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THE WORLD BANK REPORT

TRADE POLICY AND FOOD AND NUTRITION SECURITY IN AN ERA OF CLIMATE CHANGE [1]

June 4, 2024

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Abbreviations

AMIS	Agricultural Market Information System
ARIMA	AutoRegressive Integrated Moving Average
AVE	Ad Valorem Equivalent
CPI	Consumer Price Index
DAI	Distortions to Agricultural Incentives
DAP	Diammonium Phosphate
DWT	Deadweight Tonnage
ECM	Error Correction Model
EU	European Union
FAO	Food and Agriculture Organization
FNS	Food and Nutrition Security
GAEZ	Global Agro-Ecological Zones
ICG-GOFI	International Grain Council Grains and Oilseeds Freight Index
GDP	Gross Domestic Product
GHG	Greenhouse Gas
GIEWS	Global Information and Early Warning System
GLS	Generalized Least Squares
GMM	Generalized Method of Moments
GRFC	Global Report on Food Crises
IMF	International Monetary Fund
IPCC	Intergovernmental Panel on Climate Change
IPCC	Intergovernmental Panel on Climate Change
LDC	Least-Developed Country
GARCH	Generalized AutoRegressive Conditional Heteroskedasticity
MGARCH	Multivariate Generalized AutoRegressive Conditional Heteroskedasticity
MT	Metric Ton
NASA	National Aeronautics and Space Administration
NTM	Non-Tariff Measures
OECD	Organisation for Economic Co-operation and Development
OLS	Ordinary Least Squares
SPS	Sanitary and Phytosanitary
SUR	Seemingly Unrelated Regressions
TBT	Technical Barriers to Trade
TSP	Triple Superphosphate
UN	United Nations
UNCTAD	United Nations Conference on Trade and Development
US	United States
USD	United States Dollar
USDA	United States Department of Agriculture
VAR	Vector AutoRegression

VAT	Value-Added Tax
WDI	World Development Indicators
WFP	World Food Program
WTO	World Trade Organization

Executive Summary

1. **Global food and nutrition insecurity has been increasing**, with 258 million people across 58 countries classified as acutely food insecure, posing significant challenges in regions already struggling with access to sufficient food. Multiple shocks, from the intensification of climate extremes to conflicts, including Russia's invasion of Ukraine and the conflict in Gaza, have been harming the food system. The outlook is not encouraging as continued global warming is projected to increase the frequency of extreme weather events, further hampering global food production.

2. **International trade has played a fundamental role in mitigating the severity of food and nutrition insecurity (FNS) crisis.** Agricultural trade, in particular, is crucial in reducing poverty by creating rural job opportunities and boosting income in rural areas, where a large portion of the world's poorest resides. Moreover, agricultural trade is essential for FNS: it enables access to diverse food sources, smoothens out food prices spikes by balancing global food supply and demand, raises agricultural productivity and innovation through trade in agricultural inputs, promotes competition, and diversifies risk by spreading the impacts of localized shocks.

3. **Unfortunately, uncoordinated policy responses to rising food prices from governments in both food importers and exporters have also contributed to increased food price levels and volatility.** Reductions in tariffs and other taxes in importing countries to insulate their local economies from rising food prices have accompanied export restrictions in exporting countries, thereby exacerbating the initial price shock. The increasing tendency to make uncoordinated and ad hoc changes in trade policy at the sign of any crisis and then remove them contributes to the volatility and uncertainty in global markets.

4. **The pressing demands of the future world —one in which existing risks will still be present and climate-associated risks will be far worse— underscore the imperative for strengthened integration to ensure the trading system is better equipped to meet these challenges**. Global warming may have significant adverse effects on the overall food supply. It will become increasingly vital to ensure that food, as well as production inputs and technologies (some of which are embodied in inputs), move easily and cheaply across borders to contribute to climate change adaptation. Virtually all countries would have a considerably smaller risk of food and nutrition insecurity were markets better integrated; the impact is especially marked for least-developed countries (LDCs) and emerging economies.

5. **Yet, trade integration has stalled**. Multilateral negotiations have not been making progress in recent years. Furthermore, many countries impose high tariffs on agriculture productions and apply some non-tariff measures to trade in food and fertilizers that impose excessive trade costs. While introducing food safety, environmental, and other trade-related requirements serve important objectives, they can create significant trade barriers, particularly if not well-designed.

6. **This report emphasizes the continuous critical importance of international trade and integration in international markets for FNS**. The report finds that t in the long term, if governments shift toward more inward-looking trade policies, trade could become more fragmented, food less affordable, and prices more volatile, slowing much-needed food system transformation. Food self-sufficiency policies have not worked in the past and they are likely not work in the future even with more uncertain and volatile world markets.

Key findings

7. **First, the global trade system demonstrated resilience to recent significant shocks.** Recent challenges, including the COVID-19 pandemic and Russia's Invasion of Ukraine, tested the resilience of the international food system. Despite significant initial shocks, the system demonstrated resilience, with initiatives like the European Union (EU) Solidarity Lanes and the Black Sea Grain Initiative helping to maintain grain flow and avoid major shortages. General trade diversion from other exporters,

especially North America and Europe, also helped pick up the slack, avoiding major shortages. This resilience supports the argument against using national self-sufficiency as a measure of FNS.

8. **Second, international trade helped countries mitigate the impacts of recent geopolitical shocks on FNS.** After the initial shock, deliveries of grains experienced normal seasonal swings, but there was no downward trend in trade. Recovery to relative pre-war normalcy took several months in some cases, but no long-lasting reductions in imports across regions. Diversification of import sources occurred when imports from Ukraine sharply declined. Wheat, heavily affected by the conflict, prompted major producing regions to export wheat substitutes influencing import patterns of major importers from Ukraine and Russia, including Türkiye and Egypt.

9. **Third, the report finds that policy makers adhere to a particular price threshold, akin to reference price in behavioral economics, to inform their price insulating behavior.**[2] In fact, they may refrain from insulating their markets until prices approach this threshold, but once prices near a certain threshold, typically, US$250–300 per ton for wheat, US$270–280 per ton for yellow maize, and US$260–265 per ton for white maize, they respond with increased insulation. Therefore, monitoring of global food prices is critical as changes could trigger these reactions.

10. **Fourth, trade restrictions are costly and ineffective:**

    a. **Despite the recent increase in short-term price volatility, the long-term trend component dominates price variability for most food commodities**. Therefore, trade protection will do little to help countries reduce long-term food prices. However, the frequent short-term price fluctuations call for better investments in social safety nets and a smarter management of strategic grain reserves (SGRs) aligned with WTO requirements to mitigate the costs of temporary price spikes, alongside strengthening early warning and FNS response systems**.**

    b. **Price policies have systematic and idiosyncratic components, impacting domestic and world prices differently.** Systematic short-run price insulation reduces the volatility of domestic prices relative to world prices but roughly doubles world price volatility for rice and wheat. This is because systematic responses to changes in world prices are likely to be correlated across countries, magnifying the effects of shocks to world prices. However, idiosyncratic domestic price shocks from policy changes, such as shifts in trade policy goals, reduce the effectiveness of insulating policies. The combined effect of systematic and idiosyncratic shocks outweighs the efforts to stabilize domestic prices. Therefore, national policy reforms to move away from discretionary, destabilizing policies could lower costs, reduce volatility in domestic and world prices, and facilitate reform of international trade rules.

11. **Fifth, uncoordinated national policies to address external shocks have a much larger impact on global prices than the shock itself.** A large part of the negative FNS impact of Russia's invasion of Ukraine is through global markets and large spillovers, not directly via local markets. In fact, uncoordinated reactions to the disruption caused by Russia's invasion of Ukraine were over ten times more costly than the disruption itself. In addition, these impacts vary across the income distributions, with poorer households bearing the brunt of their costs.

12. **Sixth, governments impose costly non-tariff measures (NTMs), raising the costs of trading food, and hindering their own farmers' access to fertilizers.** The high fertilizer prices following the Russian invasion to Ukraine highlighted the importance of fertilizers for FNS. While tariffs on fertilizer

[2] Price insulation polices are policies used by governments to protect their domestic markets from fluctuations in international prices. For example, when world food prices fall, importing countries sometimes raise import tariffs and exporting countries use export subsidies to avoid declines in domestic prices. When world food prices rise, exporting countries frequently introduce export restrictions, while importing ones often reduce their import barriers to avoid having their domestic prices rise in line with world prices. Both measures are intended to prevent domestic prices from rising commensurate with global market prices.

trade are generally low, governments have in place NTMs on fertilizers that, in some cases, distort trade and significantly raise trade costs. In particular, technical barriers to trade (TBTs) tend to contract trade, with some exceptions noted for phosphatic fertilizer trade. In contrast, sanitary and phytosanitary (SPS) measures generally have lesser trade-distortive effects; in some instances, they even promote trade. Other NTMs not captured in the restrictiveness estimates of this report, such as pre-shipment inspections, non-automatic licensing, and quantity and price-control measures, are very likely to raise trade costs further. Unlike global food prices, governments do have a control over these NTMs and can reform them to lower trade costs.

13. **Finally, the ability of the maritime bulk shipping network to withstand disruptions, whether from natural disasters, geopolitical tensions, or market fluctuations, is paramount to FNS as well as the reliability and efficiency of the rest of the food supply chain logistics.** For instance, global seaborne trade in wheat has proved resilient against major recent disruptions, partly due to adjustments in sourcing strategies by importers in imports-dependent countries. Supply and storage management improvements prevented spillage and spoilage of food imports, reducing supply risks and allowing the grains to be stored for longer periods. Therefore, it is crucial to bolster the resilience of the maritime shipping network.

Recommendations

14. **The international trade governance system must be strengthened through multilateral action to regain momentum toward enhanced integration**. More specifically, priority issues that need to be addressed include the following (Table ES1):

    a. *Better disciplines in WTO commitments.* These should focus on constraining the kind of "beggar-thy-neighbor" ad hoc import and export policies, such as export taxes/controls, ad hoc import tariff adjustments, and levels of bound tariffs, known to exacerbate price swings and food shortages in times of crisis. Digital technologies enable countries to switch to a value-added tax (VAT) as a more efficient source of revenue than tariffs, and to electronically administered targeted income supplements, e.g., conditional cash transfers, to assist poor consumers in times of high food prices.

    b. *Continued progress in monitoring and early warning systems for food production and trade.* Such progress will save policymakers from having to make ad hoc decisions based on limited, poor-quality information. While AMIS has provided critical information on the supply and demand dynamics of key commodities and has recently expanded coverage to fertilizers and vegetable oils, challenges persist in obtaining regular and reliable information from its participating countries. In addition, AMIS does not incorporate information from several countries, including many African nations. Also, collecting comprehensive information on stocks remains difficult. Therefore, continued efforts to address these issues are needed.

    c. *Enhanced assistance to developing countries to upgrade infrastructure for trade in food and agricultural inputs and technologies*. This includes hard infrastructure alongside soft infrastructure, such as reformed domestic regulatory frameworks that encourage technological transfers from abroad. International organizations could provide this support.

15. **Action should also be taken at the national level.** Multilateral action will produce the biggest benefits for all. However, even in its absence, individual countries have incentives to undertake reforms**.** In the short run, when an FNS crisis take place, timely response is key to avoid economic and human losses. As crises preparedness is critical, countries could improve their preparedness to crisis by preparing and implementing crisis preparedness plans, such as those supported by the World Bank —in close partnership with humanitarian and development actors under GAFS, Global Network Against Food Crises (GNAFC), national governments, United Nations (UN) agencies, and donor partners**.** These plans are living contingency plans, outlining operational arrangements for monitoring and identifying

crisis risks, disseminating risk information to decision-makers, financing response activities, identifying populations targeted for support, and coordinating response efforts effectively.

