

Impacts of the conflict in Ukraine on global food security

Hans van Meijl, Heleen Bartelings, Siemen van Berkum, David Cui, Zuzana Smeets-Kristkova and Willem Jan van Zeist



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De Russische invasie in Oekraïne kan de voedselonzekeerheid in de wereld verergeren, aangezien beide landen een belangrijke exporteur van granen en andere landbouwproducten zijn. In deze modelgebaseerde scenariostudie worden de middellangetermijneffecten van de oorlog op de landbouwproductie, de handelsstromen, de marktprijzen en de voedselzekerheid gekwantificeerd. De scenario's richten zich op de mogelijke gevolgen van de macro-economische gevolgen en de gevolgen voor de landbouwproductie in Oekraïne, de gevolgen van handelssancties tegen Rusland, en de daarmee samenhangende hogere energieprijzen. Vanuit het oogpunt van de voedselzekerheid kan worden geconcludeerd dat er op mondiaal niveau voldoende voedsel is, maar dat hogere voedselprijzen een probleem kunnen worden voor een deel van de bevolking dat een laag inkomen heeft en een groot deel van zijn voedsel aan granen besteedt. Voor sommige landen die sterk afhankelijk zijn van de invoer van Oekraïens en Russisch graan, zoals Egypte, Turkije en het Midden-Oosten, zal de beschikbaarheid van voedsel enigszins onder druk komen te staan. Voor de EU zijn de gevolgen voor de voedselzekerheid zeer gering, aangezien de beschikbaarheid van voedsel in de EU geen probleem is en de bevolking over het algemeen een klein deel van haar voeding aan op granen gebaseerde voedingsproducten besteedt.

The Russian invasion of Ukraine has the potential to exacerbate food insecurity around the world as both countries are a major exporter of grains and other agricultural products. In this model based scenario study, medium-term effects of the war on agricultural production, trade flows, market prices, and food security are quantified. The scenarios focus on the possible consequences of macro-economic and agricultural production impacts in Ukraine, consequences of trade sanction measures against Russia, and related higher energy prices. From a food security perspective, we can conclude that there is enough food on the global level, but higher food prices could become a problem for a part of the population that has a low income and spends a large part of their food on cereals. For some countries highly dependent on imports of Ukrainian and Russian cereals like Egypt, Turkey and Middle East, food availability will come under some pressure. Food security impacts are very minor for the EU, as food availability is not a problem in the EU and in general people spend a small part on cereal-based food products.

Key words: food security, war, trade, energy, Ukraine, Egypt, Turkey, Middle East, scenario, economic models, MAGNET

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Preface

Wageningen Economic Research uses scenarios to carry out explorations and ex-ante evaluations. The Ministry of Agriculture, Nature and Food Safety (LNV) commissioned research into the impact of the Russian invasion of Ukraine and its implications on agriculture and food markets. At the time of the analyses and writing (April-May 2022) the war is still going on and the outcome is still unclear. Given the uncertainty, the ministry commissioned various studies that cover a part of the complexity and uncertainty.

In a first study, Bergevoet et al. (2021) provided insights into the trade of agricultural products from and to Ukraine, Russia and Belarus, with a focus on economic relations of these countries with the Netherlands. In Berkhout et al. (2022) a first analysis of the first consequences for food security in the short term (that is, less than 6 months) is given. In this study, medium-term effects (that is, impacts over 2 years ahead) of the war on global agricultural production, trade flows, market prices, and food security are quantified. The analysis of the effects on international markets, which is the core of this study, provides the input for a subsequent study on the implications of the war in Ukraine for various agricultural sectors in the Netherlands (Jongeneel et al., forthcoming). Therefore the implications for the Dutch agricultural sector are not part of this study, which has a focus on global markets, the EU and developing countries. Also, the additional impact of severe droughts in some individual African developing countries is not part of this study.

This study concerns model-based explorations of the future, and models used by Wageningen Economic Research in which the global as well as the European and Dutch state of affairs and developments are presented and linked. Wageningen Economic Research is still active in the global consortium that actively manages and further develops the global model (GTAP). The Wageningen Economic Research variant of this model with a focus on the agrifood (bioeconomy) sectors is the Modular Applied General Equilibrium Tool (MAGNET). MAGNET is an economic equilibrium model to which several non-economic parameters are linked. For example, the relationship between trade, production and energy prices, but also the implications of these themes for food security. Getting to know these effects requires embedding these in an international context. To this end, the scenarios in this study focus on the possible consequences of the Russian invasion in Ukraine on macro-economic and agricultural production in Ukraine, consequences of trade sanction measures against Russia, and related higher energy prices. Variants of these developments have been set up and the effects for global food markets and food security have been analysed. This publication reports on this research.

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- Maarten Paquaij, directorate European, International en Agro-economic Policy (EIA, chairman)
- Gerty Horeman, directorate Strategy, Knowledge and Innovation (SK&I)
- Hillefien Strijland, directorate European, International en Agro-economic Policy (EIA)

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Samenvatting

S.1 Doel van dit onderzoek

De Russische invasie in Oekraïne kan mogelijk negatieve gevolgen hebben voor de mondiale voedselzekerheid, aangezien beide landen een belangrijke exporteur zijn van granen, oliezaden en andere landbouwproducten. De twee landen zijn samen goed voor ongeveer 30% van de wereldwijde export van tarwe en maïs. De oorlog heeft ernstige verstoringen veroorzaakt in belangrijke voedselvoorzieningsketens en mede daardoor zijn de al hoge wereldmarktprijzen voor voedselgrondstoffen verder gestegen. Aangezien een groot aantal landen, voornamelijk lage-inkomenslanden in het Midden-Oosten, Afrika en Zuidoost-Azië, sterk afhankelijk zijn van de invoer van voedsel uit Oekraïne en/of Rusland, zijn er zorgen over de voedselzekerheid in deze landen. Deze zorg is er vooral gezien het gecombineerde effect van prijsstijgingen van voedsel, energie en kunstmest, wat zou kunnen betekenen dat sommige lage-inkomens- en graanimportafhankelijke landen die al worstelen met voedselzekerheid, hun situatie verder zien verslechteren.

Op basis van een scenarioanalyse schat deze studie de mogelijke effecten op middellange termijn (dat wil zeggen: effecten voor de komende twee jaar) van de oorlog op de landbouwproductie, handelsstromen, marktprijzen en voedselzekerheid, op nationaal en/of internationaal niveau.

De studie onderzoekt in het bijzonder:

- De mogelijke gevolgen van de oorlog in Oekraïne voor de productie en export van landbouwgrondstoffen, vooral granen en oliezaden, van Oekraïne;
- Gevolgen van handelssancties tegen Rusland voor de export van granen en oliezaden;
- De mogelijke gevolgen van hogere energieprijzen voor de mondiale agrarische productie en handel

en evalueert de mogelijke aanpassingen op internationale landbouwmarkten als gevolg van verwachte veranderingen in productie en export door Oekraïne en Rusland. Ook analyseert de studie de mogelijke gevolgen voor de voedselzekerheid in de EU en voor een aantal lage-inkomenslanden die sterk afhankelijk zijn van de invoer van granen en oliezaden.

S.2 Methode

De effecten van de oorlog op de internationale voedselmarkten worden gekwantificeerd met behulp van een economie breed model, namelijk MAGNET. Het MAGNET-model bevat alle landen van de wereld, gegroepeerd naar regio's en alle sectoren van de economie. Het is een globaal algemeen evenwichtsmodel, wat betekent dat uitruil mogelijk is van land, kapitaal en arbeid tussen de verschillende sectoren van de economie en via bilaterale handelsstromen tussen landen. De basis van het model is de neoklassieke micro-economie: deze bestudeert het gedrag van producenten, consumenten en overheid. In deze studie richten we ons op de effecten op de markten voor granen (tarwe en andere granen) en oliezaden, waarbij we ook rekening houden met de algemene economische effecten (Bruto Binnenlands Product (BBP)-veranderingen) en effecten op de internationale energiemarkten. We voeren een scenarioanalyse op middellange termijn uit, waarbij we een 'business-as-usual'-situatie in 2022 zonder oorlog (dat wil zeggen: het basisscenario) vergelijken met verschillende 'wat-als'-scenario's die zich naar verwachting binnen ongeveer twee jaar na de oorlog zouden kunnen voordoen. Het model is zo opgezet om de onmiddellijke gevolgen van de oorlog in dit stadium in beeld te kunnen brengen, zonder een uitspraak te hoeven doen over de zeer onzekere aard van de ontwikkelingen van de oorlog en de resulterende reacties van internationale gemeenschappen. De uitgangssituatie van het model wordt beschreven met behulp van de GTAP-database van 2014 met aannames over het BBP en bevolkingsontwikkelingen). In deze basisprojectie zijn de reële handelsgegevens van de afgelopen jaren gebruikt om de huidige bilaterale handelssituatie voor tarwe, andere granen en oliezaden voor Oekraïne en Rusland weer te geven. Gezien de vele onzekerheden rond de ontwikkeling van de oorlog en hoe de betrokken

landen op elkaars handelen zullen reageren, zijn de scenarioaannames slechts indicatief en illustreren ze wat er kan gebeuren binnen de aannames die expliciet in dit onderzoek zijn gemaakt.

S.3 Uitgangspunten

In deze studie formuleren we acht scenario's om de impact van de oorlog tussen Rusland en Oekraïne op de internationale voedselmarkten in te schatten. Elk van deze scenario's bestaat uit aannames die een afspiegeling zijn van enkele (nu al) bekende of verwachte gevolgen van de oorlog, zoals handelsbeperkingen en sancties. De scenario's zijn onderverdeeld in drie blokken om onderscheid te maken tussen:

1. De effecten van de oorlog in Oekraïne die voortkomen uit een handelsblokkade tussen Oekraïne enerzijds en Rusland en Wit-Rusland anderzijds, uitgebreid met een lager BBP en verminderde landbouwproductie in Oekraïne, en hogere handelskosten voor export uit dit land;
2. De economische gevolgen van sancties tegen Rusland, een lager BBP in en mogelijk verminderde handel door Rusland in granen en oliehoudende zaden;
3. De effecten van een wereldwijde stijging van de energieprijzen.

Als uitbreiding van de drie scenario's onderzoeken we in een (vierde) gevoeligheidsscenario de gevolgen van marktaanpassingen op de iets langere termijn (drie tot vijf jaar). Alle scenario's zijn in volgorde opgebouwd, waarbij elk scenario de aannames van het vorige scenario behoudt en vervolgens verdere aannames aan dit scenario toevoegt. Door dit te doen, isoleren we de impact van elke reeks modelschokken en aannames onder 1), 2) en 3). Dit maakt het mogelijk de grootste impact op de wereldvoedselmarktprijzen en voedselzekerheidsindicatoren te identificeren. De scenario's zijn samengevat in de onderstaande tabel:

Tabel S.1 *Scenariobeschrijving, veronderstellingen en implementatie*

Scenario	Scenariobeschrijving	Veronderstellingen en implementatie
Scenario 1: Oekraïne-effecten	1a: Handelsstop van Oekraïne met Rusland en Wit-Rusland	Tarieven stijgen om de handel met 90% te verminderen voor alle grondstoffen
	1b: 1a + Productieverlies en lager BBP in Oekraïne	Arbeid en kapitaal dalen 30%, landopbrengsten dalen 50%, bevolking daalt 10%
	1c: 1b + Extra transportkosten van Oekraïne met de rest van de wereld	Transportkosten tussen Oekraïne en de rest van de wereld stijgen 20%
Scenario 2: Oekraïne en Rusland	2a: Scenario 1 + Handelssancties VS en EU tegen Rusland.	Amerikaanse en EU-importtarieven stijgen met 90% voor Russische sectoren financiën, luchtvaart, vervoer over water, energie, telecom, defensie, ijzer en staal, luxe voertuigen, mode en kunst; ook stijging met 90% van Amerikaanse invoertarieven op Russisch vis en zeevruchten, alcoholische dranken, niet-industriële diamant, kolen, olie en gas.
	2b: 2a + Afname BBP in Rusland	Het reële BBP in Rusland daalt met 10%
	2c: 2b + Rusland vermindert export van granen en oliezaden.	Tarieven stijgen om de export uit Rusland met 50% te verminderen voor tarwe, andere granen en oliezaden
Scenario 3: Oekraïne, Rusland, energieprijzeneffecten	Scenario 2 + Hogere wereldenergieprijzen	Internationale prijzen voor kolen, olie en gas stijgen 20%
Scenario 4: Oekraïne, Rusland, effecten op de energieprijs met hogere substitutie	Scenario 3 + Een langere termijn die de handel en productie nabootst door meer substitutiemogelijkheden toe te staan	Substitutie-elasticiteiten nemen toe met 25% tussen handelspartners en met 50% tussen primaire productiefactoren in alle landen, ten opzichte van de oorspronkelijke GTAP\MAGNET-waarden.

We rapporteren modelresultaten over de impact van de scenario's op het BBP, de landbouwproductie, voedselexport en -import, wereldmarktprijzen en twee voedselzekerheidsindicatoren: voedselbeschikbaarheid en voedseltoegang. Resultaten worden gepresenteerd voor Oekraïne, Rusland en verschillende landen die sterk afhankelijk zijn van graanimport uit Oekraïne, Rusland of beide.

S.4 Conclusies

De belangrijkste conclusies zijn samengevat per economische indicator.

Algemeen economisch effect

Het BBP in Oekraïne en Rusland daalt aanzienlijk, met respectievelijk 33% en 11% in de periode 2022-2024, maar is beperkt in andere landen. Buiten Oekraïne en Rusland zijn de gevolgen voor het BBP het sterkst in Centraal-Azië, een regio met landen die sterke handelsbetrekkingen met Rusland heeft. De stijging van de energieprijzen zoals vervat in scenario 3 heeft in alle regio's de grootste impact op de daling van het BBP.

Productie

In Scenario 1 en 2 wordt de afname van de productie in Oekraïne en Rusland deels gecompenseerd door extra aanbod van andere regio's, waar de productie zich aanpast in reactie op hogere wereldmarktprijzen. De wereldproductie van oliezaden en overige granen daalt licht en die van tarwe blijft stabiel omdat de relatief hoge tarweprijzen middelen uit andere sectoren aantrekken. Volgens scenario 3 zorgen hogere energieprijzen ervoor dat de mondiale productie van tarwe en overige granen min of meer stabiel is, en die van oliezaden zelfs iets toeneemt omdat er extra vraag is naar non-foodtoepassingen zoals biobrandstoffen.

In het Oekraïne-effectenscenario (scenario 1) neemt de productie van tarwe en andere granen toe in verschillende regio's in de wereld en een klein beetje in Rusland. De productie van oliezaden groeit vooral in Midden- en Zuid-Amerika. Als Russische effecten ook worden meegenomen (scenario 2), neemt de tarweproductie in Rusland flink af en zal de productie vooral in Centraal-Azië toenemen, naast de regio's waar de productie ook toeneemt in het Oekraïne-effectenscenario.

