The War in Ukraine Disrupts Agricultural Value Chains, but Trade Policy Measures Can Mitigate the Impacts

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Abstract

The war in Ukraine is a dire human tragedy for the people of Ukraine. It also has major implications for the world agricultural and food markets, as the Black Sea region is a major supplier of crops and fertilizers. Implications of the war are further exacerbated by impacts of sanctions against Russia, spillover effects from other markets (energy), adverse weather events and domestic policies that countries around the world have implemented in pursue of food security. In this paper, using a comprehensive modelling framework, we decompose impacts of various shocks and show that net agricultural importers in the developing world are particularly vulnerable to the impacts of the war in Ukraine. However, implementation of trade facilitation measures and reduction of import tariffs on agricultural and food commodities could mitigate the impacts of the war. Such trade policies would boost agricultural trade, increase overall food availability and lead to the higher integration of agricultural and food commodities to the global value chains. The latter would make food systems more resilient to the potential future shocks and disruptions.

1. Introduction

On 24 February, Russia launched an unprovoked attack on Ukraine, invading its territory on multiple fronts, including from neighboring Belarus. The ongoing war, while changing shape and geography over these past months, has disrupted global supplies of many essential commodities, with agricultural products, food, fertilizers and energy being at the top of the list (Benton et al., 2022; Glauben et al., 2022). As Ukraine and Russia are major exporters of these essential goods, the supply disruptions and associated price spikes are being severely felt across the globe (Behnassi and Haiba, 2022; Benton et al., 2022).

Several earlier studies have explored the potential implications of the war in Ukraine on agricultural production, trade and food security. Jagtap et al. (2022) perform a literature review and identify six areas of the food supply chains that would be impacted by the war. Authors also indicate that Europe and Africa are the most adversely affected regions. A report by the World Food Programme (WFP, 2022a) suggests that the war in Ukraine could push over 47 million people into acute hunger. Hellegers (2022) stress on the need of carefully taking into account interdependencies across countries, when analysing implications of the war in Ukraine. The paper shows that the food security of vulnerable low-income regions largely depends on policies implemented by other countries in an all-connected world. Several studies that indicated that countries in the Global South are particularly vulnerable to the agricultural supply chain

disruptions, which would further exacerbate the food instability in the region (e.g. Glauber et al., 2022; Ali et al., 2022).

Some authors have also called for specific policy actions that could be implemented to ease the adverse impact of the war. These can be separated into the short-term measures, such as implementation of the social protection programmes, mobilizing resources for humanitarian assistance, fixing inefficiencies in the subsidy system and eliminating biofuel subsidies and mandates; and long-term policies that are shaped around climate-friendly agricultural investments, scaling up promising innovations, investing in policy research and in general building more resilient and sustainable food systems aimed toward nutritious and affordable diets (Ben Hassen and El Bilalli, 2022; Osendard et al., 2022).

While these earlier studies have provided valuable contributions to the topic, indicating the potential scope of the impacts of the war for agricultural trade and food security, while proposing specific measures to ease the adverse implications, several important points have not been properly addressed in the literature so far. *First,* while rich on the qualitative discussion, an existing literature lacks a detailed quantification of the potential implications of the war on the agricultural trade and value chains for the countries/regions around the globe. *Second,* most of the earlier studies that focused on the topic of agricultural/food-related implications of the war in Ukraine have not explicitly considered a broader context of sanctions, climate impacts and trade restrictions that shapes the impacts of the war on the agricultural sector. *Finally,* and most importantly, the discussion of the potential policy responses to the food crises caused by the war has been largely of a qualitative nature. Earlier studies have not provided a quantitative assessment of the available policy measures and to what extent they can overweigh the adverse implications of the war in Ukraine.

In the current study we attempt to address these points. We develop a comprehensive computational framework by linking a global computable general equilibrium model ENVISAGE (van der Mensbrugghe, 2019) with a global multi-region input-output (MRIO) database GTAP MRIO (Carrico et al., 2020) and GTAP nutritional module (Chepeliev, 2022). This allows us to distinguishes agent-based demand for imports by region of origin and trace changes in various global value chain (GVC) indicators following implementation of the policy shocks. Using this framework, we develop a set of policy scenarios that combine the impact of the war, sanctions and other disruptions, such as adverse weather events and export restrictions. The developed modelling framework allows us to disentangle impacts of various sets of shocks distinguishing between e.g. energy and agriculture/food-related channels of impacts. We then explore policy responses in a form of the reductions in tariff barriers on agricultural and food commodities, as well as implementation of the trade facilitation measures (TFMs) that can be used to ease the adverse implications of the war.

The rest of the paper is organized as follows. Section 2 discusses the importance of the Black Sea region at the global commodity markets, including agriculture, food, fertilizers and energy. Section 3 provides an overview of channels through which the war in Ukraine, sanctions and other disruptions are impacting the agricultural and food markets. These channels are further

considered in when the policy scenarios are developed. Section 4 discusses the methodological approach, including the GTAP MRIO database, nutritional accounts, ENVISAGE CGE model and scenario framework. Section 5 discusses the results of the analysis. Finally, Section 6 concludes and provides a set of policy recommendations.

2. The importance of the Black Sea region in global trade in crops, energy and fertilizer

Countries in the Black Sea region have become key global providers of grains, oilseeds, and vegetable oils over the last three decades. Russia and Ukraine rank in the top seven global producers and exporters of wheat, corn, barley, sunflower seed, and sunflower oil (Figure 1a). The majority of these products are shipped to North Africa and the Middle East, as well as Europe and China (corn from Ukraine). Ukraine is also a major supplier of sunflower oil, accounting for over half of global production. In 2019 Russia and Ukraine accounted for a combined 25 percent of global exports of wheat and 14 percent of global exports of corn (UN Comtrade, 2022).

Aside from the direct effects on agricultural production and exports, the war in Ukraine is affecting fertilizer trade. Russia and Belarus are the world's second and third largest producers of potash fertilizer, respectively (Figure 1b). Brazil, for example, the world's largest soybean producer, buys approximately half of its potash fertilizers from these two countries. The majority of Brazil's soybeans are sold to China, which utilizes much of the crop to feed livestock. As a result, a disruption in fertilizer supplies impacts meat prices in China and around the world. The EU has banned all imports of potash from Belarus as of March 4th (Euractiv, 2022).

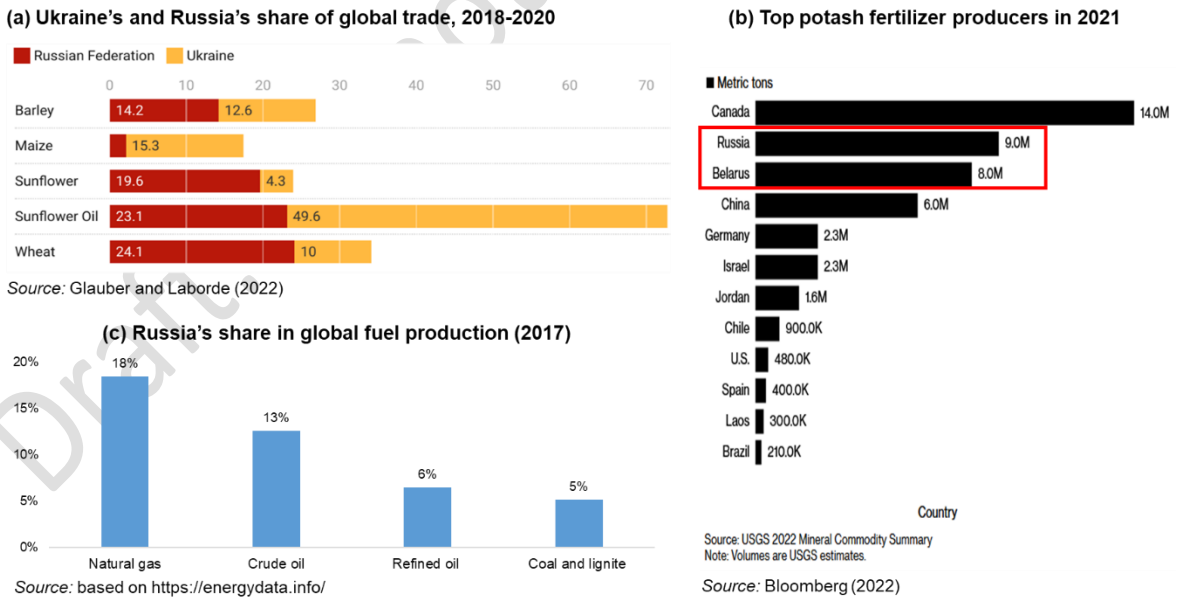

Figure 1. Role of the Black Sea region at the global commodity markets

Russia is a major producer and supplier of fossil fuels, such as crude oil and natural gas, in addition to fertilizer and agricultural commodities (Figure 1c). In 2019 Russia accounted for 14 percent of

global exports of coal briquettes and 13 percent of crude petroleum (the second biggest exporter of this commodity). Russia is also a major exporter of refined petroleum products and natural gas, accounting for respectively 10 and 9 percent of global exports[1] (Figure 1). Petroleum is a vital component of the transportation sector, and gasoline prices have already risen significantly around the world. At the same time, natural gas accounts for over half of the cost of producing ammonia fertilizer, compounding the impact on fertilizer prices.

Several developing countries rely heavily on imports of wheat from Russia and Ukraine (Annex 1, Figure 1a).[2] Such imports constitute a large share of domestic consumption in countries across all regions. Nicaragua imports 86 percent of consumed wheat from the Black Sea Region, in Sub-Saharan Africa the most heavily dependent on imports from the region are the Republic of Congo (67 percent) and Niger (60 percent), in MENA – Lebanon (86 percent) and in South Asia – Bangladesh with 41 percent. Other cereal grains dependency is also relatively high in many countries, but lower than in the case of wheat. Libya's share of imports from the region in consumption amounts to 81 percent, followed by Mauritania (78) and Mongolia (74) and a number of high-income countries, and countries from ECA region with Netherlands (30) and Portugal (24). The dependency on the imports of oil seeds is much less significant with the highest share in consumption in ECA countries such as Georgia (63 percent), Armenia (39) and Mongolia (35).

3. Agricultural commodity markets are impacted in multiple ways

The Russian invasion of Ukraine is disrupting global agricultural and food markets both directly (via limiting supply from the region) and indirectly – through impacts of sanctions against Russia, spillover effects from other markets (energy and fertilizers) and domestic policies that countries around the world have implemented in pursue of food security (Chepeliev et al., 2022b). In addition, adverse weather events, including droughts and critical hazards are disrupting agricultural production around the world further exacerbating the adverse implications of the war in Ukraine (WFP, 2022b).