16. **In the medium term**, actions are context specific. Recommendations based on the findings of the report are the following:

    - *Reducing tariffs applied to food and fertilizer*. Tariffs applied to food and fertilizers imports are high in several developing countries and reduced tariffs in those countries should diminish the food and fertilizer prices and have a positive net welfare impact for the country and benefit poor households.

    - *Reviewing and streamlining NTMs on food and fertilizers***.** An in-depth analysis of specific NTMs applied on food and fertilizers is required to determine how they can be streamlined and, some of them, removed while their legitimate objectives —such as consumer, health, and environment protection— are pursued. Harmonization and mutual recognition of some NTMs can also reduce associated trade costs.

    - *Streamlining customs procedures and improving trade facilitation***.** Initiatives, such as single windows, promoting comprehensive digitalization of trade procedures, electronic phytosanitary certificates can reduce the time and cost of trading food and lower food waste in different parts of the supply chain. Countries with cumbersome customs procedures are to gain most of these reforms.

17. Other policy priorities are based on a country's food imports dependency (i.e., share of net imports in domestic food consumption), and the share of food in households' expenditure. **Countries with high food share in household expenditure** need to protect the most vulnerable members of the population and help them cope with a surge in food prices by strengthening and scaling up safety net programs. **Countries with high food import dependency** need to prioritize the following:

    - *Strengthen early warning systems*. Countries should actively participate in both national, regional, and global early warning networks that monitor hydro-meteorological events and other significant food security shocks. Countries need to also strengthen their national capabilities to track food prices in real-time and disseminate market information.

    - *Strengthen management of strategic grain reserves and upgrade existing storage to reduce losse***s.** Options include investing in modern storage infrastructure, improving public procurement of imported food by adopting rule-based procurement and release policies to minimize fiscal impacts and food loss and waste from excessive stock build up**.** Where needed, support the technical upgrading of existing storage facilities for strategic reserves to reduce food losses from pests, heat, humidity, and disease.

    - *Avoid ad hoc trade policy reactions* such as putting in place import subsidies to prop up domestic supplies**.** Countries with low (or negative) food import dependency should avoid export restrictions**,** as these policies would bring relief for the imposing countries only in the short run, further reduce supplies and push up global prices. Countries should also desist from the use of ad hoc changes in trade policies that attempt to insulate their economies from world price movements.

    - Aligning with World Bank recommendations from previous studies, countries should review agriculture policies to remove any potential bias towards domestic food production**.**

18. **In the long term, *aligning with World Bank recommendations from previous studies*, countries need to undertake adjustments to their policies**.

    - *Repurpose agricultural policies and support toward sustainable and resilient food systems* by moving away from quantitative restrictions and policies that have proven expensive and ineffective, including minimum price support and other forms of subsidies to inputs or outputs. In their place,

agricultural support payments should be focused on providing key public goods like improved research and extension services and infrastructure and crowding in private sector investments.[3]

- *Additionally, substitute targeted safety nets for universal food subsidies, which* will realize fiscal savings and provide more effective cushioning for the poor during high food prices. Using limited strategic grain reserves, following the guidelines cited in this report, will prove much more realistic and less costly than trying to stabilize internal prices through large buffer stocks or trade policy.
- *Support climate smart agriculture*. Key actions include investing in agricultural research and development, improving infrastructure for agricultural production, disseminating climate smart agriculture technologies that improve input use efficiency and reduce the environmental footprint of food production, and promoting trade agreements that support fair and equitable food exports.

19. **In addition to policy lessons, this report provides important guidance for future research.** One key takeaway is the importance of including general equilibrium, indirect, and household-level effects in the analysis of shock events to avoid misleading conclusions.

[3] Gautam (2023) shows that repurposing a portion of distortive government support on agriculture each year towards climate-smart innovations that boost agricultural productivity while curbing greenhouse gas emissions could slash overall emissions from agriculture by over 40 percent. This investment could also lead to the restoration of 105 million hectares of agricultural land to natural habitats. Moreover, it has the potential to lower the cost of nutritious foods, thereby improving nutritional outcomes.

Table ES.1: Recommendations to Increase Food and Nutrition Security through Trade Policy

Recommendations	Timeframe Short Medium Long
MULTILATERAL ACTIONS	
(i) Better disciplines in WTO commitments.	Short
(ii) Continued progress in monitoring and early warning systems for food production and trade.	Medium
(iii) Enhanced assistance to developing countries to upgrade infrastructure for trade in food and agricultural inputs and technologies.	Long
COUNTRY LEVEL ACTIONS	
(i) Improve preparedness to crisis by:	
• Preparing and implementing crisis preparedness plans.	Short
• Strengthening early warning systems.	Medium
(ii) Reform trade policy by:	
• Reducing tariffs applied to food and fertilizer.	Medium
• Reviewing and streamlining NTMs on food and fertilizers.	Medium
• Streamlining customs procedures and improving trade facilitation.	Medium
• Avoiding ad hoc trade policy reactions	Medium
(iii) Strengthen Social protection by:	
• Strengthening and scaling up safety nets.	Medium
• Substituting targeted safety nets for universal food subsidies.	Long
(iv) Strengthen domestic policies by:	
• Repurposing agricultural policies and support toward sustainable and resilient food systems	Medium
• Introducing phytosanitary controls.	Medium
• Supporting Climate Smart Agriculture.	Long
• Strengthening management of strategic grain reserves and upgrade existing storage.	Medium
• Removing any potential bias towards domestic food production.	Long

Introduction

Trade is important for food and nutrition security (FNS) yet is undermined by many recent protectionist measures. The key theme of the report is that instead of disintegration, policymakers need to aim for closer market integration and the continued use of trade to enhance FNS.

1. **International trade significantly contributes to development and poverty reduction by fostering economic growth**. Openness to trade boosts GDP by encouraging countries to exploit their comparative advantages efficiently (World Bank and WTO 2018). Trade also facilitates access to advanced technology, driving innovation, which can increase productivity and contribute to human capital development. International trade provides consumers access to a wider variety of goods and services, often at lower prices, which can improve living standards and reduce poverty. It also provides producers access to a wider range of cheaper high-quality inputs, some of which are unavailable domestically, reducing production costs and enabling product diversification, thereby raising productivity.[4] In addition, trade cost reductions in agricultural inputs and the international transmission of productivity growth in the agricultural input sector since the 1980s induced large shifts from traditional, labor-intensive technologies to modern, input-intensive ones (Farrokhi and Pellegrina 2023). A growing economy is pivotal for enhancing a nation's FNS by increasing the purchasing power of its consumers.
2. **Agricultural trade, in particular, is crucial in reducing poverty by creating new rural job opportunities and boosting rural income**. Globally, agriculture contributes 4 percent to GDP, while in some developing nations, it can account for over 25 percent (World Bank, 2024). Around 79 percent of the world's poorest people reside in rural areas, and agriculture is their primary livelihood (World Bank, 2018). Lowering barriers to agricultural trade offers rural producers improved access to external markets and the possibility to increase exports, thereby fostering employment for low-skilled workers. Removing export barriers elevates prices for producers, stimulating production and income growth. Additionally, liberalizing agricultural trade lowers the prices of imported goods, boosting real incomes (Loayza and Raddatz 2010).
3. **Agricultural trade is also crucial in addressing hunger by providing livelihoods and enhancing FNS worldwide.** In addition to providing livelihoods to farmers and those employed throughout the supply chain, agricultural trade helps reduce food and nutrition insecurity worldwide through better access to food and provides greater choice of consumer goods (Martin 2017). Through trade, countries can export surplus agricultural products and import those they lack. Additionally, income generated from agricultural trade promotes agricultural growth because it incentivizes farmers to produce more. Widespread growth in agricultural productivity is likely to reduce the cost of staple foods, which account for a significant share of the expenditure of people experiencing poverty, including poor farmers (Ivanic and Martin, 2016).
4. **The international food trade provides a powerful mechanism for diversifying food supplies**. Agricultural trade brings a variety of food to the table, enriching diets and providing essential nutrients that might not be locally available. This diversification can significantly reduce the volatility of supply for staple foods—relative to relying only on local food production—and reduce the vulnerability of their populations to food and nutrition insecurity (Burgess and Donaldson, 2010). A diversified food supply is key to better FNS.
5. **Cereals are the most traded food category for low-income and lower-middle income countries (Figure 1) and their main source of dietary energy (Figure 2).** In 2021, cereals accounted for about

[4] The correlation between increased exports and a decline in poverty is evident, with exports rising from 18 percent to 31 percent of global GDP from 1990 to 2022. This rise coincided with higher GDP per capita and decreased poverty levels: the poverty headcount ration at US$2.15 a day decreased from 37.9 to 9 percent of the global population.

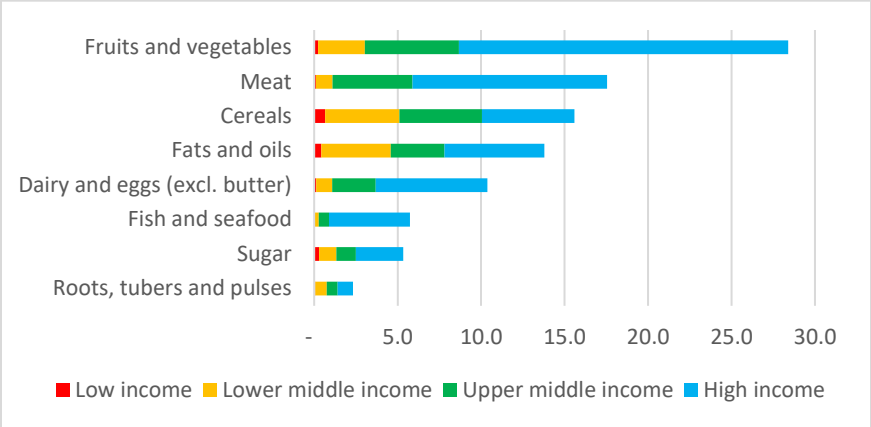
34, 29, and 21 percent of the value of total food imports in low income, lower-middle income, and upper middle income countries, respectively. In upper-middle income countries cereal imports are second to fruits and vegetables. Cereals account for a bit more than half of the dietary energy supply in low and lower-middle income countries and 45 percent in upper middle-income countries. Their contribution is lower in high-income countries (27 percent) but remains their main source of dietary energy. Wheat, rice, and maize are the most important cereals and they are internationally traded on commodity exchanges. Cereal imports concentration varies across countries. Developing countries with more cereal imports dependency and higher supplier concentration need to diversify more the source of their imports **(**

6.

7.

