The impact of Russia-Ukraine conflict on global food security

Abstract:

Ukraine and Russia are two important grain producers and exporters in the world, accounting for 12% and 17% of the world's wheat exports, respectively. The conflict between Russia and Ukraine may greatly impact Ukraine's wheat production and export as well as Russia's wheat export. Satellite observations have showed signs of wheat production reduction in Ukraine in the season 2021-2022. Considering the uncertainty of the conflict duration, we have designed three scenarios (i.e., slight, medium, and severe) depending on how the war would significantly impact the wheat harvest and trade disruption. From analysis of potential impacts of the conflict on global wheat market under the general equilibrium trade model, we have found that the conflict would lead to a trade drop (60%), soaring wheat prices (50%), and severe food insecurity with decreased purchasing power for wheat (above 30%) in the most severe scenario, especially for countries that heavily rely on wheat imports from Ukraine, such as Egypt, Turkey, Mongolia, Georgia, and Azerbaijan. Considering the role of Russia and Ukraine in agricultural input sectors including oil, natural gas, and fertilizers, especially Russia, the trade blockade caused by the conflict will give rise to price increase by 10%-30% and welfare decline by 15-25% for most affected countries. The conflict would put as many as 1.7 billion people in hunger and 276 million people in severe food insecurity. Food shortages, energy shortages and inflation have spread to many countries like dominoes which have fallen into trouble one after another with social unrest day after day. Our analysis also shows that countries including the United States, China, India, Canada, Australia, France, Argentina, and Germany would increase their wheat production and exports for the reconstruction of the global wheat supply pattern. The modeled results indicate that the conflict-induced global wheat crisis and food insecurity can be notably alleviated if these countries increase their production by 2%-3% in 2022-2023 and unnecessary trade restrictions are exempted.

Introduction

Known as the granary of Europe, Ukraine has the world's 25% black soil[1] and highly developed agricultural production that accounts for more than 10% of its gross domestic production (GDP) in 2021[2]. Both Ukraine and Russia are large grain exporters, accounting for 40% of the world's grain exports[3]. The Russia-Ukraine conflict that has lasted for more than two months since its outbreak on February 24, 2022 have raised worldwide concerns about international trade and food security (Alison,2022). Winter wheat is a primary crop exported by both Ukraine and Russia which account for nearly 30% of the global wheat exports in 2021. As such, the conflict has led to dramatic surges of global food prices (FAO,2022).

The United Nations has warned that the combination of COVID-19 pandemic and Russia-Ukraine crisis has led to the biggest food crisis after the World War II, i.e., as many as 1.7 billion

[1] https://www.globalsecurity.org/military/world/ukraine/agriculture.htm
[2] https://www.ukrinform.net/rubric-economy/3401224-share-of-agriculture-in-ukraines-gdp-exceeded-10-leshchenko.html
[3] Data from UN COMTRADE. Available online at http://comtrade.un.org/.

people are in hunger and poor, the level of which is at a new high at present[4]. There is a concentrated structure in the global grain market, with Russia and Ukraine supplying about 30 percent of wheat and barley. A total of 36 countries, including some of the world's most vulnerable and impoverished, import more than half their wheat from them. Because of this, the conflict between Ukraine and Russia quickly derailed global food supplies and led to high prices[5]. It pushed millions into extreme poverty and worsened hunger and malnutrition and there were 222 million people in 53 countries and territories suffering from severe food crises and in need of emergency assistance[6].

The ongoing conflict is expected to induce disruptions to agricultural production and global trade because it can displace population, damage civilian infrastructures and restrict the free movement of people and goods, thereby preventing farmers from cultivating, harvesting, and selling crops (Li et al., 2022). The upcoming conflict-hindered field management (e.g., fertilization and irrigation) would introduce uncertainties about the growth, production, and export of current winter wheat planted in last October. The lack of labor, termination of transportation, and disruptions to chemical fertilizers and pest and disease controls could significantly affect the wheat growth in Ukraine. Besides, the conflict has disrupted grain shipments through the Black Sea and shut down Ukrainian ports. Thus, food security in countries (e.g., Egypt, Turkey, Mongolia, Georgia, and Azerbaijan; Fig. S1) that are highly dependent on wheat imports from Ukraine are in particular affected (Glauber and Labored, 2022). As a response to the possible decline of wheat exports from Ukraine, increasing wheat exports from other countries is a plausible way to balance the global wheat demand.