First, the war in Ukraine has caused direct disruptions to agricultural production and exports from Ukraine. From the beginning of the conflict, the Ukrainian ports in the Black Sea – a key route of the Ukrainian grains' exports – were shut down. At the end of July, three ports were unblocked following the deal between Kyiv and Moscow, which was brokered by the United Nations and Turkey (UN, 2022). Despite these developments, exports of Ukrainian grain are still 46 percent down so far during the 2022/2023 season when compared year-on-year basis (Reuters, 2022). In addition, due to the temporary occupation of some Ukrainian territories by Russian forces and overall lower yields, the Ukrainian government is expecting to harvest around 50 million tonnes

[1] Annex 1 provides top the 10 countries relying on commodity imports from Russia and Ukraine as a share of total domestic consumption in a given sector (Figures 8a-8g).

[2] The calculations are based on the GTAP v. 11 data base (https://www.gtap.agecon.purdue.edu) database, which aggregates fertilizers with other chemicals.

of grain during this year, which is substantially lower than 86 million tonnes harvested during 2021. The deal has an expiration period of 120 days and might or might not be extended.

In the case of Russia, most risks stem from sanctions imposed by U.S., EU and their allies. While agricultural and food commodities so far have not been directly sanctioned, reputational risks, transportation and financial restrictions have made countries reluctant to commit to Russian grain supply. In addition, between March and June/August, Russia imposed restrictions on the exports of grains and sugar respectively in an attempt to protect domestic food markets (TASS, 2022).

Second, the Russian invasion has prompted an unprecedented reaction by most OECD members, including the United States, the European Union and other high-income countries, in the form of sanctions. These cover a broad range of measures from targeting Russian individuals and specific enterprises, bans on Russian energy and fertilizer imports, to restrictions on exports of select electronics to Russia, such as semiconductors (PIIE, 2022). Countries that have a high dependency of tourists from Russia and Ukraine, namely Egypt, Tunisia, Thailand will see significant declines in exports of tourism and accommodation services. The negative impact of the conflict will also be visible in other areas of the global economy such as increases in transportation costs, or loss of remittances in countries that are heavily dependent on inflows from Russia, such as Tajikistan and the Kyrgyz Republic. Directly, these sanctions are increasing input costs of the agricultural commodities production (fertilizers and energy) and supply (transportation and fuels), while indirectly, they are impacting the purchasing power of consumers around the world with the most adverse implications for the households in low-income countries (Chepeliev et al., 2022b).

Third, in an attempt to protect domestic consumers, a number of countries have imposed restrictions of exports of agricultural and food commodities (Laborde and Mamun, 2022). One of the most recent examples includes India – the world's leading exporter of rice, which accounts for around 40 percent of global trade in this commodity – has imposed a 20 percent duty on a number of exported rice varieties, covering around 60 percent of country's exports (Good, 2022).

Finally, agricultural market distortions are further exacerbated by the adverse weather events that lower yields around the world. Widespread drier than average conditions have been observed in the northern hemisphere, ranging from the USA to Europe and North Africa, as well as affecting large areas from the Middle East to Central Asia (WFP, 2022b). For instance, according to Good (2022), California's rice farmers are experiencing 'drought at a level they've never seen before', while rice sowing has dropped 30 percent compared to the previous year – the lowest level since 1950s.

In the current assessment we attempt to combine these ongoing shocks to the global commodity markets to analyze their implications for agricultural trade and global value chains.

4. Methods

To comprehensively explore the impacts of the Russian invasion of Ukraine on the global agricultural trade and value chains, an economy wide modelling framework is needed. Here we link a global multi-region input-output (MRIO) database with the ENVISAGE computable general equilibrium (CGE) model, which distinguishes agent-based demand for imports by region of origin (Chepeliev et al., 2022a). We also incorporate a recently developed GTAP nutritional module to the assessment framework following Chepeliev (2022). The model represents global economy with 23 aggregate regions/countries and 25 sectors (see Annex 2 for details). To capture the short-term implications of the explored policy shocks, we lower trade and labour substitution elasticities. Two broad channels of the commodity market disruptions are captured in the modelling framework. These include impacts of the conflict on international prices of food and fuel. Studies suggest that these commodity groups are among the most impacted amid fears of global supply tightening (JPMorgan, 2022; IMF, 2022). A number of other commodity- and country-specific shocks are implemented within the scenario framework, as further discussion in Section 4.3. The rest of this section provides additional details on the methodological approach and scenario framework.

4.1. GTAP MRIO database

As a key data input to our modelling framework, we rely on the GTAP 10A MRIO database with 2014 reference year (Carrico et al., 2020). A particular feature of this database is a distinguishing of bilateral trade and tariff flows by agents or so-called end-users, namely: firms, private households, government and investors. GTAP 10A MRIO is one of the few global databases that uses concordances which map between products and end-uses to differentiate between sourcing of imports across agent and tariff rates across end users. Most other global MRIO databases assume proportional sourcing of imports across agents (e.g. Lenzen et al., 2013; Peters et al., 2011; Stadler et al., 2018).[3] It has been shown that such assumption can result in a large uncertainty of the MRIO-based estimates (Schulte et al., 2021).

For the simulation purposes, we aggregate an original GTAP 10A MRIO database, which contains 141 regions and 65 sectors, to 25 sectors and 23 regions. Tables A.2.1 and A.2.2 in the Annex 2 provide corresponding concordances.

4.2. GTAP nutritional module

To allow for tracing the quantities of food, calories, fats, proteins and carbohydrates along the value chains, we incorporate the nutritional accounts to the developed modelling framework following Chepeliev (2022). This approach traces changes in key nutritional indicators across various use categories, such as food, feed, seed, losses and other uses, distinguishing the domestic and imported (across regions of origin) sources of supply across key agricultural and

[3] World Input-Output Database (WIOD) (Timmer et al., 2015) and some earlier versions of the GTAP MRIO (e.g. Koopman et al., 2014; Walmsley et al., 2014) are few exemptions from this list. WIOD MRIO, however, does not distinguish trade tariffs.

food sectors. One distinct feature of the approach is representation of the out-of-home food supply (restaurants, hotels, schools, etc.).

4.3. ENVISAGE model

The Environmental Impact and Sustainability Applied General Equilibrium (ENVISAGE) Model at its core is a recursive dynamic and global CGE model (van der Mensbrugghe, 2019). The model follows a modular set up, where different modules of the framework can be turned on or off depending on the purpose of simulations. ENVISAGE is solved as a sequence of comparative static equilibria where the factors of production accumulate over time. A more detailed description of the ENVISAGE model is available in van der Mensbrugghe (2019).

For the current analysis, we have extended the modelling framework by incorporating an MRIO module, to allow for the agent-based demand for imports by region of origin. Selected manufacturing sectors in the ENVISAGE model are represented using the MRIO specification, while all other sectors use the standard Armington assumption, treating imports as imperfect substitutes with domestically produced commodities—and sourcing is done at the national level. Identification of the sectors of the model that are represented using the MRIO specification is provided in the Table A.2.2 (Annex 2).

The core strength of the global CGE models, like ENVISAGE, is a consistent representation of inter-dependencies between sectors, agents and markets within the economy. By capturing both the supply and demand sides, the model represents adjustments in quantities and prices reacting to the policy shock. For instance, if wheat supply would be restricted/disrupted in the Black Sea region, this would lead increasing global wheat prices, reducing wheat demand and substitution toward alternative food commodities, such as other grains and rice.

4.3. Scenario framework

To evaluate the implications of the war in Ukraine for agricultural trade and value chains, we design a set of exploratory shocks:

1. *Country-specific agricultural productivity shocks* for Ukraine, Russia and Belarus are implemented to reflect reductions in supply of crops in the Black Sea region. In the case of Ukraine, a 35 percent supply (total factor productivity) shock is implemented for crops in line with the USDA forecast of 35 percent reduction in the output of wheat and sunflower in the country (USDA, 2022).
2. *Restrictions on exports of crops from India*, including wheat and rice (PIIE, 2022).
3. An *increase in the price of imported fertilizer* used in agricultural production by 50 percent. During the first half of the 2022 fertilizer prices have increased by over 30 percent and further increase is expected to occur on top of the last year's 80 percent growth (Baffer and Chian Koh, 2022).
4. A global *agricultural productivity shock* of 2 percent (total factor productivity) is implemented uniformly across countries and crops to reflect the adverse weather conditions. The 2 percent shock is consistent with a projected decline in the global cereal production of 1.7 percent by the FAO (FAO, 2022).

5. *Total factor productivity shock* of 3 percent in Russia and of 10 percent in Ukraine. These shocks are broadly calibrated to match the projected GDP declines for these countries due to the outflow of capital, infrastructural damage, etc. In the conducted simulations, GDP in Ukraine declines by 29 percent and in Russia by 10 percent. For the case of Ukraine, the reduction is close to the EBRD forecast of 30 percent decline (EBRD, 2022) and the projection of the National Bank of Ukraine with 33.4 percent drop (NBU, 2022). For the case of Russia, World Bank projects that country's GDP could decline by 8.9 percent in 2022 (WB, 2022).
6. *Restrictions on exports of electronics* to Russia imposed by high income countries and large exporters of electronics from Asia, as well as export bans on electronics form Russia.
7. *Restrictions on imports of iron and steel, metals and chemicals* from Russia and Belarus by the Western European countries (PIIE, 2022).
8. *Restrictions on imports of fossil fuels from Russia* by the US and UK (PIIE, 2022).
9. *Restrictions in the global fossil fuel supply* (15 percent downward shift in supply) reflecting supply adjustments by the Organization of the Petroleum Exporting Countries (OPEC) aimed at limiting supply and price controls (CNBC, 2022). In addition, *restrictions on the fossil fuel supply from Russia and Belarus* are implemented following reductions in the energy demand from these sources. As a result, global oil prices increase by around 21 percent, while the price of petroleum products grows by 18 percent within the simulated scenario.
10. Finally, a set of shocks that reflect *restrictions on the import of fossil fuels by the European Union from Russia and Belarus* is implemented. These are implemented following an approach outlined in Chepeliev et al. (2022c). The shocks are imposed to target a 40 percent of natural gas imports and 90 percent reduction in imports of petroleum products from Russia and Belarus. These reduction targets are supported by the plans announced by EU.[4]

In addition to the shocks listed above, which are expected to have negative implications for agricultural trade and value chains, as well as economy in general, we are exploring a set of policy responses that countries could implement in order to alleviate the adverse impacts of the ongoing shocks. These include (a) trade liberalization measures, which assume an elimination of import tariffs on agricultural primary and processed commodities and (b) implementation of the TFMs following estimates from Moïsé and Sorescu (2013). The latter are implemented in a form of the reduction in non-tariff barriers (introduced in the model as a shock to Iceberg parameter for importers) and range between 12 and 16 percent across regions. Both reductions in tariff barriers and TFMs are assumed to cover agricultural and food commodities only.