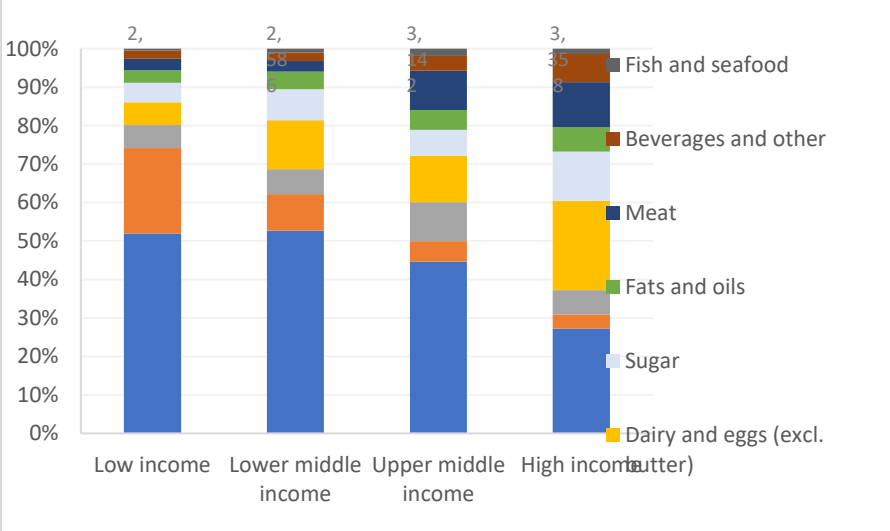
8. **Figure 3).**

Figure 1: Food Import Composition by Income groups, (in percentage) %, 2021



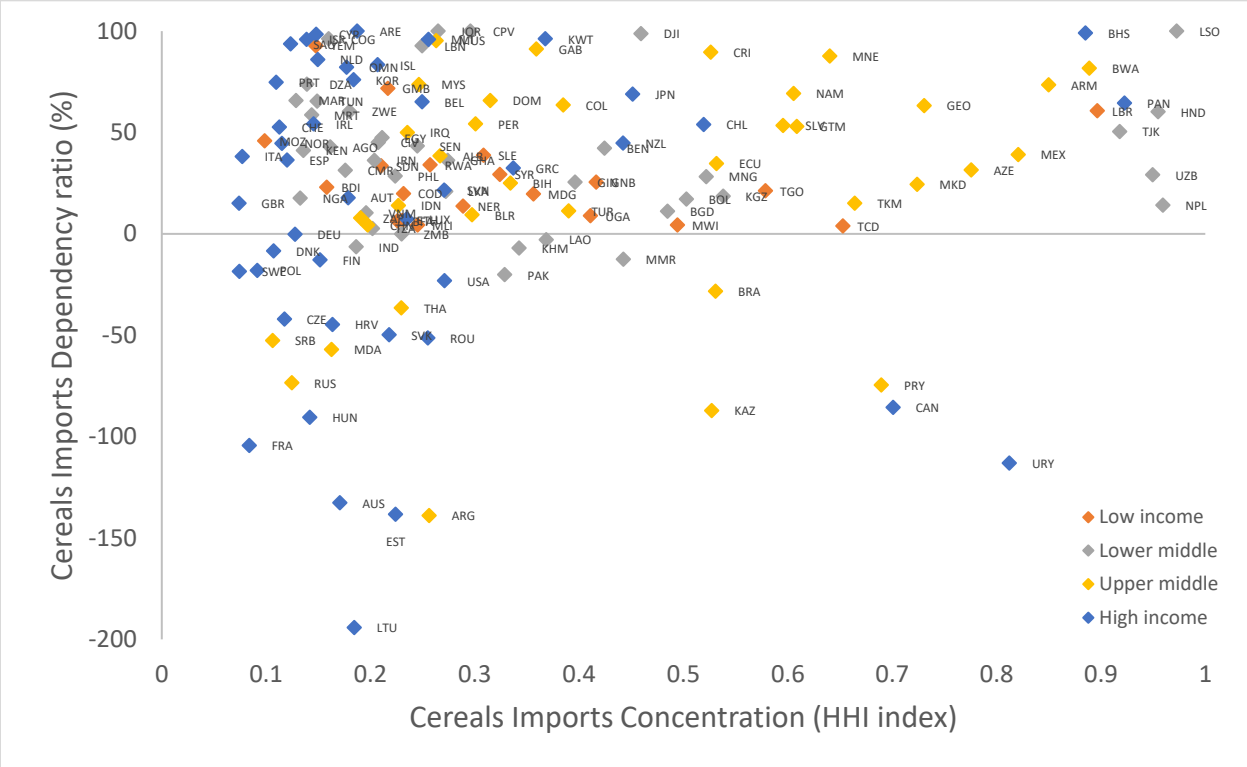
Source: Portugal -Perez et al. (2024b) with data from BACI

Figure 2: Dietary energy supply (kcal/capita/day) composition by income and food category, 2021



Source: Portugal -Perez et al. (2024b) with data from FAOSTAT

Figure 3: Cereals Imports Dependency vs Supplier Concentration



Note: The indicator of cereals imports dependency is computed as the ratio: (total cereal imports – total cereal exports)/(total cereal production + total cereal imports – total cereal exports) It only assumes values <= 100. Negative values indicate that the country is a net food exporter. The food imports diversification indicator is computed as a Herfindahl–Hirschman (HHI) index: $\sqrt{\sum_{j=1}^{J}(M_{ij}/M_i)^2}$, where M_{ij} are cereal imports of country i from country j and M_i are total cereal imports of country i It measures concentration of cereal imports across exporters and ranges between 0 (diversified) and 1 (concentrated).
Source: Staff estimates using data from FAO and BACI

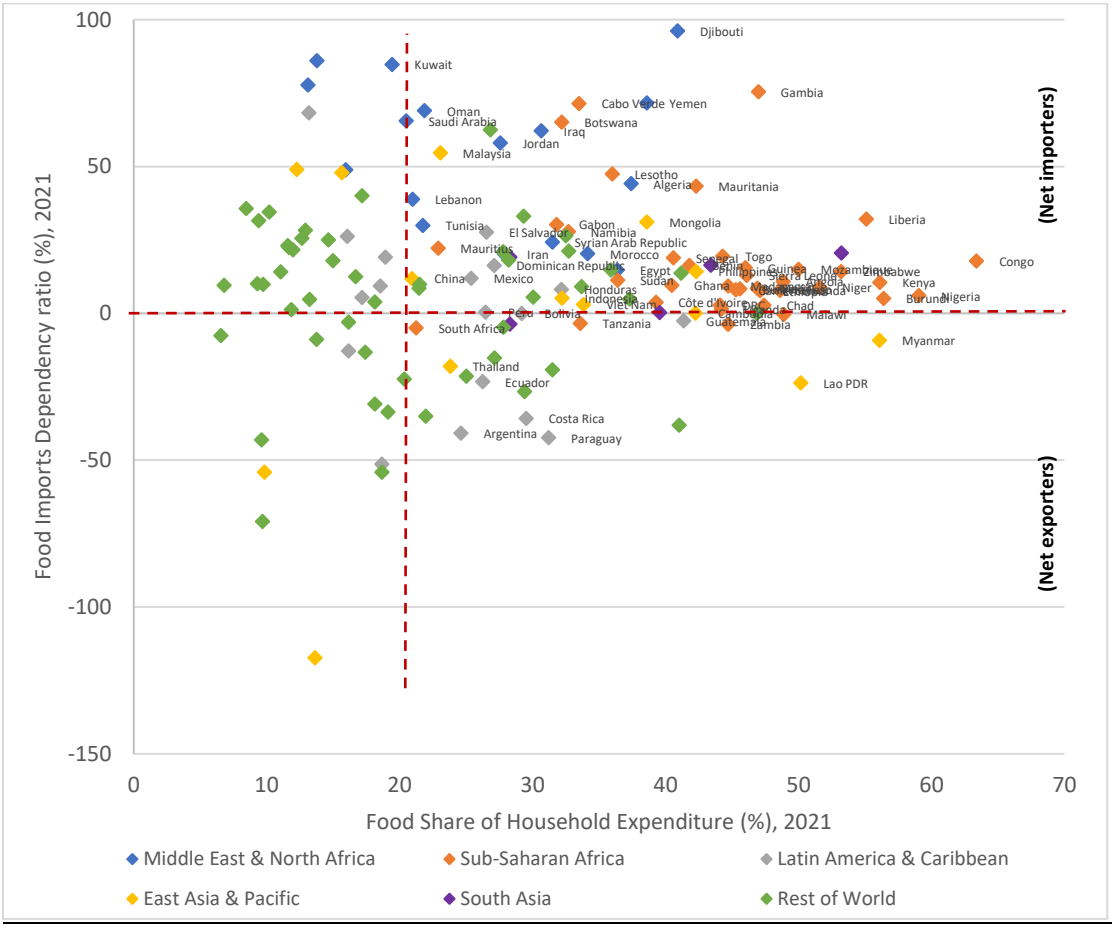
9. **In this context, the world faces the third FNS crisis in less than two decades**. Food and nutrition insecurity is currently at its highest level since 2016 and is expected to deteriorate in the coming years if appropriate steps are not taken in the present. Global food and nutrition insecurity has been increasing. It is now at a record high, with 258 million people across 58 countries classified as acutely food insecure, posing significant challenges in regions already struggling with access to sufficient food. Hunger and starvation are the manifestations of extreme poverty, with women and children bearing the brunt of food and nutrition insecurity. Globally, 148 million children are stunted, and 1.2 billion women have one or more major forms of micronutrient deficiencies. Multiple shocks, from the intensification of climate extremes to conflicts, including Russia's invasion of Ukraine and the conflict in Gaza, are harming the food system, resulting in a global FNS crisis. Weather-related events also worsen food and nutrition insecurity by displacing populations. The WFP estimates that climatic shocks of various kinds displaced 31.8 million people in 2022. Furthermore, as in the past, economic mismanagement and conflicts turn temporary disruptions into famines and social unrest.

10. **The future of FNS looks even more challenging**. The demand for food will grow as the population grows, adding pressure to global food systems. The world population is estimated to increase from roughly 8 billion to 10 billion by 2060. Most of the additional population will live in the developing

world. On the supply side, continued global warming is projected to increase the frequency of extreme weather events, such as droughts, floods, heatwaves, wildfires, and frost and freeze events, across the planet.[5] Such events negatively affect average food production and increase year-to-year supply volatility.

11. **Shocks to global food and fertilizer markets, and the resulting increases in prices and their volatility affect countries differently**. Countries that rely heavily on food imports, such as in the Middle East, North Africa, and West Africa, are subject to high import bills, reduced fiscal space and heightened vulnerability to global price fluctuations, especially for key food commodities like rice and wheat (World Bank 2012). Higher food prices are estimated to have raised the import bills of the 48 most-affected countries by around US$9 billion in 2022/23(IMF, 2022). The fiscal cost of implementing programs to protect vulnerable households is estimated at US$5–7 billion (IMF, 2022). Similarly, shocks negatively affect consumers in countries where a substantial portion of household expenses is allocated to food, as is often the case in many African and Asian countries**.** Conversely, net exporting countries in Latin America, Eastern Europe and Central Asia, benefit from increased international prices (Figure 4). However, they might be pressured to implement export restrictions or price controls, particularly if their populations allocated significant portions of their household budgets to food expenditures.

Figure 4: Countries' vulnerability to global food price shocks tracked by food imports dependency and food share in household expenditure.