Wereldmarktprijzen

De prijzen op de wereldmarkt stijgen aanzienlijk in scenario 3, vooral voor tarwe en andere granen (ongeveer 10%) en oliezaden (6%). Dit wordt veroorzaakt door leveringseffecten in Oekraïne en Rusland en door hogere energieprijzen. Bij een langetermijneffect (drie tot vijf jaar) zal de stijging van de wereldmarktprijzen minder zijn. Tarwe-exportbeperkingen uit Rusland versterken het effect van de productiedaling in Oekraïne, beide samen stuwten de wereldmarktprijzen aanzienlijk op. Wereldmarktprijzen van andere landbouwgewassen dan granen en oliezaden stijgen met ongeveer 4% in het Oekraïne-effectenscenario 1. De additionele impact van Rusland-gerelateerde aannames in scenario 2 leidt tot een extra stijging van 1% tot 2% en scenario 3 met hogere energieprijzen voegt nog eens 2% toe aan de prijsstijging van andere granen en oliezaden op de wereldmarkt.

Voedselzekerheid

Toegang tot voedsel: Toegang tot voedsel (weergegeven door een voedselkoopkrachtsindex, gedefinieerd als verhouding tussen het loon van ongeschoolde werknemers en de prijsindex van een granendieet (met name granen en rijst)) verslechtert met ongeveer 8% tot 10% in de meeste lage- en middeninkomenslanden. Het Oekraïne-effectenscenario 1 heeft de grootste invloed (-4% tot -6%), waarbij scenario 2 (Rusland-gerelateerde schokken: -1% tot -2%) en scenario 3 (hogere energieprijzen: -2%) daar nog enkele percentages aan toevoegen. De hogere voedselprijzen voor granen zijn de belangrijkste redenen voor een substantiële afname van de toegang tot voedsel in geval het dieet van arme mensen voornamelijk uit granen bestaat. Wereldmarktprijsstijgingen voor tarwe en andere granen worden direct vertaald in een verminderde toegang tot voedsel, aangezien de lonen van ongeschoolde mensen niet veel veranderen in de scenario's. Als consumenten een gevarieerder dieet hebben dan alleen granen, waarvan de prijzen het sterkst stijgen, zijn de gevolgen voor de toegang tot voedsel minder groot. De prijzen van een meer gevarieerd dieet stijgen met 4% tot 7% en een gemiddeld dieet met 2% tot 4% voor een aantal ontwikkelingslanden. Voor de EU stijgen de voedselprijzen met 5% voor gewassen en 2% voor voedsel en gezien het relatief lage aandeel van het inkomen

dat aan voedsel wordt besteed, zou dit voor de gemiddelde burger geen probleem hoeven te zijn. Wel kunnen de hogere voedselprijzen voor sommige lage-inkomensgroepen in de EU de toegang tot voedsel verminderen.

Voedselbeschikbaarheid: De beschikbaarheid van voedsel neemt af in de meeste lage-inkomenslanden als gevolg van de beperkingen aan de leveringen door Oekraïne en Rusland. De impact is het grootst in Egypte, Turkije en het Midden-Oosten, aangezien deze regio's sterk afhankelijk zijn van import uit Oekraïne en Rusland. Russische exportvermindering boven op de verminderde productie en export van Oekraïne (scenario 2) vermindert de substitutie- en aanpassingsmogelijkheden van importafhankelijke landen sterk, met grote gevolgen voor de voedselbeschikbaarheid in deze landen. De beschikbaarheid van voedsel in Europa verandert marginaal. In het Oekraïne-effectenscenario 1 neemt de voedselbeschikbaarheid af met 0,2% en in scenario 2 met 0,3%.

Situatie importafhankelijke landen: Egypte, Pakistan, Soedan, Tunesië en Turkije zijn sterk (>50%) afhankelijk van de invoer van tarwe uit Oekraïne en Rusland, en hebben een lage zelfvoorzieningsgraad (behalve Pakistan) en beperkte mogelijkheden om de binnenlandse productie uit te breiden. Deze landen zijn kwetsbaar voor prijsschommelingen op de wereldmarkt; die kwetsbaarheid wordt verergerd door hun zwakke valuta.

Vanuit het perspectief van voedselzekerheid kunnen we concluderen dat op wereldniveau voldoende voedsel aanwezig is, maar dat hogere voedselprijzen een extra probleem kunnen worden voor een deel van de bevolking dat een laag inkomen heeft en een groot deel van hun voedsel aan granen besteedt. Voor sommige landen die sterk afhankelijk zijn van de invoer van Oekraïense en Russische granen, zoals Egypte, Turkije en het Midden-Oosten, kan de voedselbeschikbaarheid onder druk komen te staan. De gevolgen voor de voedselzekerheid zijn voor de EU zeer gering, aangezien de beschikbaarheid van voedsel in de EU geen probleem is en mensen over het algemeen een klein deel van hun inkomen besteden aan voedselproducten op basis van granen. Echter, ook in de EU zullen voor sommige lage-inkomensgroepen hogere voedselprijzen de toegang tot voedsel verslechteren.

Summary

S.1 Purpose of this research

The Russian invasion of Ukraine could potentially have a negative impact on global food security, as both countries are major exporters of grains, oilseeds and other agricultural products. The two countries together account for about 30% of global wheat and maize exports. The war has caused serious disruptions in important food supply chains and has contributed to a further increase in already high world market prices for food commodities. Since a large number of countries, mainly low-income countries in the Middle East, Africa and South-East Asia, rely heavily on food imports from Ukraine and/or Russia, there are concerns about food security in these countries. This concern is especially so given the combined effect of food, energy and fertiliser price increases, which could mean that some low-income and grain-importing countries that are already struggling with food security could see their situation worsen further.

Based on a scenario analysis, this study estimates the possible medium-term effects (i.e. effects for the next two years) of the war on agricultural production, trade flows, market prices and food security, at national and/or international level.

In particular, the study examines

- The possible impact of the war in Ukraine on Ukraine's production and export of agricultural commodities, especially grains and oilseeds;
- The impact of trade sanctions against Russia on the export of cereals and oilseeds;
- The possible impact of higher energy prices on global agricultural production and trade.

and evaluates the possible adjustments in international agricultural markets due to expected changes in production and exports by Ukraine and Russia. The study also analyses the possible consequences for food security in the EU and for a number of low-income countries that are highly dependent on cereal and oilseed imports.

S.2 Method

The effects of the war on international food markets are quantified using an economy-wide model, MAGNET. The MAGNET model includes all countries of the world, grouped by regions and all sectors of the economy. It is a global general equilibrium model, which means that exchanges of land, capital and labour are possible between the different sectors of the economy and via bilateral trade flows between countries. The basis of the model is neo-classical microeconomics: it studies the behaviour of producers, consumers and government. In this study, we focus on the effects on the markets for cereals (wheat and other grains) and oilseeds, also taking into account general economic effects (Gross Domestic Product (GDP) changes) and effects on international energy markets. We perform a medium-term scenario analysis, comparing a business-as-usual situation in 2022 without war (i.e. the baseline scenario) with various 'what-if' scenarios that are expected to occur within about two years after the war. The model is designed to capture the immediate effects of the war at this stage, without making a judgement on the highly uncertain nature of the war's developments and the resulting responses of international communities. The baseline of the model is described using the 2014 GTAP database with assumptions on GDP and population trends). In this baseline projection, real trade data of the past years were used to represent the current bilateral trade situation for wheat, other grains and oilseeds for Ukraine and Russia. Given the many uncertainties surrounding the development of the war and how the countries involved will react to each other's actions, the scenario assumptions are only indicative and illustrate what can happen within the assumptions explicitly made in this study.

S.3 Starting points

In this study we formulate eight scenarios to estimate the impact of the war between Russia and Ukraine on international food markets. Each of these scenarios consists of assumptions that reflect some (already) known or expected consequences of the war, such as trade restrictions and sanctions.

The scenarios are divided into three blocks to distinguish between:

1. The effects of the war in Ukraine resulting from a trade blockade between Ukraine on the one hand and Russia and Belarus on the other, extended to lower GDP and reduced agricultural production in Ukraine, and higher trade costs for exports from this country;
2. The economic impact of sanctions against Russia, lower GDP in and potentially reduced trade by Russia in cereals and oilseeds;
3. The effects of a global increase in energy prices.

As an extension of the three scenarios, in a (fourth) sensitivity scenario we examine the effects of market adjustments in the somewhat longer term (three to five years). All scenarios are constructed in order, with each scenario retaining the assumptions of the previous scenario and then adding further assumptions to this scenario. By doing this, we isolate the impact of each set of model shocks and assumptions under 1), 2) and 3). This allows us to identify the greatest impact on world food market prices and food security indicators. The scenarios are summarised in the table below:

Table S.1 Scenario description, assumptions and implementation

Scenario	Description of scenario	Shocks and assumptions
Ukraine impacts (Scen 1)	1a: Ukraine's trade halt with Russia and Belarus	Tariffs rise to reduce trade with 90% for all commodities
	1b: 1a + Ukraine's loss in production and GDP	Labour and capital fall 30%, land yields fall 50%, population falls 10%
	1c: 1b + Ukraine's additional transport cost with rest of world	Transport costs between Ukraine and rest of world rise 20%
Ukraine and Russia impacts (Scen 2)	2a: Scen 1 + US & EU trade sanctions against Russia.	US and EU tariffs rise 90% (or a converted %) for Russia for finance, aviation, water transport, energy, telecom, defence, iron & steel, high-end vehicle, fashion & art; in US for finance, fish & seafood, alcoholic beverage, non-industrial diamond, coal, oil, LNG; in EU for finance only.
	2b: 2a + Russia's loss in GDP	Real GDP in Russia falls 10%
	2c: 2b + Russia's reduced exports on grains and oilseeds.	Tariffs rise to reduce exports from Russia with 50% for wheat, other grains and oilseeds
Ukraine, Russia, energy price impacts (Scen 3)	Scen 2 + world energy prices rise	Prices rise 20% in the world for coal, oil, and gas
Ukraine, Russia, energy price impacts with higher substitution (Scen 4)	Scen 3 + A longer term mimicking reaction in trade and production by allowing more substitution possibilities.	Substitution elasticities increase by 25% between trade partners and 50% between primary production factors in all countries to the original GTAP\MAGNET values.

We report model results on the impact of the scenarios on GDP, agricultural production, food exports and imports, world market prices and two food security indicators: food availability and food access. Results are presented for Ukraine, Russia and several countries that rely heavily on grain imports from Ukraine, Russia or both.

S.4 Conclusions

The main conclusions are summarised per economic indicator.

Overall economic impact

GDP falls significantly in Ukraine and Russia, by 33% and 11% respectively in the period 2022-2024, but is limited in other countries. Outside Ukraine and Russia, the impact on GDP is strongest in Central Asia, a region of countries with strong trade ties with Russia. The increase in energy prices contained in Scenario 3 has the greatest impact on the fall in GDP in all regions.

Production

In Scenarios 1 and 2, the decline in production in Ukraine and Russia is partly offset by additional supply from other regions, where production adjusts in response to higher world market prices. World production of oilseeds and other grains falls slightly and that of wheat remains stable as relatively high wheat prices attract resources from other sectors. Under Scenario 3, higher energy prices mean that world production of wheat and other cereals is more or less stable, and that of oilseeds even rises slightly as there is additional demand for non-food applications such as biofuels.

In the Ukraine effect scenario (scenario 1), production of wheat and other cereals increases in various regions of the world and slightly in Russia. Oilseed production grows mainly in Central and South America. If Russian effects are also included (Scenario 2), wheat production in Russia decreases significantly and production increases mainly in Central Asia, in addition to the regions where production also increases in the Ukraine effect scenario.

World market prices

World market prices rise significantly in Scenario 3, especially for wheat and other grains (around 10%) and oilseeds (6%). This is caused by supply effects in Ukraine and Russia and by higher energy prices. With a long-term effect (three to five years), the increase in world market prices will be less. Wheat export restrictions from Russia reinforce the effect of the production decline in Ukraine, both together pushing up world market prices significantly. World market prices of agricultural crops other than cereals and oilseeds increase by about 4% in the Ukraine impact scenario 1. The additional impact of Russia-related assumptions in scenario 2 leads to an additional increase of 1% to 2% and scenario 3 with higher energy prices adds another 2% to the price increase of other cereals and oilseeds on the world market.

Food security

Access to food: Access to food (represented by a food purchasing power index, defined as the ratio of unskilled workers' wages to the price index of a cereal diet (especially cereals and rice)) deteriorates by about 8% to 10% in most low- and middle-income countries. The Ukraine effect scenario 1 has the largest impact (-4% to -6%), with scenario 2 (Russia-related shocks: - 1% to -2%) and scenario 3 (higher energy prices: - 2%) adding some percentages. Higher food prices for cereals are the main reason for a substantial decrease in access to food in case poor people's diet consists mainly of cereals. World market price increases for wheat and other cereals are directly translated into reduced access to food, since the wages of unskilled people do not change much in the scenarios. If consumers have a more varied diet than just cereals, whose prices rise the most, the impact on food access is less. Prices for a more varied diet increase by 4% to 7% and an average diet by 2% to 4% for a number of developing countries. For the EU, food prices rise by 5% for crops and 2% for food and, given the relatively low proportion of income spent on food, this should not be a problem for the average citizen. However, higher food prices may reduce access to food for some low-income groups in the EU.

Food availability: Food availability is decreasing in most low-income countries due to supply restrictions from Ukraine and Russia. The impact is greatest in Egypt, Turkey and the Middle East, as these regions rely heavily on imports from Ukraine and Russia. Russian export reductions on top of Ukraine's reduced production and exports (scenario 2) greatly reduce the substitution and adjustment possibilities of import-dependent countries, with major consequences for food availability in these countries. Food availability in Europe changes marginally. In the Ukraine effect scenario 1, food availability decreases by 0.2% and by 0.3% in scenario 2.

Situation import-dependent countries: Egypt, Pakistan, Sudan, Tunisia and Turkey are highly (>50%) dependent on wheat imports from Ukraine and Russia, and have low self-sufficiency (except Pakistan) and limited opportunities to expand domestic production. These countries are vulnerable to price fluctuations on the world market; this vulnerability is exacerbated by their weak currencies.

From a food security perspective, we can conclude that there is sufficient food globally, but that higher food prices can become a problem for a part of the population that has a low income and spends a large part of their food on cereals. For some countries that rely heavily on Ukrainian and Russian cereal imports, such as Egypt, Turkey and the Middle East, food availability may come under pressure. The impact on food security is very small for the EU, as food availability in the EU is not a problem and people generally spend a small amount on cereal-based food products. However, also in the EU, for some low-income groups, higher food prices will worsen access to food.

1 Introduction

The Russian invasion in Ukraine has the potential to exacerbate food insecurity around the world as both countries play a key role as exporters of grains and other agricultural products. Based on a scenario analysis this study estimates the possible medium-term effects (that is, impacts over 2 years ahead) on agricultural production, international trade flows from Ukraine and Russia and its consequences for global food supply, world market prices, and food security.

The study investigates:

- The possible consequences of the war in Ukraine for the production and export of agricultural commodities, in particular cereals and oilseeds, by Ukraine
- Consequences of trade sanctions measures against Russia on its cereals and oilseeds exports
- The possible consequences of higher energy prices due to war and sanctions

and evaluates the possible adjustments at international markets due to projected changes in production and exports by Ukraine and Russia and assesses potential implications for food security in the EU and in a range of lower-income countries heavily dependent on cereal and oilseeds imports.

The analysis of the effects on international markets, which is the core of this study, provides the input for a subsequent study on the implications of the war in Ukraine for various agricultural sectors in the Netherlands (Jongeneel et al., forthcoming). Therefore the implications for the Dutch agricultural sector are not part of this study, which has a focus on global markets, the EU and developing countries. Also the additional impact of severe droughts in some individual African developing countries is not part of this study.