Table 1. Overview of the scenario framework

[4] https://apnews.com/article/russia-ukraine-zelenskyy-hungary-european-union-d0d4144c84749f84676a2f41b03b2ad4
https://www.cnbc.com/2022/06/29/europes-plans-to-replace-russian-gas-are-deemed-wildly-optimistic-and-could-hammer-its-economy.html

No.	Scenario name	Description
1.	UkrWarAgri	Implementation of the shocks that correspond to war-related agriculture and food dimensions only. These correspond to shocks (1)-(2) from the above list.
2.	UkrWarAgriProd	Implementation of the "UkrWarAgri" scenario, plus a broader set of agriculture-related shocks (weather impacts and fertilizer prices) covering points (3) and (4) from the list above.
3.	UkrWar	Implementation of all considered shocks related to the war in Ukraine, sanctions, energy trade restrictions and adverse weather events. These correspond to shocks (1)-(10) listed above.
4.	UkrWarTax	Shocks from the "UkrWar" scenario (except India's export restrictions from point (3)) and all countries (except Russia and Belarus) eliminate import tariffs on agricultural and food commodities.
5.	UkrWarTaxTfm	"UkrWarTax" scenario, plus all countries (except Russia and Belarus) implement TFMs for agricultural and food commodities.

Source: Developed by authors.

Three important caveats should be considered in the context of interpreting modelling results presented in this study. First, in the applied modelling framework all prices are relative and measured with respect to the global GDP deflator (indexed to "1"). Thus, nominal price changes are not captured in the applied framework. Second, an applied model provides representation of the economic flows on an annual basis, therefore observed impacts also reflect annual average implications, which are different from the short-term market volatility impacts. Finally, in the current assessment we focus on the impacts on key commodity markets – energy, crops and fertilizers, and only cover select sanctions. The analysis does not capture the potential spill-overs from the significant and broad sanctions imposed on the Russian economy (e.g., PIIE, 2022) and the increased uncertainty in markets.

The impacts of various shocks will be determined by the characteristics of trade, production and consumption in affected countries. Net exporters benefit from the terms of trade gains in agricultural and energy commodities driving exports up (if production can be scaled up or redirected from the domestic market). At the same time, higher commodity prices reduce the competitiveness of goods and services that use them as inputs and therefore make them less profitable to produce and export. In addition, the higher cost of fertilizer reduces agricultural yields, potentially reversing the terms of trade gains for agricultural exporters. On the other hand, net importers of agricultural commodities are worse off due to raising prices of final and intermediate products. However, they might be able to expand exports in manufacturing and services sectors if their production is relatively more competitive or less energy intensive than that of other countries. For all countries, trade costs are expected to increase as higher energy prices are driving the transport costs up, mostly affecting time sensitive goods. Figure 2 displays net exports as a share of GDP to show the relative strength of the crops and energy exposure at the country and regional levels. A more granular representation of potential exposure to the shocks across various developing countries is presented in Annex 1.

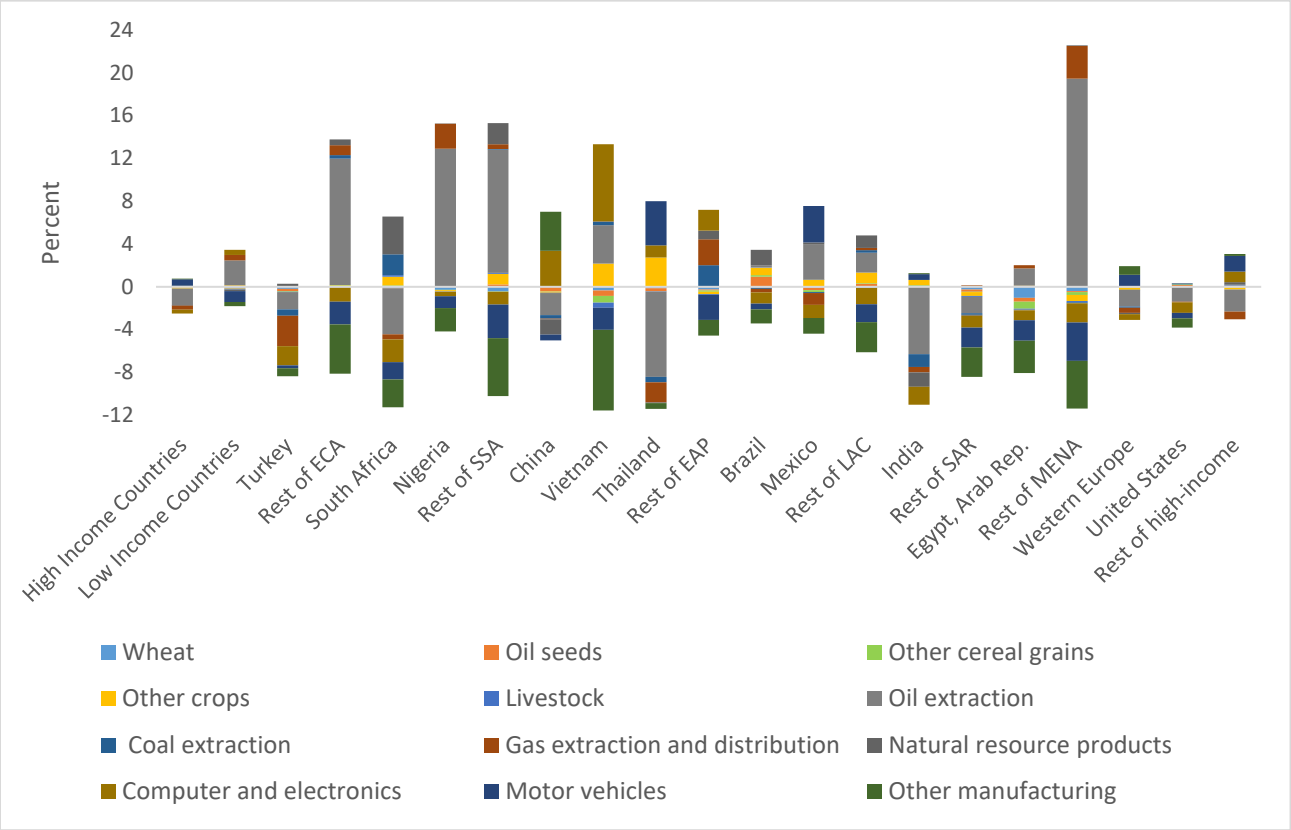

Figure 2. Net exports of commodities, percentage of GDP (2019)
Source: Author's calculations based on GTAP database data

5. Results

5.1. Net agricultural and energy importers are hit hardest by the war in Ukraine

Before examining the implications of the war on agricultural value chains, supply and demand across countries, it is important to understand the overall impacts of the war on consumers and their purchasing power. The impacts on income are driven by the overall changes on agricultural and energy markets and by their respective shares in production and consumption. Results suggest that the overall macro impacts of the war are largely driven by the energy markets, but the composition of the outcomes substantially varies across countries (Figure 3).

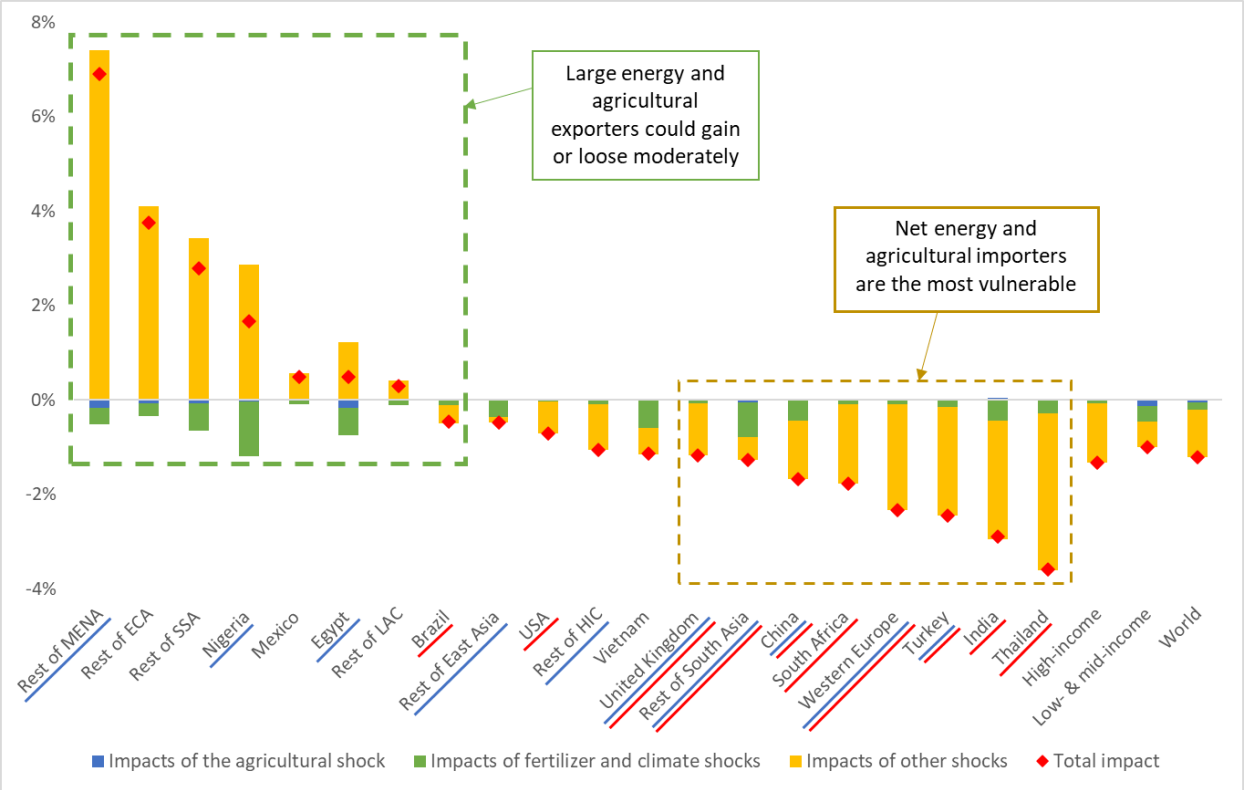

Figure 3. Change in real income in selected countries and regions, percent (decomposed across scenarios)

Note: see Annex 2 for sectoral and regional aggregations.

