium
Scenario 1	25%	100%
Scenario 2	25%	150%
Scenario 3	50%	100%
Scenario 4	50%	150%

Table 2. Percentage Changes in Harvested Area of Major Crops in 2025/26 in Select Countries under Different Scenarios Relative to the Baseline

Country	Scenario 1	Scenario 2	Scenario 3	Scenario 4
Corn				
Australia	-5.54	-7.84	-5.63	-7.91
Brazil	-6.64	-9.87	-5.38	-8.69
China	-1.91	-2.68	-1.95	-2.72
United States	-3.08	-4.47	-2.94	-4.32
Countries other than Russia and Ukraine	-3.96	-5.67	-3.75	-5.47
Wheat				
Australia	-2.74	-3.98	-2.50	-3.76
China	-3.51	-5.07	-3.26	-4.84
India	-2.13	-3.12	-1.98	-2.97
United States	0.47	0.81	-0.14	0.23
Countries other than Russia and Ukraine	-2.95	-4.26	-2.76	-4.08
Soybeans				
Argentina	2.68	3.81	2.69	3.82
Brazil	-0.49	-0.47	-1.10	-1.03
China	4.30	6.29	3.71	5.72
United States	-0.41	-0.61	-0.38	-0.57
Countries other than Russia and Ukraine	0.21	0.32	0.03	0.16
Rice				
China	1.59	2.29	1.76	2.42
India	-0.85	-1.30	-0.84	-1.28
Vietnam	-1.34	-2.01	-1.36	-2.02
Countries other than Russia and Ukraine	-1.25	-1.86	-1.18	-1.79

Source: Based on authors' calculations.

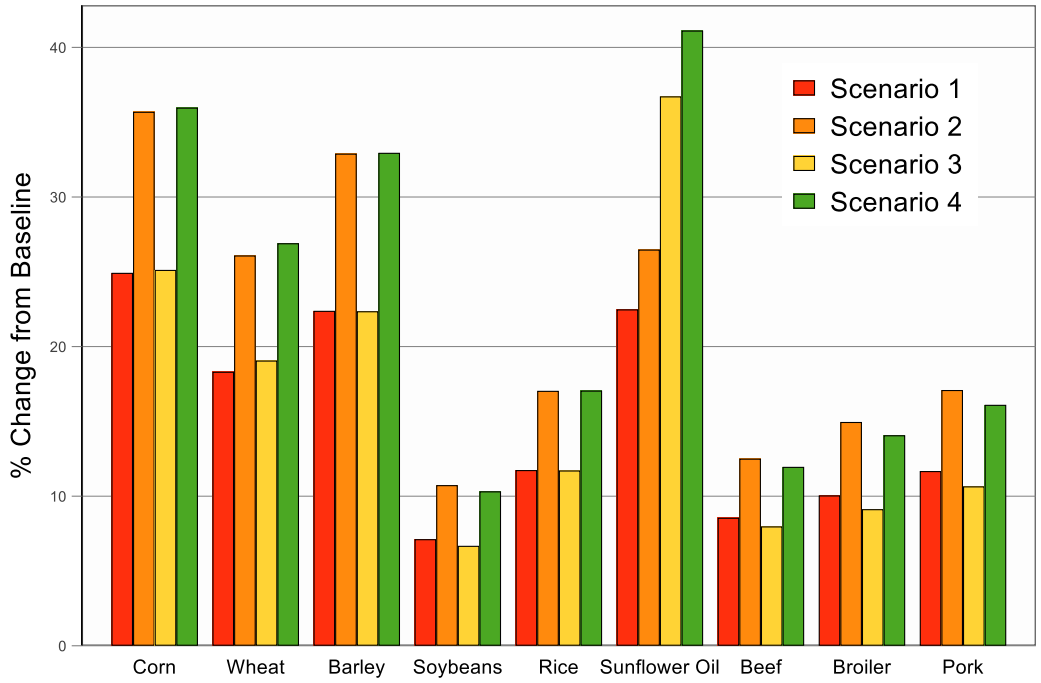
We also observe another pattern in Figure 2—the impacts of Ukraine's export reductions on agricultural prices are smaller in magnitude than the impacts of global fertilizer prices, as shown by the smaller changes between Scenarios 1 and 3 (25% and 50% export reduction, respectively/100% fertilizer price increase) than the changes between Scenarios 1 and 2 or 3 and 4 (25% and 50% export reduction/100% and 150% fertilizer price increase, respectively). This pattern indicates that global fertilizer prices have a much larger impact on commodity prices than Ukraine's export reductions, which makes sense given that fertilizer price increases affect all world producers and commodities.

These results show that the input and output shocks associated with the Russia-Ukraine conflict put upward pressure on the prices of both crop and livestock products. The impacts on affected products—including barley, corn, wheat, and sunflower oil—increase to a larger extent than the impacts on soybeans and rice, with meat prices increasing by a smaller magnitude than crop prices. These results make intuitive sense as Ukraine and Russia account for relatively large shares of the barley, corn, wheat, and sunflower oil export markets, and fertilizer is an important component of production costs for these commodities (in absolute terms and relative to those of other crops such as soybeans). The impact on the livestock sector is mostly indirect and caused by higher feed costs.

Cropland Shifts from Corn, Wheat, and Rice to Barley and Soybeans

Figure 3 presents percentage changes from the baseline for harvested area of major crops for countries other than Russia and Ukraine (note that Ukraine's production mix would change in response to world commodity prices and fertilizer prices). First, there is a clear pattern of the Russia-Ukraine conflict shifting cropland from corn, wheat, and rice to barley and soybeans. In Scenario 1 (25% export reduction/100% fertilizer price increase), the harvested areas for corn, wheat, and rice decline by 3.42%, 2.57%, and 0.97%, respectively. In comparison, soybean and barley harvested area increase by 0.54% and 0.75%, respectively. A partial explanation is that soybean production needs less fertilizer than other crops. Soybeans also compete most directly with corn at planting, and higher nutrient prices severely affect corn. Barley is a winter crop that competes

Figure 2. Percentage Changes in Prices of Major Grains, Oilseeds, and Meat Products in 2025/26 for Different Scenarios Relative to the Baseline



directly with wheat, which might explain the shift toward barley. Ottman (2012) shows that barley requires less nitrogen fertilizer than wheat to obtain maximum yield; thus, the increase in fertilizer prices in the model impact wheat more. In our model, the baseline proportions of fertilizer costs to total variable costs for barley and wheat are 24.9% and 28.3%, respectively. Another potential explanation for the shift toward barley is that, in Scenario 1, the price of barley increases more than the price of wheat as Russia and Ukraine account for a larger share of global barley exports than they do wheat. This could be an additional incentive for shifting cropland from wheat to barley.

The decline in harvested area of corn, wheat, and rice and the increase in the harvested area of barley and soybeans are larger in magnitude in Scenario 2 (25% export reduction/150% fertilizer price increase) than in Scenario 1. However, in Scenario 3 (50% export reduction/100% fertilizer price increase), the declines in harvested area of

Figure 3. Percentage Changes in the Harvested Area of Major Feed Grains in 2025/26 for Countries Other than Russia and Ukraine under Different Scenarios Relative to the Baseline

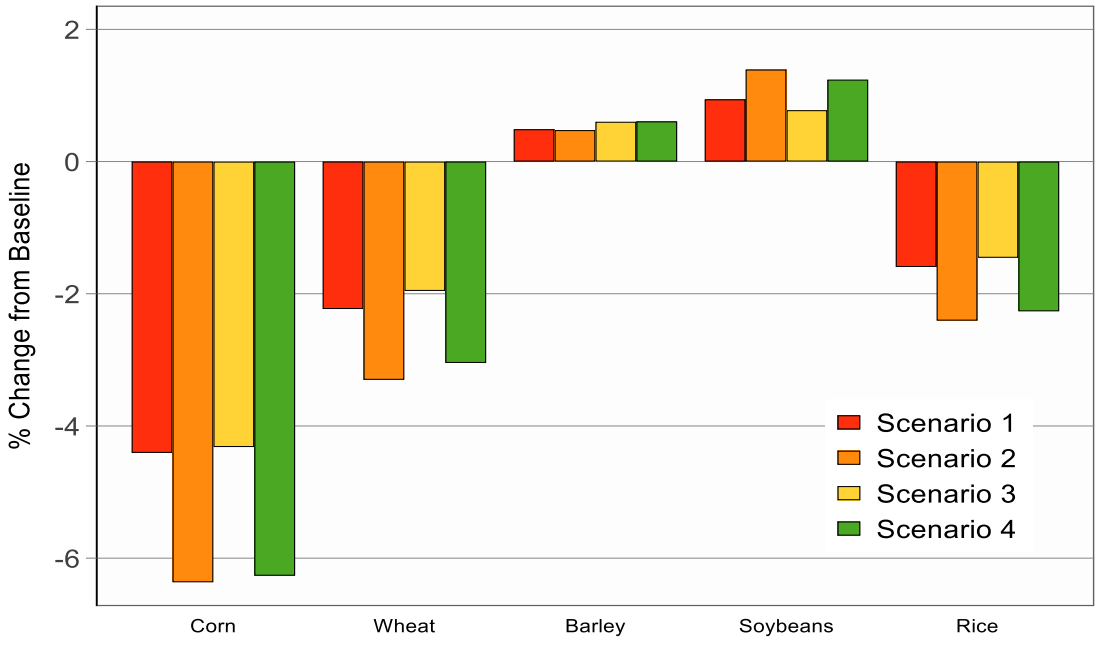
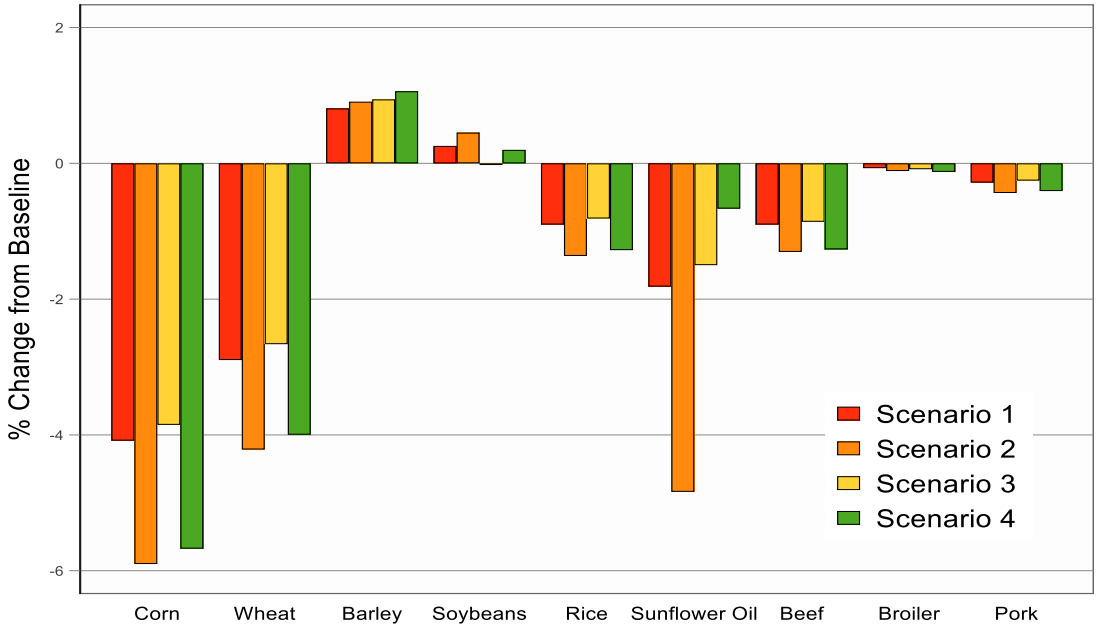


Figure 4. Percentage Changes in Global Production of Major Crop and Meat Products in Countries Other than Russia and Ukraine in 2025/26 under Different Scenarios Relative to the Baseline



corn, wheat, and rice and the increase in the harvested area of soybeans are smaller in magnitude compared with Scenario 1. This pattern indicates that because of the higher world prices shown in Figure 2, countries other than Ukraine and Russia experience lower reductions in land allocated to corn, wheat, and rice if the conflict heavily affects Ukraine's exports.

However, the aggregate harvested area across crops could mask diverse changes across countries. Table 2 presents major producing countries' percentage changes in the harvested area of major feed grains compared with the baseline. There is a significant difference in the impacts across countries and products caused by countries' different crop mixes, supply elasticities, and varying production technologies, which implies that fertilizer has a varying share of the costs of producing different crops. One point worthy of attention in the interpretation of our projections is that because we try to isolate the effects of fertilizer price increases and reduced exports from Ukraine with all other things equal, the projections in Table 2 are only due to the fertilizer price changes and changes in exports from Ukraine.

Shift in Production of Corn, Wheat, and Rice to Soybeans and Barley

Figure 4 shows percentage changes in the production of key crops and livestock products relative to the baseline. In Scenario 1, similar to the patterns in harvested area presented in Figure 3, corn, wheat, and rice production decline by 4.08%, 2.89%, and 0.90%, respectively, while barley production increases by 0.81%. Beef, broiler, and pork production also slightly decline by 0.90%, 0.07%, and 0.28%, respectively.

While similar patterns emerge, Figures 3 and 4 also show some differences that arise mainly due to the dissimilarity in the changes in crop area of different countries and the associated productivities (yields) of crops in those countries. For example, if a high-yield country reduces the area of a crop while a low-yield country increases the area for that crop, then, in terms of magnitude, the changes in area will be smaller than changes in production; the opposite can also occur. More generally, different combinations of changes in areas between countries and relative productivities arise, which explains the differences between Figures 3 and 4.

A comparison of Scenarios 1 and 2 indicates that a higher increase in fertilizer price decreases the production of all seven commodities except soybeans, which again suggests that higher fertilizer prices incentivize more land allocated to soybeans as it becomes relatively more profitable than other crops that compete for the same land. A comparison of Scenarios 1 and 3 indicates that larger reductions in Ukraine's exports of barley, corn, wheat, and sunflower oil result in smaller declines in the production of corn, wheat, rice, and meat products in other countries, reflecting higher commodity prices. This points to the fact that Ukraine's export reductions could incentivize the production of corn, wheat, and rice in countries other than Russia and Ukraine.

Changing Comparative Advantage in Global Agricultural Markets

Table 3 presents the percentage changes in exports of key crops and livestock products relative to the baseline for major exporters. There are three interesting observations.

Table 3. Percentage Changes in Exports of Major Crops and Meat Products in 2025/26 for Select Countries under Different Scenarios Relative to the Baseline

Country	Scenario 1	Scenario 2	Scenario 3	Scenario 4
Corn				
Australia	-6.12	-8.66	-6.20	-8.72
Brazil	-7.56	-11.14	-6.29	-9.96
United States	-3.66	-5.29	-3.51	-5.14
Rice				
United States	-1.53	-2.40	-1.17	-2.05
Vietnam	-1.56	-2.33	-1.58	-2.34
Soybeans				
Argentina	2.61	3.71	2.59	3.70
Brazil	-0.55	-0.56	-1.19	-1.14
United States	-0.49	-0.72	-0.48	-0.70
Wheat				
India	-2.54	-3.72	-2.36	-3.54
United States	0.07	0.24	-0.50	-0.31
Beef				
Australia	-0.08	-0.27	0.01	-0.18
Brazil	-2.67	-3.69	-2.67	-3.70
United States	0.06	0.02	0.05	0.02
Broiler				
Australia	0.58	0.78	0.58	0.78
Brazil	-0.83	-1.19	-0.75	-1.12
United States	1.07	1.47	0.93	1.34
Pork				
European Union (28)	-1.42	-1.75	-1.32	-1.66
United States	0.68	0.85	0.61	0.78

Source: Based on authors' calculations.

First, while higher fertilizer prices and lower Ukrainian exports lead to decreases in the exports of most agricultural products, some exporting countries benefit from the shocks. For example, in Scenario 1, Argentina's soybean exports increase by 2.6% while Brazilian and U.S. soybean exports fall by 0.55% and 0.49%, respectively. Australian and U.S. broiler exports increase by 0.58% and 1.07%, respectively, while Brazil's broiler exports decline by 0.83%. U.S. pork exports rise by 0.68% and those of the EU fall by 1.42%.

Second, the Russia-Ukraine conflict generally affects U.S. exports less than those of other major producers. For example, in Scenario 1, U.S. corn and soybean exports decline by 6.12% and 0.49%, respectively, while Brazil's corn and soybean exports decline by 7.56% and 0.55%, respectively. U.S. wheat exports increase by 0.07%, while India's wheat exports decline by 2.54%. U.S. beef exports increase by 0.06% and Brazil's beef exports decline by 2.67%. A potential reason for the larger impact on Brazil's corn and soybean production is that the United States relies less than Brazil does on the global fertilizer market. Another finding is that in all four scenarios, Argentina's corn exports decline and soybean exports increase, indicating that higher fertilizer prices shift Argentina's production from crops that rely more on fertilizers to crops that rely less on fertilizers.

Third, a comparison of Scenarios 1 and 2 indicates that a larger increase in global fertilizer price further reinforces the patterns in Scenario 1 with larger impacts in magnitude. A comparison of Scenarios 1 and 3 shows that a larger decline in Ukraine's exports of barley, corn, and wheat results in a smaller increase in U.S. exports of broiler and meat products.

Overall, the patterns in Table 3 indicate that the fertilizer price increase will shift trade patterns and likely increase the export share of countries that rely less on world fertilizer markets. In particular, the shocks will increase U.S. export share in the pork market relative to the EU and in the corn and soybean markets relative to Brazil.

Concluding Remarks

This article provided one of the first looks at the The Russia-Ukraine conflict has disrupted global agricultural markets via both input and output markets. Given that the duration of the conflict is uncertain, we have yet to see the actual impacts of the conflict on global agricultural production and trade. We use a global agricultural modeling system to simulate the impacts of the conflict on the prices, production, and trade of major feed grains and meat products, including barley, corn, rice, soybeans, wheat, beef, broiler, and pork.

There are several major findings. First, higher fertilizer prices and Ukraine's reduced exports will push up prices of both feed grains and meat products. The impacts on affected products—including wheat, corn, and barley—increase to a larger extent than soybeans and rice, with meat prices increasing by a smaller magnitude than crop prices. Second, higher fertilizer prices and Ukraine's reduced exports of barley, corn, wheat, and sunflower oil result in a reallocation of cropland from corn, wheat, and rice to soybeans and barley, which partially reflects that the conflict shifts cropland to crops that rely less on fertilizers. In particular, Brazil's corn and soybean harvested area decrease by more than those in the United States. While beyond the scope of this paper, these land-use changes have environmental implications based on where the shifts in crop area occur and for which crops (see Carriquiry, Dumortier, and Elobeid, 2022, for the implications on carbon emissions). Finally, we also project that the conflict will increase U.S. export share in the pork market relative to the EU and in the corn and soybean market relative to Brazil, which indicates that the conflict could potentially shift the comparative advantage in global agricultural markets.