Concerns about the impact of the war in Ukraine on global food security have been prompted by the fact that Ukraine and Russia together account for about 30% of the internationally traded wheat and maize, despite the fact that both countries' global shares in the production of these crops are modest.¹ In 2020, Ukraine exported 18.0m tonnes of wheat and 27.9m tonnes of maize, respectively 9% and 15% of the total supply for exports on the world market. Ukraine also exported 6.8m tonnes of sunflower oil and 2.4m tonnes of rapeseed. The country also has a significant share in international trade for these oilseeds (Figure 1.1). These shares indicate that a disruption in the supply of these commodities from Ukraine could have significant consequences for their prices on the international market.

¹ In terms of global production, the shares are more modest. Global production of all cereals is 2.996m tonnes and the production shares for Ukraine and Russia are respectively 2% and 4%. For wheat these shares for Ukraine and Russia are, respectively, 3% and 11% (for more info see, Berkhout et al. 2022).

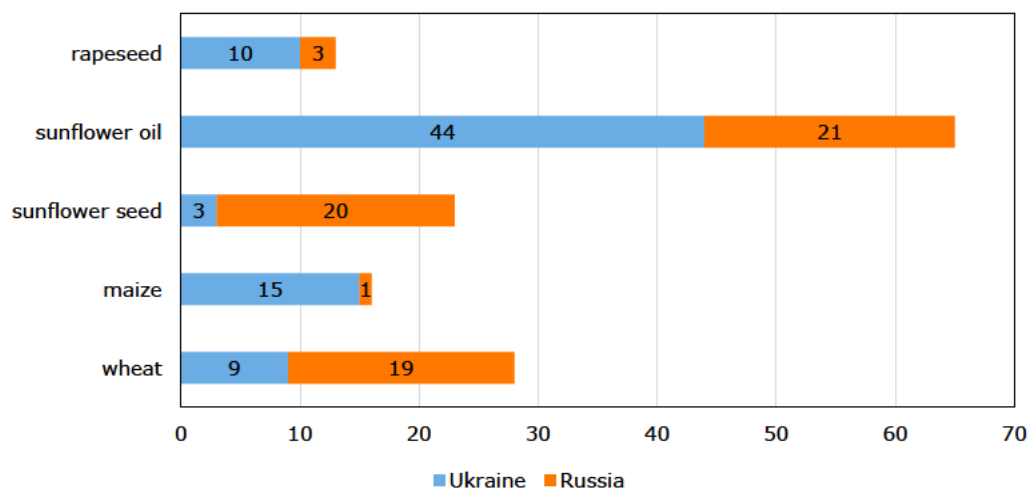


Figure 1.1 Volume shares of Ukraine and Russia in world trade of wheat, maize, sunflower seed and oil, and rapeseed

Source: UN (United Nations) Comtrade, data 2020.

Russia is also a major wheat and sunflower seed (oil) exporter. Any direct or indirect consequences of the war in Ukraine for the Russian agricultural sector (for example through trade sanctions or logistical disruptions to export flows) can therefore have major consequences for the availability and prices of these products on the world market. Countries that are heavily dependent on imports of grains and/or oilseeds from Ukraine and/or Russia will then have to deal with higher import costs, which leads to higher prices on the domestic markets. Figure 1.2 shows the import value shares of several countries and regions of wheat, other grains and oilseeds from Ukraine and Russia. Oilseeds is here a broader category including all kind of oilseeds (e.g. sunflower, soybean, rapeseeds). This shows the importance of Ukraine and Russia for the import of these crops by the countries and regions mentioned in the chart. Note that the importance of imports in terms of domestic consumption of the importing country is reflected in a self-sufficiency rate. These are explained given for a number of selected countries in Chapter 4 (Table 4.1) when import dependence is compared with possible consequences for food security.

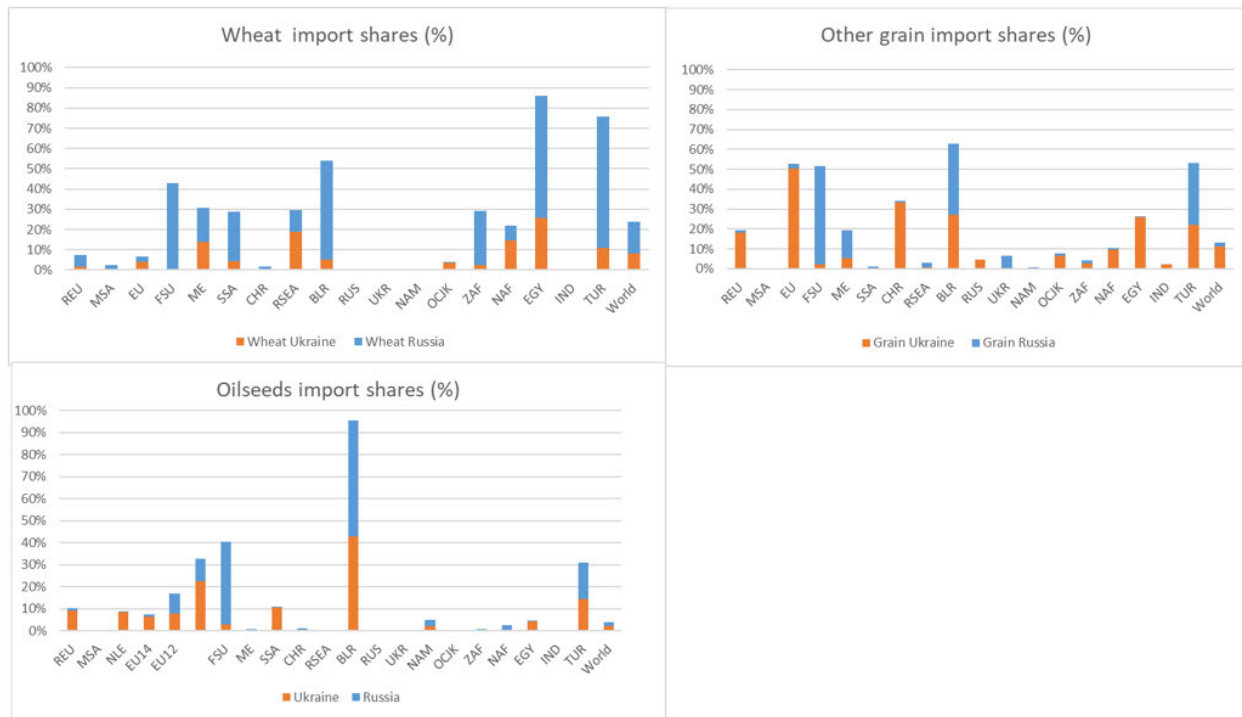


Figure 1.2 Dependency on imports from Ukraine and Russia for wheat, other grains, and oilseeds (measured by import value shares)

Source: UN Comtrade, data 2020. REU (Rest of Europe), MSA (Midden and South America), EU (European Union), CA (Central Asia), ME (Middle East), SSA (Sub-Saharan Africa), CHR (China republic), RSEA (Rest of South East Asia), BLR (Belarus), RUS (Russia), UKR (Ukraine), NAM (North America), OCJK (Oceania, Japan and South Korea), ZAF (South Africa), NAF (North Africa), EGY (Egypt), IND (India), Tur (Turkey).

Figure 1.2 shows that wheat imports from Ukraine are important for Egypt (26%), Rest Southeast Asia (19%), Middle East (14%), and Turkey (11%). Russian wheat is important for Turkey (65%), Egypt (60%), Belarus (49%), Central Asia (43%), South Africa (27%), and Sub-Saharan Africa (24%). Other grains (mainly maize) imports from Ukraine are important for EU (20%), China (33%), Belarus (27%), Egypt (26%), and Turkey (22%). Russian grain imports are important for Central Asia (49%), Belarus (36%) and Turkey (31%). The world market shares for oilseeds in general (including all kinds of oilseeds, e.g. soybeans) are much smaller. Oilseed imports from Ukraine are important for Belarus (43%) and Turkey (14%) and imports from Russia are important for Belarus (53%). So, in general, imports from Ukraine and Russia are important for Egypt, Turkey, Middle East, Northern Africa, and Sub-Saharan Africa.

World prices are key for food security within the world and already before the Ukrainian war food prices were at a high level (see FAO food index, <https://www.fao.org/worldfoodsituation/foodpricesindex/>). The rising food prices of recent years have various causes such as disrupted supply chains due to the COVID-19 pandemic (among others due to export restrictions and labour shortages due to mobility restrictions) and due to the increasing demand in 2021 as a result of economic recovery in many parts of the world which also led to higher energy and related input (fertiliser) prices, while some price increases are product specific such as in case of African swine fever in China affecting international pig meat prices (see Berkhout et al., 2022, Lucas and Von Braun 2022). Since the beginning of the war in Ukraine, daily world prices for wheat, other grains and oilseeds have continued to rise and sometimes fluctuate strongly. International wheat prices increased from about USD 800 per bushel (Bu) (24 February) to USD 1,275/Bu (7 March) and since then they declined to USD 1,062/Bu (22 April) (tradingeconomics.com). The latter level is close to the global wheat price during the 2007 food crises (USD 1,073/Bu). For maize the prices increased with 20% from USD 650/Bu (24 February) to USD 801/Bu (April 22). Soybean prices increased 'only' by 7.5% from USD 1,629/Bu to USD 1,752/Bu. The crude oil price is an important driver of food prices and it rose during the first days by 33% from USD 90/Bbl to USD 120/Bbl (8 March) and then declined to USD 102.5 /Bbl (22 April) which is 13% higher than the price just before the war. The gas price increased by 60% since beginning of war, coming a bit down from its highest point (84% on 18 April). While energy prices have been on an

upward trend since early 2020, the Russian invasion of Ukraine has further accelerated price increases but above all added a lot of uncertainty to the already volatile energy market (IEA, 2022). Driven by energy prices, supply disruptions and high transportation costs, the fertiliser price index of World Bank² increased from 197 (28 February) to 255 (30 April) which is an increase of 29%.

² https://ycharts.com/indicators/fertilizers_index_world_bank

2 Approach

The simulations of the international food market effects of the war in Ukraine are quantified using the macroeconomic model MAGNET (Woltjer et al., 2014, magnet-model.netlify.app). The MAGNET model is a multi-regional, multi-sectoral, computable general equilibrium (CGE) model based on neo-classical microeconomic theory (Van Meijl et al., 2006, Nowicki et al., 2009, Van Zeist et al., 2021; more details in Appendix). For this assessment we focus on impacts on the cereals (wheat and other grains) and oilseeds markets, considering general economic impacts (GDP changes) and impacts on the international energy markets. Our simulation is a medium-term comparative-static analysis, that is, we compare the current (2022) situation with one resulting from the 'what-if' scenario and arising after about 2 years allowing few dynamic adjustments to be made.³ The current situation is projected given the 2014 GTAP data with macroeconomic assumptions on GDP and population developments. Within this projection, the recent trade data used in Figure 1.2 were targeted to reflect the current bilateral trade situation for wheat, other grains and oilseeds for Ukraine and Russia. Given the many uncertainties surrounding the development of the conflict and how the countries involved will respond to each other's actions, the scenario assumptions are indicative, illustrating what *may* happen under the assumptions explicitly made in this study.

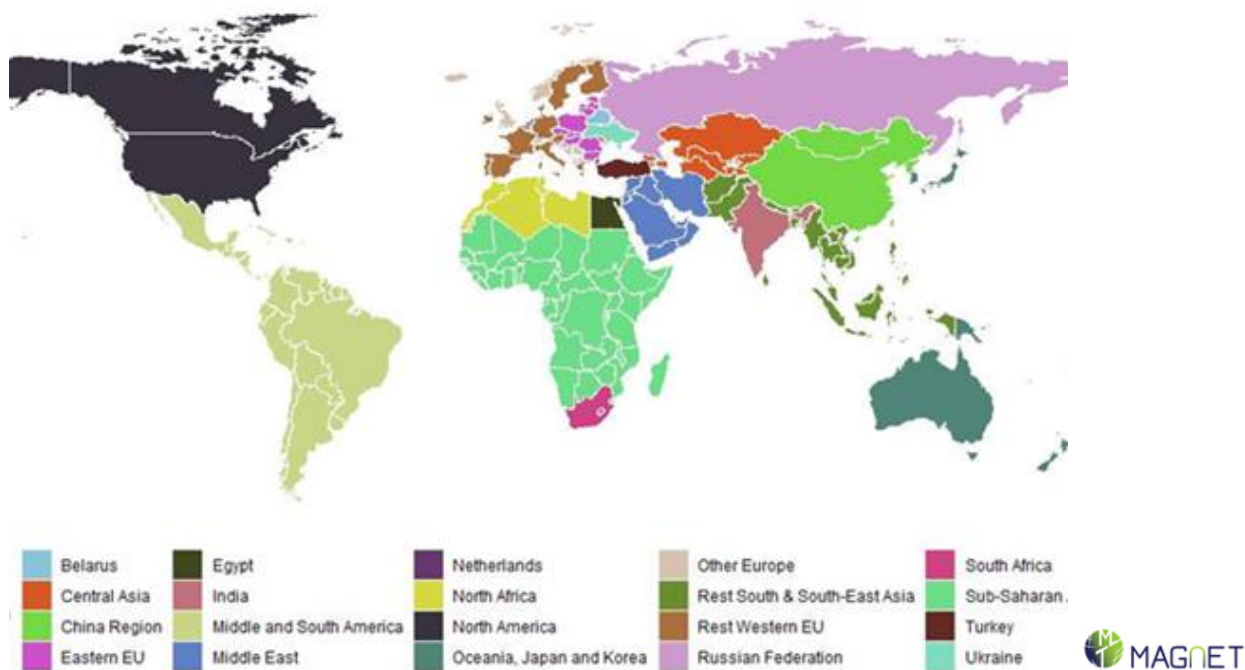


Figure 2.1 Regional aggregation of MAGNET model used within this study

Figure 2.1 shows the regional MAGNET aggregation used within this study (a more elaborated description is given in the Appendix). Twenty regions covering the whole world are distinguished with a focus on the Ukraine war impacts on food security. As key players Ukraine, Russia and Belarus are identified. Impacts are expected in neighbouring regions such as Eastern EU, Turkey, Middle East, Central Asia and in the China region. For food security reasons Turkey, Egypt, (rest of) North Africa, Middle East, Sub-Saharan Africa and Rest of South and South-east Asia are distinguished. Table A1.1 and Table A1.2 in the Appendix provide a detailed description of which countries belong to the regions specified above.

³ As the requested time frame is shorter than the normally considered adjustment period within this kind of analysis, the standard substitution elasticities between production factors are reduced by 50% relative to the level of the original GTAP and MAGNET elasticities.

For explanatory convenience, some countries and regions presented in Figure 2.1 have been combined into more aggregated regions which are used to show the results in the graphs. The more aggregated regions and which MAGNET regions they contain are described in Table 2.1.

Table 2.1 *Regional aggregation used in world market graphs*

Aggregated regions	Model regions
Ukraine	Ukraine
Russia	Russia
EU	EU14, Eastern EU, Netherlands
Rest of Europe	Other Europe
Central Asia	Belarus, Central Asia, Turkey
North Africa	Egypt, Northern Africa
Rest Africa	Sub-Saharan Africa, South Africa
Rest South & South-East Asia	Rest South & South-East Asia
Asia & Oceania	Asia & Oceania
North America	North America
Middle and South America	Middle and South America
World	World

The sectoral aggregation includes the key crops for Ukraine and Russia such as wheat, other cereal grains (includes maize) and oilseeds. Oilseeds includes all varieties of oilseeds and is therefore a mixture for products where Ukraine and Russia are important such as rape and sunflower seeds, and some where this is not the case (e.g. soybean). In addition to these key crops the aggregation includes rice, vegetables, sugar crops, rice, other crops. Cattle, pork, poultry and other cattle and related processed products are separated within the livestock sectors. Another 50 sectors cover the rest of the economy including the energy sectors (coal, gas, oil) and fertiliser sectors (N, P and K). A detailed description of all sectors is given in Table A1.3 in the Appendix.