At the global level, on average, agricultural commodities account for a lower share of consumption and intermediate use, when compared to energy. In addition, exports of energy commodities constitute a much higher share of global trade[5] and the Black Sea region plays a much more important role on energy markets, accounting for 4.3 percent of the global exports of fossil fuels compared to 0.7 percent of total global exports of crops.[6] As a result, at the global level, out of around 1.2 percent reduction in households' income under the "UkrWar" scenario, only 1/6 (or 0.2 percent) can be attributed to the agriculture- and fertilizer-related impacts, while the rest is largely associated with disruptions on energy markets (Figure 3). At the same time, in the case of low- and middle-income countries, the role of agricultural disruptions is substantially higher than for high-income regions. In the former case, out of 1 percent reduction in real income almost half is coming from the agriculture- and fertilizer-related channels, while in the case of high-income countries corresponding share is less than 1/10. In the case of high-income economies, a substantial impact of non-agriculture-related shocks can be largely attributed to disruptions to EU energy markets.

[5] Global exports of wheat amounted to $44.1 billion in 2019, while total grains exports amounted to $115 billion. On the other hand, the global exports of crude oil amounted to $986 billion and those of natural gas to $300 billion in 2019.

[6] 2017 statistics based on the GTAP 11p2 data base.

Results also suggest that while large energy and to a lesser extent agricultural exporters could benefit from terms of trade gains and see their incomes expanding, importers of energy and agricultural commodities are impacted the most adversely (Figure 3). Out of eight most negatively impacted countries and regions, all are net energy importers and five are net agricultural importers. At the same time, out of top eight countries and regions that benefit the most, only three are net agricultural importers (but these regions are also large energy exporters – MENA, Nigeria and Egypt) and one country (Brazil) is a net energy importer. In this regard, developing countries that are net agricultural and energy importers are the most vulnerable to the implications of the war in Ukraine.

The Russian invasion of Ukraine is adding inflationary pressures to food prices that were already high due to the last two years of Covid-19 disruptions, region-specific unfavorable weather events, currency devaluations, and worsening fiscal constraints.[7] Before the conflict, food prices were trending upwards due to recovery in demand after the global Covid-19 recession and due to temporary disruptions in supply chains and logistics. Bad weather has also been harming harvests in some of the world's breadbaskets, accompanied by lowering reserves of crops. Extreme heat and downpours in West Africa have been causing yields to drop in crops like sorghum and millet, while a pronounced drought in Australia also contributed to profound declines in wheat production. Supply disruptions, more due to weather conditions than to the pandemic, rising costs of fertilizers and trade restrictions also contributed to the increase of prices, although to a lesser extent.

Increases in agricultural commodity prices adds additional strain especially on the poorest households. Since poor households' budgets are biased heavily towards food, the price hikes of agricultural products that translate into higher food prices, are going to hit them especially hard. The poorest households spend 54 percent of their consumption expenditures on food, 7 percent on energy and 4 percent on transport making them the most vulnerable to the food price hikes[8] (Global Consumption Database, 2010). On the other hand, the richest households spent only 21 percent of their consumption expenditures on food, 3 percent on energy and 19 percent on transport, making them relatively more vulnerable to the energy price shock and the resulting increases in transport costs.

5.2. Impacts of the war on agricultural value chains are exacerbated by other shocks

The war in Ukraine, when combined with other disruptions at the commodity markets, leads to an overall reduction in agricultural trade. Global exports of grains and crops decline by around 1.8 percent, while exports of processed food drops by 0.3 percent. At the same time, rising agricultural commodity prices create incentives for agricultural exporters to expand production

[7] https://blogs.worldbank.org/voices/four-paths-respond-food-price-crisis

[8] Households in developing countries were categorized in four consumption segments for the Global Consumption Database: lowest, low, middle, and higher. Four levels of consumption are used to segment the market in each country: lowest, low, middle, and higher. They are based on global income distribution data, which rank the global population by income per capita. The lowest consumption segment corresponds to the bottom half of the global distribution, or the 50th percentile and below; the low consumption segment to the 51th–75th percentiles; the middle consumption segment to the 76th–90th percentiles; and the higher consumption segment to the 91st percentile and above.

and replace some of the exports from the Black Sea region (Figure 4). Wheat exports from Western Europe, rest of high-income countries, rest of ECA region and the United States expand the most. Exports of other crops that substitute wheat in consumption expand in several countries, with the biggest gains in Western Europe, Turkey, China, Brazil, Rest of South Asia, the United States. A change in the composition of agricultural trade is also observed. Large importers of wheat from the Black Sea region, such as Egypt and Turkey, increase their imports of other cereal grains and crops, substituting the declining wheat imports.

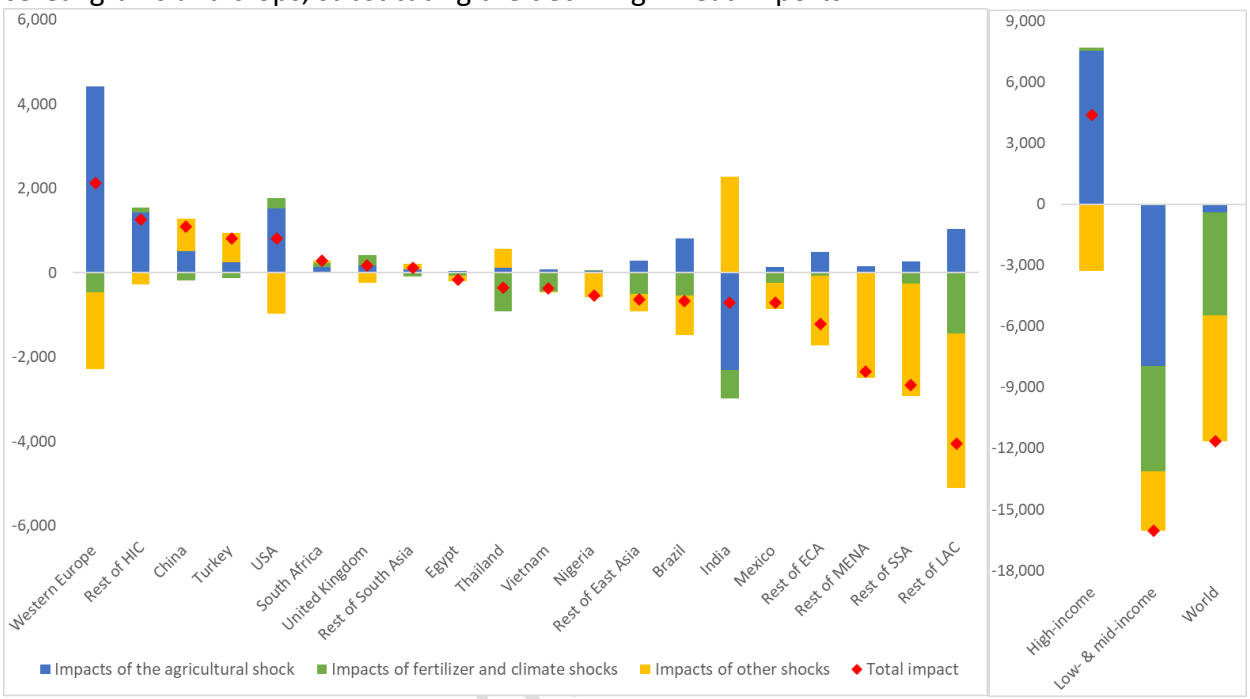

Figure 4. Change in agricultural and food exports across countries and regions, million $2014

When decomposed across drivers of the trade impacts, the results suggest that at the global level, the contribution of non-agriculture-related shocks (indicated yellow on figure 4) is even more substantial than the agriculture-related ones (Figure 4). Agricultural shocks substantially reduce exports from low- and middle-income countries (includes the Black Sea region), though these reductions are almost fully offset by increasing exports from high-income countries, like EU and the United States. Increasing prices of fertilizer and climate-induced impacts have disproportionally higher adverse implications on agricultural exporters in developing countries (Figure 4). At the same time rising energy prices and non-food-related trade restrictions (indicated yellow on figure 4) lead to agricultural export reductions both in high-income and developing countries. As a result, the latter channel accounts for around 53 percent (6.2 billion USD) of the reduction in global agricultural and food exports.

Decomposition of impacts across domestic and imported sources suggests that most reductions are coming from the domestic side (Figure 5). This further stresses a relatively more important role of the spillover effects of the war in Ukraine, including increasing energy prices and rising costs of fertilizer, as well as of other ongoing disruptions, such as climate impacts. In relative terms, we find that countries in the South and East Asia, as well as Africa could be impacted the

most adversely in terms of food availability (Figure 5). Observed reductions in daily per capita kcal supply in these regions are in a range of 45-90 kcal/capita/day, which is equivalent to a reduction of 1.7-3.3 percent. Considering that supply of wheat and other grains, which are the main source of the carbohydrates supply, is impacted the most adversely by the war in Ukraine, observed reductions in the supply of carbs are even more substantial than that of kcal (Figure 5).