In this study, we provide a comprehensive analysis of the impact of the Russia-Ukraine conflict on wheat production and the consequent impacts on global trade, using satellite observations and the Structural General Equilibrium Trade Model (SGETM) (Eaton and Kortum, 2002; Caliendo and Parro, 2015). It allows us to perform counterfactual analysis in different scenarios, as well as to track the mechanisms contributing to the main results. On the other hand, with fewer data and parameters, SGETM is more tractable in counterfactual analysis in more transparent ways. Moreover, SGETM escapes the black box denigration of traditional CGE models and has a more transparent and changeable model setting. Moreover, using Landsat and Sentinel-2 satellite time series data, we have analyzed the wheat-growing conditions in previous years (2019-2021) and estimated the wheat yield in 2022. With detailed country-industry-level wheat production and trade data from GTAP, we measured the impacts (i.e., global trade, wheat prices, and welfare) of potential conflict-induced production loss across countries under multiple scenarios (i.e., depending on the conflict duration) and got credibility conclusions (similar results with Martin-Shields and Stojetz, 2019; Balma, et al., 2022). The work shows an established paradigm for timely analysis of global trade of agricultural products by combining remotely sensed observations and quantitative economic models. Details about the adopted datasets and methods can be found in Supplementary Materials.

[4] https://www.usatoday.com/story/opinion/columnist/2022/04/13/ukraine-war-poverty-hunger-united-nations/7302438001/
[5] https://www.usip.org/publications/2022/05/ukraine-war-deepening-global-food-insecurity-what-can-be-done
[6] https://www.worldbank.org/en/topic/agriculture/brief/food-security-update

Methods

Data

Satellite data. We used Landsat and Sentinel-2 data to map the Ukraine wheat distribution (2021) and the growing status monitoring (2022). The Landsat Surface Reflectance images were provided by the US Geological Survey at a 16-day cycle. The Sentinel-2 surface reflectance data were provided by the Europe Space Agency at a 12-day revisit cycle. All available Landsat and Sentinel-2 images from 2019 to 2022 are used and processed (e.g., cloud removal)(Andrimont et al., 2021) .

European crop type data. The continental crop type map is at 10-m spatial resolution for the EU based on Sentinel-1A and Sentinel-1B Synthetic (Aguiar et al., 2019). The overall accuracy for the map is reported as 80% for grouping main crop classes and 76% for considering all of the 19 crop classes separately, including wheat, cereals, root crops, dry pulses, vegetables and flowers, and fodder crops.

Global Trade data. Data used for our trade model quantification are from the most recent Global Trade Analysis Project (GTAP). GTAP is a global database describing bilateral trade patterns (see Fig. S4 in Supplementary Materials), production, consumption, and intermediate use of goods and services. We obtained our value-added, export, domestic, and import value in intermediate trade and trade elasticities from GTAP (Aguiar et al, 2019) and Caliendo and Parro (2015).

Monitoring of wheat growth in Ukraine

First, we map the Ukraine-wide wheat distribution in 2021 by using satellite observations from Landsat and Sentinel-2. We collect training samples, relatively stable regarding their locations and temporal dynamics, from the European crop maps of surrounding countries (e.g., Portland) (2018). We use available Landsat and Sentinel-2 images in the GEE archive and implement the classification with the random forest approach. We train the model using the whole time series during the wheat growth in 2017-2018 and apply this model to Ukraine during the growth period (i.e., from October to May) in 2021-2022.

After that, we analyze the Ukraine wheat growth in 2022 by comparing the NDVI change from harmonized observations from Landsat and Sentinel-2 data relative to the mean value of the previous three years (2019-2021) for those wheat pixels. The year-on-year NDVI change for the same period can quantitatively reflect the possibly conflict-included loss of field management. Details can be found in Supplementary Materials.

Estimating the wheat yield in Ukraine

With the harmonized satellite observations from Landsat and Sentinel-2 data and the climate records, we have estimated the 2022 wheat yield for Ukraine. Given that wheat is a cross-year crop sowed in previous October and harvested around July, monthly satellite observations and climate records are used as inputs for wheat yield estimation. The wheat yield references (kg/ha) for each state in Ukraine from 2017 to 2021 are derived from the State Statistics Committee of Ukraine (http://www.ukrstat.gov.ua/). The 2022 wheat yield in Ukraine is estimated under random forest model with the R^2 and the root mean square error (RMSE) of 574 kg/ha and 0.62,

respectively. The estimated wheat yield in Ukraine is 27 million tons. Considering the harvest loss (around 25%) caused in connection with the conflict, we have estimated the ultimate wheat yield to be 20-21 million tons in 2022, which is closed to the estimate by several international organizations.