3 Scenario set-up

General principles

We estimate the impacts of the Russian-Ukraine conflict on international food markets by incorporating assumptions into a scenario in which we match some already known consequences of the conflict such as trade restrictions and sanctions. We build up the scenario in three blocks, in which we distinguish between 1) the effects of the conflict in Ukraine that arise from a trade stop between Ukraine on the one hand and Russia and Belarus on the other, extended with lower GDP and reduced agricultural production in Ukraine, and increasing trade cost for exports from the country 2) economic impacts of sanctions against Russia, resulting in lower GDP of and reduced trade by Russia in cereals and oilseeds, and 3) effects of a global energy price increase. As an extension of the three scenario components, in a (fourth) sensitivity scenario we explore the consequences of larger substitution possibilities in the model, simulating longer-term market adjustments. In this way, it can be shown which part of the storyline will have the greatest impact on global food market prices and food security indicators. The three scenario building blocks are the following.

1. *Impacts in Ukraine on GDP, agricultural production, and trade costs*

1a *Trade stop between Ukraine and Russia & Belarus*

A starting point is the assumption that in the coming years there will be no or only very limited trade between Ukraine on the one hand, and Russia and Belarus on the other, due to current hostilities and the mutual animosity between the countries that may persist for years to come.

1b *Production and GDP loss within Ukraine*

The war in Ukraine displaced a third of the country's population from their homes, of which approximately 4m (around 10% of the total population) fled abroad. In addition, many buildings and an important part of the infrastructure were damaged. Economic activities continue to come to a standstill in large parts of the country due to the constant threat of war for the time being. This has major consequences for the country's output levels and income-generating opportunities. **We assume the direct economic impacts of the conflict are caused by a 30% decline in labour and capital endowments**, which results in a significant GDP fall.

Agricultural production in Ukraine suffers in the short term from the war situation due to insecurity in the countryside, lack of inputs and working capital, and a shortage of labour. By 1 April, analysts estimate the number of areas with spring-planted grains and oilseeds will be so much less than in 2021 that the estimated total production of grains and oilseeds in 2022 is expected to be 50% lower than the record level of the previous season (APK-Inform). Due to war damage and expected ongoing difficulties in obtaining sufficient inputs, it is likely that agricultural production will continue to be significantly less than in 'normal' years for the time being. **We simulate the agricultural production fall by assuming an overall 50% decrease in crop yields** (production/hectare) during the simulation period, which will reduce Ukraine's exportable grain and oilseeds surpluses.

1c *Additional trade Cost Ukraine*

Exports are further reduced by assumed **additional trade costs of 20%** due to infrastructural damages, harbour blockages and high-risk insurance costs of transported goods.

2. *Impacts in Russia on GDP and agricultural exports*

2a *Russian trade sanctions*

The EU, UK, USA, Canada and several other countries have denied Russia access to the international payment system SWIFT and international bank loans. Moreover, Russian banks' assets are being frozen in the US, UK, EU and Canada (BBC, 6 April 2022). These financial sanctions will affect the country's investments, exchange rate and, consequently, imports. In addition, restrictions on technology exports (particularly in the energy,

telecom, aerospace, and defence industries) have been imposed by the EU, US and some other countries that have macroeconomic implications.

2b GDP reduction Russia

Following the expectations of various international organisations **we assume Russian GDP to fall by 10%**.⁴

2c Export reduction agricultural Russian exports

Russian agricultural production is assumed to be not directly affected by foreign sanctions related to the war with Ukraine, but restrictions on technology imports and services, in addition to financial restrictions and the withdrawal of Western-based multinationals active in the food industries in Russia can affect agricultural productivity. Lower productivity leads to less production and exportable surplus, which can affect international markets for agricultural commodities. In addition, news items in March indicate Russia considers export quota of grains and sunflower oil for 2022 to keep domestic prices stable. Moreover, there are signs that exports of wheat and oilseeds (meal and oil) face logistic problems and are paralysed due to high insurance risks and international payments restrictions (APK-Inform, 21 March 2022). We assume these factors will lead to a **reduced Russian export of wheat and oilseeds by 50% each**.

3. Impacts on global energy prices

Since Russia is a key player in the global energy market, the conflict and associated (threats of) sanctions may affect the energy markets significantly. The many market uncertainties make price projections extremely difficult – see Box 1 for some recent fossil fuel price developments. We assume **international energy prices will increase by 20%**, caused by the disruption in the relationship with Russia, and the consequences of sanctions on technology exports and financial restrictions, which put pressure on security of supply on the medium-term (IEA, 2022).⁵ The USA and the UK have announced a ban on importing Russian oil and gas to be implemented by the end of 2022. The EU relies on Russia for 40% of its gas and has not targeted Russian energy exports (yet).

Fertiliser prices are affected by energy prices and are endogenously determined by the model projection.⁶

⁴ For instance, OECD Economic Outlook estimations of the impact of the war in Ukraine build on simulations that incorporate ex-ante domestic demand declines of 15% in Russia and 40% in Ukraine, leading to the expectation that GDP declines are likely in the same order of magnitude. Shocks that are assumed to last for at least one year (OECD, 2022). In their updated (in April) 2022 Outlooks, IMF and World Bank expect GDP to decline in both countries in the same range or even a bit stronger (IMF, 2022; World Bank, 2022).

⁵ IEA reports that Russian oil continues to flow to Europe, which is mostly governed by term deals and being delivered by trade agreements made before the invasion. But the agency states that 'new business has all but dried up. Buyers are avoiding Russian crude because of concerns about shipping safety, insurance and sanctions. Urals crude from Russia is being offered at record discounts, but uptake is limited so far, with Asian oil importers for the most part sticking to traditional suppliers in the Middle East, Latin America and Africa'. Moreover, the organisation claims that 'The prospect of large-scale disruptions to Russian oil production is threatening to create a global oil supply shock. We estimate that from April, 3 mb/d of Russian oil output could be shut in as sanctions take hold and buyers shun exports. OPEC+ is, for now, sticking to its agreement to increase supply by modest monthly amounts. Only Saudi Arabia and the UAE hold substantial spare capacity that could immediately help to offset a Russian shortfall' (<https://www.iea.org/reports/oil-market-report-march-2022>)

⁶ There are also indications that Russia considers a ban on the export of fertilisers: early February Russia announced a temporarily restriction on export ammonium nitrate, for two months, to 1 April 2022 (<https://www.agroberichtenbuitenland.nl/actueel/nieuws/2022/02/09/export-of-ammonium-nitrate-from-russia-is-restricted>). RF exports about 4m tonnes of ammonium nitrate, which is about 40% of the world's ammonium nitrate exports. Russia also accounts for 14% of the global urea market and 21% of the potash market. Russia is considering more trade bans such as restrictions on Russian exports of telecoms, medical, vehicle, agricultural, and electrical equipment, as well as some forestry products such as timber to 'unfriendly countries' among which are the EU and the US ([Russia hits back at Western sanctions with export bans - BBC News](#)). Our scenarios do not include Russian export and/or import bans.

Text box: Fossil fuel price developments

Oil prices (Brent futures prices, considered as benchmark for many other oil types and other [fossil] fuels and energy sources) have been stable at around USD 60 per barrel (Bbl) during the period 2017-early 2020. Prices fell to a record low in April 2020 (USD 21/Bbl, due to the Covid crisis) but since then an upward trend brought prices to USD 80/Bbl at the end of December 2021. Oil prices continued to increase in Jan-Feb 2022 to reach USD 100/Bbl on 25 February and have been volatile but went up to USD 127 on 8 March before tumbling more than 20% to touch below USD 100/Bbl on 16 March 16 and went up again to reach USD 120/Bbl on 23-25 March. Energy prices are determined by both market developments and political decisions (e.g. OPEC). Volatile fossil fuel prices make forecasts very uncertain.⁷

In the fourth sensitivity scenario we simulate a longer period (3-5 years) by increasing the substitution possibilities within production that are feasible in the longer period.⁸

All the scenarios build upon each other, by including all elements of the previous scenario and at the end representing the whole impact. In this way we can assess the contribution of the various assumptions on the world markets and prices. The four scenarios, their components, their description, and implementation are given in Table 3.1.

Table 3.1 Scenario description, assumptions, and implementation

Scenario	Description of scenario	Shocks and assumptions
Ukraine impacts (Scen 1)	1a: Ukraine's trade halt with Russia and Belarus	Tariffs rise to reduce trade with 90% for all commodities
	1b: 1a + Ukraine's loss in production and GDP	Labour and capital fall 30%, land yields fall 50%, population falls 10%
	1c: 1b + Ukraine's additional transport cost with rest of world	Transport costs between Ukraine and rest of world rise 20%
Ukraine and Russia impacts (Scen 2)	2a: Scen 1 + US & EU trade sanctions against Russia.	US and EU tariffs rise 90% (or a converted %) for Russia for finance, aviation, water transport, energy, telecom, defence, iron & steel, high-end vehicle, fashion & art; in US for finance, fish & seafood, alcoholic beverage, non-industrial diamond, coal, oil, LNG; in EU for finance only.
	2b: 2a + Russia's loss in GDP	Real GDP in Russia falls 10%
	2c: 2b + Russia's reduced exports on grains and oilseeds.	Tariffs rise to reduce exports from Russia with 50% for wheat, other grains and oilseeds
Ukraine, Russia, energy price impacts (Scen 3)	Scen 2 + world energy prices rise	Prices rise 20% in the world for coal, oil, and gas
Ukraine, Russia, energy price impacts with higher substitution (Scen 4)	Scen 3 + A longer term mimicking reaction in trade and production by allowing more substitution possibilities.	Substitution elasticities increase by 25% between trade partners and 50% between primary production factors in all countries to the original GTAP\MAGNET values.

⁷ For instance, the US Energy Information Agency projects a decline of Brent oil prices up to USD 89/Bbl in 2023, based on the expectation that global oil inventories will build at an average rate of 0.5m Bbl/d from 2Q22 through the end of 2023, despite an expected reduction of Russia's oil production. The agency stresses its price forecast is highly uncertain. (<https://www.eia.gov/outlooks/steo/>)

⁸ Substitution possibilities elasticities between production factors are increased by a factor two to the level of the original GTAP and MAGNET elasticities.

4 Scenario impacts

We report on the impacts of the scenarios on GDP, agricultural production, exports and imports, world market prices and two food security indicators: food availability and food access. Results are presented for Ukraine, Russia, several regions, of which the aggregation is shown in Table 2.1, and several developing countries that are highly dependent on grain imports from Ukraine, Russia, or both.

GDP effects are presented in two panels in Figure 4.1 because country effects differ in scale. The top panel shows GDP effects in Ukraine and Russia. Ukraine's GDP decline (about 30%) is due to the (assumed) strong decline in the labour and capital endowments, which holds for all three scenarios. Russia's GDP decline (about 10%) is based on our interpretation of IMF expectations about the country's potential recession, emerging in scenario 2 and 3.

Outside Ukraine and Russia, GDP impacts are limited, with strongest impacts on 'Central Asia' of -0.8%. The assumed increase of energy prices (Ukraine, Russia, energy prices impact, scenario 3) has a strong GDP impact in all regions. For example, for the EU GDP declines by 0.4% in the energy price scenario, whereas GDP effects are about 0.0% in scenario 1 (Ukraine impacts) and scenario 2 (Ukraine+Russia impacts).

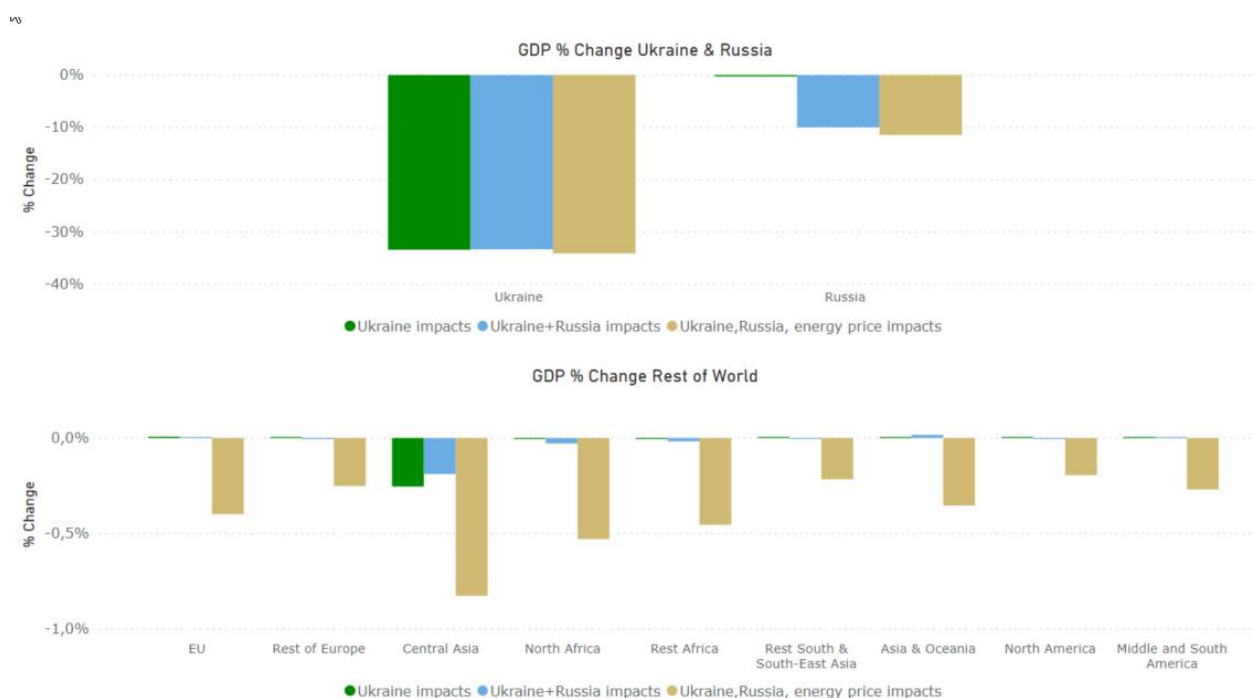


Figure 4.1 GDP developments (% change)

Presented *production effects* show percentage changes in wheat, other grains (e.g. maize) and oilseeds volumes in the Ukraine Russia energy price impact scenario. Figure 4.2 (upper panel) shows a strong production decline of these three commodities in Ukraine due to, for example, the assumed overall 50% yield decline and higher transport and energy costs, which results in a more than 55% production fall in wheat. Wheat production declines strongly in Russia as well, caused by lower export demand as Russian exports become less competitive due to higher trade costs. As production declines in Ukraine and Russia result in less exports of cereals and oilseeds, international prices for these commodities increase (see Figure 4.3). Higher international prices transmit towards domestic markets and subsequently, production in other countries than Ukraine and Russia is expected to increase. Note that the percentage increase of wheat production in (North

and Rest of) Africa and Middle East is significant (upper panel Figure 4.2), but in absolute volume terms the expansion is modest as wheat production is minor compared to other crops (lower panel of Figure 4.2).