Our results come with some caveats and limitations. Our projections do not fully capture all potential factors that impact food prices, production, consumption, and trade, such as temporary tariff and nontariff trade measures, weather shocks, exchange rate fluctuations, and the formation of regional trade agreements in the projection period. However, comparisons of results under different scenarios provide useful benchmarks and insights for predicting the impacts of the Russia-Ukraine conflict on global agricultural markets. Finally, given the impact on grain and oilseed feedstocks, the conflict has implications for biofuel markets, protein meal, and food security. (See Carriquiry, Dumortier, and Elobeid, 2022, for the implications on food insecurity.)

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Impacts of Russia's Invasion of Ukraine on U.S. Agriculture

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The invasion of Ukraine has had profound impacts on the farm and food sector (Grant, Arita, and Thompson, 2022). For one thing, it has limited Ukraine's exports of grain and vegetable oil, pushing up prices in global agricultural commodity markets (Smith, 2022; Glauber and Laborde, 2023). In addition, economic sanctions and other market disruptions have reduced Russia's exports of petroleum and natural gas, contributing to higher prices for fuel, fertilizer, and other farm inputs. The net effect is to increase both revenues and costs for U.S. farmers and to raise the price of food paid by consumers.

We use the modeling system maintained by the Food and Agricultural Policy Research Institute (FAPRI; Gerlt and Westhoff, 2019) to develop preliminary estimates of the impact of the war on U.S. agriculture. We do this by comparing a scenario that incorporates possible effects of the war on agricultural commodity and input markets to a scenario that does not.

Key Assumptions

The starting point for the analysis is FAPRI's 2022 baseline outlook (FAPRI, 2022), which was prepared based on information available before the Russian invasion of Ukraine in February 2022. For both the "war" and "no-war" scenarios, we updated that baseline for some developments not related to the war, such as the smaller-than-anticipated soybean crop in South America and the effect of unfavorable weather on 2022 U.S. winter wheat production. All quantitative analysis for this paper was completed in June 2022. Subsequent developments, both in the war and in agricultural markets, are not incorporated in the estimates. The focus is on the question, "How much difference did the invasion make?" and not on the question, "What is the current outlook for agricultural markets?"

Various researchers have developed early estimates of the war in Ukraine on global agricultural markets (Food and Agriculture Organization of the United Nations, 2022; OECD-FAO, 2022). The USDA's June 2022 World Agricultural Supply and Demand Estimates (U.S. Department of Agriculture, 2022a) provide a basis for some of the assumptions used to conduct our analysis (Table 1). In the two marketing years prior to the war, Ukraine exported an average of 19 million metric tons (MT) of wheat and 26 million MT of corn. For the 2022/23 marketing year (the year beginning with the 2022 harvest), the USDA estimated those exports would be reduced to 10 million MT of wheat and 9 million MT of corn. This 26-million-MT reduction of Ukraine's exports of wheat and corn combined is comparable to total U.S. exports of wheat in a typical year.

The Russian invasion occurred in February 2022, near the midpoint of the 2021/22 marketing year. Much of Ukraine's grain and sunflower oil had already moved into international markets before the war broke out, but exports have been severely restricted in recent months. The USDA estimated that Ukraine's stocks of both wheat and corn would be much higher than normal at the end of the 2021/22 marketing year. Sanctions and other disruptions may also have had a modest impact on limiting Russia's exports of the same products in 2021/22.

We assume that the reported increase in Ukraine and Russia's grain stocks in 2021/22 relative to the average of the previous two years is an indicator of how much additional grain the two countries might have exported had it not been for the war. Thus, we shift the export demand curve for U.S. wheat by 6.9 million MT (253 million bushels) and the export demand curve for corn by 5.7 million MT (227 million bushels). These shifts would reflect the change in U.S. exports in 2021/22 if prices had remained at the level of the no-war scenario. However, this shift in demand results in higher prices, meaning that the net change in U.S. exports is much smaller, as the quantities supplied, used, and traded in global markets adjust. Changes in trade patterns due to the conflict are discussed in detail in Grant, Arita, and Sydow (2022).

Table 1. Ukraine and Russian Exports and Stocks, Million Metric Ton			
	Wheat	Corn	Sun Oil
		Million Metric Tons	
Exports, 2019/20 – 2020/21 avg.			
Ukraine	18.9	26.4	6.0
Russia	36.8	4.0	3.5
Ending Stocks, 2019/20 – 2020/21 avg.			
Ukraine	1.5	1.2	0.2
Russia	9.3	0.8	0.2
Ending Stocks, 2021/22			
Ukraine	5.6	6.8	0.2
Russia	12.1	0.9	0.6
Stocks, 2021/22 vs. 2019/20-2020/21 avg.			
Ukraine	4.1	5.6	0.0
Russia	2.8	0.1	0.4
Exports, 2022/23			
Ukraine	10.0	9.0	3.6
Russia	40.0	4.3	3.6
Exports, 2022/23 vs. 2019/20-2020/21 avg.			
Ukraine	-8.9	-17.4	-2.4
Russia	3.2	0.3	0.1

Source: author calculations based on USDA data from PSD Online, June 2022

This approach is less useful in the case of vegetable oil. The USDA's June 2022 estimates suggested that Ukraine and Russian stocks of sunflower oil were only mildly affected by the war, but exports were nevertheless lower than in recent years. We assumed a 1.3 million MT (2.9 billion pound) shift in the demand for U.S. vegetable oil exports in 2021/22. As with the grains, the net change in U.S. vegetable oil exports was much smaller, as higher prices affected global supply, demand, and trade.

For 2022/23, it was not adequate to consider only the USDA's estimates of the change in Ukraine and Russia's exports compared to recent averages in determining the magnitude of shifts to impose. One reason is that the USDA June projected prices for 2022/23 already incorporated effect of the war, and were therefore higher than they would have been in a no-war scenario. If it had not been for the war, both Russia and Ukraine might well have produced and exported more grain than the recent average, given the

Table 2 U.S. Farm Production Expenses, Billion Dollars			
Calendar Year	2021	2022	2023
No War Scenario			
Fertilizer	28.5	36.4	34.9
Fuel and electricity	22.0	23.6	23.3
Feed	65.3	71.4	67.7
All Other	276.1	290.3	300.5
Total	391.9	421.7	426.4
Ukraine war scenario			
Fertilizer		43.2	42.2
Fuel and electricity		26.9	25.7
Feed		75.0	73.9
All Other		292.0	304.6
Total		437.2	446.4
Difference			
Fertilizer		6.8	7.3
Fuel and electricity		3.3	2.4
Feed		3.7	6.2
All Other		1.7	4.2
Total		15.5	20.1

prices projected in the war scenario. Thus, the export demand shifts we imposed on the model are larger than the projected decline in Ukraine's exports from the 2019/20 to 2020/21 average—16.3 million MT (600 million bushels) for wheat, 22.9 million MT (900 million bushels) for corn, and 1.4 million MT (3 billion pounds) for vegetable oil. For 2023/24 and subsequent years, we assumed smaller impacts on export demand, implicitly assuming either an end to the war or agreements that would facilitate a move toward more normal production and trade.

The war has also affected markets for fuel, fertilizer, and other inputs. Considering observed changes in prices of petroleum and other products since the invasion, we developed an alternative set of projections for farm input costs. The net effect of these assumptions and endogenous responses in the model is to increase U.S. farm production expenses in the war scenario by $15.5 billion in 2022 relative to the no-war scenario. In absolute terms, the largest impacts are on fertilizer, fuel, and feed, with feed cost increases primarily a function of higher prices for corn and other feedstuffs.

We projected a $30 billion increase in farm production expenses in 2022 relative to 2021 even before considering impacts of the war. Fertilizer prices, for example, had already increased sharply because of strong farm commodity prices, high natural gas prices in Europe, tariffs on some imported fertilizer products, pandemic-related supply disruptions, and a host of other factors. The war resulted in further increases in prices for petroleum and natural gas, and these contributed to additional increases in fertilizer prices, even though fertilizer exports by Russia were explicitly exempted from sanctions. We assume that these input market effects persist in 2023 before moderating in later years.

As is always the case, these assumptions about war-related shifts in farm commodity and input markets are tentative, based on preliminary information and a number of strong but reasonable assumptions. It is safe to assume that actual market shifts will ultimately prove to be different, perhaps significantly so, from those assumed here.

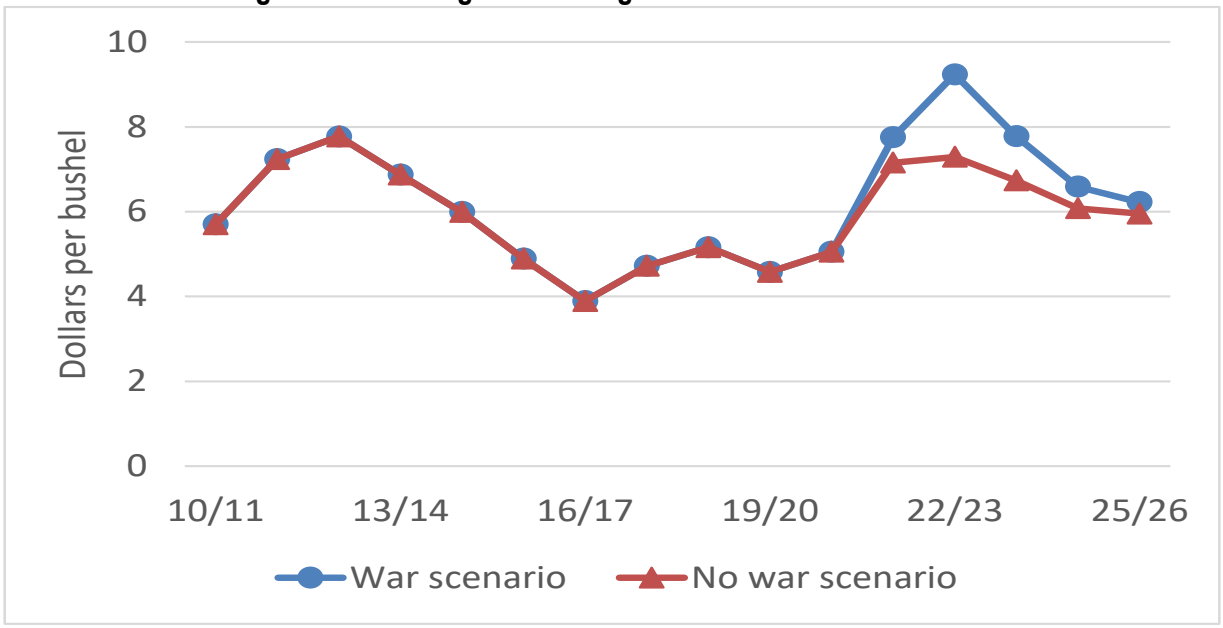
For example, the analysis assumes that the war at least slightly restrains Russian grain exports because of sanctions on financial institutions and the expected reluctance of some importers to purchase Russian products. However, since June 2022, there has been little evidence that Russia is facing major obstacles in selling its grain and oilseed products. Indeed, Russia appears to be harvesting a record wheat crop in 2022, and in its September 2022 estimates, the USDA forecast record Russian wheat exports in the 2022/23 marketing year (U.S. Department of Agriculture, 2022b), and up 6.5% from the June estimate. Similarly, the analysis does not consider impacts of the United Nations-sponsored Black Sea Grain Initiative, agreed to on July 22, 2022, that allowed grain from Ukraine to be exported through the Black Sea from particular ports (United Nations, 2022).

Commodity Market Impacts

The estimated effect of these assumed shifts in U.S. export demand and farm production expenses is to raise U.S. exports and prices of grains, oilseeds, and other agricultural products (Table 3). The largest impacts occur in the 2022/23 marketing year, when U.S. exports of wheat and corn exceed those in the no-war scenario by 15% and 29%, respectively.

Even though the projected increase in U.S. wheat prices (27% above prices in the no-war scenario) is greater than the increase in corn prices (19%), the increase in wheat exports is smaller. One reason is that exports are a much

Figure 1. Marketing Year Average Farm Prices for U.S. Wheat



smaller share of U.S. corn demand than is the case for wheat, so corn exports can more easily increase by reducing other uses. A second reason is that the 2022 winter wheat crop had already been seeded when Russia invaded Ukraine, so producers' ability change 2022 wheat production was limited.

To put these estimated impacts into context, consider projected wheat prices relative to recent history (Figure 1). In nominal terms, the 2021/22 wheat marketing year average price in the war scenario is very close to the previous record set in the drought year of 2012/13. The price rises to over $9/bushel in 2022/23 before declining in subsequent years, given the assumption of a return toward normality in world markets. Note that the USDA's June 2022 estimate of 2022/23 U.S. wheat prices was even higher, at $10.75/bushel, but grain futures prices fell in late June to levels more consistent with the projections reported here; by September, the U.S. Department of Agriculture (2022b) had reduced its projection of 2022/23 wheat prices to $9.00/bushel.

In the case of soybeans, the increase in prices relative to the baseline can be explained primarily by two factors. First, the reduction in sunflower oil exports from Ukraine provides a significant boost to U.S. exports and prices for soybean oil, a commodity that can substitute for sunflower oil in some uses. Second, other cross-commodity effects are also important. The larger increase in U.S. corn prices results in a shift from soybean to corn production in the war scenario, especially in 2023/24. Likewise, higher competing crop prices reduce acreage devoted to cotton and several other crops. The net result is an increase in the prices for all major field crops in the war scenario relative to the no-war scenario.

Our estimated price impacts are larger than those of other analyses of the price impacts of the conflict but are difficult to compare given unknown differences in assumptions. FAO's "moderate" scenario from March 2022 found that 2022 impacts relative to a preinvasion baseline were wheat prices up by nearly 9%, corn up by 8%, and "other oilseeds" up by 11% (Food and Agriculture Organization of the United Nations, 2022). The biggest difference between our estimates and theirs is on oilseeds, but these results are not directly comparable as FAO's oilseed category includes more than just soybeans and are calendar year instead of marketing year. The increase in calendar year 2022 prices in the initial (nonpublic) version of the OECD-FAO 2022-2031 outlook versus the final public version (OECD-FAO, 2022) that accounted for the conflict was 6% for wheat, 7% for corn, and 3% for soybeans.

Table 3. U.S. Grain and Oilseed Market Impacts

Marketing Year	2021/22	2022/23	2023/24
Wheat Exports (Million Bushels)			
No War Scenario	794	716	842
War Scenario	843	823	921
Difference	6%	15%	9%
Wheat MYA* Price (Dollars per Bushel)			
No War Scenario	7/15	7.29	6.73
War Scenario	7.75	9.24	7.77
Difference	8%	27%	15%
Corn Exports (Million Bushels)			
No War Scenario	2,356	2,176	2,567
War Scenario	2,494	2,797	3,014
Difference	6%	29%	17%
Corn MYA* Price (Dollars per Bushel)			
No War Scenario	5.50	5.27	4.90
War Scenario	5.75	6.27	5.17
Difference	5%	19%	5%
Soybean Oil Exports			
No War Scenario	1,302	985	1,094
War Scenario	1,467	1,1331	1,210
Difference	13%	35%	11%
Soybean MYA* Price (Dollars per Bushel)			
No War Scenario	12.88	13.83	12.07
War Scenario	13.25	14.95	13.07
Difference	3%	8%	8%

*Marketing year average price received by farmers

Table 4. U.S. Farm Income Impacts, Billion Dollars			
Calendar Year	2021	2022	2023
Crop Receipts			
No War Scenario	236.6	253.6	249.9
War Scenario		270.3	270.1
Difference		16.6	20.2
Livestock Receipts			
No War Scenario	195.9	219.2	212.3
War Scenario		218.9	213.7
Difference		-0.3	1.5
Government Payments			
No War Scenario	27.1	10.7	5.7
War Scenario		10.7	5.5
Difference		0.0	-0.2
Production Expenses			
No War Scenario	391.5	421.7	426.4
War Scenario		437.2	446.4
Difference		15.5	20.1
Other Net Farm Income			
No War Scenario	50.9	56.2	66.8
War Scenario		56.2	70.8
Difference		0.1	4.0
Net Farm Income			
No War Scenario	119.1	118.0	108.4
War Scenario		118.9	113.7
Difference		0.9	5.3

OECD-FAO's 2022-2031 Outlook (OECD-FAO, 2022) provides a sensitivity analysis of the impacts of the conflict on wheat prices for the 2022/2023 marketing year that shows substantially lower price impacts than our result. For an unspecified production cost increase and for a 50% decrease in Ukraine wheat exports and no change in Russian wheat exports, they find a wheat price increase of 9%, in contrast to our 27%.

While it is important to recognize that futures prices are affected by a wide range of factors unrelated to the war, it is interesting to note that July 2022 Chicago wheat futures prices increased from $7.82/bushel on February 16, 2022, to $12.77 on May 17 before dropping back to $8.69 on June 30 (Barchart, 2022).

Farm Income Impacts

The war in Ukraine increases both the value of farm product sales and farm production expenses (Table 4). Higher prices are primarily responsible for the estimated $16.6 billion increase in 2022 crop cash receipts in the war scenario relative to the no-war scenario. Production expenses increase by a similar amount in 2022, $15.5 billion, and there are only small changes in other components of the farm income accounts. As a result, net farm income is nearly identical in the war scenario as in the no-war scenario in 2022, and the 2022 value is also very close to the USDA-reported value of $119 billion in 2021 (the USDA subsequently revised the estimate of 2021 net farm income upwards, primarily because of a downward revision of its estimates of farm production expenses). Note that all of these estimates are based on a series of assumptions; even a slight change in one or more assumptions could change the direction of impacts on net farm income.

In 2023, the balance of effects on farm income is again very even. Livestock sector sales receipts increase slightly, as the impact of higher feed costs both reduces meat and milk production and raises livestock sector prices, with the latter effect dominating. The net income of livestock producers is reduced in the war scenario, as the increase in feed and other costs outweighs the increase in gross revenues from sales. What is labeled as "other net farm income" increases for a variety of reasons in the war scenario. One reason is that higher commodity prices increase the value of crops insured and thus the expected value of crop insurance indemnity payments. Note that net farm income declines in 2023 relative to 2022 in both the war and no-war scenarios, as sales and government payments decline while production expenses continue to increase.

Government payments (which do not include crop insurance indemnities) are reduced somewhat in the war scenario, as prices for most crops are too high to generate significant payments under either the Agriculture Risk Coverage (ARC) or Price Loss Coverage (PLC) programs. Under those programs, payments for the 2022/23 crop are mostly made in October 2023.