Quantitative general equilibrium trade model

We use the model to quantify the effect of the Russia-Ukraine conflict. Our model features real-world mechanisms that could affect the global wheat market. Its key features are briefed here and detailed in the Supplementary Materials.

Multi-country and multi-sector. Cross-country and across-sector trade is a key determinant of the global wheat crisis. We include 51 countries and a constructed rest of the world as well as 33 sectors in the model. Details about the selection criteria for countries and sectors are in the Supplementary Materials.

Country-sector productivity difference. Productivity varies depending on countries and sectors which could react differently to the wheat crisis.

Input-Output (IO) linkage. The output from one sector can be used for final consumption or as intermediate input for other sectors. In this way, a drop of wheat productivity in Ukraine can directly affect the final consumption for each country and global wheat production through the IO linkage.

Sector trade barriers. Trade across countries can vary from one sector to another in our model.

Model implementation. The model is closed by three market clearing conditions in each country-sector market, consumption equals output, labor demand equals labor supply, and trade is balanced. Then we can match the real-world trade and gross output exactly and perform the counterfactual analysis, i.e., what will be the wheat price and gross output after the conflict compared with a world where the conflict did not happen. The analysis is conducted in the following steps. Firstly, we calibrate our model to match the pre-conflict trade and gross output for all sectors and countries. Secondly, we calculate the counterfactual economy that satisfies all equilibrium conditions (rational consumers maximize utility at given prices and income by buying food from the cheapest sources, firms maximize profits, and factor market is cleared) in the model when the conflict leads to a reduction in Ukraine wheat production and trade disruption. Thirdly, with the equilibrium calculated for the counterfactual economy, we derive conflict-driven changes in gross wheat output and price for each country and sector. Fourthly, we adjust the levels of productivity drop and trade disruption to investigate the outcomes in different potential cases and how the conflict exacerbates the crisis of global food security as time goes by. Finally, we can evaluate the effect of other policies following the conflict. For example, several countries have planned to increase their wheat production and export. This model can help quantitatively estimate to which extent these policies mitigate the global wheat crisis.

Results

Signs of wheat production reduction based on satellite observations

Wheat production in Ukraine is likely to decline due to the Russia-Ukraine conflict. Using satellite observations from Landsat and Sentinel-2, we analyzed the winter wheat growth in Ukraine in early 2022 (Fig. 1a) (see Methods in Supplementary Materials). The total wheat area in Ukraine revealed by satellite observations is about 6.57 million hectares, close to the official statistics of Ukraine (i.e., 6.87 million hectares in 2021)[7]. Winter wheat is mainly distributed in southern and eastern parts of Ukraine, the main battlefields in the conflict. Wheat growth comparison, indicated by the time series of normalized difference vegetation index (NDVI), between 2022 and historical years (i.e., 2019-2021) shows that averaged Landsat and Sentinel synthetic NDVI in Ukraine has declined considerably by about 40% in the early growing season of 2022 (Fig. 1b). The possible reason for this decline is the weak seedlings in the early stage, and necessary field management measures, such as irrigation and fertilization, and the harvest. Given that no significant change in wheat NDVI in Russia (Fig. S2), the current study focuses on Ukraine for it is the main battle field of the conflict.

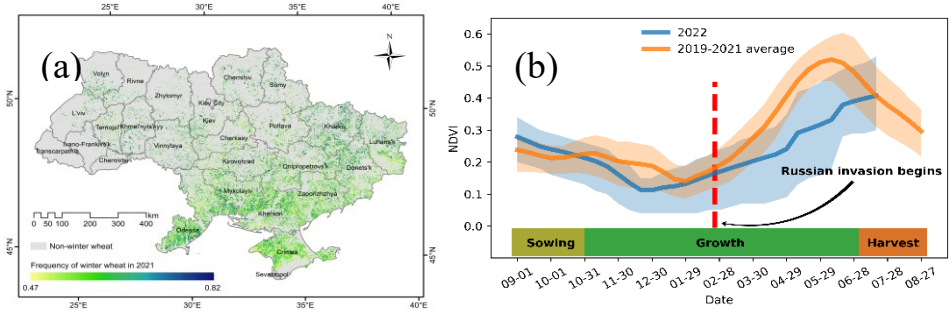

Fig. 1. Satellite observations reveal weakened wheat growth in Ukraine in 2022. (a) Mapped wheat distribution in 2021, each grid represents the derived percentage of wheat in a 1 km grid. (b) The NDVI of 2022 versus historic average (i.e., 2019-2021). Bounds of shadowed areas represent the 25th and 75th quantile levels, respectively.