In the Ukraine-Russia-energy price impact scenario 3 world production of wheat and other grains is more or less stable (+0.1%), but oilseeds increases by 3% due to additional non-food demand (e.g. biofuels). The overall effect is spelled out in more detail in the Appendix. Figure A2.1 shows that world production in scenario 1 is slightly negative for other cereal grains (-0.2%) and oilseeds (-0.3%), and stable for wheat. In scenario 2 results are a bit more negative for other cereal grains and oilseeds and a bit more positive for wheat. The higher price increase for wheat than for other crops shifts land use and production a bit to wheat in other regions of the world (see Figure 4.3).

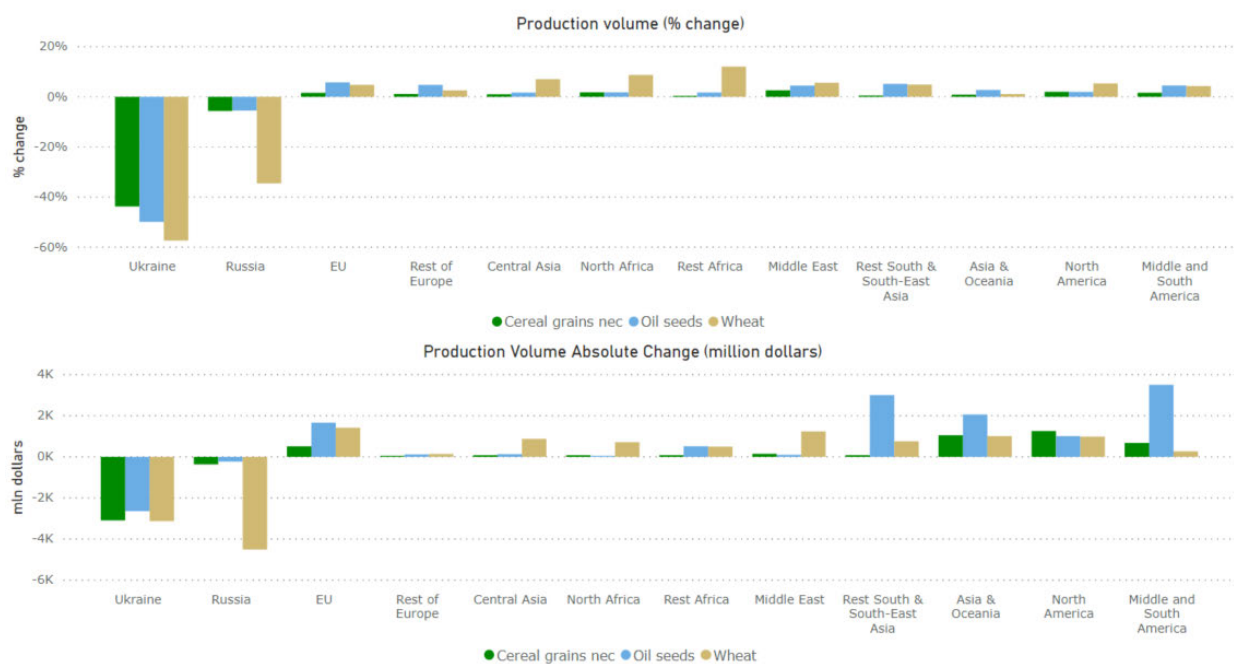


Figure 4.2 Production volume developments (% change in upper panel; absolute change (USD million) in lower panel) for wheat, oilseeds, and other cereals in the Ukraine-Russia-energy price impact scenario (scenario 3)

In Appendix 2 production effects are also shown when only Ukraine impacts (scenario 1) and Ukraine-Russia impacts (scenario 2) are applied. If only Ukraine impacts (scenario 1) are applied, then Figure A2.1 shows that different regions slightly increase production. Wheat production is expanding in Asia and Oceania, North America, Rest of South, Europe, Middle East, Southeast Asia, and also a little in Russia. For other grains, production expands especially in Europe, Asia, and Oceania, and Middle and South America. Oilseed production expands especially in Middle and South America. Figure A2.2 shows the impacts of the Ukraine-Russia scenario (scenario 2) in which wheat production in Russia in particular is negatively affected and production increases mainly in Central Asia and the regions that also do so in scenario 1.

International price impacts for primary products show a significant rise of wheat, other cereals (including maize) and oilseeds prices, of respectively 9.9%, 9.5% and 6.5% (Figure 4.3). This is due to several reasons:

- Ukraine’s production fall in Ukraine impacts scenario (scenario 1, blue bars in Figure 4.2) leads to a significant decline of the country’s exports (see Figure 4.4) of wheat and other grains (i.e. maize), which impact world markets through its weighty global role of exporter of these commodities. Due to this decrease in Ukraine production and exports of wheat and other grains, world prices fall by, respectively, 2% and 4%. Oilseeds prices increase slightly less (1%) as Ukraine’s share in world exports (of this product category) is less than for wheat and maize. Hereby, we have to remark that this is an aggregated category including key products for Ukraine such as sunflower seeds and oilseeds and less important products for Ukraine as soybean. The price effects for a specific product like sunflower seeds where Ukraine has a high market share will be higher.

- Russia's decline of wheat, other grains, and oilseeds exports (difference between blue and green bars in Figure 4.2) further exacerbates the impact on world market prices. Due to the Russia related shocks (scenario 2) wheat world prices are rising by 4% and other grains world prices by 2%.
- In both scenarios the prices of other crops increase as well due to higher production factor prices as the production of wheat and other grains in other countries (than Ukraine and Russia) expand. Especially land prices rise due to increased cereal production and demand for land.
- Increased energy prices (following the assumed 20% higher for coal, oil, and gas) in scenario 3 have a significant impact on food prices; this scenario 3 adds 3-4%-points to global price increases for cereals and oilseeds. This is caused by higher energy and fertiliser cost in food production (production cost effect) and due to increased demand for biobased products (demand effect) for energy purposes, as the competitiveness of bio-based substitutes increases due to higher fossil energy prices.
- Fertiliser prices increase especially due to higher energy prices in scenario 3:
 - Nitrogen prices increase a lot as the production process uses a lot of gas.
 - When gas prices increase by 20%, the fertiliser (nitrogen) prices go up by almost 14%. The increase in phosphorous and potassium prices is more modest with about 4% in scenario 3.

Fertiliser price effects show to be strongly affected by our assumed energy price increase (implemented as an exogenous shock to the model). Energy prices for gas, oil, coal, and electricity are closely related.

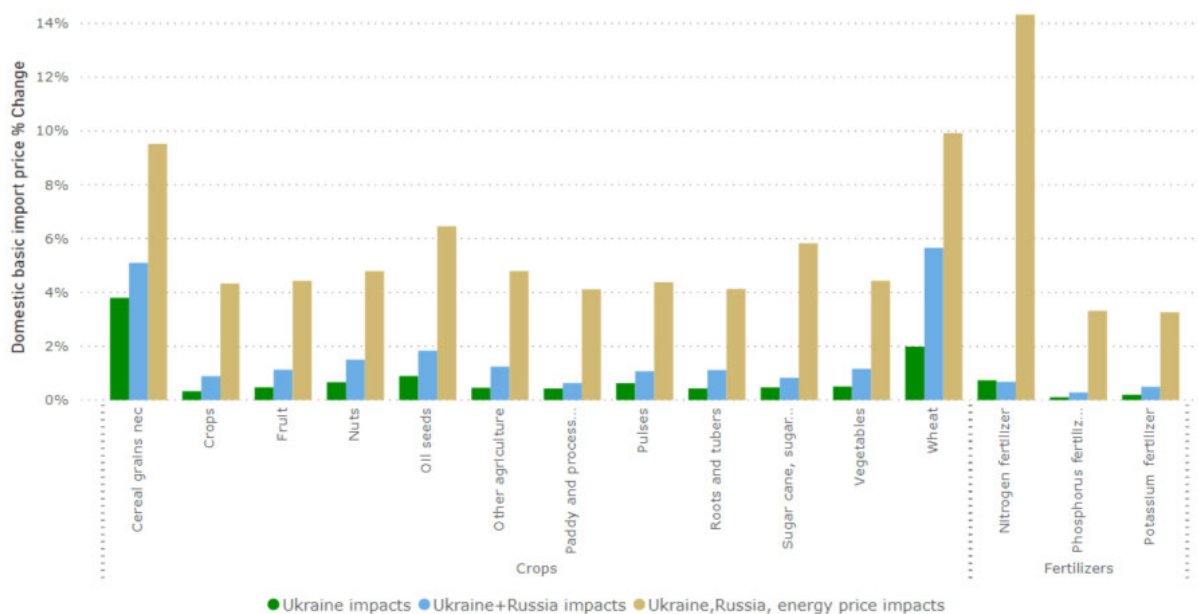


Figure 4.3 Development of world crop and fertiliser prices (% change)

Figure A2.3 shows more disaggregated impacts of each of the different shocks as described in Chapter 3. Comparison of the various scenarios shows that the production decline in Ukraine (scenario 1b) and the energy price increase (scenario 3) have most impacts on world market prices. Export reduction of cereals and oilseeds from Russia (scenario 2) adds 2.5 percentage points to the world price increase of wheat and 1.5 percentage points to the world price of other cereal grains. A trade stop between Ukraine and Russia\Belarus (scenario 1a) and increased trade cost for Ukraine exports (scenario 1) have negligible impacts on global crop prices. Western sanctions restricting exports to Russia (scenario 2) also have little effect on global food market prices, which is understandable as these sanctions are targeted towards other sectors than primary agriculture.

Import and export impacts (for wheat, other cereal grains and oilseeds) in the Ukraine, Russia price impacts scenario 3 show the steep decline of exports of these commodities from Ukraine (e.g., wheat exports decline by 64% in volume terms; or USD 2.6bn in value terms; all other commodities show high percentage changes and high value changes as well). Also, Russian exports significantly decline. Figure 4.4 shows trade effects

for Middle East, South and South-East Asia, Egypt and Turkey, as major cereal importing regions/countries with great dependency on imports from Ukraine and Russia. These countries show reduced wheat imports of 6%, 8%, 23% and 30% respectively. In absolute terms the story is dominated by wheat and other cereal grains, and to a lesser extent by oilseeds. Substantial changes occur for Ukraine (mainly less export of other cereals and wheat) and for Russia (especially less wheat exports). The impacts on other countries/regions in the world not shown in this figure are dominated by wheat imports falling. Figure A2.4 and Figure A2.5 show these trade effects for the Ukraine impacts (scenario 1) and the Ukraine-Russia impacts (scenario 2) to identify the impacts of the Ukraine and Russia related shocks separately. The Ukraine impacts scenario (Figure A2.4) shows that Russia increases especially their wheat exports covering about 9% of reduced exports of Ukraine.

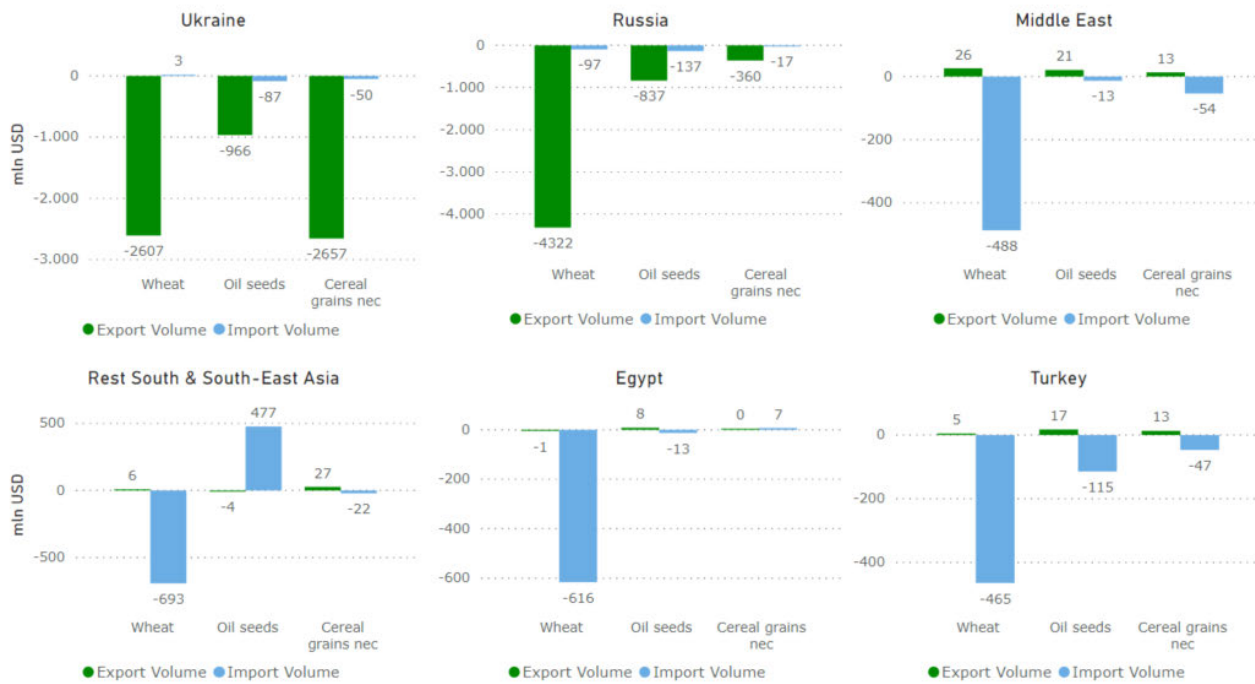


Figure 4.4 Changes in exports and import of wheat, other cereals and oilseeds, scenario 3 (absolute change in million USD)

The results presented in Figure 4.4 are the net effect of declining imports from Ukraine and Russia, as well as increases in imports from other sources. Figure 4.5 then shows which trade shifts are taking place for Turkey, Egypt and some regions. In contrast to a decrease in imports of 'other grains' (mainly maize) from Ukraine and Russia, there is more import in the selected countries/regions from Central and South America and North America. The same goes for oilseeds. In the wheat trade, imports from Ukraine and Russia are mainly replaced by an increase in imports from the EU, North America and Asia/Oceania.