Table 5. U.S. Consumer Food Prices and Expenditures			
Calendar Year	2021	2022	2023
Wheat Effective Reference Price, Dollars per Bushel			
No War Scenario	3.9%	4.5%	3.0%
War Scenario		6.0%	3.5%
Difference		1.5%	0.6%
Corn Effective Reference Price, Dollars Per Bushel			
No War Scenario	1,990	2,124	2,200
War Scenario		2,155	2,238
Difference		31	38

Food Consumer Impacts

In the war scenario, 2022 consumer food price inflation is 6.0%, well above the 4.5% in the no-war scenario (Table 5). Higher farm commodity prices account for much of the increase in consumer food prices, but higher energy prices increase the cost of processing and transportation, and other food sector costs increase as well. Actual food price increases in 2022 have been even greater. For example, the consumer food price index for food was 11.4% above year-ago levels in August 2022 (U.S. Bureau of Labor Statistics, 2022). In contrast to most recent years, supermarket food prices have increased more rapidly than food-away-from-home prices; in August 2022, food-at-home prices were up 13.5% from the same month in 2021.

Consumer food expenditures have rebounded from the pandemic-induced reduction in 2020. In the war scenario, 2022 expenditures are $31 billion (1.4%) higher than in the no-war scenario. In dollar terms, this increase is even greater than the increase in farm cash receipts, primarily because of assumed war-related increases in energy and other costs. Consumer food price inflation in the war scenario continues to exceed no-war scenario levels in 2023, and the increase in consumer food expenditures is therefore slightly larger in 2023 than in 2022. These effects moderate in later years. Note that in real terms, consumer food expenditures are slightly reduced. In 2022, for example, the increase in nominal food expenditures (1.4%) is slightly less than the increase in consumer food prices (1.5%).

Government Program Impacts

Short-term impacts on payments under current farm commodity programs are small, but higher commodity prices could increase the value of 2023 crop insurance indemnities by increasing the value of crops insured. While most of the impacts of the war tend to fade over time given the assumptions of this analysis, there is an interesting anomaly in the case of payments under the ARC and PLC programs (Table 6). Higher prices in the near term affect the moving average of prices used to compute ARC benchmark revenue and the effective reference price used to calculate PLC payments. Under provisions of the 2018 Farm Bill, effective reference prices can exceed the statutory minimums if a moving average of prices exceed those levels by a sufficient amount. For the 2025/26 crop, for example, the relevant period used to compute the moving averages is 2019/20 to 2023/24 for both ARC and PLC.

The estimates of ARC and PLC payments, as with other estimates reported here, are mean values from 500 stochastic solutions for both the war and no-war scenarios. Even though mean projected prices exceed the projected effective reference prices for most commodities, PLC payments occur in some of the 500 outcomes where the projected price is less than the average and less than the effective reference price. Note that by 2028/29, projected ARC and PLC payments in the war scenario are over $6 billion, much higher than they are in the near term. This could have implications for the next farm bill debate, as new legislation will be affected by Congressional Budget Office

Table 6. Some Longer-run Impacts on Farm Programs			
Marketing Year	2022/23	2025/26	2028/29
Consumer Food Price Inflation			
No War Scenario	5.50	5.54	5.69
War Scenario	5.50	5.82	5.93
Difference	0.00	0.29	0.24
Consumer Food Expenditures, Billion Dollars			
No War Scenario	3.70	4.02	5.04
War Scenario	3.70	4.16	6.10
Difference	0.00	0.14	1.06
ARC and PLC* Payments, Billion Dollars			
No War Scenario	0.71	4.06	5.04
War Scenario	0.49	4.33	6.10
Difference	-0.21	0.28	1.06

*Agricultural Risk Coverage and Price Loss Coverage

estimates of the budgetary cost of current and prospective new legislation.

Final Comments

This analysis suggests that the war in Ukraine is likely to result in higher farm commodity prices, higher crop cash receipts, higher farm production expenses, and higher consumer food costs, with only small effects on aggregate net farm income. Given the assumptions of the analysis, U.S. wheat, feed grain, and oilseed producers are likely to be net beneficiaries of the war, as the war-induced increase in commodity prices outweighs the increase in production expenses, while the reverse is likely to be true for livestock producers facing higher feed costs.

The results, as always, are sensitive to both assumptions and model parameters. It is easy to imagine scenarios where the impacts on production costs (or crop receipts) are much larger or smaller than estimated here. There is also a question of how to attribute certain market events. For example, the Federal Reserve has taken steps to fight inflation by raising short-term interest rates. If one reason they are doing so is to offset the impacts of the Ukraine war on inflation in food and energy prices, one might argue that the analysis here should have attributed to the war at least a portion of the observed change in interest rates.

Finally, it is important to recognize that the actual course of the war in Ukraine is uncertain as this is written. Even a quick resolution of the war at this point would not eliminate many of the market impacts reported here, but further escalation could have even greater impacts on world agricultural markets and the global economy, as well as on all the people directly affected by the war itself.

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Russia-Ukraine Conflict and the Global Food Grain Price Analysis

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JEL Classifications: Q11, Q17, Q18
Keywords: Agricultural exports, Equilibrium displacement model, Futures and options

The Russian invasion of Ukraine on February 24, 2022, had drastic impacts on agriculture, trade, and food grain prices. As a result of the invasion, an estimated 22 million metric tons (MMT, including about 6.8 MMT of corn, 5.6 MMT of wheat, 4.6 MMT of sunflower, and others) of grains and oilseeds were jammed in Ukrainian silos due to port closures and logistical challenges (Nichols, 2022). Since the Russian invasion of Ukraine, alternative brokered agreements were negotiated to reopen Ukraine ports and relax the logistical constraints. The initial and renewed agreement were each for 120 days. Resolution of the logistic problems could take months to resolve, and ramping up shipments to normal (5–6 MMT monthly average) would take a long time.

The purpose of this paper is to determine the price impacts if these additional grain flows into the international market with the reopening of Ukraine ports. Specifically, we illustrate the price changes that occurred using two different methods. Our price analysis is restricted to corn and wheat. First, the equilibrium displacement model (EDM) is used, combining supply and demand elasticities with the change in export flows due to reopening of Ukraine ports. Second, we use distributions derived from the futures and option markets to place upper and lower bounds on future price scenarios.

Background

Global food grain markets have faced dramatic developments in recent years. In the case of corn, Ukraine has emerged as one of the dominant exporters to China and other key markets previously dominated by the United States. Ukraine is a major exporter of wheat to the Middle East and Africa and is the dominant exporter of sunflower oil. Indeed, Ukraine is referred as the “Breadbasket of the World.” Since the early 2000s, Ukraine has expanded its grain production and exports, particularly for corn, wheat, and sunflower oil. Concurrently, the Ukraine agriculture (Lyddon, 2021; Pleasant, 2021) and its grain marketing system have evolved (Salin, 2020; Sizov, 2020; Wilson, 2020). Ukraine has had some of the lowest interior rail shipping costs in the world and a historically important river system (most prominent is the Dnieper River). In recent years, the Dnieper River has been underdeveloped, underutilized, and in need of upgrades (Center for Transport Strategies, 2014; Wilson, Lakkakula, and Bullock, 2022). In addition to the logistical differences between the United States and Ukraine, there are substantial trade interventions affecting competition in the global markets. As examples, in the case of corn, these trade interventions include the European Union’s retaliatory tariffs on U.S. corn imports, tariff rate quotas for imports into China, tariff rate quotas for Ukraine exports to the European Union, and varying forms of quality restrictions related to phytosanitary and genetically engineered corn. Recently, China has become increasingly more dominant in the global corn import market. Finally, Ukraine is continuing to evolve and has been confronting land reform that is expected to increase productivity and competitiveness (Day, 2021; Polityuk and Hogan, 2021; VanTrump 2021; Verbyany and DeSousa, 2021). A combination of changes in logistical systems and trade interventions has resulted in intense rivalry between the United States and Ukraine, particularly when serving common importers.

Recently, many factors have strained global grain and oilseed markets. These include the 2021 drought in the U.S. northern plains, the emergence of renewable diesel and sustainable aviation fuels, an increase in oil prices to $120/barrel, Chinese restrictions on fertilizer and other agricultural chemicals, the post-COVID economic expansion, and supply chain issues. These factors have had drastic impacts on prices, increasing their volatility even before the Russian invasion of Ukraine.

Though the Russian invasion was promoted as a “special operation” focusing on eastern Ukraine, its scope has broadened and, over time, agriculture has become an integral element in the war. Now, the war includes the bombing of farms and equipment and other agricultural

facilities—including elevators and railroads—and stealing grain from farms and silos. Additionally, sea/naval mines in the Black Sea and other waterborne logistical channels had a significant impact in closing the Black Sea ports and Odessa, a critical port in Ukraine. In part, this is due to the geography of the war but also because ocean carriers were reluctant to allow ships to enter those waters; as a result, insurance costs escalated.

Compounding problems resulting from these developments include 1) a shortage of storage space for the 2022 crop (Yale School of Public Health, 2022); 2) landmines causing problems for field work; 3) cash flow problems, which will constrain seeding the 2023 crop; and 4) the need to develop alternative logistical channels. All export trading companies are exploring alternative logistical channels. However, such efforts confront export capacity, noncompatibility of multiple rail gauge tracks, higher export costs, and other border crossing constraints. For perspective, prior to the Russian invasion, Ukraine had one of the lowest logistical costs in the world. As a result of the invasion, logistical costs are estimated to increase by between $55/mt and $125/mt (or more). In addition, it is believed that Ukraine, which normally exports 5 MMT-6 MMT per month, has a reduced capacity restricted to about 2.0 MMT per month (Angel, 2022). The combined effects of these developments has led to reduced exports and higher export costs, resulting in adverse implications for much of the world, including concerns of starvation and food price inflation (Steinhauser, 2022). On May 16, 2022, the European Union began promoting the need to develop "solidarity lanes," an effort to either reopen the Black Sea and Odessa ports for shipments (either after mines were removed or byusing some type of convoy) or to facilitate and improve the efficiency of cross-border movements through eastern European countries—including Romania, Poland, and others—to effectively utilize the Danube River, Europe's second-longest river (European Commission, 2022).

Solidarity Lane Proposal and Price Impacts

This approach is less useful in the case of vegetable oil. The most direct observation of the change in prices due to the Russian invasion can be interpreted from behavior of the futures prices. It is important that commodity prices had been increasing before the Russian invasion of Ukraine. On May 16, 2022, the EU announced a strategy to develop "solidarity lanes." Prior to that date, there were strong expectations of a permanent closure of the Black Sea for exports. Commencing on this date, both futures and basis values (for export) began declining. As shown in Figure 1, wheat futures price decreased from $469/MT on May 17, 2022, to $291/MT on July 6, 2022. U.S. basis values decreased similarly. Corn futures prices also declined from $319/MT on May 17, 2022, to $290 on July 5, 2022. Similarly, U.S. basis values for wheat also decreased. Of course, numerous other factors impacted and/or accelerated the price decline during this period, including favorable corn planting, fund liquidation, seasonal selling, wheat harvest, favorable conditions for Brazil corn. Nevertheless, notable changes in grain price dynamics were evident fol lowing the announcement of solidarity lanes.

Figure 1. Solidarity Lane Proposal (green vertical line, May 16, 2022) and Decrease in Futures Prices of Corn and Wheat

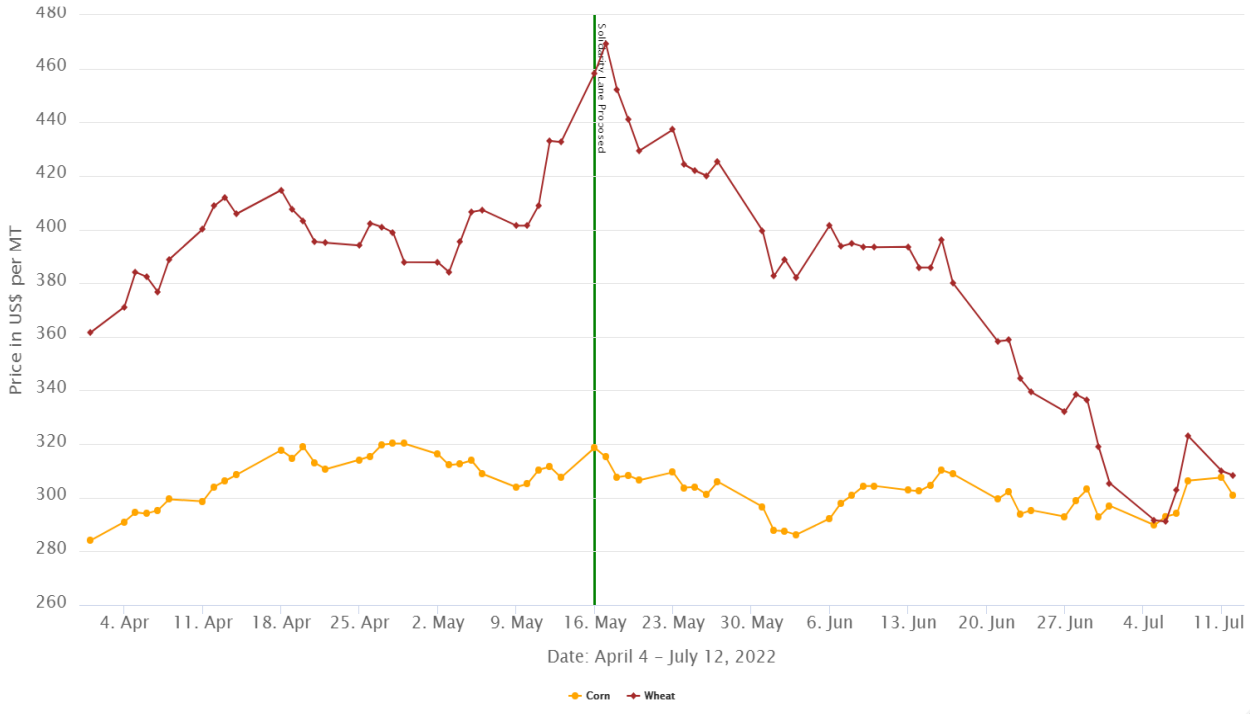


Table 1. Ukraine's Historical Exports and Their Increase Due to Opening of the Port

	Normal Exports (MMT)	Prospective Increase in Exports Due to Port Opening (MMT)	Percentage Change in Exports
Corn			
Minimum	9	6.8	75
Mean	20	6.8	34
Maximum	30	6.8	23
Wheat			
Minimum	7	5.6	80
Mean	15	5.6	37
Maximum	21	5.6	27

Source: Exports are collected from Production Supply and Demand (PSD) database (U.S. Department of Agriculture, 2022a) between 2012 and 2022. Potential increase in Ukraine exports in the global market (because of port opening) are gathered from USDA Office of the Chief Economist office.

Equilibrium Displacement Model

One of the problems with simply looking at price changes is that other factors (as described above) are changing concurrently, making it difficult to isolate the impacts. In order to better depict the impacts of the constrained exports from Ukraine on global market prices, we used an equilibrium displacement method (EDM) (Wohlgenant, 2012). Specifically, we analyze the price impact if Ukraine ports were to reopen and to add about 6.8 MMT of corn and 5.6 MMT of wheat into the global market. In the following section, we then use futures and options markets to derive market distributions for predicting future price scenarios with both lower and upper bounds.

The EDM was applied to this problem as It captures the status of export sensitivities given the supply and demand in both the world and Ukraine. Specifically, we solve a six-equation system (demand system and supply system, each with two equations for Ukraine and the world, a market clearing condition, and a price equation). We use a range of inelastic supply and demand elasticities (instead of point elasticities) to analyze the effect (to make the model simple, the cross-price elasticities are set to zero). We use a uniform distribution (with 500 iterations) of the elasticities to analyze the effect of increased Ukraine exports available in the global market due to the reopening of Ukrainian export ports.

Ukraine's traditional wheat and corn export levels are compared with the additional levels that flow into the global market from reopening Ukraine's export ports to analyze the impact on the global prices. Baseline scenarios that indicate minimum, maximum, and mean levels of Ukraine exports between 2012 and 2022 are used for the analysis (Table 1).

We collected historical supply, demand, and exports for both Ukraine and world from the Production, Supply, and Demand database of the USDA's Foreign Agricultural Service (U.S. Department of Agriculture, 2022). Table 2 shows the range of supply and demand elasticities used, taken from the Commodities and Food Elasticities database of the U.S. Department of Agriculture (2021) and industry experts.

The results of price decline are shown in Figures 2 and 3. Overall, the results show that the reopening of Ukraine's export ports would have a greater impact on wheat price compared with the corn price. In the case of wheat, the results show that global wheat price would decline on average by 11%, with the 95% confidence intervals showing the decline would be between 5% and 17%. Similarly, in case of corn, the results show that the global price decline by 4.26% on an average, but the price decrease would be between 2% and 8% based on the 95% confidence interval. Generalizing the results, on average, each million metric tons of Ukrainian corn and wheat entering the global market would reduce the global price of corn by 0.62% and of wheat by 1.96%.

Short and Long-Term Option-Based Market

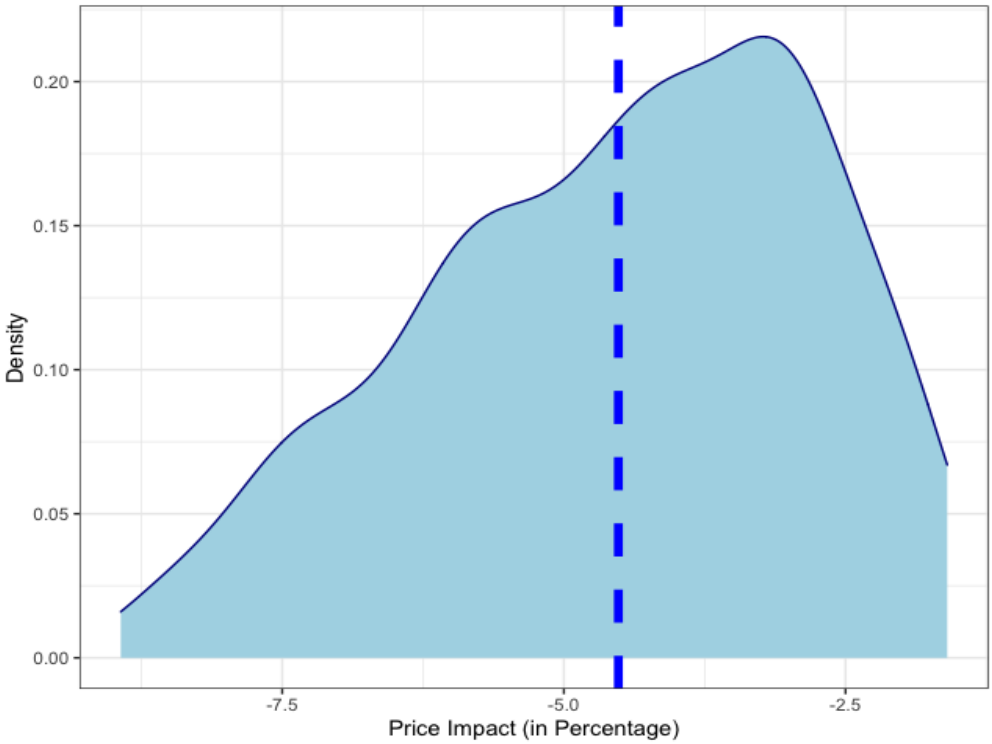
The preceding equilibrium displacement model analyzes price impacts using a fundamental modeling approach. To complement these model results, we utilized the market's own distributional price projections in this section to validate that our fundamental results are in line with the information currently contained in the forward markets. The futures and options markets reflect substantial information and can be used to infer the prospective distribution of prices in response to these events. While a futures price represents the collective wisdom of market participants regarding the mean of the distribution, the option premium contains the collective estimate of the standard deviation of the distribution (Bullock and Hayes, 1992, 1993).