Potential impacts on global trade of agricultural products

The duration of Russia-Ukraine conflict would impact wheat harvest and therefore exacerbate the global food insecurity crisis already challenged by the Covid-19 pandemic (Yan et al., 2021). First, we estimate the 2022 wheat yield in Ukraine with reference to 2017 to 2021 wheat yield data for each state from the State Statistics Committee of Ukraine. The 2022 total wheat yield in Ukraine is estimated to be 27 million tons from continuous satellite observations and climate records (Fig. S3) if no other disturbances are in the way. Since the conflict did not end before July, it had a negative impact of the conflict on agricultural management. Ukraine's grain trader's union expected the war-hit Ukraine to harvest 20.8 million tonnes. Agritel, a French consultancy, predicted 21.8 million tonnes of wheat to be harvested[8]. In light of these predictions, we assumed a 25% yield loss in harvest as our baseline scenario (Slight), so that the ultimate wheat yield estimation is 20-21 million tons. With an uncertain duration of the conflict, we have designed other two scenarios about the potential reduction of wheat

[7] http://www.ukrstat.gov.ua/operativ/operativ2021/sg/ovuzpsg/Arh_ovuzpsg_2021_e.html

[8] https://www.nasdaq.com/articles/agritel-forecasts-ukraine-wheat-crop-at-21.8-mln-tonnes

production in Ukraine and the consequent global trade disruptions (Table 1). We include these scenarios in the SGETM and quantify the potential effect on the global wheat market, including imports, wheat prices, and welfare, indicated by food purchasing power. We also assume the wheat production in Russia does not change significantly because the battlefield is in Ukraine.

Table 1. Scenarios of conflict-induced decline of winter wheat production in Ukraine in 2022

Scenario	Conflict duration	Estimated wheat production
Slight	Current situation	Production: 20-21 million tons with impacted field management (irrigation, fertilization, and spraying and harvest)
Medium	Until the end of the winter wheat harvest	Production: 16 million tons, wheat harvest cannot be completed due to shortage of agricultural machinery and labor
Severe	Until the next sowing season of winter wheat	Production: 13 million tons, the next wheat sowing season is impacted

Developing countries, especially those that heavily rely on wheat imports from Ukraine, are likely to be significantly impacted by the conflict (Fig. 2). Wheat prices are estimated to increase by 7%~13% in countries such as Mongolia (13%), Egypt (10%), Turkey (9%), Georgia (7%), and Azerbaijan (7%), although the global wheat price would go up by 3% in the Slight scenario in 2022. Wheat price increases in these countries are mainly driven by declined imports (i.e., 8%~22%) in global trade, resulting in significant drop of welfare (i.e., 6%~13%). If the conflict did not end until the harvesting season (i.e., the Medium scenario), the wheat price would increase by about 6% for the globe, but by more than 20% in highly dependent countries and the imports and welfare for those countries would decrease by 28% and 17%, respectively. Under the Severe scenario, wheat prices in those countries would increase by 46% on average, three-folds more than the world average (12%), and consequently their imports and welfare would decline by 60% and 32%, respectively.