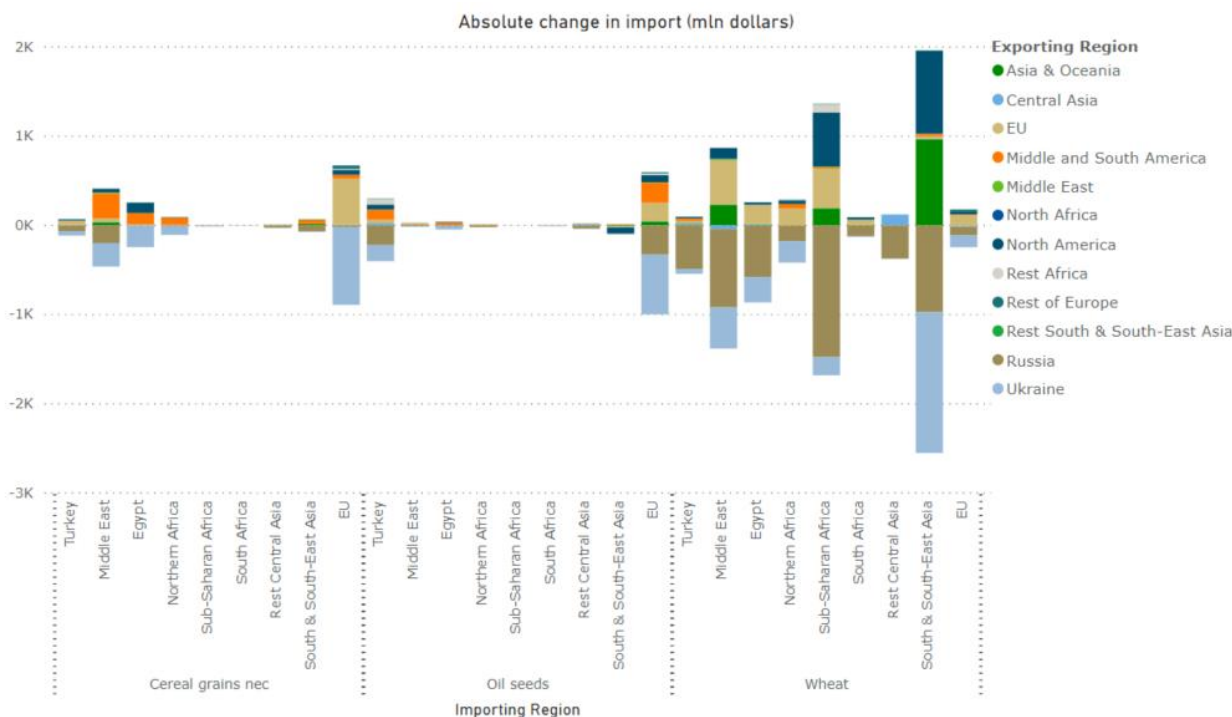


Figure 4.5 Import shifts in selected countries and regions, scenario 2 (in million USD)

Food security

A widely accepted definition of food security is 'Food security exists when all people, at all times, have physical and economic access to sufficient, safe and nutritious food that meets their dietary needs and food preferences for an active and healthy life' (FAO1998). The FAO definition consists of four key dimensions: availability (i.e., sufficient quantities of food; 'sufficient'), access (i.e. adequate resources to obtain food; 'access'), utilisation (i.e., 'nutritious and safe' diets, and clean water) and stability (i.e., the temporal dimension of the other three dimensions; 'at all times'). In this study food security is measured by the food availability and food access dimensions. Food utilisation which looks more into nutritious food and food stability are beyond the scope of this study.

- Food availability is proxied by the 'food available for consumption' indicator, which is measured in kcal per capita per day, and is a well-known indicator of food availability (e.g., Nelson et al., 2013, von Lampe et al., 2014, Van Meijl et al., 2021a, 2021b). It includes all domestically produced and imported food available for consumption at household level.
- Food access relates to people's food purchasing power and therefore to food prices, dietary patterns, and income developments (Lele et al., 2016). First, we use a 'food purchasing power' indicator, by relating price developments of a specific food consumption basket to income developments of a particular income group.
- Food Purchasing Power (% change) = % change in income of specific income group minus % change in the price of a food basket

For the food basket, we use consumption of cereals (including paddy rice, wheat and 'other grains') as a proxy for the diet of people potentially in poverty, as rice is an important food component for poor people in Asia, while grains are important in Africa. As cereals are the hardest hit in the scenarios this is the worst case scenario and we include in the description some references to a diet of all kind of primary products (average diet in a country/region) and an average diet of primary and food products. The prices of these diets are given in Figure A2.6 and Figure A2.7. As world cereal prices rise by about 10% (see Figure 4.6 in scenario 3) the prices for, for instance, Turkey increase by about 5.5% for all crops, 2.5% for livestock products and almost 3% for food products. In the EU we see similar price developments. We use changes in the wages of unskilled (production) workers in the cereals sector as a proxy for the income component of poor people. The wage of unskilled people in the cereal sector is fairly representative for wages in all agricultural sectors. The development of unskilled wages in the rest of the economy is about 1% lower in most countries. The reason for this is that especially agricultural production benefits in other countries and

takes some resources from other sectors. Since we segmented factor markets between agriculture and non-agriculture in our model, wages in agricultural sectors increase a bit more than in the other sectors of economy as labour cannot move very easily between sectors due to different knowledge requirements (Van Meijl et al., 2006).

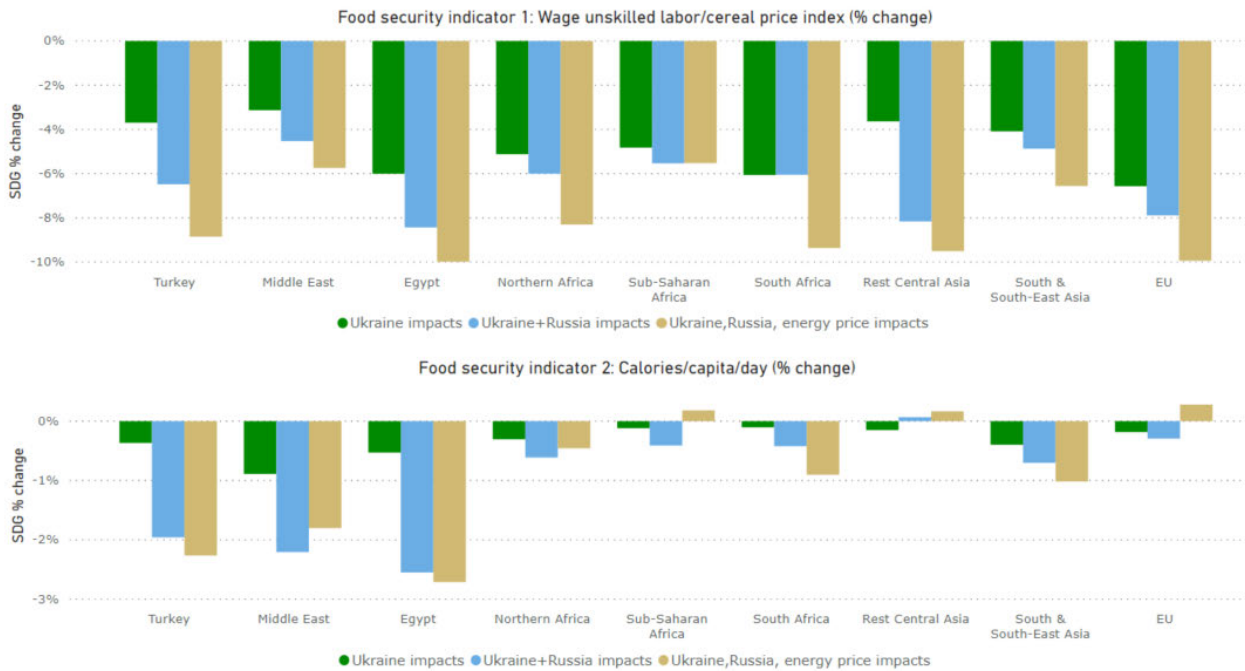


Figure 4.6 Indicators for food availability (upper panel) and food access (lower panel), Scenario 3

The food availability indicator (upper panel of Figure 4.6) shows that food availability decreases in all LDCs due to supply effects of the war in Ukraine and Russia, which is more strongly affected by the Russian export reduction than by less exports from Ukraine (compare the green with the blue bar in the figure). Russian export reduction on top of the reduced production and exports of Ukraine significantly reduces substitution and adjustment possibilities for importing countries, as it restricts two major grains exporters. This implies that Russian exports cannot even partly compensate for the reduced Ukrainian exports as it itself will decline, leaving all other regions in the world to continue supplying the import markets. This has a larger impact on food availability. The impact is highest in Egypt, Turkey and Middle East as these countries are highly dependent on imports from Ukraine and Russia. Lower Russian exports in addition to lower exports by Ukraine also reduce food availability in the African and Asian regions presented. Yet, the impact of less grains imports on food availability is modest in the regions included as the availability of calories per capita per day is also determined by the availability by domestic production of all other commodities and additional imports from other regions. Also, the 2-year time span leads to a supply response in all other countries around the world for all agricultural commodities; as Figure 4.2 shows, this is the case in all African and Asian regions for cereals and oilseeds. Food availability in Europe has changed marginally. In the Ukraine impacts scenario food availability declines by 0.2% and in the Ukraine + Russia impact scenario by 0.3%.

Food access for poor people is determined by cereal prices as they spend a substantial part of their income on this commodity (definitions included at beginning of this chapter). Food access decreases more substantially than food availability with about 8% to 10% lower wage/food price ratio in most LDC regions, caused by Ukraine impacts (-4% to -6%), Russia-related shocks (-1% to -2%) and energy prices (-2%; Figure 4.6, upper panel). The higher cereal food prices (Figure 4.3) are the main drivers for substantial food access decline as these are the key ingredient of the diet of poor people and therefore have a major impact on food access. World prices for wheat and other cereal grains increase by about 10% and this is directly translated to reduced food access as the wages of unskilled people change less due to the scenario assumptions. If consumers have a more varied diet than just cereals, which are affected most, food access impacts are less severe. Figure A2.7 shows that prices of a more varied crop diet increase by 4% to 7% and

an average food diet by 2% to 4% for the selected developing countries. As unskilled wages increase slightly the food access indicator also decreases relative to the case with a pure cereals diet. For the EU, food prices increase by 5% for crops and 2% for food and given the relatively low share of income spent on food this should not be a problem for the average citizen. Only, for some low-level income groups in the EU, the higher food prices can reduce access to food.

From a food security perspective, we can conclude that there is enough food on the global level, but higher food prices could become a problem for a part of the population that has a low income and spends a large part of their food on cereals. For some countries highly dependent on imports of Ukrainian and Russian cereals like Egypt, Turkey and Middle East, food availability will come under some pressure. Food security impacts are very minor for the EU, as food availability is not a problem in the EU and in general people spend a small part on cereal-based food products. However, for some low-level income groups, higher food prices reduce access to food.

Sensitivity scenario with higher substitution elasticities (Scenario 4)

In the fourth sensitivity scenario the substitution elasticities between production factors are doubled to the level of the original GTAP and MAGNET elasticities to introduce an element of a longer run impact scenario, assuming more substitution options are possible. In general all impacts are a bit less severe due to these additional substitution possibilities. The decomposition for world crop prices (Figure A2.3, compare scenario 3 and scenario 4) shows that the higher substitution possibilities cause wheat and other cereals world prices to increase by 1% and 1.5% less respectively. The impacts is somewhat smaller for the other commodities but all world market prices increase slightly less than in scenario 3..

5 Further explanation of the consequences of the war in Ukraine for low-income countries highly dependent on cereal imports

In this chapter we examine the grain import dependency of ten low-income countries, which are among the major wheat importing countries of the world, their dependence on imports of wheat from Ukraine and Russia and the possible alternatives for these countries to deal with the disruption in grain imports from Ukraine and/or Russia.

Import volumes in themselves mean little but must be interpreted in relation to own production and use to be able to indicate a country's dependence on the international market. Table 5.1 shows wheat imports and self-sufficiency rates (SSR) for the ten countries considered. High SSRs indicate that a country can meet domestic needs with its own production. This is the case, for example, for Ethiopia and Pakistan, while this applies to a lesser extent to Turkey (two-thirds of the need is covered by own production) and Egypt (only half). The other countries in the list are highly dependent on imports for domestic wheat consumption.

Table 5.1 *Wheat import volumes and self-sufficiency rates (SSRs) of selected countries (2020 data)*

	imports (m tonnes)	SSR (%)
Bangladesh	6	14.6
Egypt	9	49.9
Ethiopia	1.1	83.9
Indonesia	10.3	0
Nigeria	5.9	0.9
Pakistan	2.5	91.1
Sudan	5	13
Tunisia	1.9	34.3
Turkey	9.7	68.3
Yemen	3	3.2

Source: FAO (Food and Agriculture Organization), FAOSTAT data.

Figure 5.1 shows the import dependency of the ten countries presented in Table 5.1 on wheat sourced from Ukraine and Russia. Five countries – Egypt, Pakistan, Sudan, Tunisia, and Turkey – rely heavily (>50%) on wheat imports from Ukraine and Russia. Ukraine is an important source of wheat imports of Egypt, Indonesia, Pakistan, and Tunisia (>20%). Russia is the major source of wheat imports for Egypt, Pakistan, Sudan, and Turkey. Figure 5.1 also shows that Bangladesh, Ethiopia, Indonesia, Nigeria, and Yemen source the majority of their wheat imports from other countries than Ukraine and/or Russia (such as from Canada, USA and/or EU, from Romania). These countries have more diversified sourcing of their imports and established trade relationships with suppliers from North America and Europe which can help to cushion a sharp drop in the supply from Ukraine and Russia.

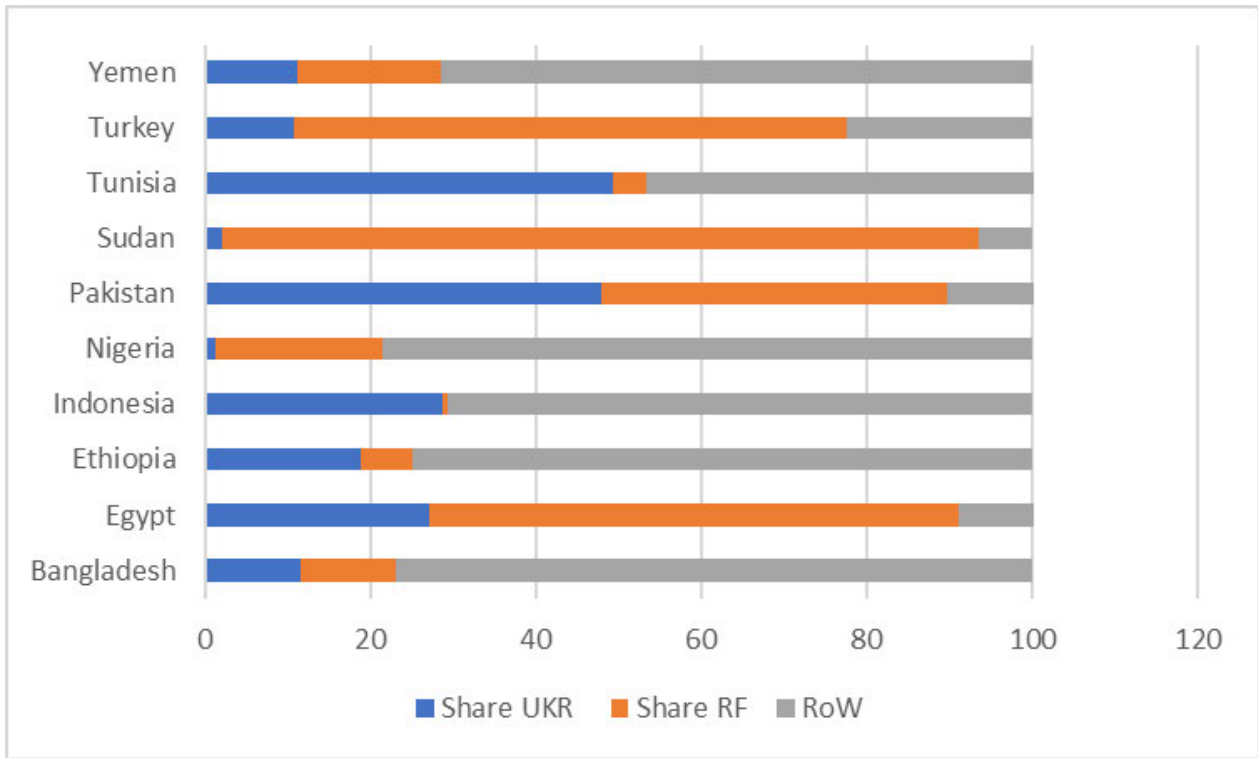


Figure 5.1 Shares of Ukraine and Russia in total wheat imports of selected countries

Due to their strong orientation towards Russian and Ukrainian grain to cover the import requirement, several countries presented in Figure 5.1 will experience major consequences of a decline in the supply from those countries. In Egypt, for instance, the consequences of a lower supply on the world market and consequently higher import prices are great because bread is a basic product for the Egyptians: the average consumption is very high (at 200 kg per person per year) due to its low price as a result of government subsidies. In Turkey, where government subsidies on bread have been used for decades, bread consumption per person is even slightly higher than in Egypt. In Sudan wheat consumption has increased sharply in the last 15 to 20 years due to population growth and changing consumption preferences. Wheat is mainly imported from Russia; own production only covers 15% of own needs. The government heavily subsidised bread consumption, but cut these subsidies (including fuel) in summer 2021, which was followed by political protests. Rising wheat prices exacerbate tensions in a country that has been coping with high domestic inflation, a depreciating currency and low productivity for several years now (Dorosh, 2021). Due to the regular devaluations of their currencies against the dollar in recent years, the costs of imports (including wheat but also other food products) for all three countries have increased continuously in recent years.⁹ In addition, the average Egyptian, Turk and Sudanese spends around 30-40% of income on food; if food prices rise due to more expensive imports, this contributes significantly to rising costs of living in these countries.