[5] Intergovernmental Panel on Climate Change (IPCC), 2021

Note: The indicator of food imports dependency is computed as the ratio: (total food imports – total food exports)/(total food production + total food imports – total food exports) It only assumes values <= 100. Negative values indicate that the country is a net food exporter. While the two dimensions reflected in the above figure are important contributors to vulnerability, other factors include whether a country has a safety net program in place and fiscal space to scale it up and mitigate impacts on the poor.
Source: Staff elaboration using data from FAO for food imports dependency, and USDA for food share in household expenditure

12. **Short-term and long-term drivers—including COVID-19, Russia's invasion of Ukraine, and climate change—have contributed to recent FNS crises.** The COVID-19 pandemic led to disruptions in production and supply chains, declines in demand for commodity exports, and disruptions to local labor and food markets. Russia's invasion of Ukraine added to the uncertainty, particularly in markets where Russia and Ukraine are major providers of key agricultural products, fertilizers, and energy, exacerbating food and nutrition insecurity and inflation. These shocks have come against the backdrop of the increasing frequency of extreme weather events due to climate, including in big agricultural producers, such as Argentina, Brazil, India, and the United States.

13. **Our understanding of FNS—the term's meaning and what makes populations food secure—has evolved significantly over time.** In the past, many governments believed that FNS was synonymous with domestic self-sufficiency in production. This belief led to poor public expenditure policy choices and isolationist agricultural trade policies. Over time, FNS has become commonly understood as a much more multi-dimensional concept, but alarmingly, some governments still base policies on this view of FNS. The 1996 World Food Summit defined FNS as a situation where all people have both physical and economic access to sufficient, safe, and nutritious food that always meets their dietary needs and food preferences, allowing them to lead an active and healthy life. The concept of FNS comprises four dimensions: (a) availability, (b) economic and physical access, (c) utilization, to maintain good health and nutrition, and (d) stability, to ensure consumption resilience to shocks. When domestic production is not competitive and must be protected from imports by trade barriers that raise domestic prices, it undermines the economic access to food or affordability for consumers, which is a key determinant of food insecurity, and reduces FNS. In countries where domestic supply cannot meet local demand and is more volatile than global supply at an internationally competitive cost, imports become a critical pillar of FNS due to the lack of competitiveness of the domestic market. It also underscores the importance of maintaining an open and efficient trading system with low policy barriers to trade and low-cost trade logistics. The findings of this report strongly reinforce this conclusion.

14. **In food-importing countries, there is a common belief that a population's FNS is equivalent to the degree of national self-sufficiency in production. In contrast, food-exporting countries commonly believe that the local population should be given priority access to low-cost, domestically produced food.** Some countries have imposed export taxes or quantitative restrictions in the past to keep domestic food prices artificially low. While this action has made food more affordable for local consumers, it has also disadvantaged local producers, undermined the reliability of the country's exporters on the global market, and reduced the supply available for consumers in importing countries. In addition, export taxes and lowered import barriers can lead to a surge in the international price of food as they shift the export supply curve and shift out the import demand. This surge in food prices may lead to a new wave of export policies, which, in turn, affect food prices, as was the case during the 2011 food crisis (Giordani, Rocha, Ruta, 2016).

15. **Surges in food prices and reactive export policies often occur in times of rising world prices, including in response to recent shocks like Russia's invasion of Ukraine.** While some of these export restrictions have been lifted, others remain. Data collected by the World Bank and the Global Trade Alert showed that 101 export restrictions—including quotas, licenses, and outright bans—remained in place a year after the invasion of Ukraine. This fact suggests that contrary to WTO principles, the limits have not all been temporary. In 2022, these restrictions covered more than 11 percent of the pre-COVID food trade. Export bans—the most severe type of export restrictions—cover

up to 3.8 percent of the global food trade alone. Reductions in tariffs and other taxes in importing countries have accompanied export restrictions in exporting countries. The increasing tendency to make ad hoc changes in trade policy at the sign of any crisis and then remove them contributes to the volatility and uncertainty in global markets, a central theme of some of the research reported here.

16. **Against this backdrop, the report aims to demonstrate that trade is still important for FNS, and many recent anti-trade measures undermine that security.** Several shocks can affect FNS. These include meteorological shocks that can be caused by weather in the short term and climate change in the long term, pests and diseases affecting crops, livestock, and people, as well as conflicts. This report focuses on climate change and the ongoing Russia's invasion of Ukraine given the global nature of their impacts.

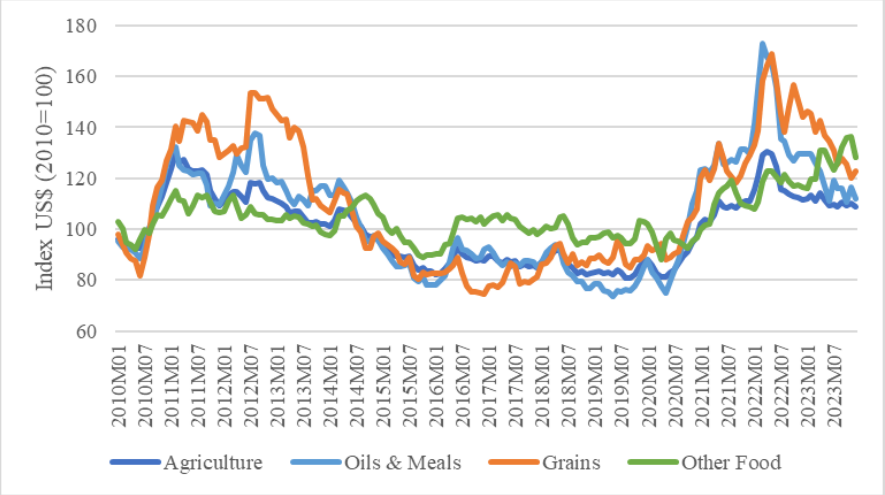
17. **The report is divided into four chapters and concludes by outlining the main recommendations.** Chapter 1 describes recent trends in food markets, focusing on food prices. Chapter 2 uses retrospective and simulation-based analyses to assess the impact of Russia's invasion of Ukraine and policy responses on food and fertilizer markets. Chapter 3 examines the impacts of price insulation on international and domestic markets and explains its political-economy underpinnings. Chapter 4 showcases the role of trade in mitigating the negative impacts of shocks and highlights its importance in mitigating the effects of climate change. The last section concludes with key messages and recommendations.

CHAPTER 1: Recent Trends in Food Markets

There have been three medium-term food price cycles between 1970 and 2023. Volatility was most pronounced from 2009–2023 and was characterized by multi-shocks, mainly caused by macroeconomic variables. Despite the recent increase in short-term price volatility, the long-term trend component dominates price variability for most food commodities. This implies that trade protection will do little to help countries reduce long-term food prices but will impose significant FNS costs. Better investments in social safety nets are needed to mitigate the costs of temporary price spikes and to strengthen early warning and FNS response systems, given the frequent short-term price fluctuations.

18. **Global markets for agricultural commodities experience many ups and downs, and dealing with these swings is a major objective and driver of agricultural trade policy on both national and multinational levels** (**Figure 5**). These fluctuations reverberate through external trade, exchange rate movements, and inflation rates, influencing economies' stability and growth paths. Understanding the nature and causes of this volatility is a foundation for improving the quality of agricultural and trade policymaking. At the microeconomic level, volatility shapes farm income, FNS, and rural poverty, pivotal factors in socioeconomic development. Through an innovative methodology of analyzing price series supplemented by a review of existing literature, this chapter looks in depth at the causes and nature of price instability in global food commodity markets.

Figure 5: Agricultural Prices Across Multiple Indexes, 2010–23



Source: World Bank data.

19. **Depending on the underlying origin, shocks to commodity prices can be very short-term, of medium duration, or more permanent.** Annex 1 summarizes the findings of the literature on the origin and determinants of volatility in agricultural commodity prices. Transitory demand-side shocks can originate from several sources, including recessions, such as the 1997 East Asian financial crisis and the 2008 global financial crisis, both of which impacted a wide range of commodities (Kabundi et al. 2022b). Sometimes, they reflect ad hoc policy measures, such as the escalation in trade tensions between the United States and China in 2018–19, which impacted metals and soybeans. Other ad hoc policy measures include bans such as those placed on grain exports from several countries during the 2007 and 2011 food price spikes and the trade restrictions following Russia's invasion of Ukraine in 2022 (World Bank, 2022). Transitory shocks can also arise on the supply side from adverse weather conditions such as the recurring El Niño and La Niña episodes or droughts, causing production

shortfalls in agriculture, such as grains in 1995 and coffee in 1975 and 1985. Other transitory shocks include disruptions in supply chains, such as those experienced during the pandemic, or stemming from Russia's invasion of Ukraine or the ongoing conflict in the Middle East.

20. **Other shocks, especially those associated with technological innovation, shifters of demand (population growth, changes in consumer preferences), and policies, can affect commodity markets more permanently.** For example, advances in biotechnology during the 1990s increased crop productivity by more than 20 percent (Klümper and Qaim, 2014). Policies that encouraged the production of biofuels shifted as much as 4 percent of global land from food to biofuel production (Rulli et al., 2016). Agricultural policies, including domestic support measures, have for many years exerted downward pressures on global agricultural prices (Aksoy and Beghin, 2004).

21. **Shocks in related markets, particularly those associated with energy markets, can propagate subsequent shocks in food markets**. The oil price shocks of 1972 and 1979 induced policies that favored the use of coal, nuclear power, and renewable energy sources in electricity generation and fuel-saving technologies in transportation. Energy price booms exert upward pressure on food production costs through higher fertilizer and fuel prices (Baffes et al., 2022a). The oil price boom of the early 2000s was one factor resulting in the biofuel policies mentioned earlier (Baffes, 2013).

22. **Given these potential underlying causes of commodity price movements, what has been the empirical evidence regarding trends, cycles, and volatility?** Several conclusions emerge from reviewing the literature:

    a. *Various hypotheses have been advanced over the history of economics regarding very long-term trends***.** The "Prebisch-Singer" hypothesis (Prebisch, 1950; Singer, 1950) predicts a long-term decline in the terms of trade for developing countries. These countries are assumed to export food and import manufacturing goods, and the hypothesis prescribes interventionist policies to reverse this trend. The hypothesis was influential from the 1950s through the 1980s and provided the intellectual underpinnings for much bad development policy. However, empirical attempts to detect systematic long-term trends have generally not found them.