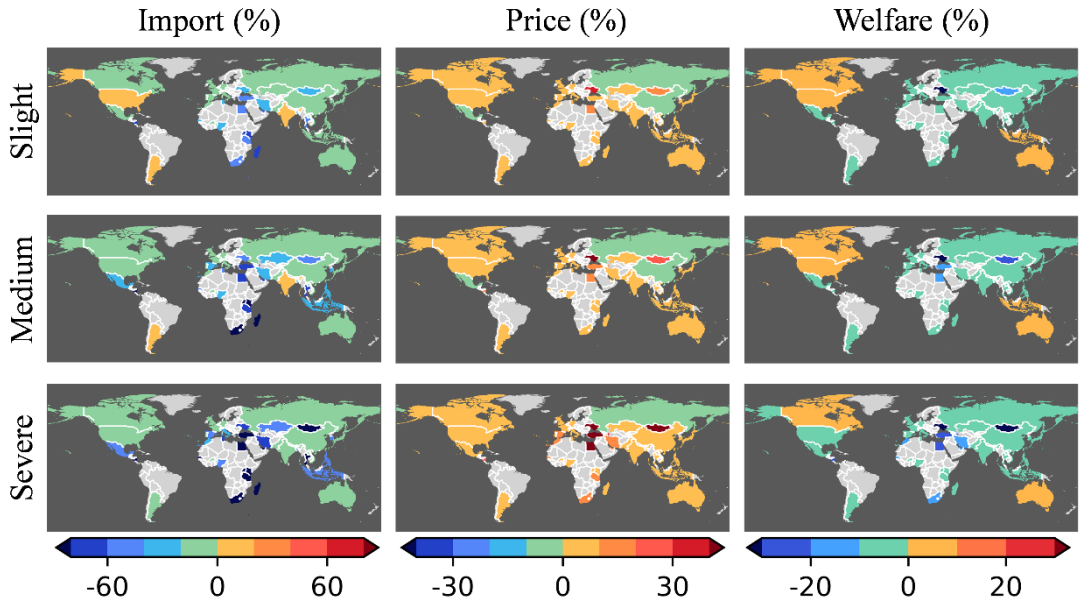

Fig.2. Modeled impacts of Russia-Ukraine conflict on wheat imports, wheat prices, and welfare for different countries.

The supply interruption is the main reason for the uneven impacts of wheat trade for these highly dependent countries. Middle East and North Africa countries are expected to face severe wheat shortage due to import decline (Fig.2). For instance, more than 60% of wheat imported by Egypt comes from Ukraine and Russia (Abay et al. 2022). In addition, Egypt, Tunisia, Turkey, Iran, and the Least Developed countries and Low-Income Food Deficit Countries such as Yemen and Bangladesh are large wheat importers from Ukraine (Fig. S2 in the Supplementary Materials), and would suffer from severe food shortage and even starvation due to trade collapses and soaring prices. The conflict-induced global food insecurity will put 8~13 million people in malnourishment by 2022-2023[9], if no mitigation strategy is put in place.

Countries with high capability of crop production can adjust their production and exports to balance the global agricultural production and trade given the possible substitution between different crops in the proposed multi-sector model. The model shows such adjustment effects for wheat. These highly capable countries are major producers and exporters in the global wheat market, including developed countries in North America and Europe, as well as developing countries in Asia (e.g., China and India) and South America (i.e., Argentina) (Fig. 3). The impact of Russia-Ukraine conflict on the regular global trade pattern and on the global wheat market can be mitigated and offset if these countries can increase their outputs and exports. Fig. 3 shows how major exporters respond to the crisis under three scenarios from the model. These countries increase their outputs and exports in Severe scenario. The US, Canada, Argentina, and Australia would be dominant countries that increase (i.e., 5~6%) both outputs and exports to mitigate the global food crisis. Whereas, increasing exports is a probable option for China and India because their domestic production increases are limited given their large populations and available arable lands; substitution between wheat and other crops in domestic consumption

[9] https://www.agriland.ie/farming-news/fao-ukraine-crisis-could-lead-to-malnutrition-and-higher-food-prices/

in the two countries is also possible. Interestingly, small developed European countries (e.g., Belgium and Portugal) would have their exports increased but with decreased domestic production, given that they are centers for entrepot trade and the possible substitution between wheat and other crops in domestic consumption.