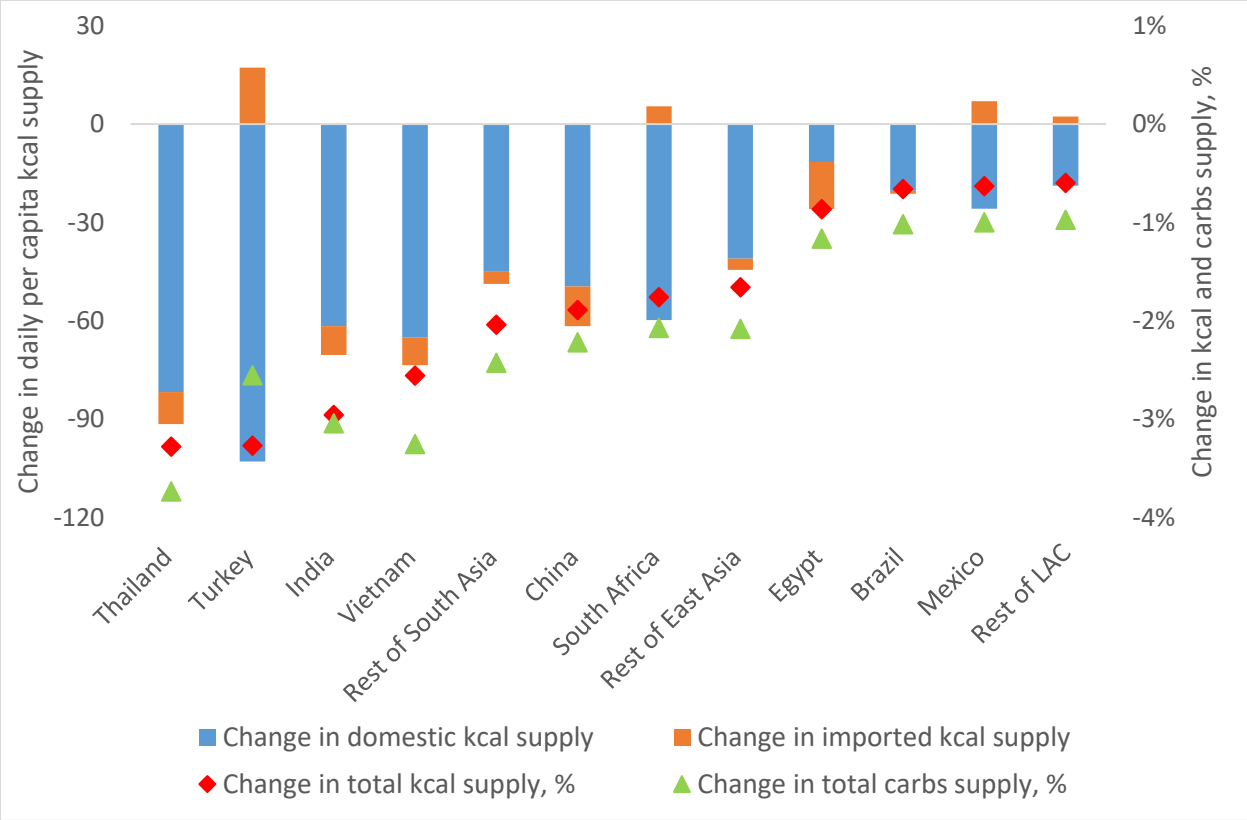

Figure 5. Changes in kcal and carbohydrates supply across most-impacted developing countries and regions under the "UkrWar" scenario

When analysing trade effects, it is important to distinguish between value and volume changes in trade flows. As discussed above, in volume terms global imports of agricultural and food reduce substantially, while the overall trade-to-GDP ratio falls, as the trade flows contract more than the overall output. At the same time, rising prices of agricultural commodities, result in a different global trade flows restructuring patterns when measured in value terms. When accounting for the price effect, exports of primary agricultural commodities increase by over 2 percent under the "UkrWar" scenario, while when combined with the trade in processed food, a minor decline of 0.1 percent is observed. With a nominal global GDP decline of around 2.2 percent, a trade-to-GDP ratio increases, as the global trade flows contract by 1.1 percent (when measured in nominal terms).

This distinction between nominal and real terms valuation is important in the context of interpreting changes in the GVC participation rates, since in our assessment the latter are measured using nominal valuation. Results suggest that the global GVC participation rate

increases by around 0.6 percentage points – from 39.7 to 40.3 percent under the "UkrWar" scenario. As agricultural and food sectors are among the most adversely impacted activities, thus experiencing substantial increases in prices following supply restrictions, when measured in nominal terms, they substantially boost their GVC participation rate. Out of top 10 sectors with the largest relative increases in the GVC participation rates, five are agricultural sectors (Figure 6). Largest increases are observed in the case of other grains and wheat activities (16 and 12 percent respectively), followed by other crops, oil seeds and livestock. An aspect of the increasing GVC participation rate of the agricultural and food commodities stresses an important role that trade plays as an adaptation mechanism to the external shocks, such as fertilizer shortages, rising production costs, supply disruptions and adverse weather events (channels considered in the provided assessment).

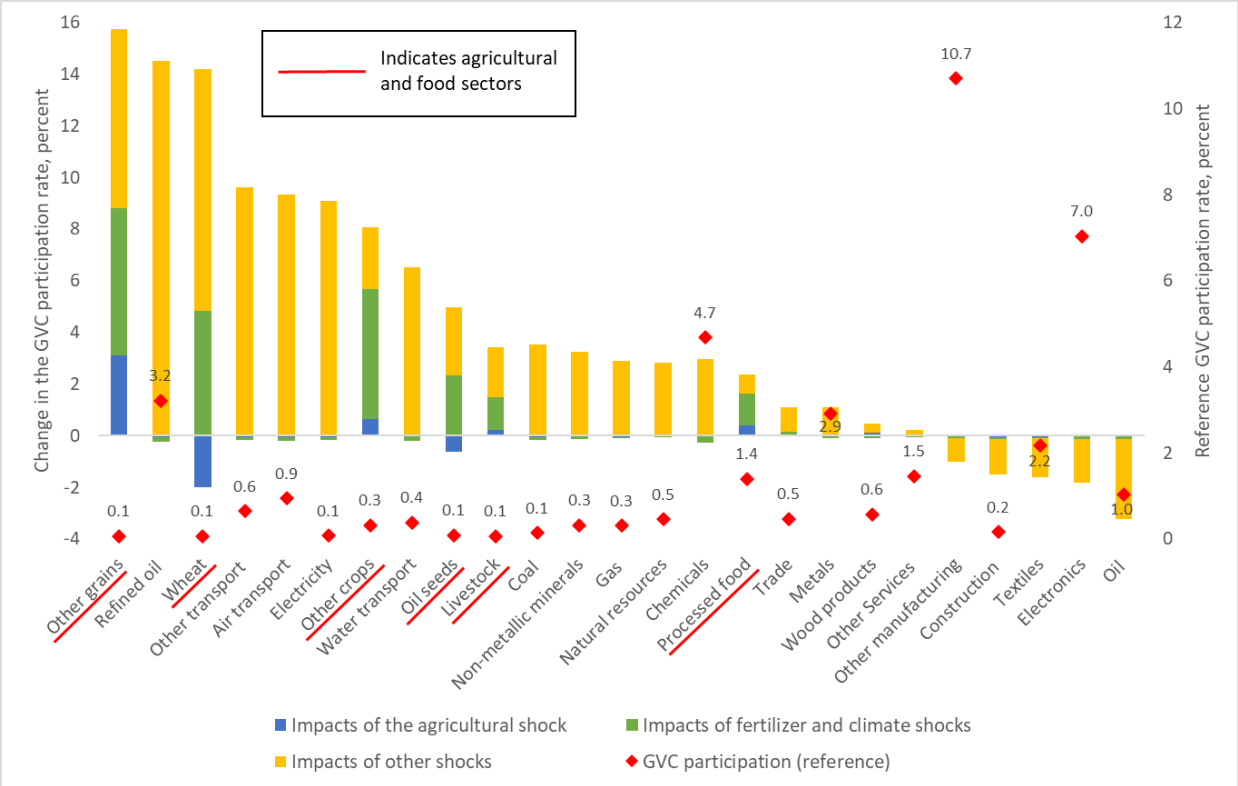

Figure 6. Change in global average GVC participation rate across sectors and a reference level of GVC participation, percent

Notes: GVC participation is estimated as a sum of forward and backward GVC participation rates (measured as a share of global exports). Forward GVC participation = Domestic value added embodied in third country exports (percent of exports). Backward GVC participation = imported inputs in exports (percent of exports). Callouts with numbers on the chart correspond to the reference GVC participation rates (indicated by red diamonds and plotted on the secondary vertical axis). Percent changes are measured relative to the reference level of the GVC participation rate.

5.3. Reductions of import tariffs and trade facilitation measures could mitigate the adverse impacts of the war

As suggested by the analysis provided in Sections 5.1 and 5.2, the war in Ukraine and interacting commodity market disruptions could have major adverse implications for the global economy in general, as well as agricultural and food sectors in particular. However, if countries implement policies toward reducing trade barriers, they could to a large extent mitigate the negative impacts of the war. Results suggest that at the macro level, impact of eliminating tariffs on imported agricultural and food commodities together with an implementation of TFMs, could overweigh the reductions in income that are attributed to agricultural, fertilizer and climate shocks ("UkrWarAgriProd" scenario shocks) (Figure 7).

We find that the developing countries and regions, such as Vietnam, Thailand, and countries in MENA and Sub-Saharan Africa tend to benefit the most from considered trade policies (in terms of gained income). In relative terms, countries benefit from the implementation of TFMs, though in such countries like Thailand, Egypt, Turkey and India, elimination of import tariffs contributes around half of the overall benefit. In a number of country cases, agricultural tariff reductions and trade facilitation measures are even enough to overweigh an overall adverse impact of the war in Ukraine and related market disruptions (Figure A.3.1, Annex 3). Examples of such regions include Thailand and the Rest of East Asia.