Table 2. Elasticity Ranges Used for the Equilibrium Displacement Analysis

	Corn		Wheat	
	Supply Elasticity	Demand Elasticity	Supply Elasticity	Demand Elasticity
Ukraine	0.25 to 0.35	-0.50 to -0.35	0.40 to 0.50	-0.57 to -0.35
World	0.15 to 0.25	-0.60 to -0.30	0.35 to 0.40	-0.50 to -0.30

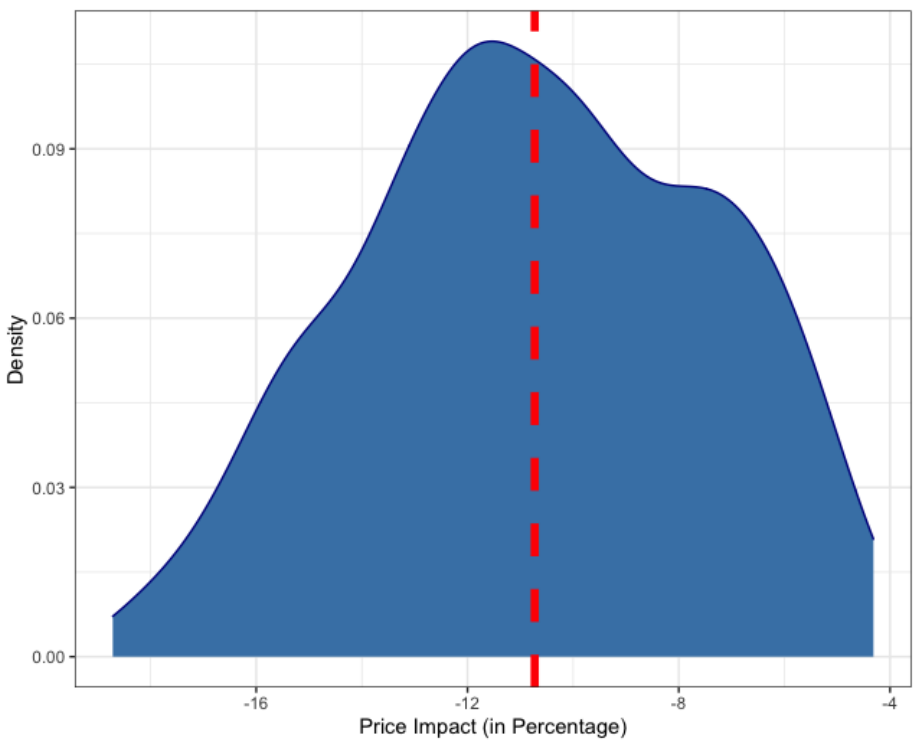
Source: Elasticities are used from Commodity and Food Elasticities database (U.S. Department of Agriculture, 2021) and world commodity elasticities and industry experts in Ukraine.

Figure 2. Global Corn Price Declines



Note: Global corn price decline by 4.26% on an average (with 95% confidence interval decline: 2%-8%) as a result of 6.8 MMT in additional Ukraine corn exports.

Figure 3. Global Wheat Price Declines



Note: Global wheat prices declined by 11% on an average (with 95% confidence interval decline: 5%-17%) as a result of 5.6 MMT in additional Ukraine wheat exports.

Unlike futures, options are an actuarial market since they contain insurance-like features. Put options generate indemnity payments (intrinsic value) when prices fall below a coverage level (strike price), and call options generate payments when prices go above the coverage level.

Actuarial formulae, such as Black's (1976) Option Pricing Model (BOPM), can be inverted to derive the market estimate of future price volatility called implied volatility, which represents the price standard deviation as an annualized percentage of the futures price. The BOPM model provides a risk-neutral market valuation for options on futures by utilizing risk-adjusted probabilities to calculate the expected, fair terminal value of the option contract. These probabilities are calculated based on the absence of risk-free arbitrage in a portfolio containing commodity options.

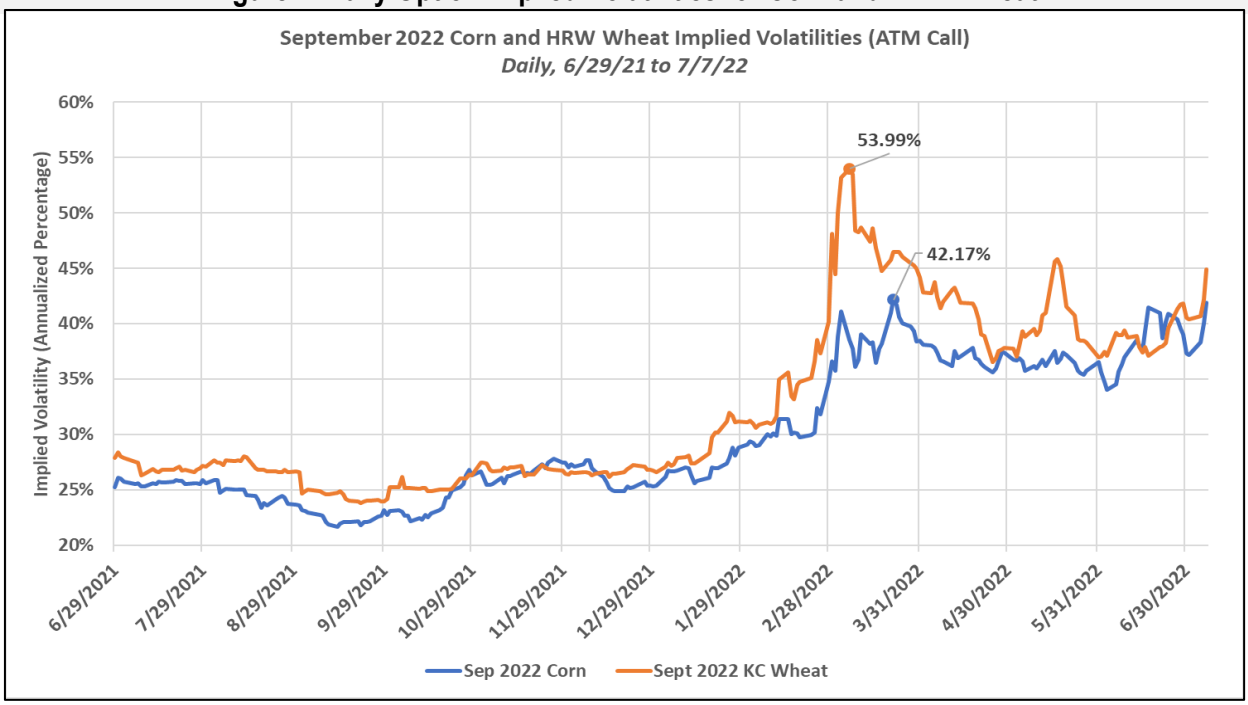
Annualization of the implied volatility allows the forecast to be time-scaled to any forward time horizon via the simple formula $\sigma(t)=\sqrt{t}\cdot iv\cdot f$, where $\sigma(t)$ is the forecasted standard deviation for the period t years into the future, iv is the market-derived implied volatility percentage, and f is the current futures price. Black (1976) implicitly assumes a lognormal distribution of prices, therefore the complete forecast distribution can be derived by substituting f for the mean and $\sigma(t)$ for the standard deviation into a normalized lognormal distribution.

It is important to note that since the invasion, the volatility of futures prices has escalated substantially. Figure 4 shows a plot for the daily option implied volatilities for the September 2022 contracts using the at-the-money (ATM) call values for the past year. For the last half of 2021, the implied volatility for corn and hard red winter (HRW) wheat averaged 24.8% and 26.3%, respectively. Beginning around mid-January 2022, as rumors of an impending Russian invasion of Ukraine started to heat up, the implied volatilities for both commodities began to slowly rise. In early March, volatilities spiked to their maximum values of 42.2% and 54.0% for corn and HRW wheat, respectively, following the February 24 commencement of the Russian "special operation" in Ukraine.

Following their peaks, the implied volatilities for both corn and wheat fell into the upper 30s range as the initial Russian attack on Kyiv was repelled. The wheat implied volatility rose to a temporary peak in early to mid-May as the Russian offensive was renewed in the Donbas region: however, the volatility collapsed lower after negotiations of the "solidarity lanes" proposal announced on May 16, even though negotiations were not consummated until July 14, 2022. However, both events had no noticeable effect on the implied volatility of corn.

For this analysis, we applied the Black (1976) model to the July 7, 2022, futures and option market price quotes for corn and soybean futures to derive the likely upside and downside pricing scenarios and their probabilities of occurrence. While no specific fundamental scenario, such as the resolution of the Ukrainian grain export situation, can be directly attributed to these price scenarios, it is reasonable to assume that all current Ukraine possibilities have been incorporated into the current market prices. Therefore, these estimates can be used to place both upside and downside bounds on any fundamental projections based upon current information.

Figure 4. Daily Option Implied Volatilities for Corn and HRW Wheat



Source: DTN Prophetx.

The futures/option implied volatility forward market price forecasts from July 7, 2022, are summarized in Figures 4 (for wheat) and 5 (for corn). The 50%, 70%, and 90% confidence intervals are shaded around the futures forward curve (mean). Due to the skewed nature of the lognormal distribution, the median (blue line) lies slightly below the futures price indicating a slight upward skew in the projections. There is a 5% chance of realized prices occurring above the 90% confidence upper limit and same chance for below the lower limit.

For wheat, the results indicate that, given the current (July 7) spot price of $9.12/bushel, there is a 5% chance that prices could fall below $5.75/bushel (decline of $3.37) by mid-December 2022 (Dec 22 futures). By mid-May 2023 (May 23 futures), there is the same chance that prices could fall below $5.18/bushel (decline of $3.94). For corn, the results indicate that, given the current spot price of $7.35/bushel, there is a 5% chance that prices could fall below $3.92/bushel (decline of $3.43) by mid-December 2022. By mid-May 2023, there is the same chance that prices could fall below $3.73/bushel (decline of $3.62). These values place lower bounds on potential price scenarios (forecasts) through those periods resulting from the Russian invasion of Ukraine.

Summary and Implications

The Russian invasion of Ukraine has had and continues to have a significant impact on global food grain prices threatening food security and food inflation globally, especially in poor countries. The invasion blocked about 22 MMT of food grain exports from Ukraine due to closure of export ports in the Black Sea region. This study analyzes the global price impact of 6.8 MMT tons of Ukraine corn and 5.6 MMT of Ukraine wheat exports flowing into the global market with reopening of Odessa port in Ukraine. We used two methods to analyze the price impacts. The equilibrium displacement model for wheat shows a higher price decline ranging between 5% and 17%, while global corn prices decline by about 2%–8%. That is, for each MMT of Ukrainian corn and wheat entering the global market, the global price would decline by 0.62% for corn and 1.96% for wheat. These results are consistent with the market outlook scenarios embedded in the July 7, 2022, futures and option markets, with all our projections well within the 90% confidence interval of the implied market forecast distribution.

The results of this study have many implications. First, given the importance of Ukraine's production and exports of these crops, any restrictions can have potentially dramatic impacts on commodity prices. The constrained logistics had the impact of elevating overall price levels, changing the international price spreads, and increasing basis values for suppliers competing with Ukraine's exports. As a result, the quest for alternative routes come at greater costs. Ultimately, grain flows have changed radically because of the changes in relative logistics costs and constraints. Second, the escalation in volatility in both futures and basis has resulted in many opportunities for trading firms with increased profits, albeit prospectively lower volumes. Third, with rising global inflation in agricultural and food products in 2022, the opening of Ukraine ports and the resulting decline in prices would be welcome, especially for North African countries and others that are highly dependent on agricultural/grain imports for their food consumption. Finally, the decline in prices would also have implications for marketing margins of the agribusinesses involved in processing food grains (corn and wheat as inputs) to finished products.

Figure 5. Kansas City Wheat Forward Projections Based upon July 7 Prices

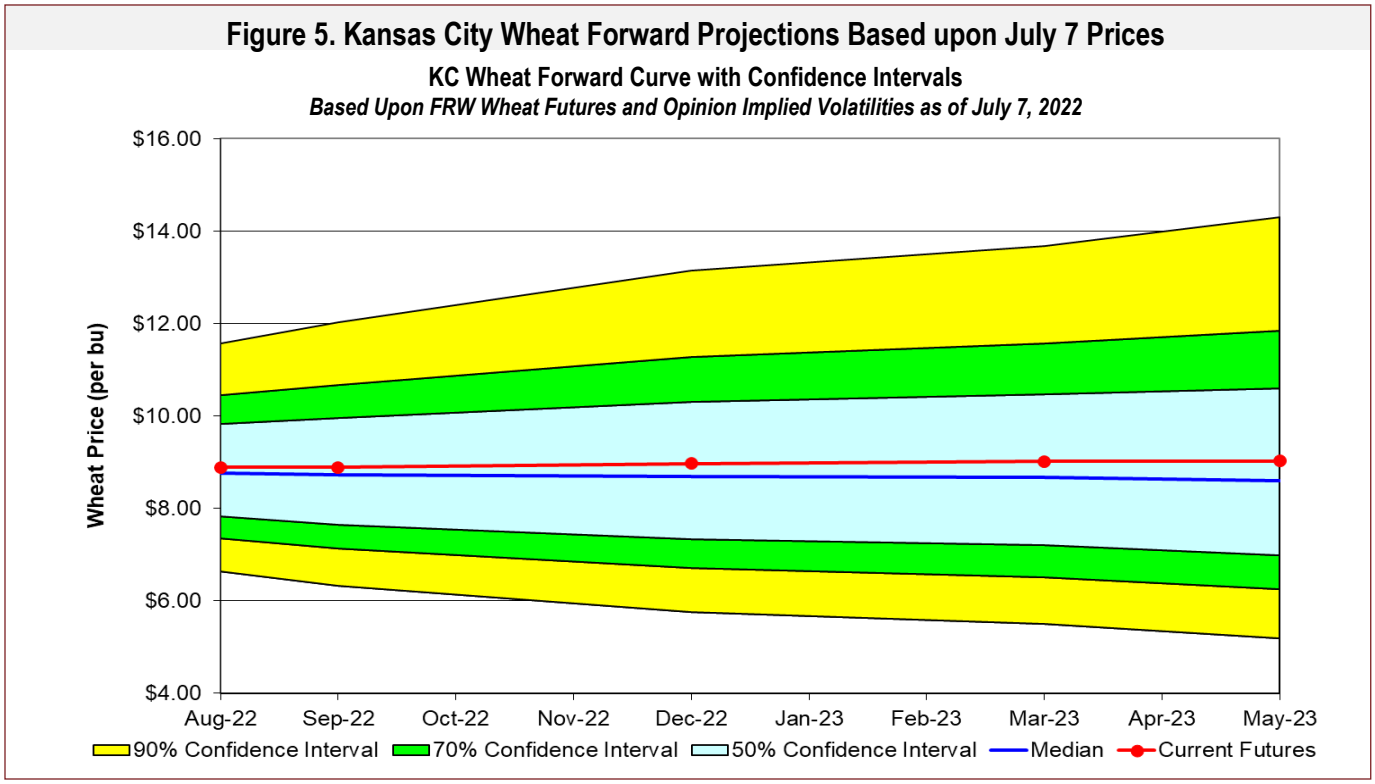
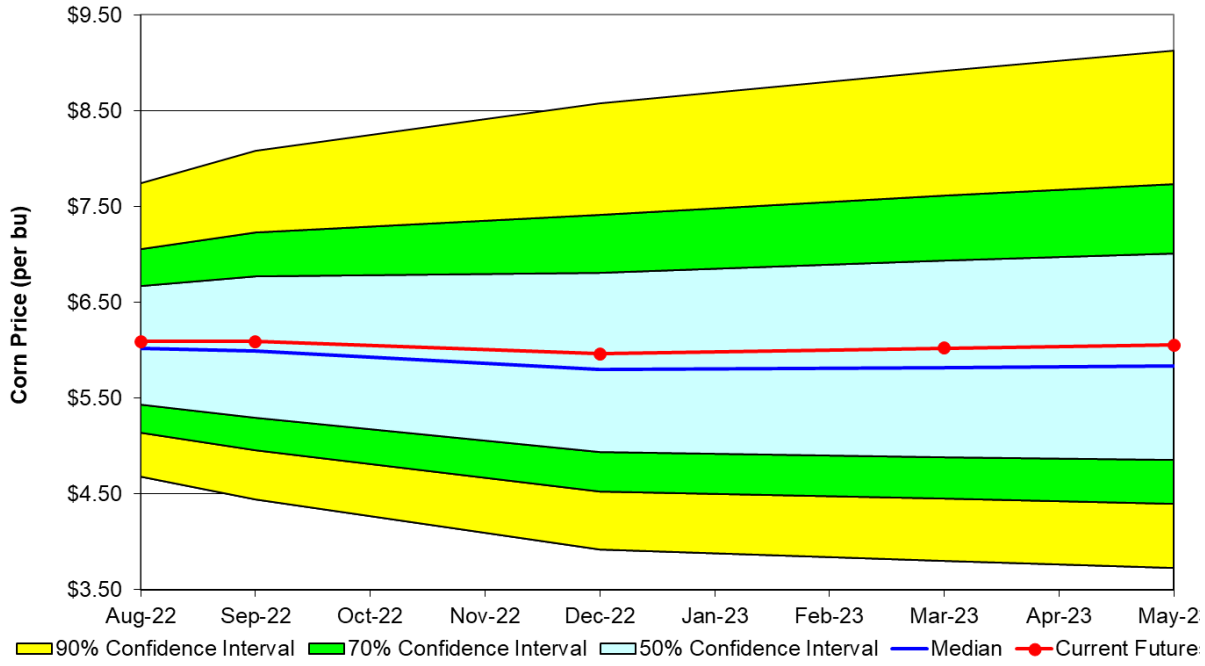


Figure 6. CBOT Corn Forward Curve with Confidence Intervals

Based Upon FRW Wheat Futures and Opinion Implied Volatilities as of July 7, 2022



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Decomposing a Year of Uncertainty in Agricultural Markets

Jayson Beckman and Maros Ivanic

JEL Classifications: Q1, Q17
Keywords: Computable general equilibrium, Trade, Yields

The stability of agricultural commodity prices is of great interest to economists and the global community as they provide consistent income to farmers and are important for global food security, especially for food importers. Research on this topic has generated interest since at least the 1800s (for example, Patten, 1889), and the more recent volatility in prices of 2008 and 2011 generated a large amount of research aimed at explaining the causes (for example, Abbott, Hurt, and Tyner, 2008, 2011). Although agricultural commodity prices have been relatively stable since 2008/11 (with a bit of an increase in 2014), prices started becoming more volatile during the COVID-19 pandemic and, more recently (the end of 2021, beginning of 2022), have started increasing to previous 2008/11 levels.