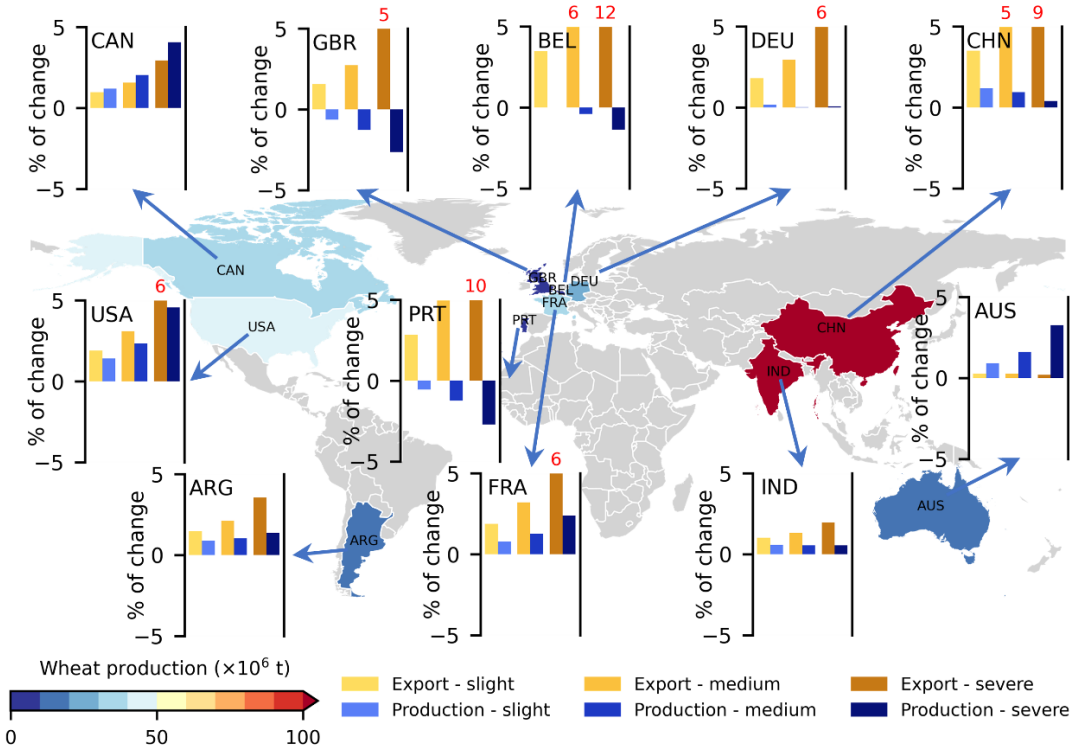

Fig 3. Modeled impacts of Russia-Ukraine conflict on countries that could increase exports and productions. Colors indicate different wheat productions. Yellow and blue bars from light to dark indicate scenarios from slight to severe for wheat export and production, respectively.

Russia and Ukraine are also key players in the global fertilizer and resource market. They account for a significant part of the world export in oil, natural gas and fertilizers. The Russia-Ukraine conflict would also lead to a trade blockade in these resource sectors and cause larger losses through the input-output linkage. Therefore, we further assume that the war causes a disruption on both Ukraine's and Russia's resource trade. By shutting down resource trade completely for Ukraine and Russia, our model shows that welfare loss (**Fig. S5**) for most countries nearly doubled when compared to Fig. 2. Ukraine's welfare decreases by 30% in this case while the loss is only 15% when Russia resource trade is not blocked. For the most affected countries (Mongolia, Egypt, Georgia, Turkey, Azerbaijan), welfare decreases by 15%-25% more than the baseline scenarios. Even though major exporters could benefit from the increasing global prices in the baseline scenarios, the welfare changes are negligible or even turn to negative when considering the resource effect. Agriculture prices increase in all countries now with the most affected countries experiencing 10%-20% higher increase than the baseline scenarios. The addition increases in prices mainly come from the increasing price of fertilizers, which accounts for a large share of input of agriculture production. These results emphasis the importance of resource trade and its role in production network.

Beside the agriculture sector, upstream and downstream sectors could also be affected by the conflict though the input-output linkage. Our model allows us to investigate these indirect effects and perform an overall cost/benefit analysis. In the most severe case where Ukraine suffers from the largest productivity drop and resource trade is blocked, all countries experience aggregate welfare losses (**Fig. 4**). Countries that rely heavily on Ukraine's wheat export still have the largest welfare losses (4%-10%). Moreover, the gains for major exporters from increasing agricultural prices are offset by the losses in other sectors. The overall welfare changes are therefore reduced to zero or negative for them. Since subsistence and resources are also major inputs for other sectors, manufacturing and service prices also increase in response to the conflict as shown in the **Fig. S6** and **Fig. S7**. Prices for food manufacturing increase by 5%-10% for most countries. Service industry, though relies less on agriculture input, still witnesses a moderate increase in prices (1%-2%). These increasing prices in other sectors exacerbate the food crises and lead to a larger aggregate welfare loss.