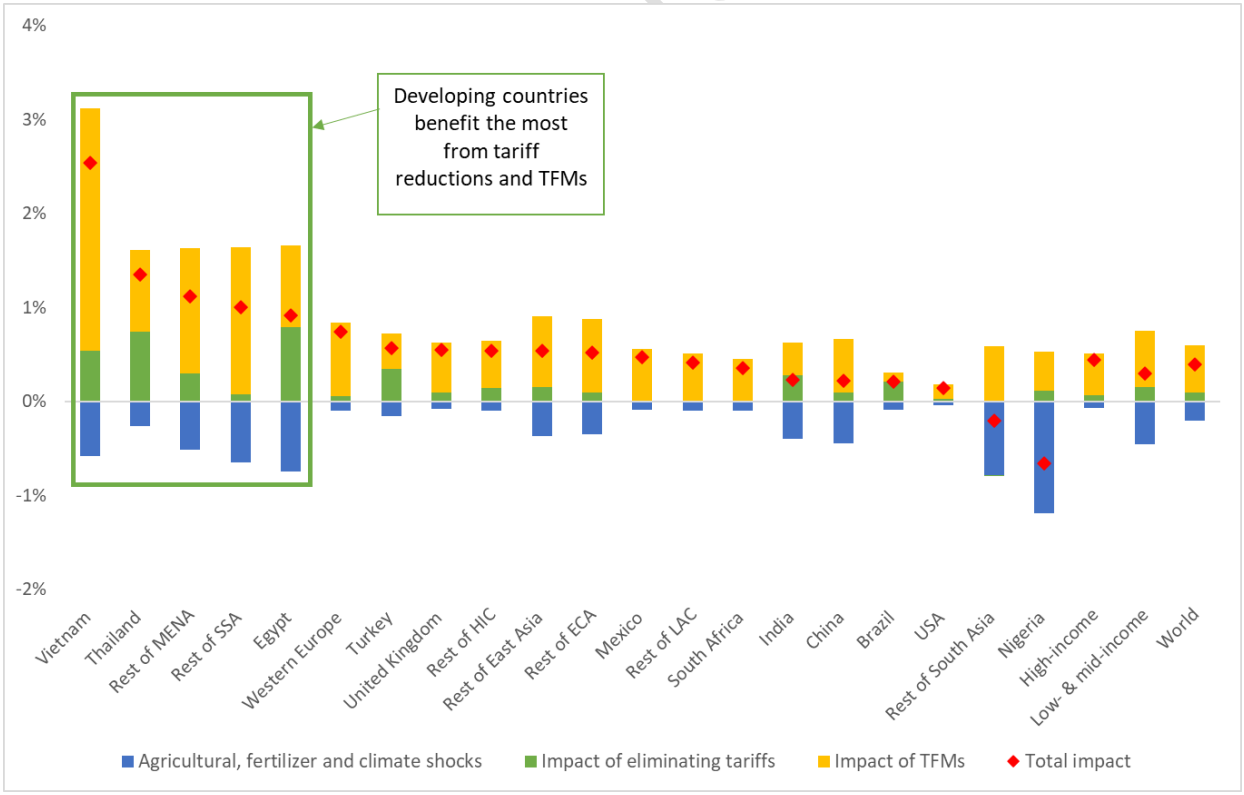

Figure 7. Change in real income in selected countries and regions following and implementation of trade policies, percent

In terms of trade implications, considered trade policies lead to the substantial export expansions, as an overall value of agricultural and food trade increases by over 102 billion USD (Figure 8a). While a substantial share of export expansions is happening in the high-income countries, such as Western Europe, the United States and other HIC (Figure 8a), net agricultural importers in developing world also benefit from the reduction in trade barriers. As a result, when measured in terms of the overall caloric supply, considered trade policies fully mitigate the adverse implications of the war in Ukraine and increase daily per capita caloric supply by around 90 kcal in the low- and middle-income countries (Figure 8b) or net increase of around 1.6 percent in relative terms. While in terms of trade expansion, elimination of import tariffs contributes the most, in terms of total food availability a role of TFMs is more substantial.

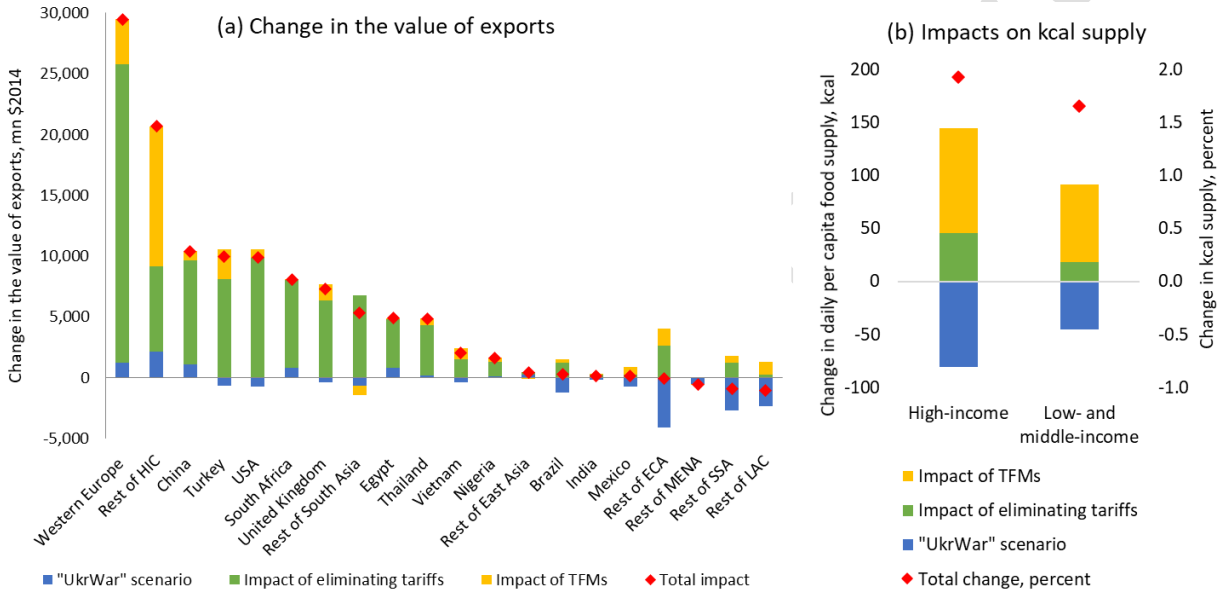

Figure 8. Impacts of trade policies on the value of exports (panel a) and caloric food supply (panel b)

Finally, results suggest that considered trade policies could further boost countries' integration into agricultural and food value chains. As shown in the earlier studies, higher GVC participation, in general, make countries more resilient to the external shocks, helping to reduce their income and GDP losses, compared to the cases of countries with lower GVC integration rates (Chepeliev et al., 2022b). In this regard, we find that the elimination of import tariffs on agricultural and food commodities, together with an implementation of TFMs, in many country-cases leads to an increase in GVC participation rates above 5 percent (Figure 9a). In India and Thailand an increase is over 10 percent. In the top five most-benefiting countries and regions, most of an expansion in GVC participation is coming from forward GVC linkages (domestic value added embodied in third country exports), as corresponding countries, being large exporters, are able to expand their trade flows, following a reduction in trade barriers.

At the commodity level, we find that other grains and wheat – sectors impacted the most adversely by the war in Ukraine – benefit the most from the trade policy measures, in terms of increasing GVC participation rates (Figure 9b). In both cases, the GVC participation rates increase by over 11 percent, while most of the benefits are coming from an implementation of TFMs.

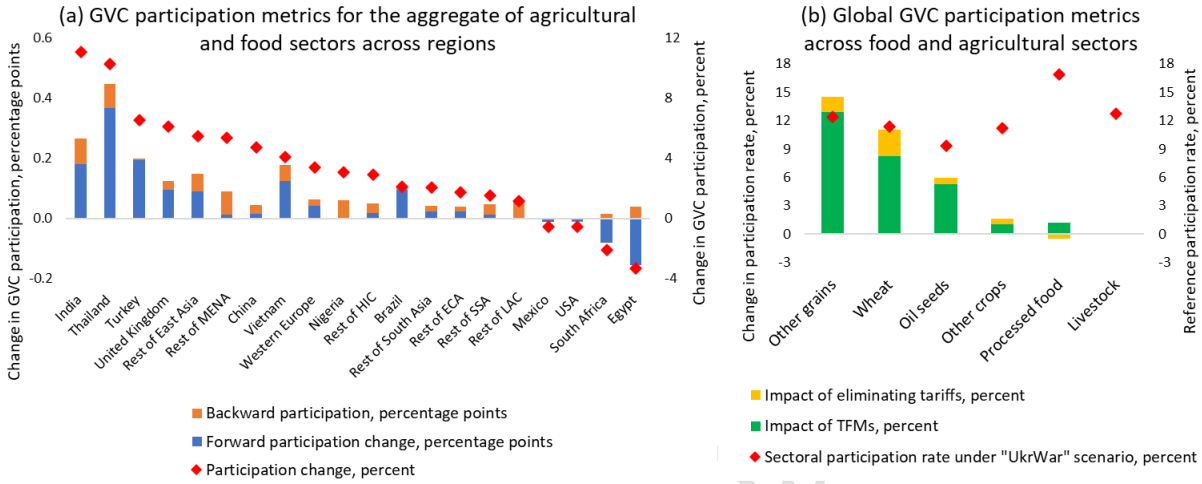

Figure 9. Impacts on agricultural and food GVCs following an implementation of trade policies

Notes: Panel (a) reports changes in forward and backward participation rates across countries and regions. Changes are reported in percentage points and percent change relative to the reference participation rate under the "UkrWar" scenario. GVC participation is measured as a share of global exports of all goods and services. Panel (b) provides estimates of changes in global GVC participation rates across agricultural and food sectors. GVC participation is measured as a share of country's sectoral exports.

6. Conclusions and policy implications

The war in Ukraine is a dire human tragedy for the people of Ukraine. It also has major implications for the world agricultural and food markets, as the Black Sea region is a major supplier of crops and fertilizers. Impacts of the war are further exacerbated by implications of sanctions against Russia, spillover effects from other markets (energy), adverse weather events and domestic policies that countries around the world have implemented in pursue of food security. In this paper, we show that due to disruptions in supply chains and sharply rising commodity prices, net agricultural importers in the developing world are particularly vulnerable. However, implementation of trade facilitation measures and reduction of import tariffs on agricultural and food commodities could mitigate the impacts of the war. Such trade policies would boost agricultural trade, increase overall food availability and lead to the higher integration of agricultural and food commodities to the global value chains. The latter would make food systems more resilient to the potential future shocks and disruptions.

In addition to the policy measures analyzed in the paper, several other policy steps could be considered in the context of mitigating the potential longer-term consequences of the war for agricultural and food markets.

First, with rapidly increasing food prices, some countries have started imposing agricultural trade restrictions to protect domestic consumers. Such actions should be avoided as they are likely to further jeopardize global food security (Ruta et al. 2022).

Second, direct efforts on extending the grain deal between Russia and Ukraine should be further supported by the United Nations and other involved parties. Any further disruptions to the supply of wheat and other grains from the Black Sea region would have devastating consequences for the global food security.

Third, the consequences of the war in Ukraine have already put a disproportionate pressure on lower-income households in developing countries, who spend a large share of their budget on food and energy. Buffering the impacts on poor households via targeted support measures, such as direct lump-sum payments, is a crucial step to ease the burden on the most vulnerable.

Finally, the magnitude of adverse impacts of the war on food and agricultural markets largely depends on the future dynamics and duration of the conflict. Broadening sanctions would help to increase the economic pressure on Russia. Introducing a ban on energy imports (Chepeliev et al. 2022c) and an embargo on Russian capital goods (van Bergeijk 2022) could serve such a purpose. Combining the former with energy price caps on Russian energy exports, could be a feasible solution (Sonnenfeld and Tian, 2022).