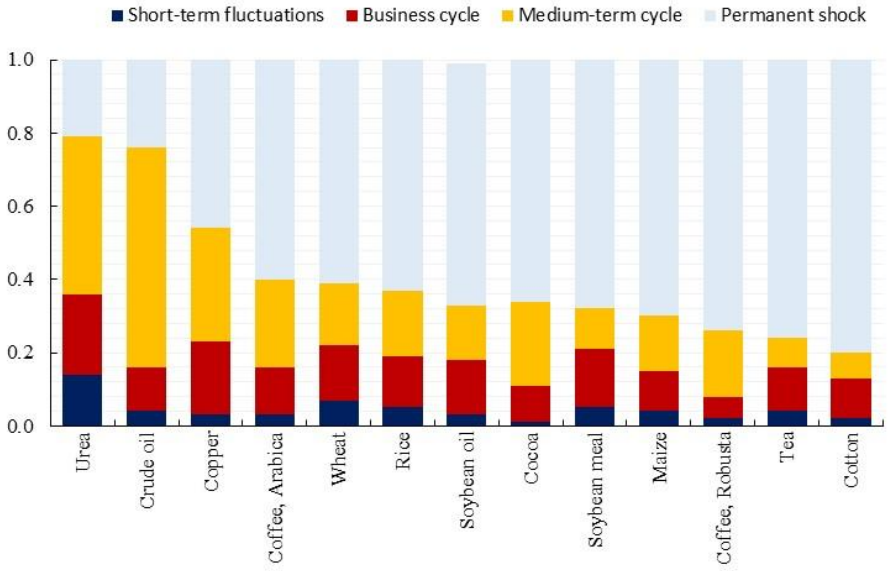
    b. *Analyses of price movements over the past century and a half have detected three or four commodity price cycles that lasted several decades: "supercycles" and other shorter-term cycles*. Early research on supercycles established supercycles in metal prices (Cuddington and Jerrett, 2008; Jerrett and Cuddington, 2008), followed by an expanded set of commodities (Erten and Ocampo, 2012; Jacks, 2019; Ojeda-Joya et al., 2019). More recent research on supercycles in several commodities concluded that they have a much shorter duration than the literature typically assumes (Baffes and Kabundi, 2024). Except for the last two supercycles in the 1970s and 2000s, they are not synchronized, implying that they are affected by idiosyncratic rather than common factors (Baffes and Kabundi, 2024). The decomposition analysis in the current report using monthly data spanning 1970–2022 identified medium-term cycles with a duration of 8–10 years. These cycles were particularly evident in the 1970s, 1990s, and early 2000s to the present, providing further insights into the cyclical nature of commodity markets.

    c. *Short-term price volatility is associated with various kinds of idiosyncratic shocks (some mentioned above) and market features***.** Examples of the latter include higher volatility of futures prices as the contracts approach maturity and higher price volatility when inventories are low. There has been much speculation that the financialization of markets, including index, futures, and derivative markets, could increase price volatility in agricultural commodities. Some have alleged that the derivative markets caused the 2007/08 food price spike and have suggested that this argues for more regulation of these markets. However, in reality, a significant body of the literature suggests that there is no

evidence linking index investment activity to price volatility in agricultural futures markets (Boyd, Harris, and Li, 2018; Hamilton and Wu, 2014; Aulerich, Irwin, and Garcia, 2014; Brunetti, Büyükşahin, and Harris, 2016; Capelle-Blancard and Coulibaly, 2011; Irwin and Sanders, 2012; Stoll and Whaley, 2010). Irwin and Sanders (2012) even argue that the expanding market participation in commodity futures markets may have reduced price volatility by decreasing risk premiums. This argument is similar to findings from Peck (1981), who observed an inverse relationship between trading activity levels and price volatility three decades earlier. As discussed below, this study indicates that speculative activity in commodity markets did not amplify the price spikes associated with Russia's invasion of Ukraine.

23. **The extent of volatility composition varies by commodity, but short-term volatility is generally lower than for the cyclical components and permanent shocks.** Figure 6 decomposes global price volatility for 13 commodities into 4 components of various lengths. The results indicate that each component's share of overall volatility differs among commodities. However, the share of very short-term price swings is generally quite low compared to the cyclical components and permanent shocks.

Figure 6: Price Decomposition of Individual Commodities, 1970–2022



Source: Baffes, Khadan and Mekonne (2024)

24. **Macroeconomic variables significantly influence price volatility.** This report conducted an original analysis of commodity price movements to investigate the determinants of price volatility for nine agricultural commodities over various time sub-periods.[6] The findings show that macroeconomic variables, including the equity index, crude oil prices, and the US dollar exchange rate, significantly influence price volatility across most commodities. Notably, during the 2002–23 "multiple shock" period characterized by the global financial crisis, the 2015 oil price collapse, the COVID-19 pandemic, and Russia's invasion of Ukraine, macroeconomic factors became particularly prominent in driving volatility; the equity index and the US dollar exchange rate consistently exhibited statistical significance for most commodity prices. Furthermore, there was a heightened persistence in price

[6] It employed a Generalized AutoRegressive Conditional Heteroskedasticity (GARCH) statistical model, using daily data spanning the past two decades. GARCH models are used in analyzing time-series for which the variance error is likely to be serially autocorrelated. These models assume that the variance of the error term follows an autoregressive moving average process.

volatility during both the commodity boom (2002–08) and multiple shock periods compared to the pre-boom era (1985–2001). These findings underscore the pivotal role of macroeconomic conditions in shaping agricultural commodity price dynamics amidst economic uncertainty.

25. **This chapter concludes that the long-term trend component dominates price variability for most food commodities, implying that trade protection will do little to help countries reduce long-term food prices but impose significant costs on FNS**. Trade remains important to smooth out food price spikes. However, the recently increased price volatility cannot be ignored. The frequent short-term price fluctuations call for better investments in social safety nets to mitigate the costs of temporary price spikes, alongside strengthening early warning and FNS response systems.

CHAPTER 2: Impact of Shocks and Policy Responses on the Food Trade System: Evidence from Russia's Invasion of Ukraine

The food trade system withstood Russia's invasion of Ukraine reasonably well, but there is room for improvement in preparation for the more frequent and severe shocks likely in the future. This kind of evidence demonstrating the resilience of the trade system supports the argument against the use of national self-sufficiency as a measure of FNS (FNS). Striving for self-sufficiency has high costs for countries adopting this metric, and this policy objective has very small benefits if global shocks are not likely to seriously disrupt food supplies from abroad.

One channel through which Russia's invasion of Ukraine affected global food security is through fertilizer markets. Tariffs on fertilizer trade are typically low, but governments have in place non-tariff measures (NTMs) on fertilizers that sometimes distort trade and significantly raise trade costs. Compared to technical barriers to trade (TBTs), sanitary and phytosanitary (SPS) measures generally have lesser trade-distortive effects; in some instances, they even promote trade. Conversely, TBTs tend to contract trade, with some exceptions noted for the phosphatic fertilizer trade. Other NTMs not captured in the analysis of restrictiveness, such as pre-shipment inspections, non-automatic licensing, and quantity and price-control measures, are very likely to raise trade costs further. An in-depth analysis of specific NTMs is required to determine how they can be streamlined or removed while their legitimate objectives are pursued. Harmonization and mutual recognition of some NTMs can also reduce associated trade costs.

In addition to direct impacts on food security, a large part of the negative impact of Russia's invasion of Ukraine on FNS is through international markets and large spillovers. In fact, simulations of the impact of this shock show that uncoordinated reactions to the disruption were ten times more costly than the disruption itself. In addition, these impacts vary across the income distributions, with poorer households bearing the brunt of the costs.

2.1. Russia's Invasion of Ukraine as a Case Study

20. **Studying the effects of Russia's invasion of Ukraine is important for several reasons: firstly, the shock to major food markets**. The countries involved are major suppliers of food products, especially cereals, as well as fertilizers and energy products that affect food production and transport. Russia and Ukraine rank in the top seven global producers and exporters of wheat, corn, barley, sunflower seed, and sunflower oil. Ukraine accounts for over half of the global production of sunflower oil. In 2019, Russia and Ukraine accounted for 25 percent of global exports of wheat and 14 percent of global exports of corn (UN Comtrade, 2022). Russia and Belarus are the world's second and third-largest potash fertilizer producers, respectively. Russia produces around 13 percent of the world's crude petroleum and is the second largest exporter. Additionally, Russia exports 10 and 9 percent of the world's refined petroleum products and natural gas, respectively. These commodities account for over half of the cost of producing ammonia fertilizer. Clearly, significant disruption of production or transport in and from these countries can have big ripple effects.

21. **Second, the agricultural disruptions were major**. The war directly caused significant disruptions to agricultural production and exports from Ukraine. From the beginning of the conflict, the Ukrainian ports in the Black Sea, which are a key route of Ukrainian grain exports, were shut down. At the end of July 2022, three ports were unblocked following the deal between Kyiv and Moscow, which was brokered by the United Nations and Türkiye (UN, 2022). In July 2023, Russia announced the

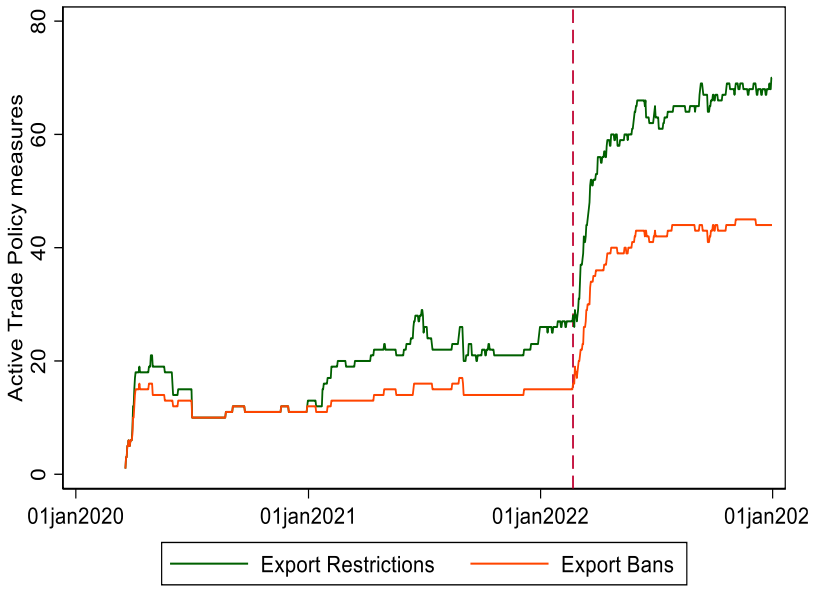
termination of the Black Sea Grain Initiative (European Council, 2023). Due to Russian forces' temporary occupation of some Ukrainian territories and overall lower yields, Ukraine harvested only 55 million tons of grain (wheat, corn, and barley), compared to 85 million tons in 2021. Furthermore, the area sown with grain was 11.62 million hectares, a decrease of 4.0 million hectares compared to the previous year (USDA, 2024). In the case of Russia, most disruptions stemmed from sanctions imposed by the US, the EU, and their allies. While agricultural and food commodities have not been directly sanctioned, reputational risks, transportation, and financial restrictions have made countries reluctant to commit to Russian grain supply and increased the costs of trading with Russia. In addition, between March and June/August 2022, Russia imposed restrictions on the exports of grains and sugar, aiming to protect domestic food markets (TASS, 2022).

22. **In addition to the direct effects, there were second-order market impacts. Numerous exporting-countries imposed export restrictions on agricultural and food commodities and other trade policy measures, while net importers reduced import tariffs to protect domestic consumers** (Laborde and Mamun, 2022). The war triggered a large jump in export bans and restrictions (Figure 7). In 2022, export restrictions covered the equivalent of over 11 percent of the pre-pandemic global food trade (Rocha and Espitia, 2023). These restrictions included India, the world's leading rice exporter, which accounts for around 40 percent of the global rice trade. In September 2022, India banned the export of broken rice and a 20 percent export duty on non-Basmati rice (except parboiled rice), covering around 60 percent of the country's exports (Good, 2022). The country introduced a new rice export ban in July 2023 (Glauber and Mamun, 2023). Governments appear reluctant to dismantle export restrictions, even after international food prices have declined. This political inertia may be due to the need to stabilize local food prices in the face of ongoing uncertainties about potential shocks that could disrupt food supply chains. These restrictions carry several costs and disadvantage domestic producers who cannot capitalize on higher prices in foreign or local markets without export restrictions. These costs can potentially deter investment and production and skew the agricultural production mix. Export restrictions also impact the country's balance of payments by diminishing the inflow of foreign currency from exports. Additionally, they can strain international trade relations and may provoke retaliatory measures.