There are numerous reasons why agricultural commodity prices have recently increased. The COVID-19 pandemic has continued, impacting supply chains, and affecting farmers' ability to source inputs for production; Russia's invasion of Ukraine has led to difficulties in trade leaving the region (in addition to many countries' sanctions on Russia, although some sanctions have explicit exemptions for agricultural and fertilizer products); drought during the 2021/2022 agricultural year in South America restricted exports from that region; countries have put export restrictions in place; and energy prices have reached record highs. The Russia invasion has impacted global grain markets as around a quarter of the countries in the world (47 countries) depend on Russia and Ukraine for more than 30% of total wheat imports; 27 countries source more than 50% of their wheat imports from Russia and Ukraine (Food and Agriculture Organization of the United Nations, 2022). In addition, a notable share of the grain coming out of Russia and Ukraine is used for animal feed, driving up the cost of animal products (e.g., milk, eggs, and meat). Fertilizer prices have increased (likely, in part due to the invasion), further impacting agricultural production. For example, prospective plantings in the United States show an increase in soybean acreage and a decrease in corn acreage as the latter uses fertilizers in larger amounts than the former (U.S. Department of Agriculture, 2022).

This study decomposes the impacts to agricultural markets in 2022. To do so, we use a computable general equilibrium (CGE) model that provides a range of estimates (using three shocks—low, medium, and high) based on how impactful the shocks are for 2022. Simultaneous shocks applied in each of the three scenarios include 1) yield reductions (from higher energy and fertilizer prices); 2) export losses for coarse grains, oilseeds, vegetable, oils, and wheat from Russia and Ukraine; 3) changes in labor supply in Russia and Ukraine; and 4) a reduction in the price Russia receives for their energy exports (representing the sanctions by many importing countries).

Computable General Equilibrium (CGE) Model

To consider how the factors affecting agricultural markets in 2022 might impact the agricultural sector, we use a CGE model. CGE models simulate economy-wide and sectoral effects while considering the links and interactions between sectors, competition among these sectors for limited economic resources, and interactions among production, consumption, and trade activities. We use the Global Trade Analysis Project (GTAP) model and database, which has been used to analyze the European Union's Farm to Fork program and its impact on agricultural production and trade (Beckman et al., 2020).

GTAP is a static model in that it provides estimates of economic impacts for a one-time shock. The model has 65 sectors representing the entire economy that are aggregated into rice, wheat, coarse grains (barley, corn, oats, and sorghum), oilseeds, vegetable oil, processed agriculture, manufacturing, and services. We use the latest database, which has a 2017 baseline. The model has 161 countries and regions, which we aggregate into 75 groups to understand how these shocks affect poorer countries.

Simulation Scenarios

The shocks in our model are based on changes that might occur from higher agricultural input prices and changes in Russia/Ukraine's agricultural production and exports, Russia's energy prices, and Russia/Ukraine's labor supply.

Given the uncertainty in knowing when these changes will end, we specify three scenarios for the model with varying levels of impacts (low, medium, and high). We assume a one-year time horizon, where endowments (land, labor, and capital) are somewhat immobile (land is completely immobile), representing that agricultural producers have very limited options in changing production in this time frame.

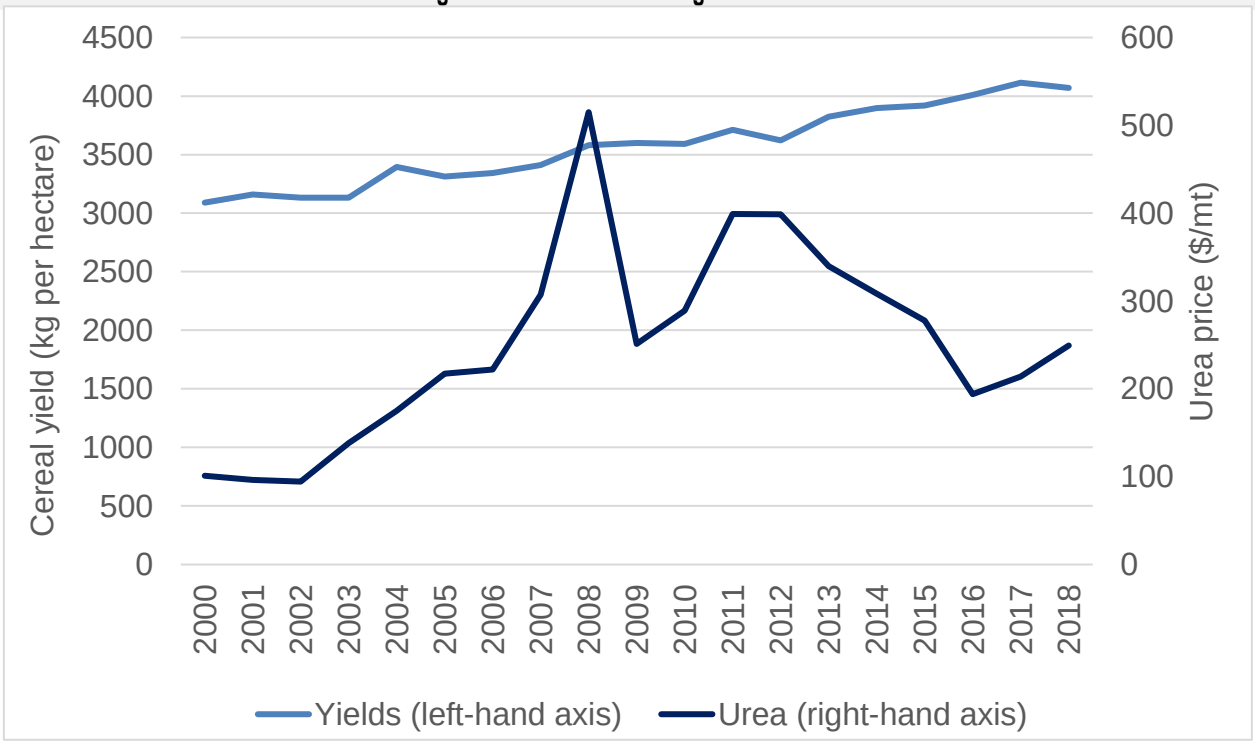
To represent the potential effect of higher agricultural input prices, we specify yield reductions for each region in the model—that is, we assume that higher prices reduce the amount of agricultural inputs used by farmers, which ultimately impacts yields. One could directly shock these input prices, but there is no consensus on what the price changes might look like. In addition, farmers purchase fertilizers at different times throughout the world (for example, due to differences in seasons), so specifying a yield shock ensures that everybody is affected in the same way.

Figure 1 presents information on cereal yields by various regions over time since 2000, along with urea, a commonly used fertilizer. As indicated, global yields have increased over time, although, there was a decrease in 2012. As noted, the 2008 spike in urea prices—which coincided with the increase in agricultural commodity prices—did not seem to impact yields. Individual regions did experience a decrease (for example, North America yields decreased from 5,933 kg/hectare to 5,915 kg/hectare). This continuation of yields could have been a result of the higher commodity prices inducing farmers to use more fertilizers. Beckman and Schimmelpfennig (2015) present research that indicates that higher input and output prices are favorable to farmers in terms of farm income, although they note that most farmers would rather have stable prices. In terms of 2012, we note that the increase in urea prices occurred in 2011 and 2012, and 2012 is when the largest decrease (of 2.4%) in global yields occurred. However, it is also important to point out that the decrease in North American yields could also have been due to a large drought. Nearly 80% of agricultural land in North American was impacted by the 2012 drought (U.S. Department of Agriculture, 2012).

Along with the assumption that higher energy and fertilizer prices affect yields, we also assume that they will affect countries differently. As noted in Table 1, the yield reduction for low- and middle-income countries is more than double that for high-income countries, an assumption we make as farmers in high-income countries are more likely to be able to purchase these inputs or have sufficient fertilizer stored. One other point related to fertilizers is that a one-year increase could be negligible given that farmers can skip applications but make it up in the subsequent year. However, a more prolonged period of elevated prices, such as in 2022, can have a more detrimental impact on yields.

The next set of shocks is based on export losses and the difficulties that both Russia and Ukraine face in exporting their products due to political or transportation constraints. It could also be the case that they wish to keep products

Figure 1. Cereal Yield Changes Over Time



Source: World Bank (2022)

Table 1. Three Scenarios (low, medium, and high) Considered in the Simulation Exercise

	Low	Medium	High
Yield restriction for low- and middle-income countries	2.5%	5%	7.5%
Yield restriction for high-income countries	0%	1.5%	3%
Export losses of Ukraine's coarse grains, oilseeds, vegetable oils, and wheat	25%	50%	99%
Russia export losses on coarse grains, oilseeds, vegetable oils, and wheat	10%	20%	30%
Decrease in Russia's energy export price	10%	20%	30%
Skilled labor losses in Russia	0.5%	1.5%	2.5%
Unskilled labor losses in Russia	1%	3%	5%
Skilled labor losses in Ukraine	5%	10%	15%
Unskilled labor losses in Ukraine	10%	20%	30%

Source: Author estimates.

available for domestic consumption by restricting exports (see Laborde, 2022, for information regarding the export restrictions in place). Note that the export losses in the medium scenario are close to the range of estimates estimated by Grant et al. (2022) in this issue. We also include a decrease in Russia's energy prices to mimic the discounts they have had to offer to have China, India, and others that buy their products. Restrictions on exports are based on those products that each country exports the most: coarse grains, oilseeds, vegetable oils, and wheat for Ukraine and coarse grains and wheat for Russia.

Finally, we include changes in labor in Russia and Ukraine due to fewer people being available to work the fields. GTAP differentiates between skilled and unskilled labor; we assume that unskilled labor is more impacted (double that of skilled) since these types of workers are more likely to be fighting in the war.

Global Price Changes due to the Invasion

For the CGE results, we focus on changes in prices and GDP. The model estimates that wheat, coarse grains, and oilseeds all have price increases, and they are similar across all scenarios. This is because the model reallocates production to the most profitable commodity to plant. The price changes across the low to medium and high scenarios are similar across all agricultural products, with increases for the medium scenario of more than twice that of the low scenario and further increases in the high scenario. Note that wheat and coarse grains have the largest price increases across all crops in each scenario as these are the commodities most exported by Russia and Ukraine

The model also estimates the percentage change in prices. Figures 2 and 3 show the decomposed price changes for wheat and coarse grains respectively, disaggregated by region. For wheat, the yield shocks primarily drive price

Table 2. Global Prices Changes for Agriculture (percentage changes) in the Three Scenarios

	Low	Medium	High
eat	4.9	11.3	19.1
Coarse grains	5.1	11.6	19.6
Oilseeds	3.8	9.2	15.5
Vegetable oils	1.6	3.6	6.1
Processed agriculture	0.3	0.6	1.0
Food	0.9	2.0	3.4

Source: Author estimates.

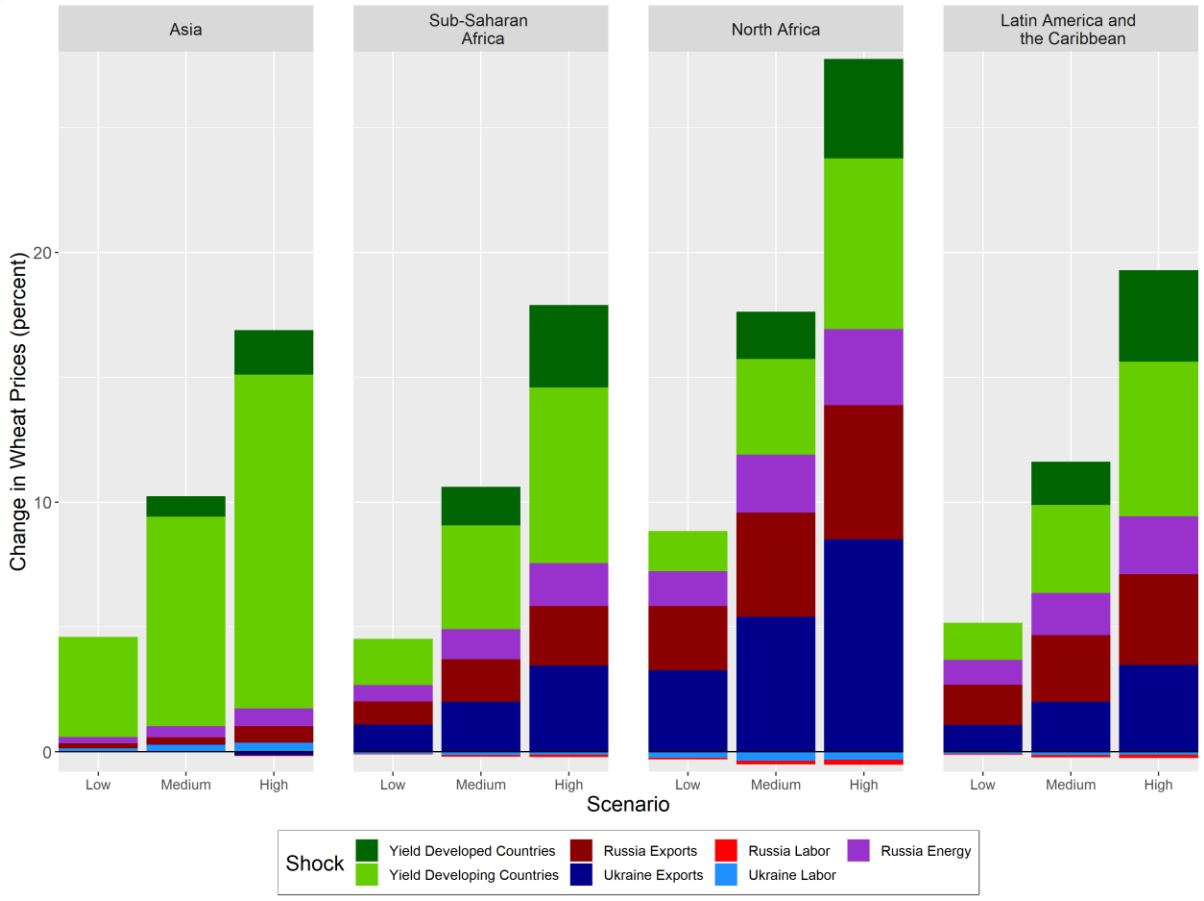
Table 3. Impacts on Global GDP, Agricultural Production, and Agricultural Trade (percentage changes)

		Low	Medium	High
	GDP	**-0.2**	**-0.3**	**-0.5**
Agricultural production	Wheat	0.6	0.9	1.0
	Coarse grains	0.5	0.8	1.0
	Oilseeds	-0.1	-0.3	-0.8
	Total agriculture	-0.2	-0.2	-0.3
Agricultural trade	Wheat	4.1	6.8	8.1
	Coarse grains	3.2	5.1	6.3
	Oilseeds	1.0	1.7	2.3
	Total agriculture	0.0	0.0	-0.1

Source: Author estimates.

changes in Asia. However, in North Africa, the export losses for both Russia and Ukraine comprise a large portion of the shocks. For coarse grains, reduced Ukrainian exports drive the price spikes in North Africa. The largest changes in price are for corn and wheat, which are major exports of Russia and Ukraine and are traded in high volumes. Changes in wheat prices are estimated to be highest in North Africa, as expected, as the region relies on wheat imports from the Black Sea region, and includes Egypt, the largest importer of wheat globally. The North Africa region also see the largest changes in corn prices, from 14% in the low scenario and rising to over 42% in the high scenario. Three countries in North Africa—Morocco, Tunisia, and Algeria—source a significant portion of their corn from Ukraine. For vegetable oils, the largest changes in price are expected in Asia, which includes India, a major importer of vegetable oils from Russia and Ukraine.

Figure 2: Changes in Wheat Prices by Shock and Region



Source: Author estimates

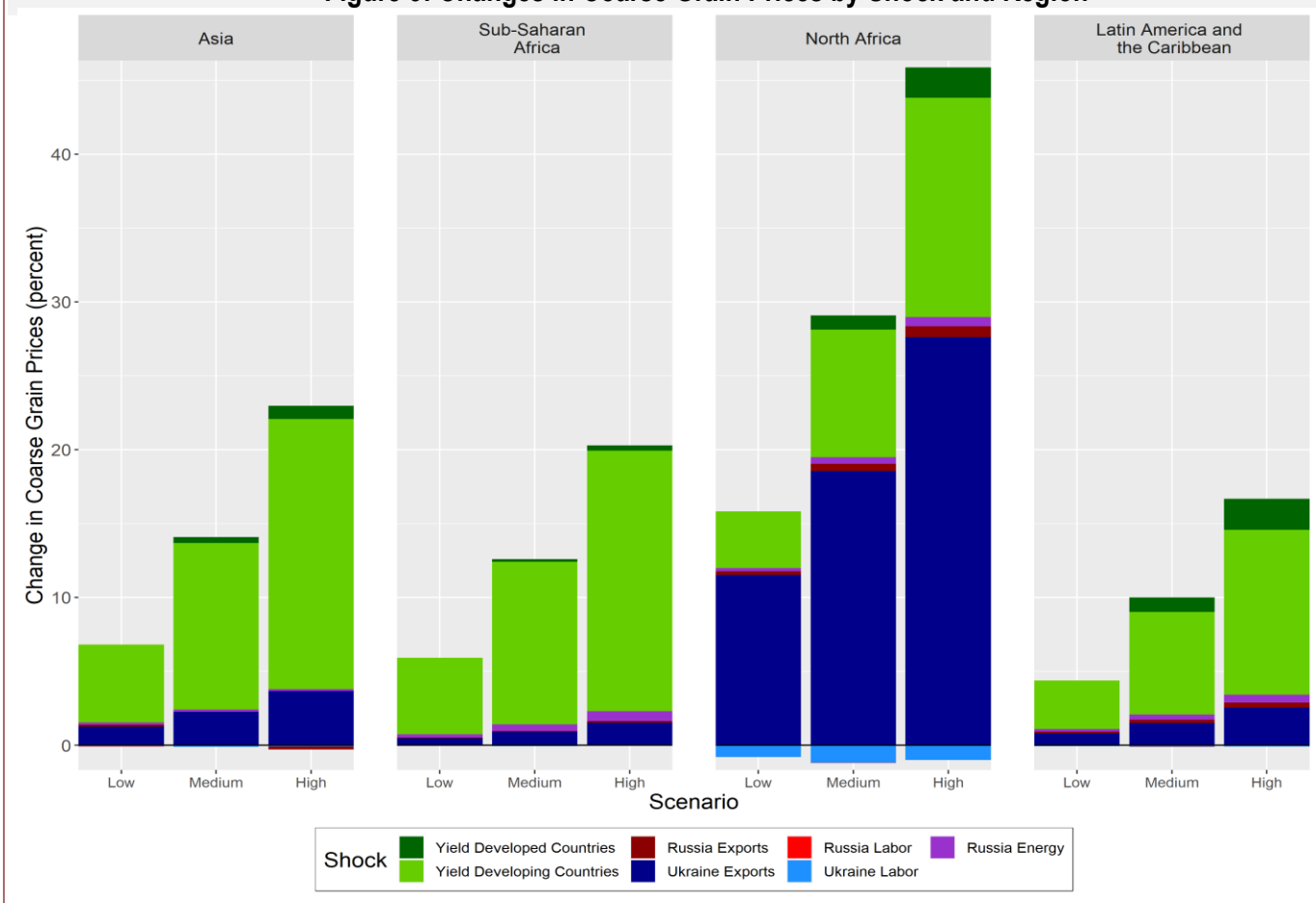
Global GDP, Agricultural Production, and Agricultural Trade Changes

We also report changes in global GDP, agricultural production, and trade (Table 3). The model estimates that global GDP decreases in each scenario. Production changes are mixed. The model estimates a decrease in oilseeds production and an increase for wheat and coarse grains. Of the other crops, oilseeds compete for land in many countries with wheat and coarse grains; hence, they are the commodity that has a decrease in production (as land is shifted to wheat and coarse grains). The model indicates an increase in wheat trade (the largest increase for any agricultural commodity), despite the restrictions on Ukraine and Russia (and the fact that they make up a sizeable portion of exports). This is due to an increase in exports from other major producers such as Canada and the European Union. For coarse grains, the United States experiences an increase in exports, but many countries choose to produce wheat, and the export losses on Ukraine and Russia lead to a decrease in global trade.