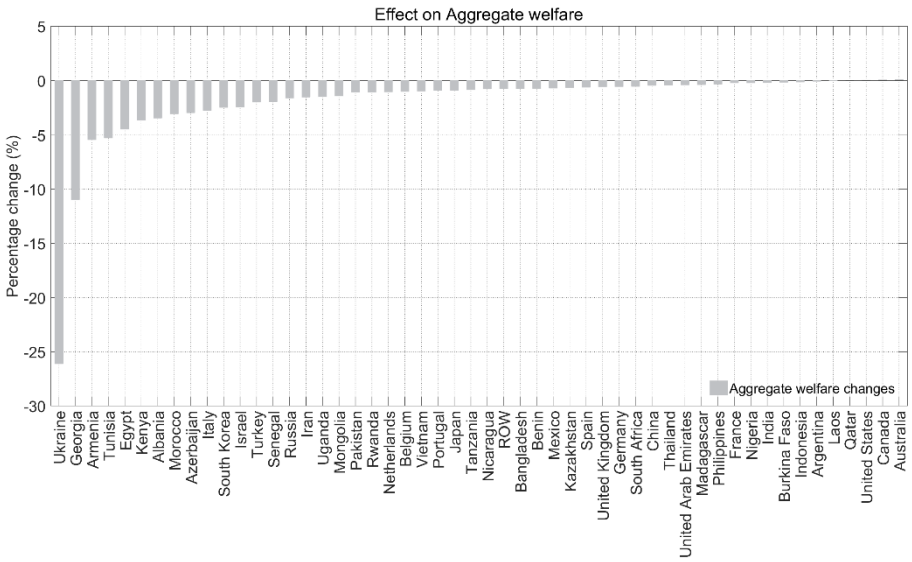

Fig. 4 Modeled impacts of Russia-Ukraine conflict on aggregate welfare in the most severe case.

Adaptions to the potential conflict-induced global wheat production loss

It is worth noting that specific policy interventions would help recover global wheat trade balance in exporting countries. The results presented in Fig. 3 are a simplified response to increasing wheat prices across countries, while the restoration of global wheat market to the pre-conflict price equilibrium depends on actual wheat supplies in these countries. These policies could subsidize agriculture inputs, increase land supply, and lower land rents, some of which have been witnessed. For example, the European Union plans to enhance agricultural production by providing subsidies to farmers[10]. India tries to increase wheat exports to 10-15 million tons in 2022-2023 to deal with the crisis compared with 8.5 million tons in 2021-2022[11].

[10] https://english.news.cn/20220324/4c2fd9a0b2774a0b8db9d354b0946bf3/c.html

[11] https://www.dtnpf.com/agriculture/web/ag/blogs/canada-markets/blog-post/2022/03/16/india-seeks-increase-

Brazil and Argentina plan to increase their 2023 wheat production by 12.7 and 10 million tons, respectively[12].

Increasing the production through productivity gains (a key variable in SGETM) and decreasing tariff costs are two practical solutions to balance the global wheat market (Fig. 5). We define the productivity by factors that could increase the wheat production per hectare, i.e., better management (e.g., breeding technique improvement), increasing inputs (possible in a short period), or new technologies which although are not possible soon. We assume that 1% increase in productivity leads to 1% increase in total output. As shown in Fig. 3, we choose eight countries (i.e., the US, Canada, Australia, Argentina, France, India, China, and Germany) and implement a counterfactual analysis to explore the response of these countries to the crisis under different scenarios. These countries are selected for two reasons. First, modeled results (Fig. 3) indicate that they are the only countries that see increases in wheat output under all three scenarios. Second, they are the top wheat producers in the world. Overall, without any other intervention, a simultaneous increase in wheat productivity by 2%-3% in these countries could restore the global wheat price to the pre-conflict level with market equilibrium (Fig. 5b).

In addition, it is feasible to stabilize the global market by decreasing tariff and non-tariff costs; that is low-price wheat is available to wheat importers. Our model suggests that the price would increase, and welfare decrease for all wheat importers when the trade mode shifts from free-trade to no-trade since tariff barriers and possible substitutions between wheat and other crops for all countries (Fig. 5, c & d) are considered in our model. Specifically, if the conflict did not block Ukraine's wheat export, the global price would increase by up to 0.5% as a result of the decrease in Ukraine's wheat production. If, however, the trade between Ukraine and the rest world was entirely blocked, the global price would increase by up to 5%, ten times more than in the free trade case. Similarly, welfare decrease would be 3.6% under the no-trade case and 0.4% under the free trade scenario. This clearly highlights importance of free trade and policies designed for reducing trade costs. For instance, the average import tariff for wheat in Turkey is 22% according to the World Trade Organization[13]; lowering the tariff would significantly increase the wheat flowing into the Turkish market. Like Turkey, countries including Angola, Israel, and Morocco impose high average tariffs on wheat imports (more than 25%).

wheat-exports.