23. **One reason governments have acted in seemingly detrimental ways to other countries and the global trading system, including ad hoc adjustment of trade policies and panic buying of imports, is the lack of timely and reliable information on food availability in world markets.** Faced with a poor information base, governments tend to react with excessive caution despite the high cost of doing so for their own countries and others. This tendency can also be encouraged and exploited by well-connected actors who benefit from such actions. In 2011, in recognition of the need to improve such data availability, quality, and timeliness, the G20 launched the AMIS.[7] Under this initiative, the G20 countries agreed to provide timely and accurate production, consumption, and stock data. International organizations agreed to improve monitoring, reporting, and analysis of market conditions and policies, including supporting enhancements to national and regional systems. The AMIS has improved the accessibility of high-quality data and information on market conditions and policies affecting food markets. However, it has limitations, including not incorporating information from several countries, including many African nations. Also, information on stocks is inherently difficult to collect comprehensively, making this data an important "weak link" in the overall monitoring of grain markets. Therefore, continued efforts to improve this situation are needed.

[7] Improving_global_governance_for_food_security AMIS.pdf

Figure 7: Evolution of Trade-Policy Measures Affecting Grains



Source: Global Trade Alert database.

24. **The third reason the report uses Russia's invasion of Ukraine as a case study is that understanding what happened during this episode and why is important not just for its own sake but also because of the lessons it holds for future shocks to world food markets**. In this light, the direct and indirect effects of the invasion can be considered a kind of "stress test" of the international food production and trading system. This experience has implications regarding how well the global system responds to shocks and how it might be improved.

2.2. Impact on Food Markets

25. **The global food trade system proved resilient in response to recent shocks**. The generalized pandemic–related supply chain disruptions and the more localized disruptions resulting from Russia's invasion of Ukraine certainly created spot shortages. However, disruptions were not the widespread acute food crises some had feared.[8] Estimating what trade flows would have been from Ukraine and Russia in the absence of the invasion and comparing this with actual flows revealed that, apart from the initial shock, the war had only modest impacts on global trade in the grain and oilseed markets. The EU Solidarity Lanes and the Black Sea Grain Initiative helped keep grain flowing out of Ukraine. General trade diversion from other exporters, especially North America and Europe, helped pick up the slack, avoiding major shortages.

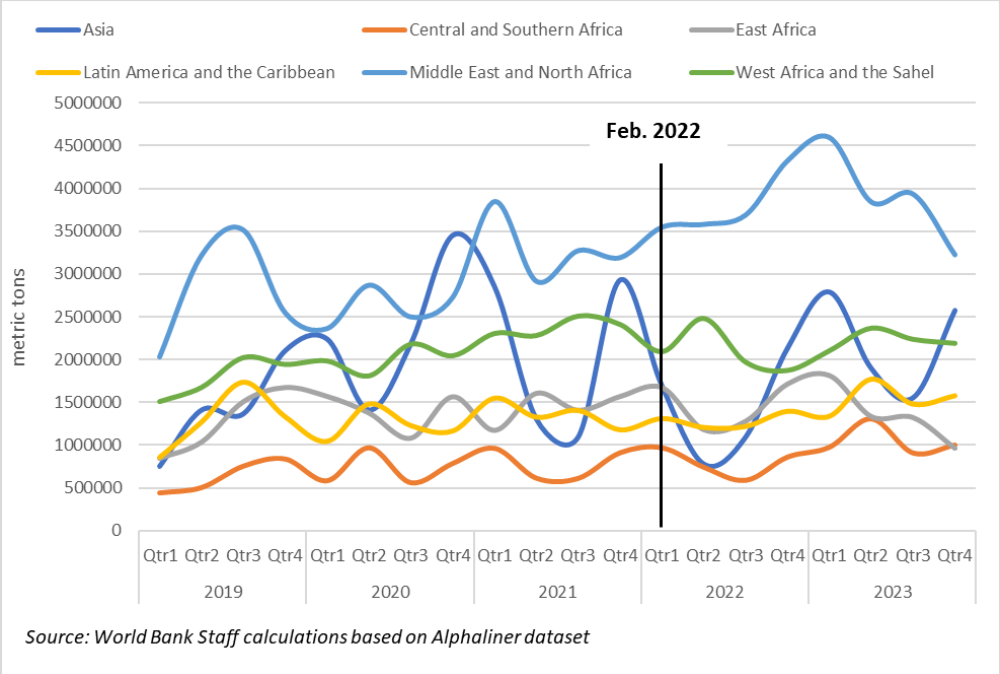
26. **In fact, there has been minimal disruption according to empirical evidence on the flow of grains to the countries identified as the most at risk by the Global Report on Food Crises (GRFC).**[9] After the initial shock, the normal seasonal swings in deliveries occurred, but there was no downward trend (Figure 8). Recovery to more or less pre-war normalcy on global markets took several months in some cases, but no regions appear to have experienced long-lasting reductions in imports (Figure ***8***). Looking at the composition of imports for each region by source country, the analysis finds that when imports from Ukraine fell to almost nothing, there was substantial diversification. However, different regions

[8] See for instance lead article in The Economist (2022)" The coming food catastrophe", May 19, 2022: https://www.economist.com/leaders/2022/05/19/the-coming-food-catastrophe

[9] For exact country composition of each region, refer to the note or directly to The Global Report on Food Crises (GRFC) report.

relied upon different sets of exporting countries to replace the Ukrainian imports. For example, West Africa and the Sahel increased shipments from Poland and Lithuania, likely made up of largely Ukrainian wheat re-routed through Europe. Other regions like MENA and the Central African region increased imports from EU countries but also from other major exporters, including Argentina and Australia. In addition to the diversification of source countries, there were changes in the product composition of trade. Along with maize, wheat was the commodity most affected by the war. As such, major producing regions expanded exports of wheat substitutes for consumption. This trend to substitute other grains for wheat is also observed in the imports of some major importers from Ukraine and Russia, including Türkiye and Egypt.

Figure 8: Total Wheat Imports to Regions with Acute Food Insecurity



Source: Cordula Rastogi and Daria Ulybina (2024)
Note: Regions are as listed in the GRFC (WFP 2023).

27. **Morocco's experience during Russia's invasion of Ukraine demonstrates the value of trade diversion in making the global trade system more flexible**. Before the war, the EU, Argentina, Ukraine, and Canada were the primary wheat suppliers to Morocco, with Russia playing a less significant role. However, recent data reveals that Morocco essentially ceased wheat imports from Russia, while imports from Ukraine experienced a substantial decline. Nevertheless, Morocco's total import volume has seemingly been unaffected by the war, with potential imports from Ukraine possibly redirected through the EU, passing through Romania or Türkiye in the process.

28. **This kind of evidence demonstrating the resilience of the trade system reinforces the argument against the use of national self-sufficiency as a measure of FNS**. Striving for self-sufficiency has high costs for countries adopting this as a metric. Martin et al. (2024) find that the cost of trade distortions to wheat is around US$12 billion per year for the countries imposing these barriers. This figure is 6.8 percent of the value of wheat production at world prices. The total cost of trade distortions to rice in the countries imposing them comes to US$33 billion per year at average 2010 to 2021 prices – more than 10 percent of the value of rice production at world prices. In addition, this policy objective has very small benefits if global shocks are not likely to seriously disrupt food supplies from abroad.

29. **Of course, the overall conclusion that the system is resilient does not imply that it is perfect.** Some actions would strengthen the system's overall resilience and build confidence to enhance the willingness of governments to refrain from heavy reliance on ad hoc, discretionary trade policies, thereby reducing the negative effects of national policy on price volatility at the global level. These confidence-building measures include strengthening the early warning systems and improving transparency and accuracy of the information on food stocks, e.g., through AMIS.[10]

30. **Small-scale and well-designed strategic grain reserves are a confidence-building strategy that may help governments of net food-importing countries manage food price spikes more efficiently and avoid using trade-policy instruments.** In the past, large grain reserves ("buffer stocks") were used in many countries to try stabilize domestic prices. These efforts almost universally resulted in very high costs and meager benefits in achieving their objectives. One major problem is that a large component of price variability is long-term cyclical or permanent (as revealed by the analysis discussed in Section 1), which means that buffer stock schemes will inevitably run out of either storage capacity or stocks. Another major issue is that successful schemes that reduce price swings tend to crowd out private storage activity. As a result, the net effect may not be any net increase in the country's overall storage capacity (total public plus private). Notwithstanding buffer stock schemes' infeasibility and deleterious consequences, more limited food emergency and safety net reserves may be a more practical and desirable strategy to achieve FNS outcomes than buffer stocks aiming at stabilizing prices. However, before undertaking such programs, alternatives must be carefully considered. If the decision is made to proceed, it is crucial to do so with appropriate design and implementation arrangements. An upcoming World Bank report will examine strategic food reserves, including adoption, design, and operation considerations.[11]

31. **In summary, analyses of the impacts of Russia's invasion of Ukraine show that the global food trade system weathered recent shocks reasonably well but could be enhanced further to prepare for a future when shocks are likely to be more frequent and worse.** This kind of evidence demonstrates the resilience of the trade system and supports the argument against using national self-sufficiency as a measure of FNS. Striving for self-sufficiency has high costs for countries that adopt this as a metric, and this policy objective has very small benefits if global shocks are unlikely to seriously disrupt food supplies from abroad.

2.3. Impacts on Fertilizer Markets

32. **Global FNS is vulnerable to long-term and short-term disruptors of food trade and shocks and policies obstructing trade in fertilizers**. Synthetic fertilizers are a critical input for high-yielding, efficient agricultural production and are essential for global FNS**.** They provide essential nutrients such as nitrogen, phosphorus, and potassium to crops, which are often depleted during intensive farming. Replenishing depleted nutrients in the soil promotes crop growth, increases yields, and improves harvest quality. Synthetic fertilizers are critical for feeding growing global populations since they enable farmers to maximize food production on existing arable land. Estimates generally conclude that nitrogen fertilizers are responsible for feeding 40–50 percent of the world's population (Hannah, 2017). A recent World Bank study (Ghose et al, 2023) focused on an unprecedent natural experiment where the government of Sri Lanka imposed an abrupt and unexpected ban on the imports of all chemical fertilizers in May 2021. Using high-frequency firm-level trade data, detailed agricultural ground production data, the study found that the fertilizer ban led to dramatic declines in agricultural production, fertilizer imports, and exports of fertilizer-dependent crops. It estimated that the ban's

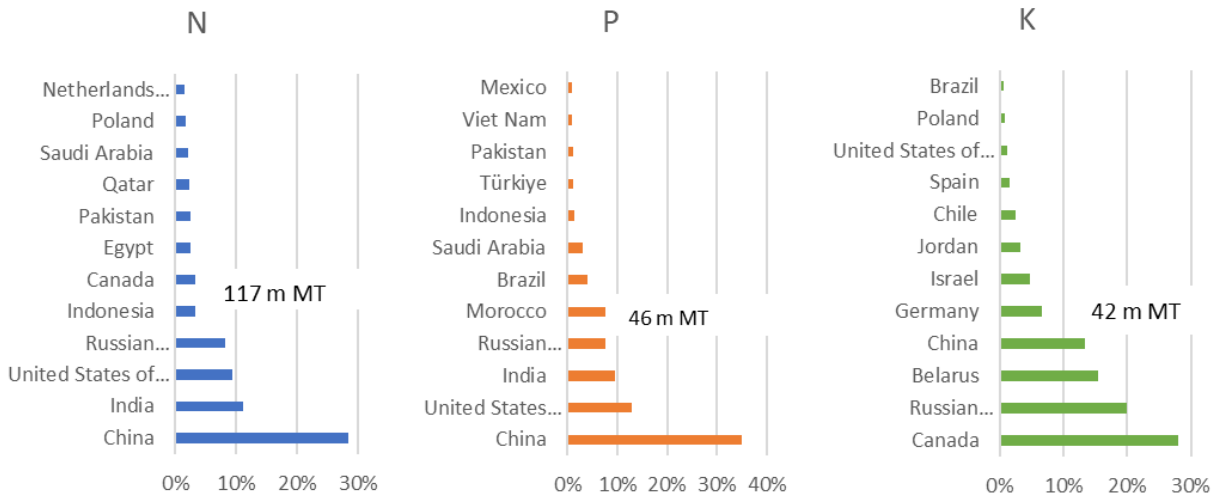
[10] Agricultural Market Information System: About (amis-outlook.org)Agricultural Market Information System (https://www.amis-outlook.org/amis-monitoring)

[11] The World Bank has started a preparation of the report on using strategic grain reserves for improving FNS. The report is being prepared jointly with the WFP. It will be published in the first quarter of 2025.

welfare effects were equivalent to a 1.5 percent income reduction on average, with losses disproportionately concentrated on regions specialized in the cultivation of relatively fertilizer-intensive crop.