In Figure 4, we show the decomposition of GDP changes by shock and region. In Asia, GDP decreases are driven by declines in yield and Ukrainian labor. In North Africa, the largest driver is the decrease in Ukrainian exports, as the region purchases wheat from the Black Sea region and sells wheat flour. Global GDP is estimated to decrease in 2022 by 0.2% under the low scenario and 0.3% under the medium scenario. The steepest declines are in Asia and North Africa. By subregion, the largest decline in GDP is estimated in the CIS subregion, which includes Ukraine, with the region experiencing a decline of 1.5% under the low scenario, representing a loss of $5.7 billion (in 2015 USD), and a nearly 4.5% decline under the high scenario, equivalent to $17 billion (in 2015 USD). We do note that these estimates are only based on the shocks in this paper and do not consider the many other aspects Ukraine is experiencing due to the war that could further decrease its GDP (such as consumer spending or investment).

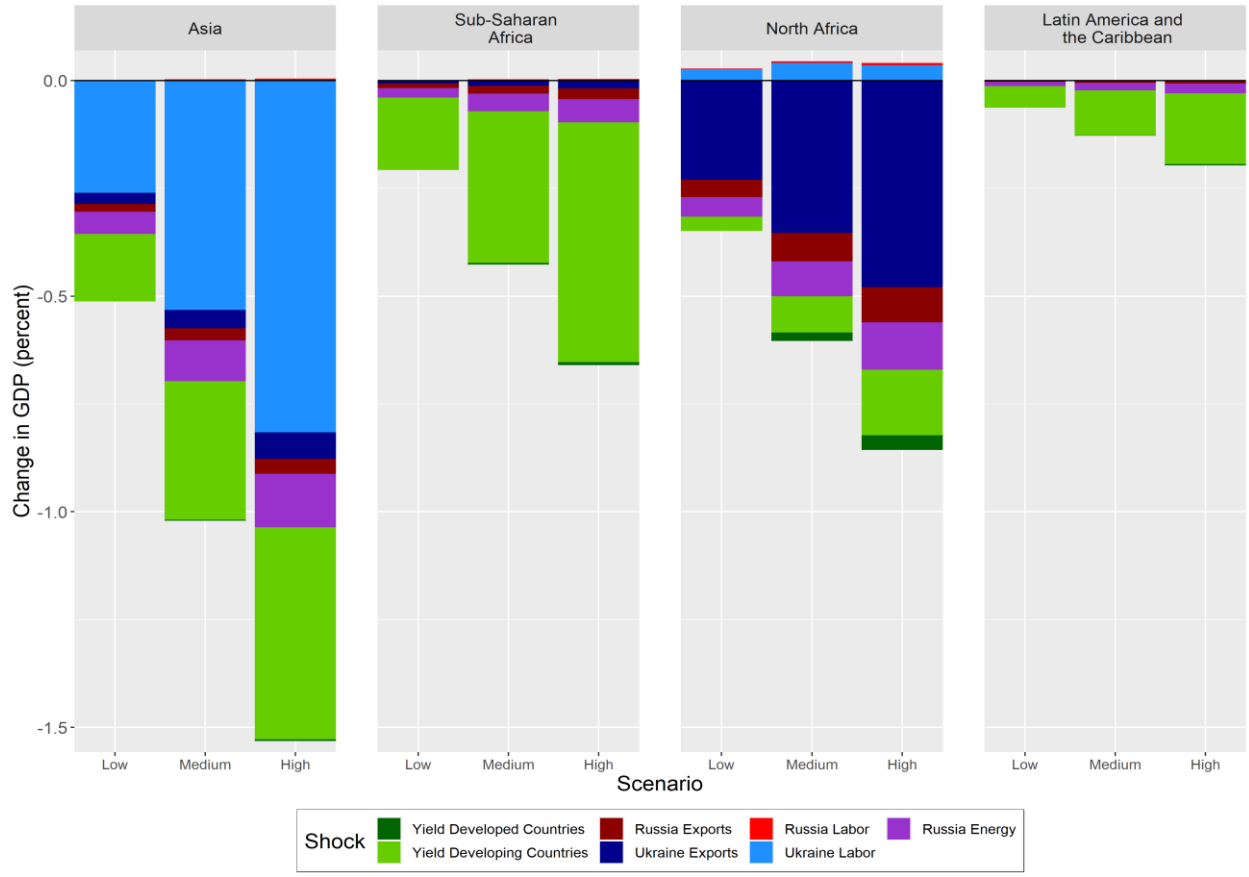
Finally, we include U.S. estimates in Table 4. The decrease in GDP is negligible as the United States is largely insulated from the changes (except for the yield reduction) and prices, production, and exports are estimated to increase. Like the global results, U.S. commodity prices increase, and the production response largely follows those changes. The United States may see an increase in agricultural production largely for exports, as the percentage changes for exports are all larger than for production.

Figure 3: Changes in Coarse Grain Prices by Shock and Region



Source: Author estimates

Figure 4: GDP Changes by Shock and Region



Source: Author estimates

Conclusion

Previous food price increases in 2008 and 2011 were noted as the result of a "perfect storm" of factors affecting agricultural markets. The end of 2021 and 2022 have also witnessed a perfect storm affecting agricultural markets. The COVID-19 pandemic has continued to impact supply chains, affecting farmers' ability to source inputs for production; Russia's invasion of Ukraine has led to difficulties in trade leaving the region (in addition to the sanctions in place on Russia by many countries); drought during the 2021/2022 agricultural year in South America restricted exports from that region; countries have put export restrictions in place; and energy prices have reached record highs. There has been a safe passage deal brokered by Turkey and the UN to transport grains, but the amount is still short of what Ukraine typically exports.

To consider how these factors might affect agricultural markets, we use a computable general equilibrium model to estimate changes in prices, production, trade, and GDP. Results indicate that agricultural prices would increase across all agricultural commodities, particularly for commodities exported by Russia and Ukraine. Thus, export supply (as opposed to the yield restrictions) is the main driver of price changes in regions which are more reliant on product from the Black Sea region. Countries that tend to import grains from Russia and Ukraine are also those expected to be the most impacted in terms of food security (Zereyesus et al., 2022). Under a medium shock scenario (which most closely resembles the impacts so far this year), agricultural prices increased by between 0.6% and 11.6% across commodities. Results indicate that global GDP decreases by 0.3% in the medium scenario.

Table 4. Impacts on U.S. GDP, Agricultural Prices, Agricultural Production, and Agricultural Exports (percentage changes)

		Low	Medium	High
	GDP	**0.0**	**0.0**	**0.0**
Agricultural prices	Wheat	4.2	10.7	18.9
	Coarse grains	1.3	5.0	9.4
	Oilseeds	2.5	7.1	12.5
Agricultural production	Wheat	5.6	9.2	13.1
	Coarse grains	1.8	3.2	5.1
	Oilseeds	3.3	5.0	7.0
Agricultural exports	Wheat	6.9	11.6	16.5
	Coarse grains	7.8	14.0	22.4
	Oilseeds	5.4	8.5	12.0

Source: Author estimates.

For More Information

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Russia's Invasion of Ukraine: The War's Initial Impacts on Agricultural Trade

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JEL Classifications: Q11, Q17, Q18
Keywords: Agricultural trade, Food security, Russia-Ukraine war

It has been over a year since Russian forces launched an unprovoked attack on Ukraine on February 24, 2022. Beyond the serious humanitarian impacts (United Nations, 2022)—more than 7 million Ukrainians were initially displaced by the war—Russia's invasion of Ukraine has far-reaching economic implications, including disruptions to the availability of key staple commodities, exacerbating already soaring food inflation not seen since the early 1980s, further bottlenecking of international supply chains, and reducing incomes and purchasing power in some of the world's poorest net food importing countries. There are few certainties right now as to when and how this war ends. What is clear is that Russia's war against Ukraine could have long-lasting geopolitical and economic consequences.

Russia and Ukraine are significant exporters of key staple grains, vegetable oil, meal and seed, and fertilizer and energy products (Paulson et al., 2022; Glauber and Laborde, 2022). Many lower-income economies depend on Russia and Ukraine for grains and oilseeds. As a result, the world finds itself grappling with a tight global supply situation and questions about food availability for the over 1 billion people residing in vulnerable net food importing countries.

For example, USDA's July 2022 World Agricultural Supply and Demand Estimate (U.S. Department of Agriculture, 2022) projected that Ukraine will export 10 million metric tons (MMT) in the 2022/23 marketing year, nearly half its historical export totals. Global ending stocks of wheat are expected to fall by 12.6 MMT in 2022–2023, to 267.5 MMT. This could be the third consecutive decline in stocks and would represent the largest year-over-year drop in global wheat stocks since 2012. April and May were also key planting months in Ukraine for corn, spring wheat, oilseeds and pulse crops, and Ukraine's larger winter wheat crop is planted in the fall for harvest in June of the following year (Smith, 2023; Westhoff et al., 2023).

Key Questions for Global Agricultural Markets

Russia's invasion of Ukraine has major implications for global agricultural markets. However, important questions remain:

1. How significantly has Russia's invasion impacted Ukraine's agricultural exports?
2. How severe is the war's impact on the low-income countries most dependent on grain and oilseed imports for subsistence consumption?
3. What impact has the war had on Russia's agriculture and fertilizer exports? Specifically, has Russia's policy of restricting trade, currency, and diplomatic ties with "unfriendly" countries altered the pattern of its agricultural and fertilizer trade?

A related question is the role of Western sanctions against Russia. Russia has claimed that sanctions have impaired global food supply, contributing to global food insecurity. The United States and European Union have denounced such claims, stating that agriculture and fertilizer products are specifically exempt (Herszenhorn, 2022; Reuters, 2022b). The U.S. Department of the Treasury (2022) issued a fact sheet to clarify that the United States has not imposed sanctions on the export of agricultural or fertilizer products from, to, transiting, or related to Russia, and these sanctions do not prohibit transactions involving insurance and reinsurance services in transportation. The EU has issued a similar fact sheet. Despite these exemptions, however, some news reports have suggested that certain banks and trading firms may still avoid transactions with Russian companies due to general uncertainty or other factors (sometimes referred to as "self-sanctioning") (Polansek and Mano, 2022). While this study does not attempt to unpack all potential indirect effects of Western sanctions against Russia, we do provide some early empirical evidence of the de facto impact of the war on Russia's agricultural and fertilizer exports and differential impacts on trade with its "friendly" and "unfriendly" partner countries.

This article provides an early econometric assessment of the impacts of the war on key food and agricultural exports by Ukraine and Russia to 51 partner countries using the latest available monthly bilateral trade data (January 2017 through December 2022). We control for product seasonality of commodity exports, product-specific historical trade relationships, import dependence, and export restrictions recently legislated by some countries. As of this writing, Ukraine has reported its export statistics through December 2022, which allows us to identify some preliminary impacts on the food insecure countries it serves (e.g., Egypt, Somalia, Lebanon, Bangladesh), as well as the Black Sea Grain Initiative (BSGI) which was brokered on July 22, 2022 by Turkey and the United Nations to allow the safe navigation of Ukrainian grain and oilseed exports from three ports around Odessa (Durisin, Quinn, and Nardelli, 2022; Fahim, 2022). To our knowledge, this study is one of the first to provide an initial ex post empirical assessment as to how Russia's invasion of Ukraine has altered agricultural commodity exports from these regions.

The Importance of Agricultural Exports from Russia and Ukraine

Russia and Ukraine produce and export several staple agricultural products (Abay et al., 2022; Food and Agriculture Organization of the United Nations, 2022; Glauber, Laborde and Mamun, 2022). Table 1 illustrates key export totals and the share of Russia and Ukraine exports in world exports for calendar year 2021 (CY2021). Ukraine and Russia supply 10% and 18% of global wheat exports by value, respectively, with a combined share of over one-quarter of global wheat exports. Ukraine is also responsible for 13% of corn exports and Russia and Ukraine each account for 14% of global barley exports, or 28% combined. Ukraine, and to a lesser extent Russia, is also an important exporter of vegetable oils (namely sunflower oil). Vegetable oils are used worldwide for everything from cooking oil and dairy spreads to the making of soaps, perfumes, and hydraulic fluid. Their coproduct, vegetable meal, is an important protein ingredient for livestock feed and pet food. While Ukraine and Russia account for 73% and 81% of global sunflower oil and meal exports, respectively, their contribution to the larger overall vegetable oil and meal market is smaller at 7% (Table 1).

Finally, Russia is a major producer of all three fertilizer nutrient blends: nitrogen, phosphate, and potassium. Globally, 44% of fertilizer production is exported (Jones and Nti, 2022; Myers and Nigh, 2021). Russia is the largest nitrogen exporter, supplying 23% of ammonia and 14% of urea exports in 2021, and the third-largest exporter of phosphate and potash (potassium), accounting for 9% and 16% of global exports, respectively. Combined, Russia and Belarus— a close ally of Russia—account for more than 40% of potash exports. In 2021, several countries, including the EU and the United States, imposed sanctions on imports of potash fertilizer from Belarus in response to ongoing political repression and corruption associated with the Belarussian government.

Import Reliance on Russia and Ukraine: The Case of Wheat

According to the Food and Agriculture Organization of the United Nations (2022), nearly 50 countries depend on Russia or Ukraine for more than 30% of wheat imports. Figure 1 combines data from the USDA's Production, Supply and Distribution tables (PSD, Left Panel) and historical (2017–2021) bilateral trade from CEPII's BACI international trade database for 32 (mostly) low-to-middle-income economies in which wheat imports account for over 20% of total use. Iran is also included because over 20% of Iran's wheat imports are sourced from Russia and Ukraine. Countries are sorted largest to smallest in terms of their reliance on wheat imports to satisfy domestic use (left panel).

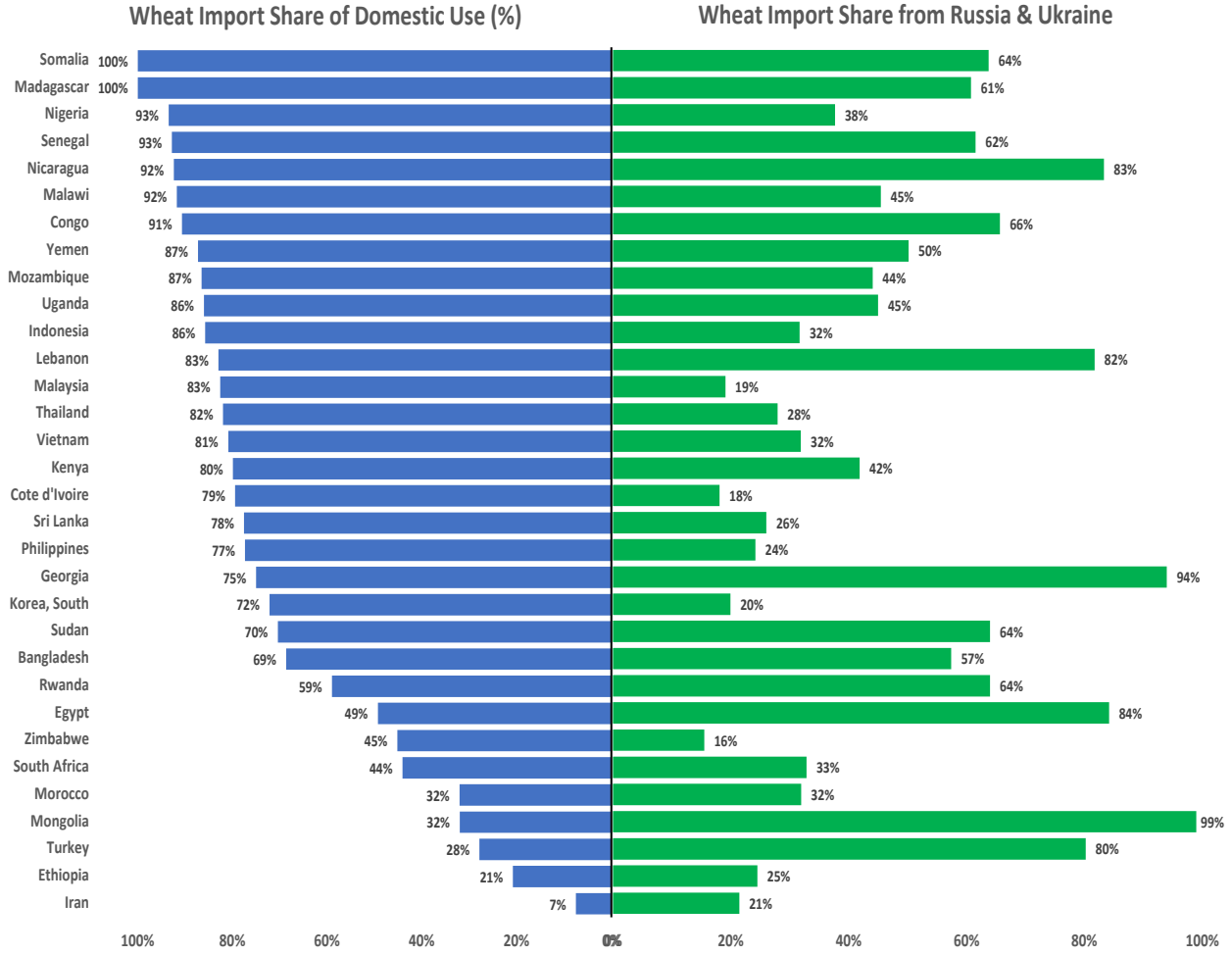
At the top of the list, Somalia, Madagascar, Nigeria, Senegal, Nicaragua, Malawi, and Congo are 90%–100% reliant on wheat imports to satisfy subsistence consumption. For Somalia, Madagascar, Senegal, and Nicaragua, over 60% of these imports are sourced from Russia and Ukraine (right panel). Other countries in which imports make up a large share of domestic use and a high dependence on Russia and Ukraine include Lebanon (82%), Georgia (94%), and Egypt (84%). Conversely, Nigeria, Indonesia, Malaysia, Thailand, Vietnam, Côte d'Ivoire, and South Korea have import shares of domestic use greater than 70%, but a relatively smaller share of those imports (<40%) depend on Russia and Ukraine. At the other extreme, Mongolia is only 32% reliant on imports for domestic use but sources 99% of its wheat imports from Russia.