[12] https://www.nasdaq.com/articles/argentina-raises-2022-2023-wheat-export-quota-to-10-mln-tonnes.
[13] The figure is from WTO tariff dataset. http://tariffdata.wto.org/ReportersAndProducts.aspx.

Fig. 5. Modeled impacts of productivity and trade costs on global wheat output, price, and welfare. The "%" indicates productivity, price, and welfare changes under different scenarios relative to the baseline solution, as illustrated in Fig. 2.

Discussion

In addition to abandonment of crop management in Ukraine, the compounded effects of other factors could cause potential risks. The first risk is that major wheat exporters, such as Russia, have started to develop trade policies for limiting their exports, which are expected to drive shocks in the global wheat market (Glauber et al., 2022). Our model shows that major wheat producers should increase their production and exports to mitigate the looming food crisis. As such, export restriction measures must be carefully weighed against their potentially detrimental effect on the global market over the long term. Specifically, despite of being able to improve food availability in domestic market in the short term, export restrictions would inevitably intensify the upward price pressure on international market and worsen the global situation. Short-sighted policies should always be avoided according to our modeled results in Fig. 5, c & d. For the avoidance of such policy reactions, international policy dialogue and global governance should be strengthened as they play critical roles when the wheat market is under uncertainty; and trade disruptions need to be minimized to ensure international market keeps functioning and global wheat trade works smoothly.

The second risk arises from that Russia being a prominent supplier of critical fertilizer components, including natural gas and potash. Due to rising energy prices and transport costs, and increasing sanctions, fertilizer prices have doubled or even tripled (FAO,2022). For example, Russia, an exporter of 20% of the world's potash, now finds the international economic sanctions have made potash export difficult; fertilizer prices could rise further. Because world's 80% potash is traded internationally, some agricultural regions may experience

potash supply shortage due to significantly increased prices. With agricultural input sectors such as crude oil, natural gas and fertilizer taken into account, for the conflict-driven food insecurity, our modeled results show nearly doubled welfare loss when compared to Fig. 2. The most affected countries see a welfare loss by 15%-25% and an increase in average price by 15% (Fig. S5). The input trade disruptions through input-output linkage increase the raw material prices for agricultural output sectors.

The third risk is relating to climate and threatening the global wheat market. The drought in Canada (especially in southern Alberta and central Saskatchewan), a major wheat producer and exporter in the world, is affecting the world's wheat supply (Deschênes and Greenstone,2007. Burke and Emerick ,2016). Drought is also happening in Brazil and the western US (Chiang et al., 2021), which challenges their wheat supplies and the global exports. Covid-19 is another worsening factor for the global wheat trade in terms of social distancing and other restrictions (Guerrieri et al.,2022). Exchange rates also play a vital role in food security. Agriculture is the economic backbone of many developing countries, most of which rely on the US dollar for their borrowing needs. For this, a lasting appreciation of the US dollar against other currencies may have negative significant economic consequences for these countries.

Finally, in view of the COVID-19 pandemic and the Russia-Ukraine conflict, the United Nations has cautioned that up to 1.7 billion people will go hungry[4]. The number of people seriously lacking food security has doubled from 135 million before the pandemic to 276 million. The conflict between Russia and Ukraine have caused food shortages, energy shortages, inflation and other crises, which have spread to the Middle East, North Africa, South Asia and even South America. Many countries, such as Lebanon, Sri Lanka, Egypt, Sudan and Tunisia, like dominoes, have fallen in trouble with social unrest. It is possible that these crises will result in a hunger revolution or trigger other political turmoil in these countries[6].

Conclusions

We have designed three scenarios based on the duration of Russia-Ukraine conflict and quantified their potential effects on the global wheat market. According to the modeled results, the global average wheat price would increase by 3% under the Slight scenario to 12% under the Severe scenario. The largest increase would happen in countries that rely heavily on Ukraine wheat export, including Mongolia, Egypt, Turkey, Georgia, and Azerbaijan, their average price would increase by 46% under the Severe scenario, almost four times higher than the global average. Also, their wheat import and welfare would drop by 60% and over 30%, respectively. These indicate that countries with higher reliance on Ukraine wheat export would suffer more from the conflict. We also find that these effects are stronger as trade costs increase. In terms of the global wheat output, we find that major wheat producers such as China, India, the US, Canada, France, and Germany could increase their export to alleviate the global wheat crisis.

Competing interests

The authors declare no competing financial interests.

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