33. **Several characteristics of the international fertilizer trade make it vulnerable to disruptions and other shocks, such as those caused by Russia's invasion of Ukraine. First, most fertilizer production is carried out in a small number of countries, making the supply chain susceptible to disruptions caused by geopolitical conflicts or natural disasters** (Figure 9). The top four suppliers of nitrogen fertilizer (China, India, the United States, and Russia) account for half its global supply; Canada, Russia, and Belarus supply two-thirds of potassium fertilizer; and China produces 36 percent of phosphorus fertilizer, and the top 5 producers supply over 75 percent of this type fertilizer. Problems affecting the supply chain of any of these major producers could have important ripple effects in the market. These effects could lead to food prices surging, making them less affordable.

Figure 9: Major Fertilizer Suppliers (Average 2012–21)



Source: FAOSTAT (April 25, 2024)
Note: Figures in millions of metric tons.

34. **Second, nitrogen fertilizers are heavily dependent on natural gas, a critical input in their manufacturing process**. Ammonia, an essential ingredient in nitrogen-based fertilizers such as urea and ammonium nitrate, is primarily synthesized through the Haber-Bosch process. This method involves combining nitrogen from the air with hydrogen derived from natural gas or other hydrocarbons under high pressure and temperature. This energy-intensive process requires substantial quantities of natural gas as a feedstock. As a result, variations in natural gas production, availability, and prices can significantly influence nitrogen fertilizers' production costs and supply chain dynamics. Disruptions or instabilities in gas production can lead to supply shortages and increased costs and contribute to price volatility in the nitrogen fertilizer market. This underscores the complex interdependence between natural gas production and nitrogen fertilizer manufacturing, a relationship that is evident in the correlation between fertilizer prices and natural gas prices (Figure 10).

35. **The Russian invasion of Ukraine and the subsequent trade-policy responses intensified the surges in both natural gas and fertilizer prices that were ongoing before the war.** Since Russia is a significant supplier of both natural gas and fertilizer, especially nitrogen and potassium, the direct and

indirect disruptions caused by Russia's invasion of Ukraine exacerbated the spike in both natural gas and fertilizer prices that was already ongoing (Figure 8). In mid-2021, a spike in natural gas prices, particularly in Europe, decreased ammonia production. Concurrently, rising coal prices in China prompted electricity rationing, forcing several fertilizer production facilities to cut back on production. Decreased production caused China to impose a quota on fertilizer exports, particularly phosphates, until June 2022, citing the need to safeguard domestic availability and FNS. China's reduction of fertilizer exports substantially reduced global supply and contributed to higher prices.

Figure 10: International Prices for Selected Commodities

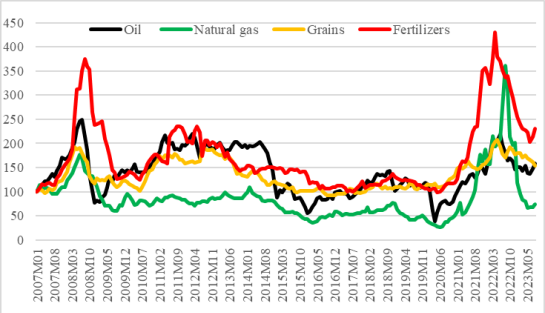
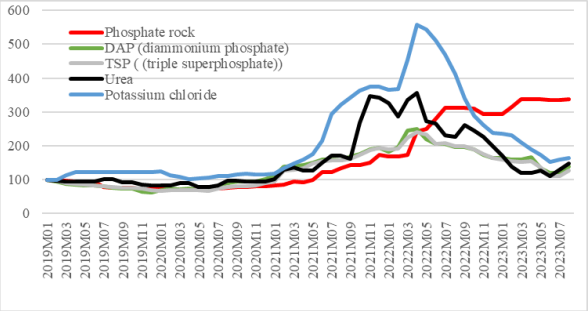


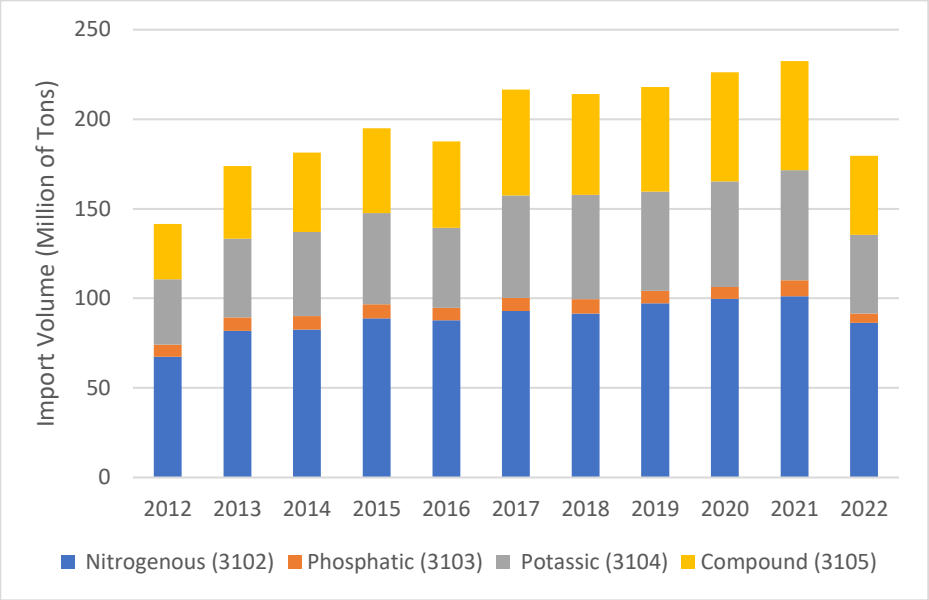
Figure 11: International Prices of Various Fertilizers (2019M1=100)



Source: World Bank Pink sheet monthly prices
2019M1=100, the fertilizer prices shown above are indexed to their values in January 2019, with the baseline value set at 100.

36. **The disruption reversed what had been a steady upward trend in fertilizer trade**. The decline in global fertilizer trade volumes in 2022 (Figure 9) is concerning, as it suggests that future agricultural production could fall short of its potential, especially during a period of relatively high food prices. Simulations of the disruptions show that in food-insecure countries, the nutritional deficit resulting from lower domestic food production, which presumably was at least in part due to lower fertilizer use, was higher than the nutritional deficit caused by lower imports. It is crucial to track the downturn in fertilizer trade to determine whether it is a transient occurrence or indicative of a longer-term issue.

Figure 12: Fertilizer Trade in Volumes by Product (Million Tons)



Source: Portugal-Perez et al (2024a) using data from COMTRADE.

37. **Much of the fertilizer trade is subject to various NTMs across countries, which introduces additional unpredictability and volatility.** While tariffs on fertilizer imports are generally low, with some notable exceptions (see Box 1), a large and growing proportion of global trade in fertilizers is covered by NTMs. While NTMs have also proliferated for other goods, those on fertilizer trade have increased even more in recent years (Figure 13). The most prevalent types of NTMs applied to imports of fertilizers are TBTs, non-automatic import licensing, and SPS measures (Figure 14).

Figure 13: Non-Tariff Measures on Fertilizer Trade

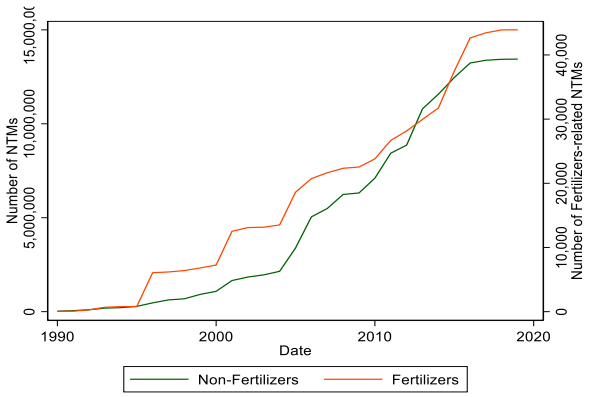
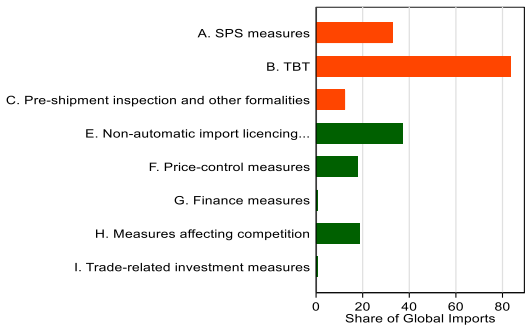


Figure 14: Share of Global Imports Covered by Import-Related Non-Tariff Measures on Fertilizer, 2019



Source: Data from UNCTAD.

Box 1: Low Tariffs on Fertilizer Imports, with a Few Exceptions.

Tariffs on fertilizers are close to zero in most countries and have been falling over time. However, some notable exceptions impose 10 percent or higher tariffs, as displayed below. The government may look upon some of these as revenue-raising measures. However, it seems likely that most have protectionist objectives and impose the same kinds of costs on domestic food producers and consumers as other protectionist tariffs.

Table 1: Countries with Fertilizer Tariffs Above 10 Percent, 2021

Importer	Type of Fertilizer	Product	Ad Valorem Tariff
China	Compound	310520	27.00
China	Compound	310530	27.00
China	Nitrogenous	310210	27.00
Zimbabwe	Nitrogenous	310210	25.00
Zimbabwe	Nitrogenous	310230	25.00
Zimbabwe	Compound	310520	25.00
Cuba	Compound	310520	16.66
Algeria	Nitrogenous	310210	13.52
Antigua and Barbuda	Nitrogenous	310210	10.00
Trinidad and Tobago	Nitrogenous	310210	10.00
Uzbekistan	Nitrogenous	310230	10.00
Uzbekistan	Nitrogenous	310240	10.00
Uzbekistan	Nitrogenous	310280	10.00
Uzbekistan	Potassic	310490	10.00

Source: World Bank staff using data from COMTRADE.