Table 1. Key Russia and Ukraine Exports and Global Market Shares, CY2021

	Ukraine ($billions)	Russia ($billions)	Combined Trade ($billions)	World Trade ($billions)	Ukraine Share (%)	Russia Share (%)	Combined Share (%)
Wheat	5.1	9	14.1	51.1	10	18	28
Corn	6	1.1	7.1	45.2	13	2	16
Barley	1.27	1.26	2.5	8.9	14	14	28
Sunflower oil	6.5	4	10.5	14.3	45	28	73
Sunflower meal	1.2	0.5	1.7	2.1	57	24	81
All veg. meals (soy, rape, palm, etc)	1.54	1.07	2.61	35.4	4	3	7
Fertilizer (N, P, K)	0.43	4.71	5.14	24.9	2	19	21
Oil, natural gas	0.084	120	120.1	776	0	15	15

Source: Authors' calculations from Trade Data Monitor.

Figure 1. Import Reliance: A Ranking of Wheat Import Shares of Domestic Use and the Share of Wheat Imports Sourced from Russia and Ukraine



Notes: Domestic use includes wheat for feed, food, seed, and industrial use. Historical import shares from Russia and Ukraine are an average over calendar years 2017–2021. Not all countries have available domestic production and use data (i.e., Laos).

Source: Authors' calculations from USDA's Production, Supply and Distribution (PSD) database (https://apps.fas.usda.gov/psdonline/app/index.html#/app/home) and BACI International Trade Database (http://www.cepii.fr/CEPII/en/bdd_modele/bdd_modele_item.asp?id=37).

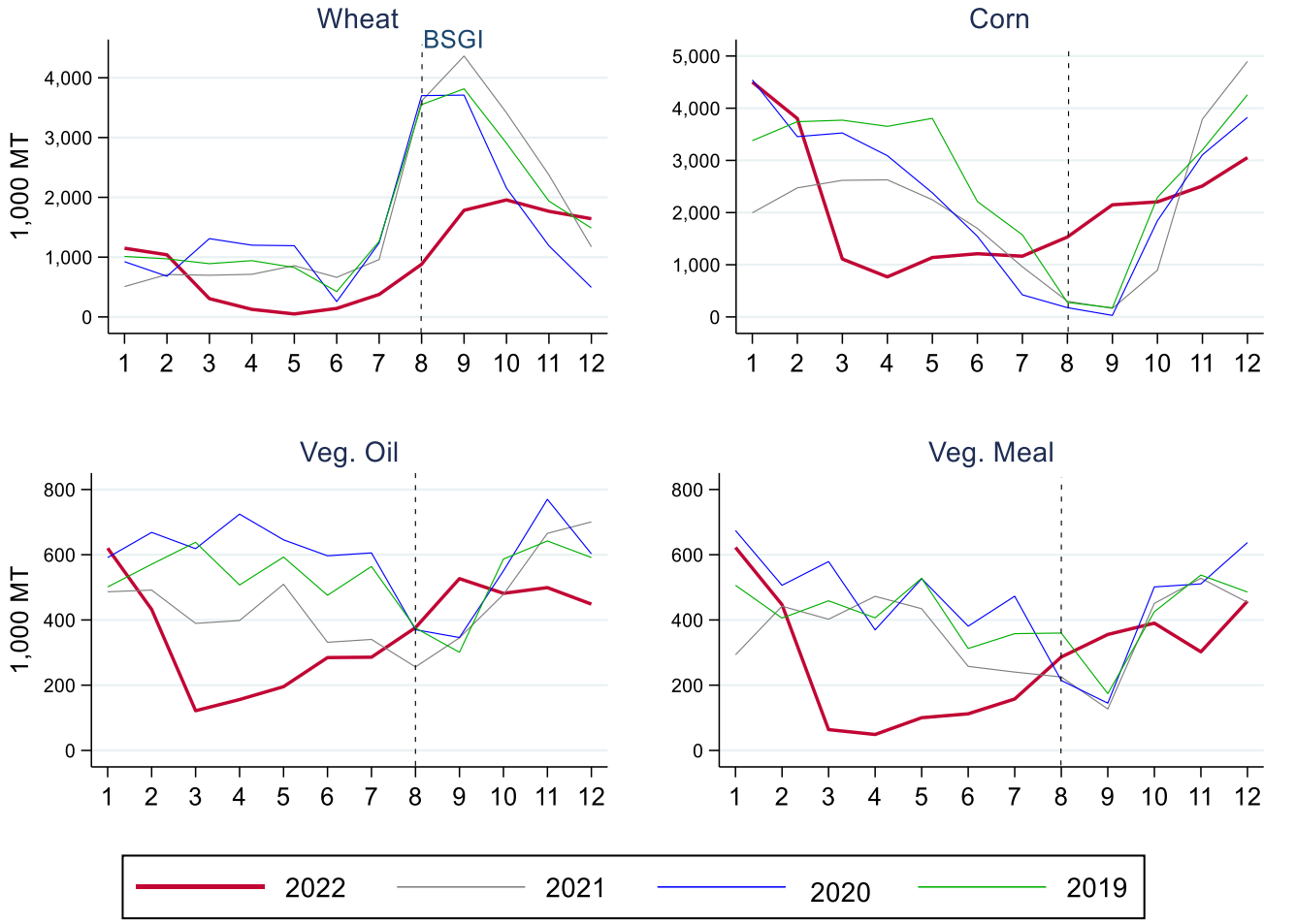
Seasonality of Ukraine's Agricultural Exports

When evaluating the impact of Russia's war in Ukraine, an important consideration in the estimation of counterfactual trade losses is the seasonality of exports. Grant et al. (2019) and Grant et al. (2021) illustrate that a large share of the estimated trade damage to U.S. exports during the 2018/19 U.S.-China trade dispute occurred during the United States's peak export months (fall season). Figure 2 plots Ukraine's total monthly wheat, corn, vegetable oil and meal exports from January 2019 through December 2022. Several important trends are worth mentioning. First, Ukraine's peak wheat exports occur in August–October (months 8–10, Figure 2). Historically, Ukraine's in-season wheat exports averaged close to 4 MMT/month, compared to its offseason exports (January–July), which averaged close to 1 MMT/ month. A similar seasonal pattern exists for Russian wheat exports (not shown to save space).

Second, Ukraine's monthly corn exports are counterseasonal to its wheat exports, and peak (in-season) from December through May. Up to 30% of Ukraine's $4.8–$5.8 billion in annual corn exports (roughly 25–30 MMT) since 2019 has been exported to China. Other key destination markets include the EU, Egypt, Turkey, Iran, Tunisia, and South Korea. In-season Ukrainian corn exports averaged 3–4 MMT/month and are exported to over 100 countries, compared to less than 1 MMT/month in the offseason months (May–September).

Third, Ukraine is also an important exporter of vegetable oil and meal (predominantly sunflower but also rapeseed and soy), with peak exports of between 400,000 and 600,000 MT/month and serving over 170 countries (Figure 2). With

Figure 2. Monthly Global Exports of Wheat, Corn, and Vegetable Oil and Meal from Ukraine through December 2022



Source: Authors' calculations from Trade Data Monitor.

Notes: BSGI denotes Black Sea Grain Initiative. Volumes illustrated are based on Ukraine's reported export statistics.

the exception of September each year, Ukraine's vegetable oil and meal exports exhibit less seasonality.

Finally, the heavier red line in Figure 2 traces Ukraine's exports in 2022 and provides a first look at the economic toll of Russia's invasion. In the initial months March–June 2022, Ukraine's out-of-season wheat shipments were down by 75% or more, with total losses averaging 750,000 MT/month; corn exports declined 75% or more from an average of 3-4 MMT/month to 1 MMT/month or less; vegetable oil exports dropped from 600,000 MT to less than 200,000 MT in March–May 2022 but have since slowly recovered; and vegetable meal exports were down from 500,000 MT/month to less than 100,000 MT/month and remained below trend through July 2022.

The vertical dashed line over August (month 8) in Figure 2 illustrates the entry into force of the BSGI. Note how the BSGI initially facilitated Ukraine's out-of-season corn exports above trend, and relatively larger exports of vegetable oil and meal compared to historical export levels. In November and December 2022 (months 11–12), corn, vegetable oil and meal exports have since fallen below trend. Ukraine's wheat exports were in-season when the BSGI entered into force, and while the grain deal has increased Ukraine's 2022 wheat exports, export shipments in August through October 2022 were not enough to reach Ukraine's historical export levels during these months.

Empirical Methods and Data

We conducted a short-run, ten-month, ex-post econometric evaluation of the Russia-Ukraine conflict on key agricultural exports by the two countries. The model includes controls for seasonality (within-year dimension), country-pair-product specific effects capturing historical trade relationships and import dependencies, export restrictions recently legislated by some countries on certain food and fertilizer exports (Laborde, 2022), and the August 2022 Black Sea Grain Initiative. The impact on exports of Ukraine and Russia's exposure to the war are specified as indicator variables equal to 1 for Ukraine and separately for Russian exports beginning in March 2022 and extending through December 2022 relative to monthly historical exports in these same months in 2017–2021.

Table 2. Econometrically Estimated Trade Impacts of Russia's Invasion of Ukraine

	Top Ag. Sectors Combined	Cereal Grains	Cereal Grains, pre- and post-BSGI	Vegetable Oil, Meal, Seed	Vegetable Oil, Meal, Seed, pre- and post-BSGI	Meat (Poultry and Pork)	Fertilizers	Top Non-Ag Sectors Combined
March–December 2022 Trade Impacts								
Imports from Ukraine	-0.61***	-0.74***		-0.39**		-0.42*		-1.11***
	(0.15)	(0.20)		[0.13]		[0.20]		[0.17]
Ukraine, pre-BSGI			-1.25***		-0.97***			
			[0.25]		[0.18]			
Ukraine, post-BSGI			-0.41*		-0.08			
			[0.21]		[0.14]			
Imports from Russia	-0.13	-0.16		0.04		-0.44*	-0.08	-0.19**
	(0.16)	(0.24)		[0.12]		[0.48]	[0.12]	[0.06]
Russia, pre-BSGI			-0.12		0.07			
			[0.24]		[0.13]			
Russia, post-BSGI			-0.22		0.01			
			[0.12]		[0.14]			
Implied Percentage Trade Effects								
Ukraine	-46%	-52%	—	-32%	—	-34%	—	-67%
Ukraine, pre-BSGI	—	—	-71%	—	-62%	—	—	—
Ukraine, post-BSGI	—	—	-34%	—	—	—	—	—
Russia	—	—	—	—	—	—	—	-17%
Russia, pre-BSGI	—	—	—	—	—	—	—	—
Russia, post-BSGI	—	—	—	—	—	—	—	—
Pseudo-R^2	0.93	0.90	0.90	0.96	0.96	0.97	0.91	0.97
No. of obs.	574,421	186,046	186,046	245,458	245,458	9,525	220,068	911,490

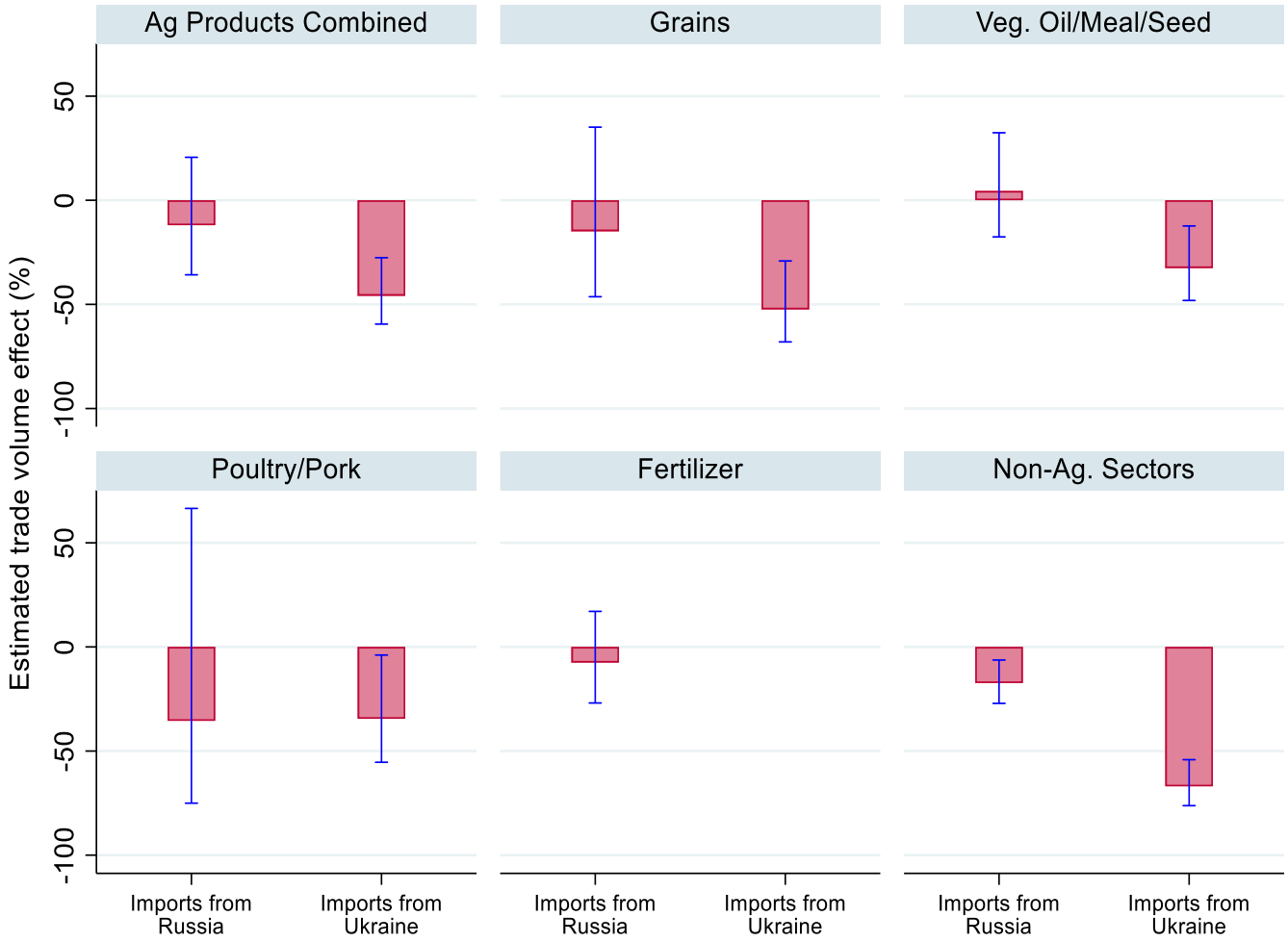
Notes: Values in parentheses are standard errors. Single, double, and triple asterisks (*, **, ***) denote statistical significance at the 10%, 5%, and 1% levels, respectively. The sample period runs from 2017M1-2022M12 and includes 51 countries' reported bilateral import volumes as well as Ukraine's reported export volumes to 19 low-income countries. The dependent variable is the volume (converted to metric tons) of bilateral trade converted to common units (metric tons). All models are estimated using Poisson Pseudo-Maximum Likelihood estimation with high-dimensional fixed effects. Implied percentage trade impacts are computed as the exponential of the estimated coefficient minus one multiplied by 100.

In April 2022, the Federal Customs Service of Russia suspended its national statistics until further notice. In May 2022, Belarus followed. Thus, to capture the potential trade impacts of the war on Russia's exports, we rely on 51 countries' reported imports. High-frequency monthly bilateral trade volumes are retrieved from Trade Data Monitor (https://tradedatamonitor.com/). The initial analysis is constrained to "early reporters"—a set of 51 countries that have reported HS6-digit bilateral imports from and exports to their partner countries through December 2022. Appendix Table A groups these countries regionally along with other lower-income countries using Ukraine's reported export statistics. Appendix Table B lists the product sectors included in the empirical analyses.

Destructive Trade Impacts of the War in Ukraine

To what extent has Russia's war in Ukraine impacted key agricultural exports? Table 2 presents the results across eight categories: Ukraine's top agricultural export sectors combined (cereal grains, oilseeds and coproducts, and meat products) and individually for cereal grains, oilseed, meat, fertilizer, and a combined category of Russia and Ukraine's top nonagricultural exports (see Appendix Table B). For grains and oilseeds, we also report coefficient estimates from a model that includes separate variables before (pre-BSGI) and after (post-BSGI) the Black Sea Grain Initiative. We focus on two econometric coefficients in the model: (i) 51 countries' imports from Ukraine given the war and (ii) the same 51 countries' imports from Russia given the latter's claims of (indirect) sanction effects. The results in Table 2 are suggestive of a large, negative, and statistically significant trade volume effect across most product categories exported by Ukraine and underscores the significant economic toll of the war on its staple food exports. Overall, from March through December 2022, model results suggest that Russia's invasion has reduced Ukraine's top agricultural exports by 46% on average. Among agricultural export categories, Ukraine's cereal grain exports show the largest percentage trade reductions at 52%. Oilseeds and coproducts and Ukraine's poultry and pork meat exports experienced smaller but still economically significant overall trade volume reductions of 32% and 34%, respectively in 2022. With the exception of meat and

Figure 3. Model Estimated Percentage Trade Effects of Russia's Invasion of Ukraine for March–December, 2022, Relative to Historical



Notes: Implied trade estimates are derived from econometric model results in Table 3. Upper and lower 95% confidence intervals are included to illustrate the range and precision of the exponentially transformed estimates.

nonagricultural exports, none of the coefficients for Russia's agricultural exports of cereal grains, oilseeds, or fertilizer are economically or statistically significant. This suggests that Russia's exports have experienced little impact from its invasion of Ukraine relative to the same product-month exports in the historical period (2017–2021). This finding is consistent with the exemptions for agriculture and fertilizers from sanctions and may also suggest some indirect effects whereby countries not enforcing any type of sanctions, or that have more neutral or allied relations with Russia, could be absorbing additional Russian exports. In the next section we try to unpack some of these results. Figure 3 plots the overall implied percentage trade effects of the March–December 2022 model specification.