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Annex 1. Shares of imports of selected commodities from the Black Sea region in consumption

Figure 1a. Wheat imports from Russia and Ukraine as a share of consumption, 2017 (percent)

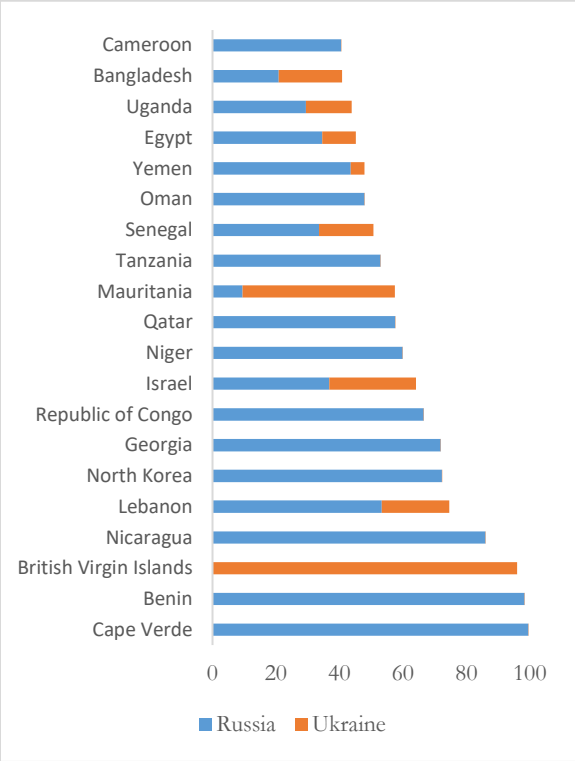


Figure 1b. Cereal imports from Russia and Ukraine as a share of consumption, 2017 (percent)

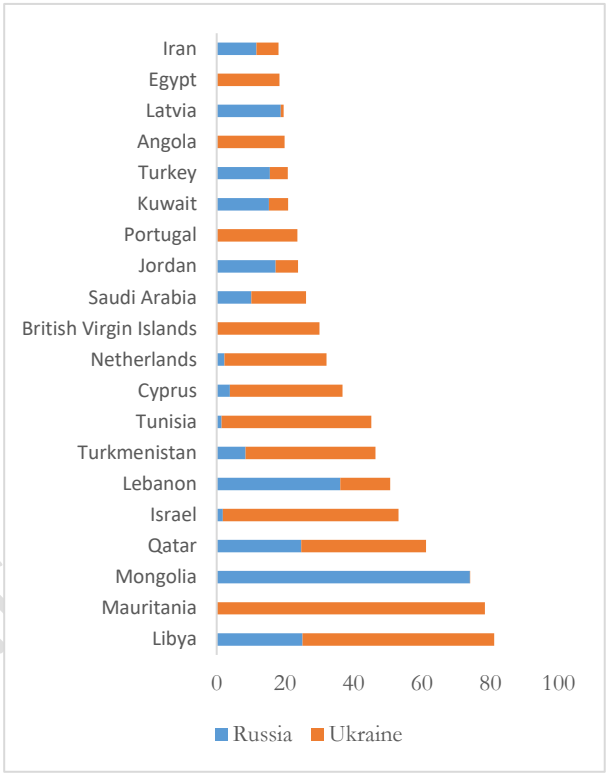


Figure 1c. Seed oil imports from Russia and Ukraine as a share of consumption, 2017

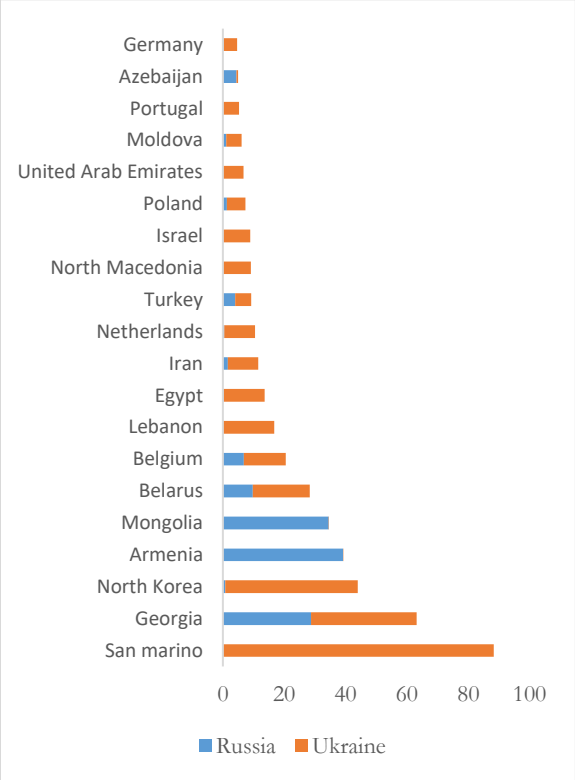


Figure 1d. Coal imports from Russia and Ukraine as a share of consumption, 2019

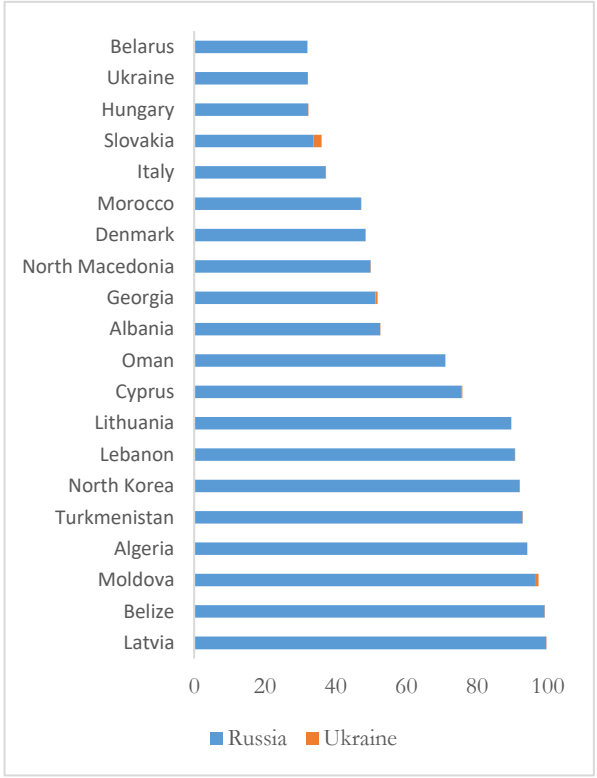


Figure 1e. Crude petroleum imports from Russia and Ukraine as a share of consumption, 2019

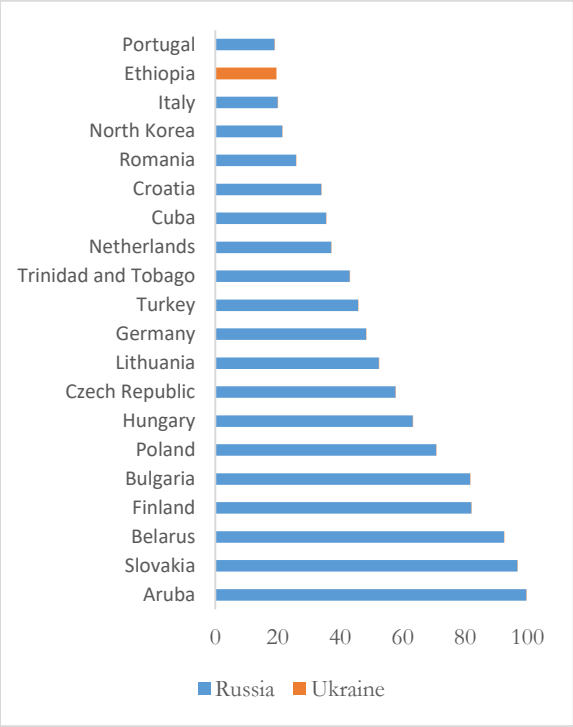


Figure 1f. Petroleum and coal products imports from Russia and Ukraine as a share of consumption, 2019

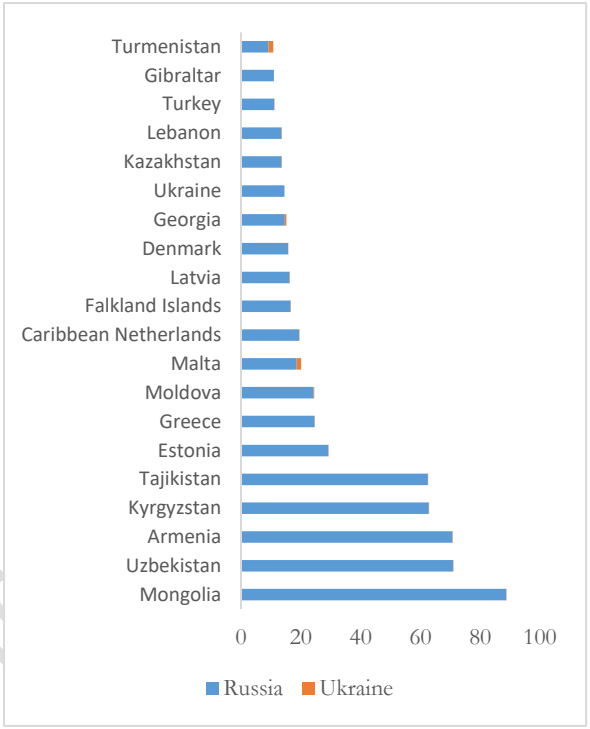
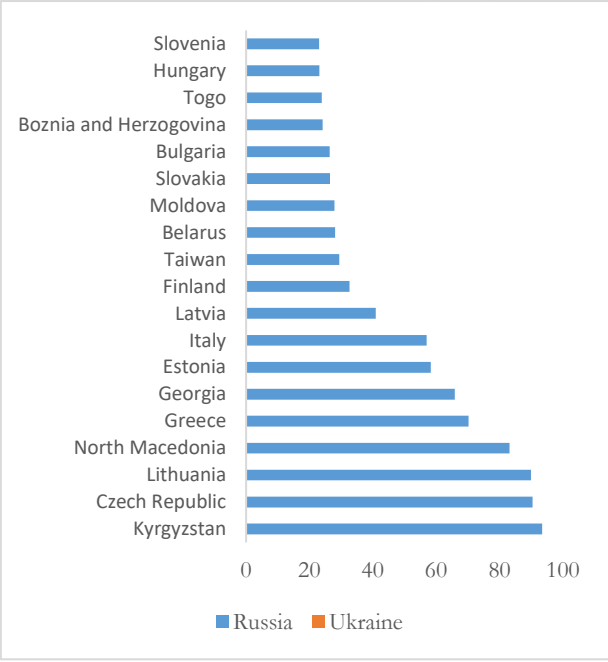


Figure 1g. Natural gas imports from Russia and Ukraine as a share of consumption, 2019



Note: GTAP data underestimates the imports of Russian natural gas by Germany, hence this data point has been dropped. Source: GTAP 11p2.