The possibilities to expand their own wheat production are limited in countries such as Turkey, Egypt, Pakistan, Sudan, and Tunisia due to the often short and (too) dry growing seasons and the limited water availability in these countries. Irrigation cultivation, preferably in combination with drought-resistant seeds, can boost production (e.g., Atar, 2018; Sadok et al., 2021; FAO, 2013), but requires quite a bit of investment that, if made at all, may only contribute to a greater degree of self-sufficiency in the longer term. The consequence is that these countries will remain dependent on imports, at least for some time, and that the price fluctuations that occur on international markets will feed through to domestic food prices.

Our estimates of the world market price effects of the war in Ukraine are 10% for wheat in the medium term. That does not seem like a significant increase, compared to price increases that occurred in the last few months. The recent fast rise in wheat prices in some countries is due to promised deliveries from Ukraine and Russia not taking place and the fear of further disruptions, including, as is often the case in uncertain

⁹ For example, the wheat price in Turkey doubled in 2021 from TRY 2,500 to 4,500/tonne due to lower own production as a result of drought, but also mainly due to the devaluation of the Turkish currency (<https://www.apk-inform.com/en/news/1524788>).

times, some commodity speculation such as the increase in the commodity futures trading can be inferred (AMIS, 2022; IPES-Food, 2022). This is a (very) short-term effect, which will gradually be dampened by changes in supply, including imports from alternative sources than from Ukraine and/or Russia. The countries that rely heavily on wheat and other food imports are especially vulnerable to price increases if at the same time their own currencies depreciate against the dollar - this is what has happened in recent years in Egypt, Tunisia, and Turkey (and all other countries in this overview except Indonesia and Nigeria, where the depreciations against the dollar have been limited in the past 5 years). Food security of import-dependent countries is therefore determined, in addition to price fluctuations on the world market, by the weak competitive position of a country, which is reflected in the development of its currency exchange rate.

6 Conclusions

- GDP impacts are significant in Ukraine and Russia yet limited in other countries. Outside Ukraine and Russia, GDP impacts are strongest in Central Asia, a region that contains countries which have strong trade relations with Russia. Scenario 3 in which also world energy prices rise, has the greatest impact on GDP decline in all regions.
- Production decline in Ukraine and Russia for other cereal grains and oilseeds will be partly compensated by additional supply by other regions who adjust production due to higher world market prices in scenario 1 and scenario 2. World production of wheat remains stable as the relatively high wheat prices attract resources from other sectors. In scenario 3, where high energy prices are included, world production of both wheat and other cereal grains become stable, but increases for oilseeds due to additional non-food demand (e.g. biofuels). In the Ukraine impacts scenario, wheat production expands in Asia and Oceania, North America, Rest of South, Europe, Middle East, Southeast Asia, and a little bit in Russia. For other grains production expands especially in Europe, Asia, and Oceania, and Middle and South America. Oilseed production expands especially Middle and South America. If Russian impacts are also included (scenario 2), wheat production in Russia in particular will be negatively affected and production will increase especially in Central Asia in addition to the regions where production also increases in the Ukraine impact scenario.
- World market prices increase significantly, especially for wheat and other cereal grains (about 10%) and oilseeds (6%). This is caused by supply impacts in Ukraine and Russia as well as higher energy prices. When running longer-term impacts (4-5 years), world market prices increase less.
- Wheat export reductions from Russia have a considerable add-on effect in addition to the fall in production in Ukraine and the two together push world prices up substantially.
- World prices of other agricultural crops than cereals and oilseeds increase by about 4%. Ukraine-Russia impacts cause 1% to 2% and higher energy prices add an additional 2%.
- Food access decreases with about 8% to 10% in most LDC regions, caused by Ukraine impacts (4% to 6%), Russia related shocks (+ 1% to 2%) and energy prices (+ 2%). The higher cereal food prices are the main drivers for substantial food access decline when the diet of poor people is mostly a cereal diet. World prices increases for wheat and other cereal grains are directly translated to reduced food access as the wages of unskilled people do not change a lot in our scenarios. If consumers have a more varied diet than cereals alone, which are affected most (a price increase of 10%), the impact on access to food is less severe as prices for a more varied crop diet increase by 4% to 7% and an average food diet by 2% to 4% for developing countries we looked at in our analysis.
- Food availability decreases in all LDCs due to supply restrictions in Ukraine and Russia. The impact is highest in Egypt, Turkey and Middle East as these regions are highly dependent on imports from Ukraine and Russia. Russian export reduction on top of Ukraine's reduced production and exports reduces substitution and adjustment possibilities for import-dependent countries a lot, with a larger impact on food availability in these countries.
- Egypt, Pakistan, Sudan, Tunisia, and Turkey rely heavily (>50%) on wheat imports from Ukraine and Russia, and have low self-sufficiency rates (except Pakistan) and limited possibilities to expand domestic production. These countries are vulnerable to price volatility in the global market, which is exacerbated by their weak currencies.
- From a food security perspective, we can conclude that there is enough food on the global level, but higher food prices could become a problem for a part of the population that has a low income and spends a large part of their food on cereals. For some countries highly dependent on imports of Ukrainian and Russian cereals like Egypt, Turkey and Middle East, food availability will come under some pressure. Food security impacts are very minor for the EU, as food availability is not a problem in the EU and in general people spend a small part on cereal-based food products. However, also in the EU for some low-level income groups, higher food prices reduce access to food.

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Appendix 1 Regional aggregation used in MAGNET model simulation

A1.1 Regional aggregation

Table A1.1 Model region mapping (MAGNET to GTAP)

Regional Aggregation	Description	Mapped GTAP region
OCJK	Oceania, Japan and Korea	aus, nzl, xoc, jpn, kor, xtw
CHR	China Region	chn, hkg, mng, twn, xea
RSEA	Rest South & South-East Asia	brn, khm, idn, lao, mys, phl, sgp, tha, vnm, xse, bgd, npl, pak, lka, xsa
IND	India	Ind
NAM	North America	can, usa, xna
MSA	Middle and South America	mex, arg, bol, bra, chl, col, ecu, pry, per, ury, ven, xsm, cri, gtm, hnd, nic, pan, slv, xca, dom, jam, pri, tto, xcb
EU14	Rest Western EU	aut, bel, dnk, fin, fra, deu, grc, irl, ita, lux, mlt, prt, esp, swe
EU12	Eastern EU	bgr, hrv, cyp, cze, est, hun, lva, ltu, pol, rou, svk, svn
NLE	Netherlands	nld
REU	Other Europe	gbr, che, nor, xef, alb, xer
BLR	Belarus	blr
RUS	Russian Federation	rus
UKR	Ukraine	ukr
FSU	Central Asia	xee, kaz, kgz, tjk, xsu, arm, aze, geo
ME	Middle East	bhr, irn, isr, jor, kwt, omn, qat, sau, are, xws
TUR	Turkey	tur
EGY	Egypt	egy
NAF	North Africa	mar, tun, xnf
SSA	Sub-Saharan Africa	ben, bfa, cmr, civ, gha, gin, nga, sen, tgo, xwf, xcf, xac, eth, ken, mdg, mwi, mus, moz, rwa, tza, uga, zmb, zwe, xec, bwa, nam, xsc
ZAF	South Africa	zaf

Table A1.2 Model region mapping (MAGNET to ISO)

Regional Aggregation	Description	Mapped ISO region
OCJK	Oceania, Japan and Korea	AUS, CXR, CCK, HMD, NFK, NZL, ASM, COK, FJI, PYF, GUM, KIR, MHL, FSM, NRU, NCL, NIU, MNP, PLW, PNG, PCN, WSM, SLB, TKL, TON, TUV, UMI, VUT, WLF, JPN, KOR, BVT, ATA, IOT, ATF
CHR	China Region	CHN, HKG, MNG, TWN, PRK, MAC
RSEA	Rest South & South-East Asia	BRN, KHM, IDN, LAO, MYS, PHL, SGP, THA, VNM, MMR, TLS, BGD, NPL, PAK, LKA, AFG, BTN, MDV
IND	India	IND
NAM	North America	CAN, USA, BMU, GRL, SPM
MSA	Middle and South America	MEX, ARG, BOL, BRA, CHL, COL, ECU, PRY, PER, URY, VEN, FLK, GUF, SGS, SUR, GUY, CRI, GTM, HND, NIC, PAN, SLV, BLZ, DOM, JAM, PRI, TTO, AIA, ATG, ABW, BHS, BRB, CYM, CUB, DMA, GRD, HTI, MSR, ANT, KNA, LCA, VCT, TCA, VGB, VIR
EU14	Rest Western EU	AUT, BEL, DNK, ALA, FIN, FRA, GLP, MTQ, REU, DEU, GRC, IRL, ITA, LUX, MLT, PRT, ESP, SWE
EU12	Eastern EU	BGR, HRV, CYP, CZE, EST, HUN, LVA, LTU, POL, ROU, SVK, SVN
NLE	Netherlands	NLD
REU	Other Europe	GBR, CHE, NOR, SJM, ISL, LIE, ALB, AND, BIH, FRO, GIB, GGY, VAT, IMN, JEY, MKD, MCO, MNE, SMR, SRB
BLR	Belarus	BLR
RUS	Russian Federation	RUS
UKR	Ukraine	UKR

Regional Aggregation	Description	Mapped ISO region
FSU	Central Asia	MDA, KAZ, KGZ, TJK, TKM, UZB, ARM, AZE, GEO
ME	Middle East	BHR, IRN, ISR, JOR, KWT, OMN, QAT, SAU, ARE, IRQ, LBN, PSE, SYR, YEM
TUR	Turkey	TUR
EGY	Egypt	EGY
NAF	North Africa	MAR, TUN, DZA, LBY, ESH
SSA	Sub-Saharan Africa	BEN, BFA, CMR, CIV, GHA, GIN, NGA, SEN, TGO, CPV, GMB, GNB, LBR, MLI, MRT, NER, SHN, SLE, CAF, TCD, COG, GNQ, GAB, STP, AGO, COD, ETH, KEN, MDG, MWI, MUS, MOZ, RWA, TZA, UGA, ZMB, ZWE, BDI, COM, DJI, ERI, MYT, SYC, SOM, SDN, SSD, BWA, NAM, LSO, SWZ
ZAF	South Africa	ZAF

A1.2 Commodity aggregation

Table A1.3 Commodity mapping

Commodity Aggregation	Description	Disaggregated MAGNET sets	Mapped GTAP sets
pdr	Paddy and processed rice	pdr	<-
wht	Wheat	wht	<-
grain	Cereal grains nec	gro	<-
veg	Vegetables	v_f, veg	<-
oils	Oil seeds	osd	<-
sug	Sugar cane, sugar beet	c_b	<-
oagr	Other agriculture	pfb	<-
crops	Crops nec	ocr	<-
othctl	sheep,goats,horses	ctl	<-
pigpls	Pig and other animal product	oap	<-
milk	Raw milk	rmk	<-
wol	Wool, silk-worm cocoons	wol	<-
frs	Forestry	frs	<-
wfish	Wild fish	fish	<-
coa	Coal	coa	<-
c_oil	Crude oil	oil	<-
gas	Gas	gas	<-
manu	Manufacturing	oxt, nmm, i_s, nfm, fmp, ele, eeq, ome, mvh, otn, omf, cns	<-
othcmt	Meat: other cattle,sheep,goats,horse	cmt	<-
othmt	Other meat product nec	omt	<-
vol	Vegetable oils and fats	vol	<-
dairy	Dairy products	mil	<-
pcr	Processed rice	pcr	<-
sugar	Sugar and molasses	sgr, mola	sgr, sgr
ofd	Processed food	ofd, b_t	<-
othind	Other industry	tex, wap, lea, lum, ppp	<-
petro	Petroleum, coal products	p_c, aviaf, ftavia	p_c, p_c, p_c
chm	Chemical products	chm, bioch	chm, chm
bph	Basic pharmaceutical products	bph, bioph	bph, bph
rpp	Rubber and plastic products	rpp, lsug, pe, pla, bfchem, biopl	rpp, sgr, chm, chm, chm, rpp
ely	Electricity	ely, edt	ely, ely
gas_dist	Gas manufacture, distribution	gdt	<-
ser	Services	wtr, trd, cmn, ofi, ins, rsa, obs, osg, edu, dwe	<-
foodserv	Food services	afs, ros, hht	<-

Commodity Aggregation	Description	Disaggregated MAGNET sets	Mapped GTAP sets
trans	Transport sector	otp, wtp, atp, whs	<-
fruit	Fruit	fruit	<-
nuts	Nuts	nuts	<-
roots	Roots and tubers	roots	<-
pulses	Pulses	pulses	<-
feed	Animal feed	feed	ofd
cvol	Crude vegetable oil	cvol	vol
biog	Biogasoline	biog, bf_g, bf_s, bf_m	p_c, p_c, p_c, p_c
biod	Biodiesel	biod, bf_o	p_c, p_c
fert_n	fertilizer nutrient n	fert_n	chm
fert_p	fertilizer nutrient p	fert_p	chm
fert_k	fertilizer nutrient k	fert_k	chm
ftfuel	ftfuel 2nd gen biofuel	ftfuel	p_c
eth	ethanol 2nd gen biofuels	eth	p_c
ely_c	electricity from coal	ely_c	ely
ely_g	electricity from gas	ely_g	ely
ely_n	electricity from nuclear	ely_n	ely
ely_h	electricity from hydro	ely_h	ely
ely_w	electricity from wind and solar	ely_w	ely
bioe	bioelectricity 2nd gen	bioe	ely
res	residue sector	res	p_c
pel	pellet sector	pel	lum
plan	Plantation	plan	frs
pltry	poultry sector	pltry	oap
pulmt	poultry meat	poum	omt
cattle	cattle sector	bfctl	ctl
bfmt	beef meat	BFCMT	cmt
aqcltr	Aquaculture	Diad, Fresh, Crust, Marin, Molus	fsh, fsh, fsh, fsh, fsh
fishp	Fish processing	Fishp	ofd
heat	heat	heat	ely
bioh	bioheat	bioh	ely
ddgs	Biogasoline byproduct	ddgs	p_c
oilcake	Oil cake byproduct of cvol used as animal feed	oilcake	vol
r_pdr	residue pdr	r_pdr	pdr
r_wht	residue wheat	r_wht	wht
r_gro	residue gro	r_gro	gro
r_osd	residue osd	r_osd	osd
r_ocr	residue ocr	r_ocr	ocr
r_frs	residue frs	r_frs	frs
r_veg	residues vegetables	r_v_f, r_veg	v_f, veg
fishm	fish meal	fishm	ofd
r_frt	residue fruits	r_frt	fruit
r_nuts	residue nuts	r_nuts	nuts
r_root	residue roots	r_root	roots
r_puls	residue pulses	r_puls	pulses