The Importance of the Black Sea Grain Initiative (BSGI)

For cereal grains and oilseeds, we also report the results from a model that incorporates pre- and post-BSGI trade effects in Table 2. This scenario allows us to examine the importance of the BSGI in restarting Ukraine's exports in the August–December 2022 period relative to the impacts of Russia's invasion before the agreement (March–July 2022). Two key results are worth emphasizing. First, the onset of Russia's invasion in the pre-BSGI period (March–July 2022) resulted in a 71% decline in Ukraine's cereal grain exports. The war's impacts in the pre-BSGI period was also significant for Ukraine's oilseed exports resulting in a 61% reduction. Second, the entry into force of the BSGI has significantly improved Ukraine's cereal grain and oilseed exports. Although the trade flow effect of Ukraine's cereal grain exports is estimated at -34% compared to export levels predicted by the model (Table 2), the estimated effect is less than half the pre-BSGI trade effect for cereal grains of -71%. In the case of Ukraine's oilseed product exports, the post-BSGI trade flow effect is insignificant meaning there is no statistical difference between Ukraine's oilseed exports in the August–December 2022 period compared to the same months in the historical period. In other words, not only has the BSGI helped restart the safe passage of Ukraine's grain and oilseed exports, in the latter product category, the initiative has essentially resumed Ukraine's export volumes at levels consistent with its export capacity.

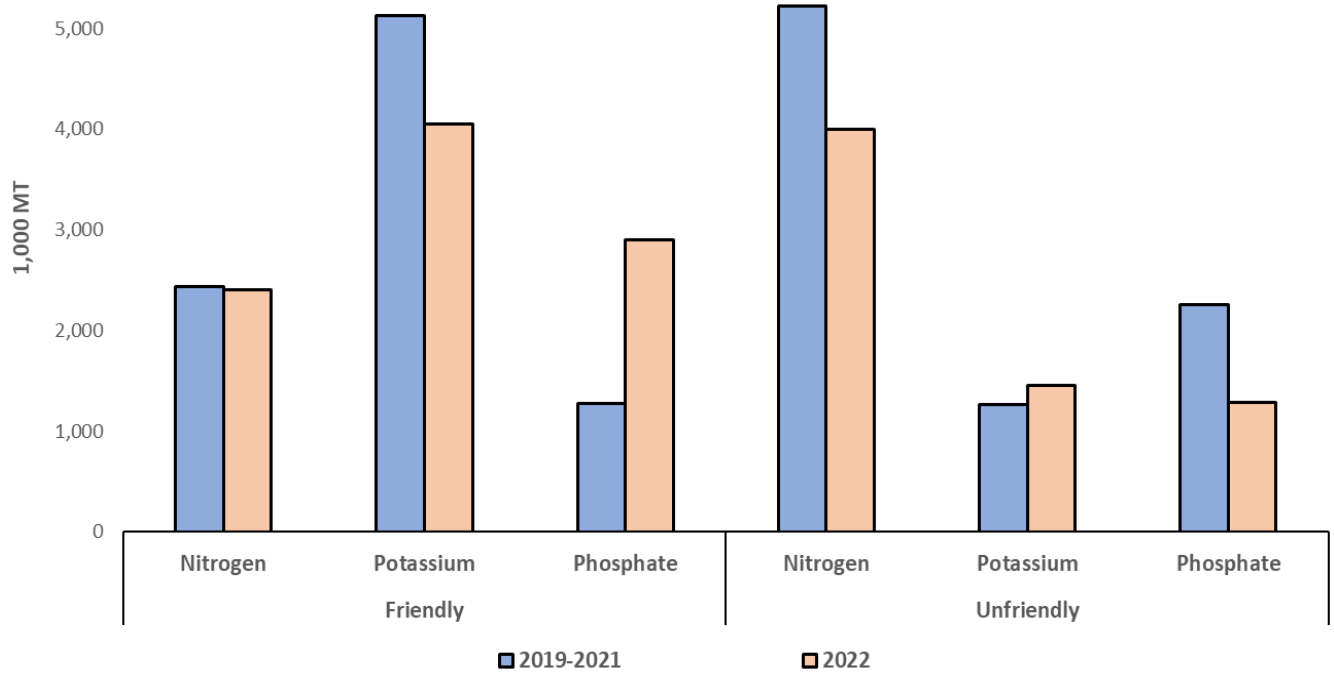
Russian Exports to "Friendly" vs. "Unfriendly" Countries

Russia has made several announcements threatening to restrict or halt exports of agricultural and fertilizer products to so-called "unfriendly" nations, those that have applied sanctions or otherwise supported the use of sanctions against Russia. In April 2021, nearly a year prior to the invasion, Russia published an "unfriendly list" of countries as a means to introduce countermeasures, including currency and trade restrictions. Initially the list included the United States and Czech Republic over diplomatic rifts that preceded Russia's invasion of Ukraine (The Economist, 2021). Following its invasion of Ukraine and in response to countries imposing sanctions, by March 2022 Russia's "unfriendly list" of countries had increased to 48. The role of this "unfriendly list" and its potential impacts on Russia's export patterns is not clear. While Russia has brought attention to using its food exports as a geopolitical instrument—former Russian president Dmitry Medvedev threatened that Russia "will not supply [its] products and agricultural products to [its] enemies" and "will supply food and crops only to [its] friends" (Gijs, 2022)—it has also repeatedly accused Western sanctions of impairing its agricultural exports and the global food security crisis. Setting aside Russia's contradicting statements as well as the specific exemption of agriculture and fertilizer items from Western sanctions, a private importer from a Western or other "unfriendly" country may still engage in "self-sanctioning" Russian products either voluntarily or because of logistical, shipping, finance, and insurance challenges currently affecting trade transactions with Russia (Quinn, Ribeiro, and Almeida, 2022).

While it is difficult to disentangle the various dimensions of these geopolitical effects, Figure 4 illustrates Russia's exports of potassium, nitrogen, and phosphate fertilizer to "friendly" and "unfriendly" partner countries in March–December period of 2022 relative to 2019-2021. "Friendly" countries—which include Brazil, India, China, South Africa (BRICS countries) plus Iran, Saudi Arabia, and the United Arab Emirates—have provided some level of public support for Russia, have not publicly condemned Russia's attack on Ukraine, or have not participated in Western sanctions.

Russian exports of phosphate fertilizer are up over 1.6 MMT to "friendly" countries in 2022, and more than makes up for the decline in phosphate exports of 1 MMT to "unfriendly" countries. Conversely, nitrogen exports of 2.4 MMT to "friendly" countries in 2022 is very close to Russia's historical average for this fertilizer nutrient. However, Russia's nitrogen exports to "unfriendly" countries are down 1.2 MMT. One reason for the larger increase of Russian phosphate exports to "friendly" countries in 2022 may be that prior to the war, "unfriendly" countries were a relatively larger destination market (compare 2019-2021 phosphate exports between "friendly" and "unfriendly" groups). Thus, "friendly" markets may have more capacity to absorb additional Russian phosphate exports relative to nitrogen or potassium exports. In efforts to assist its domestic farmers, Russia also extended its quotas on nitrogen fertilizer exports (Reuters, 2022a).

Figure 4: March-December Fertilizer Imports from Russia by "Friendly," and "Unfriendly," Countries, 2019-2021 versus 2022



Source: Authors' calculations from Trade Data Monitor.

Notes: 2019-2021 is the average total imports from Russia by friendly and unfriendly countries over the March-December months. 2022 is the total friendly and unfriendly reported import volumes from Russia during March-December months of 2022.

Are Trade Effects Worse for Lower-Income Countries More Reliant on Ukraine?

We return to an important question raised by many international organizations: Are trade losses from Russia's invasion of Ukraine more severe for lower-income countries? Using wheat and corn as a case study, we illustrate this relationship in Figure 5, which plots the change in countries' March–December 2022 cumulative wheat and corn import volumes from Ukraine (relative to the average of the same months in the previous five years) on the vertical axis against each country's average historical March–December (2017–2021) share of wheat and corn imports sourced from Ukraine.

The further down and to the right the scatterplots are (i.e., moving southeast) in the Figure 5, the greater the reduction in import volumes from, and historical reliance on, Ukraine for wheat and corn imports. Although the relationship is not as tight as presumed, the results underscore a general trend: The line of best fit slopes downward, indicating that the negative trade volume effects of the war are increasing, in absolute value, for countries that have been historically more reliant on imports from Ukraine. Egypt is an example of a middle-income country that has relied on 17% of its wheat and 26% of its corn imports—from Ukraine—and has experienced a decline of nearly 2 MMT of wheat and 1.3 MMT of corn in March–December 2022, compared to Egypt's 2017–2021 average in these same months. Other lower-income countries with relatively high import dependence and larger trade volume reductions include wheat imports into Bangladesh (-1.1 MMT; 20% import reliance on Ukraine), Tunisian wheat (-613,000 MT; 45% reliance) and corn (-265,000 MT; 53% reliance) imports, Moroccan wheat imports (-843,000 MT; 22% reliance), wheat imports into Yemen (-405,000 MT; 15% reliance) and Pakistan (-609,000 MT; 54% reliance), and Libya's wheat (-426,000 MT; 38% reliance) and corn (129,000 MT; 73% reliance) imports. Indonesian wheat and Chinese corn imports are examples of upper-middle and high-income markets that have been similarly impacted by Russia's war in Ukraine.

Conclusions and Global Implications

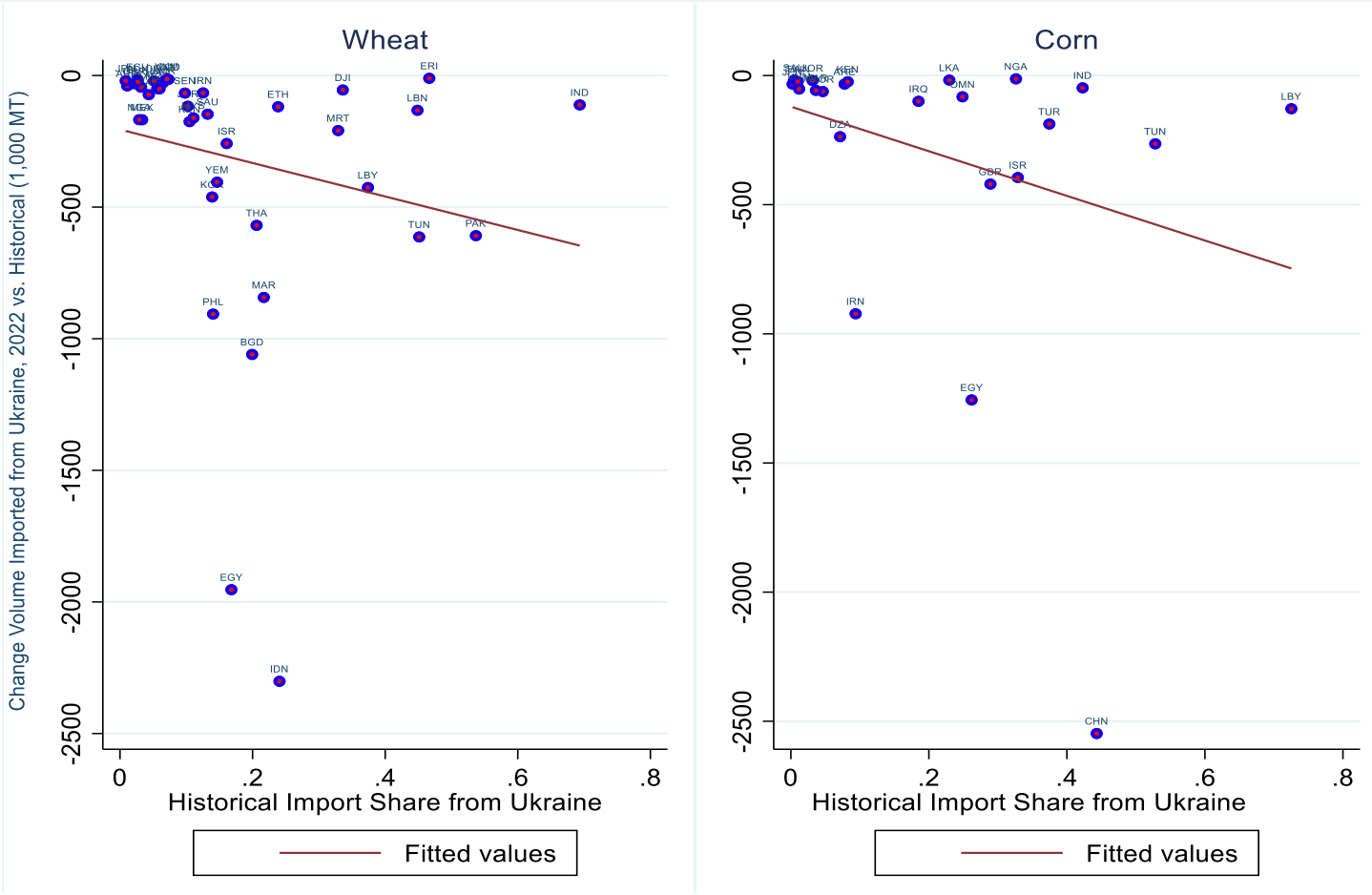
This article provided one of the first looks at the agricultural trade impacts of Russia's invasion of Ukraine. We found sharp and immediate effects: Russia's war has reduced Ukraine's grain and oilseed exports by an average of 52% and 32%, respectively, during March–December 2022. This is equivalent to restricting 23.6 MMT of Ukraine's potential wheat, corn, barley, and other coarse grain exports in 2022 and an additional 4.6 MMT of vegetable oil, meal, and seed from the global market. These amounts represent nearly 45% and 24% of Ukraine's average annual global exports in these two sectors, respectively. These trade volume impacts occurred on top of FOB export price discounts due to the war.

Much of the impact of Russia's invasion on Ukraine's cereal grain and oilseed exports occurred in the months prior to the BSGI (March–July 2022). Our estimates suggest Ukraine's cereal grain and oilseed product exports were reduced by 71% and 62%, respectively, during this period. However, in the months following the entry into force of the BSGI (August–December 2022), Ukraine's cereal grain exports were down just 34% compared to export levels predicted by the model, and its oilseed exports showed no significant impacts.

Our estimated effects on most Russian agricultural and fertilizer exports were not significant. However, we find some geographical reorientation of Russian fertilizer exports away from "unfriendly" and toward "friendly" countries—particularly for Russian exports of phosphate fertilizer. This is likely leading to shifts in the relative cost of imported fertilizer products that may negatively impacting some countries while benefiting others. However, we leave this analysis to future research.

On November 19, 2022, Russia and Ukraine agreed to extend the BSGI for an additional 120 days to continue Ukrainian grain and oilseed exports from three ports; Odesa, Yuzhny, and Chernomorsk. On March 18, 2023, the BSGI was renewed a second time but only for at least 60 days, or half the time of the previous extension. The BSGI has been one of the only diplomatic breakthroughs since the war began, and even if the deal continues to be honored, our results suggest it will take time to rebuild Ukraine's port capacity and for traders and inspection officials to kick-start trade flows to levels that existed prior to Russia's invasion. Ukraine faces the task of clearing a pathway in mined seas, finding enough ships to carry the backlogged grain, rerouting trains and trucks that are now being used elsewhere, and rebuilding storage capacity at these ports. What this means for the many lower-income countries dependent on Ukrainian food exports remains unclear. Much will depend on how easily these markets can source product from other exporters. We leave this and many other important questions for further research.

Figure 5. Historical Import Shares of Wheat and Corn Sourced from Ukraine and March–December 2022 Trade Flow Changes Relative to Five-Year Previous Average



Notes: Authors' calculations from Trade Data Monitor. Country codes are listed in Appendix A

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Appendix Table A. List of 51 Early Reporting Countries in Sample and their ISO-3 Digit Country Codes

Africa	Middle East	Asia	Europe	Oceania	North America	Central/South America and Caribbean
Senegal* (SEN)	Iran* (IRN)	China (CHN)	Switzerland (CHE)	Australia (AUS)	Canada (CAN)[a]	Argentina (ARG)
Madagascar* (MDG)	Qatar (QAT)	Japan (JPN)	Norway (NOR)	New Zealand (NZL)	US (USA)[a]	Brazil (BRA)
Cote d'Ivoire* (CIV)	Saudi Arabia (SAU)	Singapore (SGP)	Serbia (SRB)		Mexico (MEX)	Chile (CHL)
Ethiopia* (ETH)	Israel (ISR)	South Korea (KOR)	Georgia (GEO)			Dominican Rep. (DOM)
South Africa (ZAF)		Sri Lanka* (LKA)	Uzbekistan* (UZB)			Uruguay (URY)
Kenya* (KEN)		Indonesia (IDN)	Turkey (TUR)			Peru (PER)
Morocco* (MAR)		Thailand (THA)	UK (GBR)			Costa Rica (CRI)
Namibia* (NAM)		Malaysia (MYS)	Albania (ALB)			
Mozambique* (MOZ)		India* (IND)	Bosnia and Herz. (BIH)			
Nigeria* (NGA)		Taiwan (TWN)	EU (EUR)			
Zimbabwe* (ZWE)		Philippines (PHL)	N. Macedonia (MKD)			
			Kazakhstan (KAZ)			
			Montenegro (MNE)			
TOTAL: 11	4	11	13	2	3	7

Additional Lower-Income Countries Included in the Sample Using Ukraine's Reported Exports:

Algeria, Egypt, Jordan, Lebanon, Tunisia, Libya, South Sudan, Iraq, Pakistan, Bangladesh, Somalia, Yemen, Vietnam, Nepal, Myanmar, Ghana, Tanzania, United Arab Emirates, Nicaragua

Note: Total = 51 countries. The sample excludes Hong Kong, Bolivia, Paraguay, El Salvador, Paraguay, Bahrain, Iceland, and Panama, which have very little historical agricultural trade with Russia or Ukraine (< $1,000,000 annually). Single asterisk (*) denotes low-income or lower-middle income economies according to the World Bank Country Classification for 2022 fiscal year. Some countries only report monthly trade values (i.e., Dominican Republic and Israel). In these cases, we approximated monthly volumes from the value data using average unit value prices for the same product and month of the nearest neighboring countries, where trade volume = trade value / unit value price.

Appendix Table B. Product Sectors Included in the Analysis Appendix Table B. Product Sectors Included in the Analysis				
Top Agricultural Sectors			Non-Agriculture Sectors	Fertilizer
Cereal Grains and Pulses	**Oilseeds and Coproducts**	**Meat Products**		
Corn	Oilseeds (sunflower, rapeseed, and soy)	Poultry	Ferrous metals (iron/steel)	Nitrogen
Wheat	Vegetable oils (sunflower, soy, and rapeseed)	Pork	Electrical equipment	Phosphate
Coarse grains	Vegetable meal (sunflower, soy, and rapeseed)		Nonferrous metals	Potassium
Pulses			Chemicals	
			Mineral extractions	
			Coal	
			Oil	
			Petroleum	

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