Annex 2. Model aggregations

A.2.1. Regional Aggregation

No.	Region code	Region description	GTAP 10 regions
1.	WER	Western Europe	Austria (AUT), Belgium (BEL), Bulgaria (BGR), Croatia (CRO), Cyprus (CYP), Czech Republic (CZE), Denmark (DNK), Estonia (EST), Finland (FIN), France (FRA), Germany (DEU), Greece (GRC), Hungary (HUN), Ireland (IRL), Italy (ITA), Latvia (LVA), Lithuania (LTU), Luxembourg (LUX), Malta (MLT), Netherlands (NLD), Poland (POL), Portugal (PRT), Romania (ROU), Slovakia (SVK), Slovenia (SVN), Spain (ESP), Sweden (SWE), Switzerland (CHE), Norway (NOR), Rest of EFTA (XEF), Rest of Europe (XER), Rest of the World (XTW)
2.	GBR	United Kingdom	United Kingdom (GBR)
3.	USA	United States	United States (USA)
4.	CHN	China	China (CHN)
5.	BRA	Brazil	Brazil (BRA)
6.	MEX	Mexico	Mexico (MEX)
7.	IND	India	India (IND)
8.	TUR	Turkey	Turkey (TUR)
9.	RUS	Russia	Russia (RUS)
10.	UKR	Ukraine	Ukraine (UKR)
11.	BLR	Belarus	Belarus (BLR)
12.	ZAF	South Africa	South Africa (ZAF)
13.	NGA	Nigeria	Nigeria (NGA)
14.	VNM	Viet Nam	Viet Nam (VNM)
15.	THA	Thailand	Thailand (THA)
16.	EGY	Egypt, Arab Rep.	Egypt, Arab Rep. (EGY)
17.	XSS	Rest of Sub-Saharan Africa	Benin (BEN), Burkina Faso (BFA), Cameroon (CMR), Côte d'Ivoire (CIV), Ghana (GHA), Guinea (GIN), Senegal (SEN), Togo (TGO), Rest of Western Africa (XWF), Central Africa (XCF), South-Central Africa (XAC), Ethiopia (ETH), Kenya (KEN), Madagascar (MDG), Malawi (MWI), Mauritius (MUS), Mozambique (MOZ), Tanzania (TZA), Uganda (UGA), Zambia (ZMB), Zimbabwe (ZWE), Rest of Eastern Africa (XEC), Botswana (BWA), Namibia (NAM), Rest of South African Customs Union (XSC)
18.	XHY	Rest of high-income	Australia (AUS), New Zealand (NZL), Canada (CAN), Hong Kong (HKG), Japan (JPN), South Korea (KOR), Taiwan (TWN), Singapore (SGP)
19.	XLC	Rest of Latin America & Caribbean	Argentina (ARG), Bolivia (BOL), Colombia (COL), Ecuador (ECU), Venezuela (VEN), Chile (CHL), Paraguay (PRY), Peru (PER), Uruguay (URY), Rwanda (RWA), Rest of South America (XSM), Costa Rica (CRI), Guatemala (GTM), Honduras (HND), Nicaragua (NIC), Panama (PAN), El Salvador (SLV), Rest of Central America (XCA), Dominican Republic (DOM), Jamaica (JAM), Puerto Rico (PRI), Trinidad and Tobago (TTO), Rest of Caribbean (XCB), Rest of North America (XNA)

No.	Region code	Region description	GTAP 10 regions
20.	XEA	Rest of East Asia	Rest of Oceania (XOC), Malaysia (MYS), Mongolia (MNG), Rest of East Asia (XEA), Brunei Darussalam (BRN), Cambodia (KHM), Indonesia (IDN), Laos (LAO), Philippines (PHL), Rest of Southeast Asia (XSE)
21.	XSA	Rest of South Asia	Bangladesh (BGD), Nepal (NPL), Pakistan (PAK), Sri Lanka (LKA), Rest of South Asia (XSA)
22.	ECA	Rest of Europe & Central Asia	Albania (ALB), Rest of Eastern Europe (XEE), Kyrgyzstan (KGZ), Tajikistan (TJK), Rest of Former Soviet Union (XSU), Armenia (ARM), Georgia (GEO), Kazakhstan (KAZ), Azerbaijan (AZE)
23.	XMN	Rest of Middle East & North Africa	Bahrain (BHR), Iran (IRN), Kuwait (KWT), Oman (OMN), Jordan (JOR), Qatar (QAT), Saudi Arabia (SAU), United Arab Emirates (ARE), Rest of Western Asia (XWS), Israel (ISR), Rest of North Africa (XNF), Morocco (MAR), Tunisia (TUN)

Notes: Full list of the GTAP 10 Data Base regions is available at https://www.gtap.agecon.purdue.edu/databases/regions.aspx?version=10.211.

A.2.2. Sectoral Aggregation

No.	Sector code	Sector description	GTAP-Power 10 sectors	Categories used for aggregate reporting
1.	wht	Wheat	wht	Agriculture
2.	gro	Other cereal grains	gro	
3.	crp	Other crops	pdr, pcr, gro, v_f, c_b, pfb, ocr, sgr	
4.	osd	Oil seeds	osd	
5.	lvs	Livestock	ctl, oap, rmk, wol	
6.	coa	Coal	coa	Natural Resources
7.	oil	Oil	oil	
8.	gas	Gas	gas, gdt	
9.	nrs	Natural resources	frs, oxt	
10.	wdp	Wood, paper and lumber products	lum, ppp	Energy intensive and trade exposed (EITE) sectors
11.	p_c	Refined oil	p_c	
12.	chm*	Chemical products (incl. rubber and plastics)	bph, chm, rpp	
13.	nmm	Non-metallic minerals	nmm	
14.	met	Metals	i_s, nfm	
15.	pfd	Meat products and other food	cmt, omt, mil, fsh, vol, ofd, b_t	Non-EITE sectors
16.	twp	Textiles and wearing apparel	tex, wap, lea	
17.	ele*	Electronic and optical products	ele	
18.	xmn*	Other manufacturing	fmp, eeq, ome, mvh, otn, omf	
19.	ely	Electricity and heat production	ely	Services
20.	cns	Construction	cns	
21.	trd	Trade including warehousing	trd, afs, whs	
22.	wtp	Water transport	wtp	
23.	atp	Air transport	atp	
24.	xtp	Other transport	otp	
25.	xsv	Other Services	wtr, cmn, ofi, ins, rsa, obs, ros, osg, edu, hht, dwe	

Notes: Full list of the GTAP 10 Data Base sectors is available at https://www.gtap.agecon.purdue.edu/databases/v10/v10_sectors.aspx#Sector65.

"*" indicate sectors that are treated as MRIO sectors in the model, allowing agent-based demand for imports by region of origin.

Annex 3. Additional results

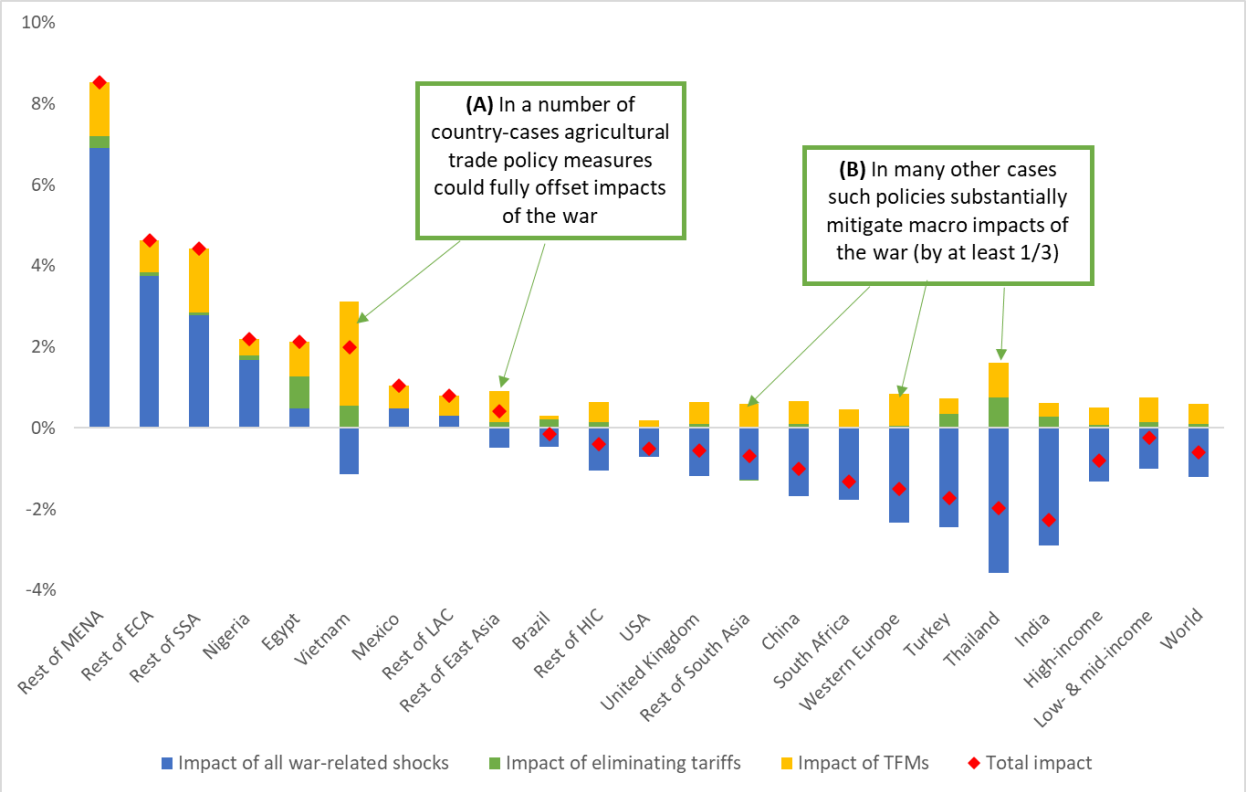


Figure A.3.1. Changes in real income across regions and policy scenarios