Appendix 2 Additional scenario results

Production



Figure A2.1 Production volume developments (% change in upper panel, absolute change (million US dollars) in lower panel) for wheat, oilseeds, and other cereals in the Ukraine impacts scenario (scenario 1)



Figure A2.2 Production volume developments (% change in upper panel, absolute change (million USD) in lower panel) for wheat, oilseeds, and other cereals in the Ukraine Russia impacts scenario (scenario 2)

World price decomposition

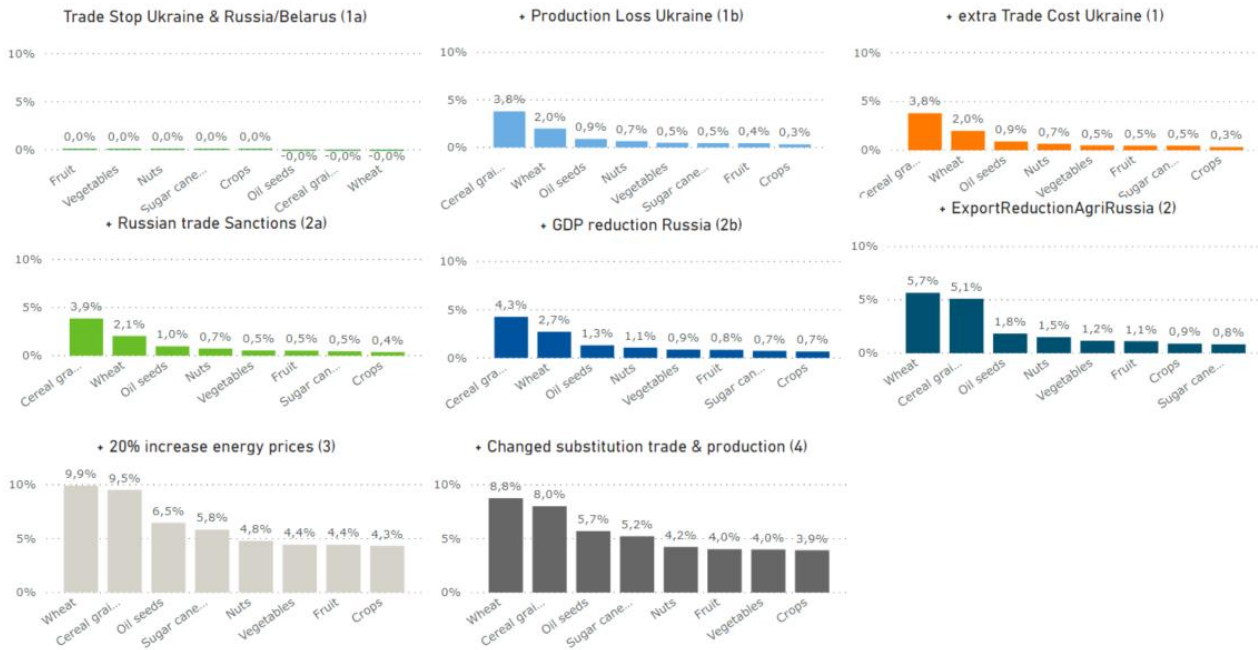


Figure A2.3 Decomposition: World price impact of agricultural commodities in each scenario (% change).

Trade in Ukraine impacts and Ukraine-Russia scenarios

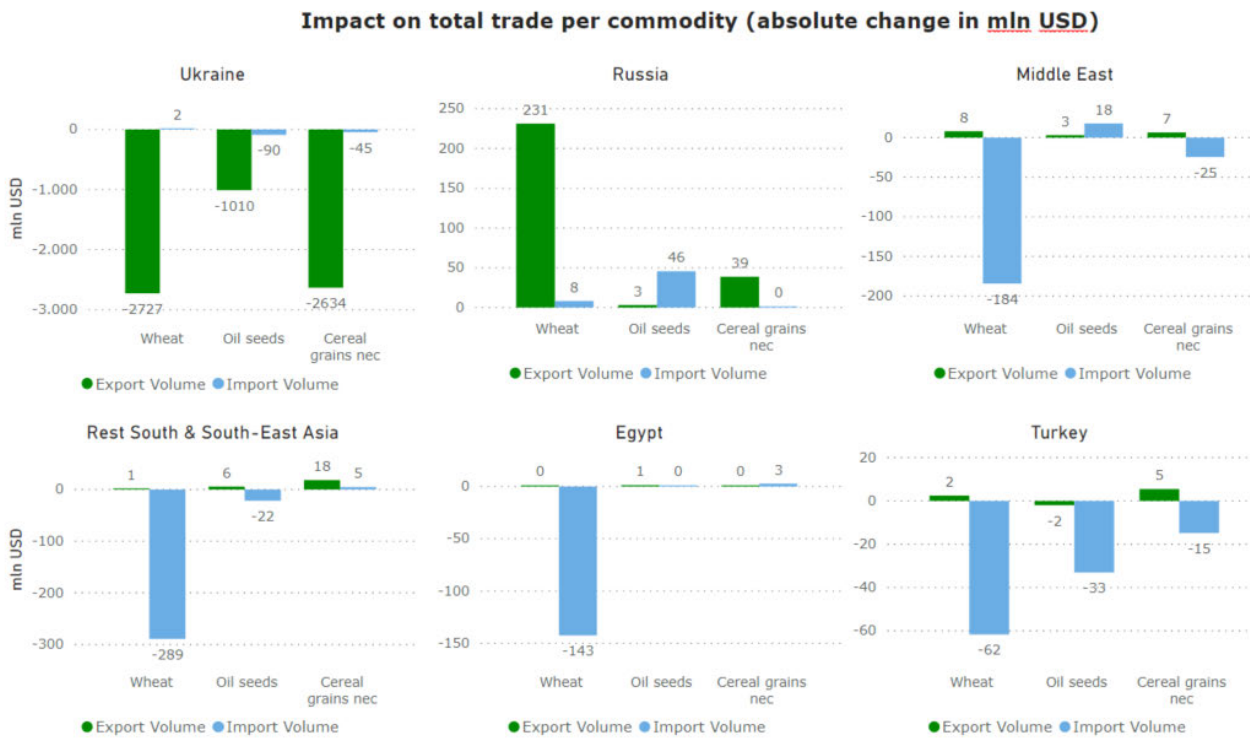


Figure A2.4 Changes in exports and import of wheat, other cereals and oilseeds, Ukraine impacts scenario (scenario 1, absolute change in million USD)

Impact on total trade per commodity (absolute change in mln USD)

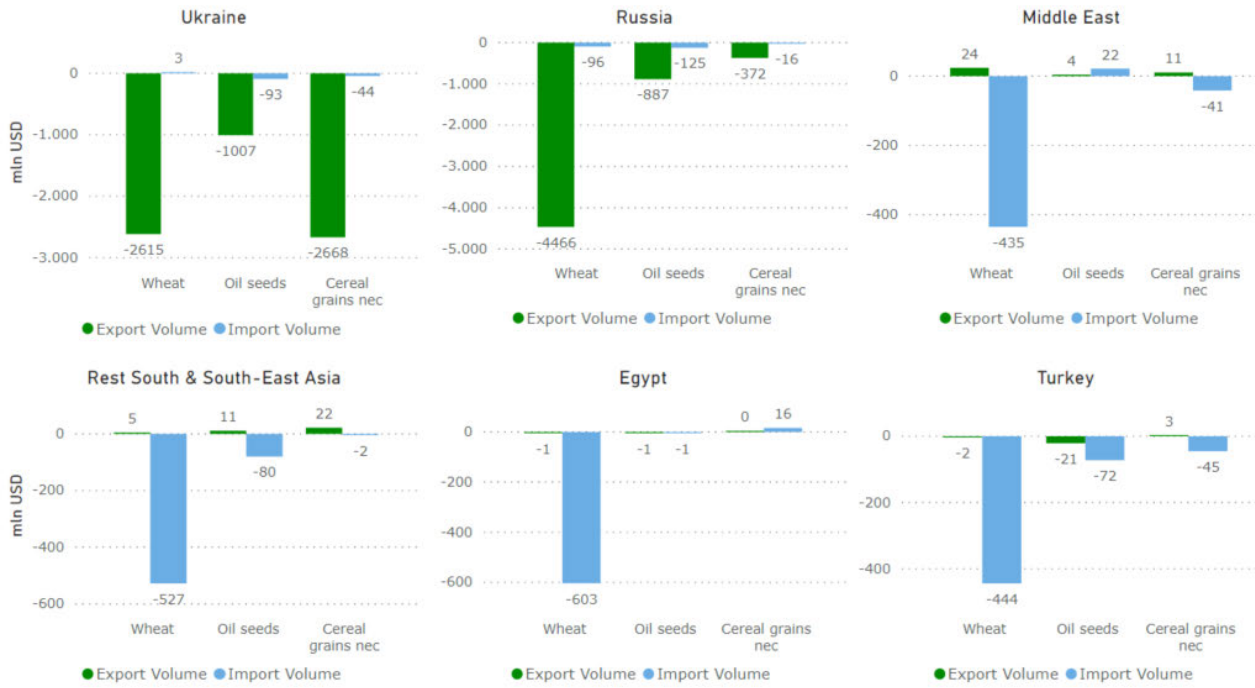


Figure A2.5 Changes in exports and import of wheat, other cereals and oilseeds, Ukraine+Russia impacts scenario (scenario 2, absolute change in mln USD)

Consumer price impacts

Decomposition: Consumer price impact food commodities (% change)

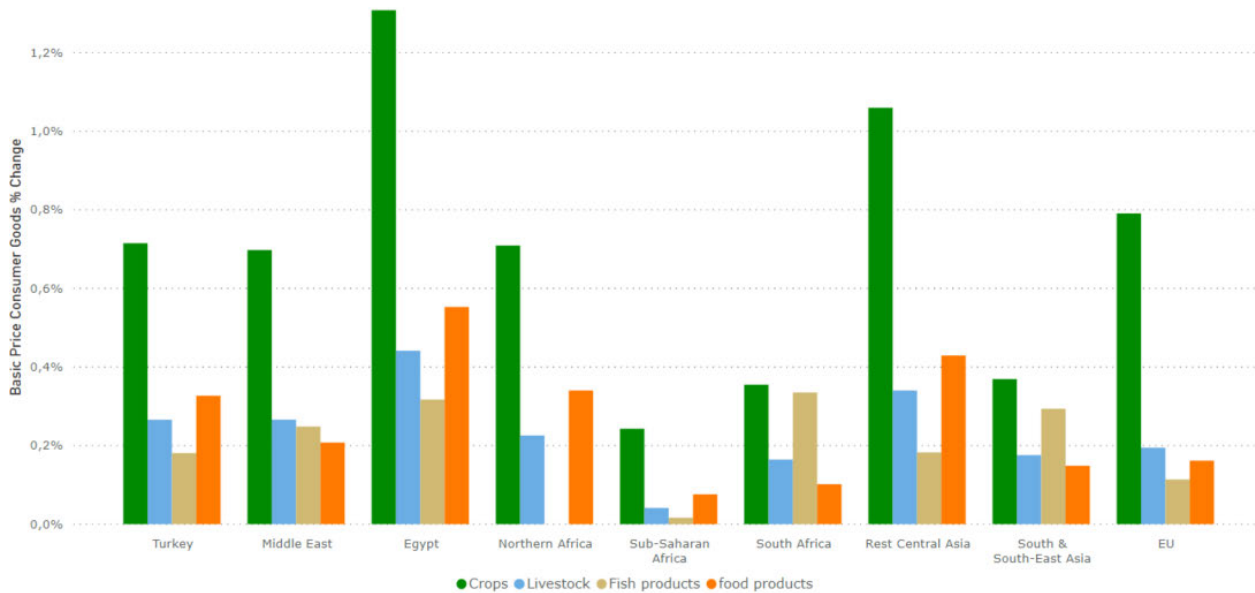


Figure A2.6 Basic consumer price impacts for different groups of agri-food products in Ukraine impact scenario 1 (% change)

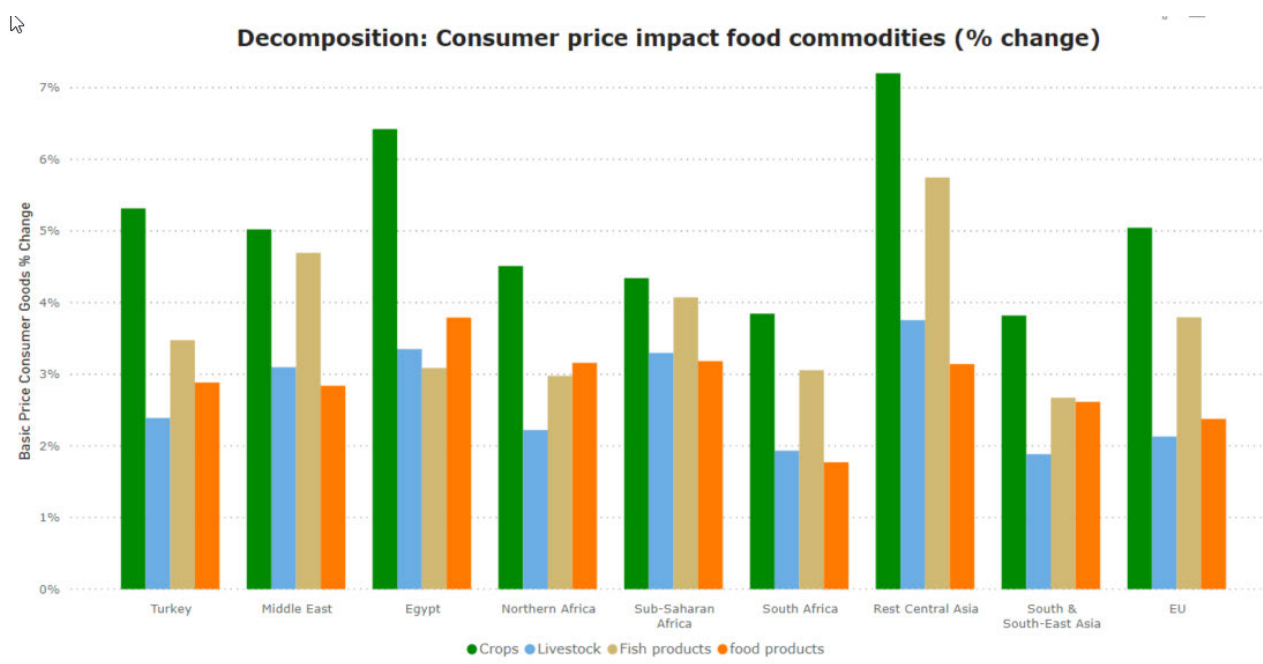


Figure A2.7 Basic consumer price impacts for different groups of agri-food products in Ukraine, Russia, energy prices impact scenario 3 (% change)



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