38. **This report uses estimates of the ad valorem equivalent (AVE) of the restrictiveness of some NTMs applied to fertilizer imports.** AVEs represent the additional costs that the presence of NTMs have on imports. They can also be thought of as the uniform tariff that will have the same impact on imports of the product as the NTM applied to it. Estimates of bilateral annual AVES of NTMs are an updated version of estimates by Adarov and Mahdi (2023). The data on the stocks of NTMs were drawn from the WTO I-TIP notifications database focusing on (a) SPS measures and (b) TBTs, two of the most prevalent NTMs in fertilizers. The methodology is based on Kee et al.'s (2008 and 2009) approach and used a three-step framework: (a) estimating bilateral import demand elasticities, (b) estimating the impact of two types of NTMs—TBTs and SPS measures—on the quantity of trade for each HS-6-digit product in each year, and (c) using the bilateral import demand elasticities estimated in the first step and the estimated impact of NTMs for each product in each year from the second step, the authors calculate the annual bilateral AVEs of each type of NTM.

39. **Since the objectives of SPS measures are not overtly protectionist, it is expected that this type of NTM would have less trade-reducing effects than TBTs; our results confirm this is the case**. AVEs can also be interpreted as the additional cost of importing fertilizer. The median of AVEs for SPS is close to zero, with some even negative (i.e., they have a trade expanding effect) for nitrogenous and potassic fertilizers. In contrast, the median of AVEs for TBTs is positive (i.e., they have a trade contracting effect), except for phosphatic fertilizer. The distribution of AVEs for SPS is more compact than that of TBTs, with a significant number of negative observations for SPS, and none larger than the 0–5 percent range. For TBTs, many estimated AVEs fall in the highest two categories, i.e., they are above 5 percent, indicating significant trade-distorting costs. One reasonable interpretation of the

negative AVEs for some countries' SPS measures is that the appropriate SPS regulations provide information on the quality and safety of fertilizers, which outweigh the compliance costs they impose, so the net effect is facilitating trade. TBTs are technical regulations that aim to provide valuable information and protection to consumers. Yet, the design and implementation of some TBTs lead to higher benefits than costs in the pursuit of legitimate goals.

Table 2: Number of Importer-Product Pairs by Range of AVEs for SPSs (left) and TBTs (right)

	Number of Importer-Product Pairs (SPSs)					
Fertilizer product	**<0**	**0**	**0-5**	**5-10**	**10-15**	**>15**
Nitrogenous	392	408	283	0	0	0
Phosphatic	2	282	0	0	0	0
Potassic	249	164	2	0	0	0
Compound	5	605	477	0	0	0
Total	648	1459	762	0	0	0

	Number of Importer-Product Pairs (TBTs)					
Fertilizer product	**<0**	**0**	**0-5**	**5-10**	**10-15**	**>15**
Nitrogenous	0	834	14	20	73	142
Phosphatic	0	185	8	3	2	86
Potassic	1	173	67	58	12	104
Compound	2	633	49	92	41	270
Total	3	1825	138	173	128	602

Source:Estimates from Portugal-Perez et al. (2024a).

40. **AVE estimates presented in the report can be considered as lower-bound estimates of total trade costs associated to NTMs, as other types of NTMs not captured in the WTO I-TIP databasesuch as pre-shipment inspections, non-automatic licensing, as well as quantity and price-control measures can further raise trade costs.** For instance, non-automatic import licensing can provide opportunities for rent-seeking behavior to government officials and perpetuate weaknesse in the regulatory system. For instance, a World Bank (2019) report discusses how non-automatic licenses to import fertilizer in Cambodia gave rise a to a scheme in which public officials asked for unofficial payments to fertilizer importers, thereby raising the price of imported fertilizer and hurting downstream farmers.

41. **Russia's invasion of Ukraine also triggered a surge in trade-policy actions affecting both fertilizer imports and exports**. While some policy actions were "liberalizing"—many probably in the form of tariff reductions aimed at insulating domestic markets from higher global prices—the majority were restrictive. Export restrictions, including export bans and taxes, were particularly detrimental to the broader trade system. They aim to insulate domestic markets in countries exporting fertilizer by increasing the locally available supply and preventing domestic prices from rising, similar to food markets, as discussed above. Due to a lack of coordination, export restriction measures and import tariff reductions have the perverse effect of exacerbating price swings in the world market. Consequently, numerous countries have in place some kind of restriction on exports or imports of fertilizer, amplifying price volatility and hindering the ability of the world trading system to respond optimally to further shocks (Figures 12 and 13).

Figure 15: Evolution of Trade-Policy Measures Affecting Fertilizer

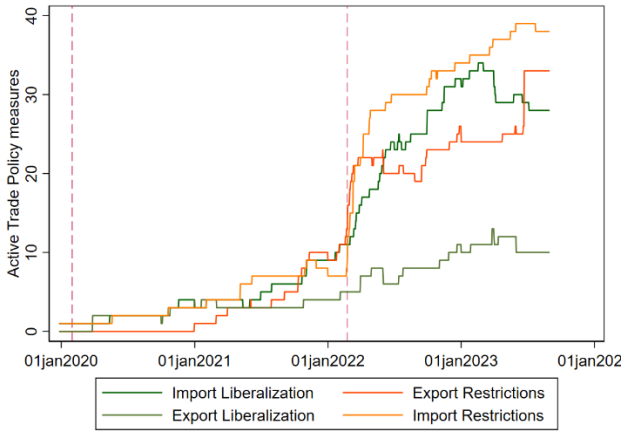
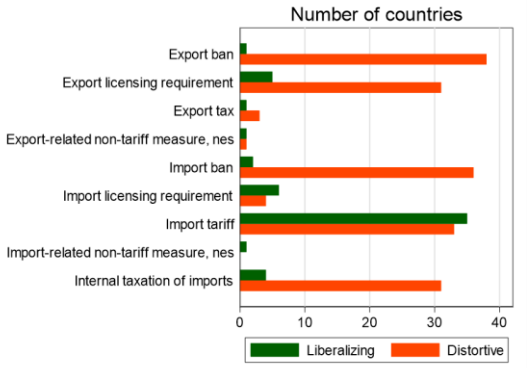


Figure 16: Number of Countries with Active Trade-Policy Measures Affecting Fertilizers, Aug 31, 2023



Source: Data from Global Trade Alert.

42. **To summarize, the Russian invasion of Ukraine drew attention to the importance of fertilizers for food security as they are key inputs for food production**. While tariffs on fertilizer trade are typically low, a large and growing proportion of global trade in fertilizers is subject to various NTMs. TBTs tend to contract trade, with exceptions noted in the phosphatic fertilizer trade. Other NTMs not captured in the AVE estimates, such as pre-shipment inspections, non-automatic licensing, and quantity and price-control measures, can raise further trade costs. Therefore, it is important to analyze in detail specific NTMs and determine how some of them can be streamlined to reduce trade costs or, in some cases, removed while pursuing the goals they intend to pursue. Harmonization and mutual recognition of some NTMs can also reduce associated trade costs.

2.4. General Equilibrium, Indirect, and Household-Level Effects

43. **The Russian invasion caused both direct first-order impacts on FNS. It also triggered second-order and indirect "knock-on" effects stemming from other countries' policy responses and disruptions to the fertilizer and energy markets**. Some other countries' responses were intentionally disruptive, e.g., the sanctions imposed on Russia, while others were not, e.g., food importers lowering import tariffs and exporters imposing export restrictions. A key question that emerges is the significance of these secondary impacts relative to the direct effects. It appears that they were indeed "quite important." Another question concerns how these impacts were distributed among countries.

General equilibrium and indirect effects

44. **This section breaks down the disruptions' impacts and quantifies each source's effect on changes in real income and agricultural exports. Doing so allows comparison of different sources of effects that stemmed directly or indirectly from the war and contemporaneous weather events** (Chepeliev et al. 2023)**.** An economy-wide modeling framework was used to explore the impacts of the Russian invasion of Ukraine on the global agricultural trade and value chains (Box 2). The modeling framework decomposes the impacts of Russia's invasion of Ukraine into four core impact channels: war-related agricultural shocks; trade restriction shocks; fertilizer-related and weather shocks; and energy-related

shocks and sanctions (other shocks). The modeling allows the identification of the individual impact of each component.

Box 2: Methodology of Estimating General Equilibrium and Indirect Effects from Russia's Invasion of Ukraine

An economy-wide modeling framework was used to explore the impacts of the Russian invasion of Ukraine on the global agricultural trade and value chains. A global Multi-Region Input Output (MRIO) database is linked with the Environmental Impact and Sustainability Applied General Equilibrium (ENVISAGE) computable general equilibrium (CGE) model, which distinguishes agent-based demand for imports by region of origin (Chepeliev et al., 2022b). A recently developed GTAP nutritional module is also incorporated into the assessment framework following Chepeliev (2022). The model represents the global economy with 39 aggregate regions/countries and 33 sectors). Annex describes the different components of the model. The modeling framework decomposes the impacts of Russia's invasion of Ukraine into four core impact channels (Table 3).

Table 3: Shock Descriptions

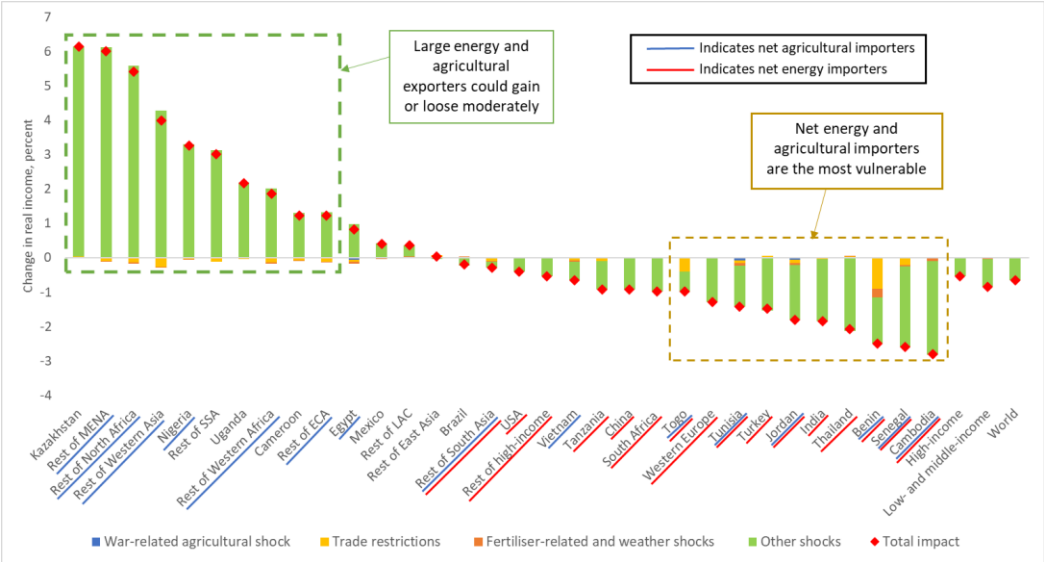
Grouping	Shock channel
War-related agricultural shock	Agricultural productivity shock in Ukraine
Trade restrictions shock	Food and fertilizer export restrictions imposed by countries around the world (bans or export taxes) during 2022
Fertilizer-related and weather shocks	An increase in the price of imported fertilizer
	Weather-related agricultural productivity change
Energy-related shocks and sanctions (other shocks)	Economy-wide productivity shock in the Black Sea Region
	Restrictions on exports of electronics to Russia
	Restrictions on exports of electronics and manufacturing production from Russia
	Restrictions on imports of metals and chemicals from Russia and Belarus by the European countries
	Restrictions on imports of fossil fuels from Russia by the US and UK
	Restrictions in the global fossil fuel supply
	Restrictions on energy imports by the EU from Russia

The analysis has four caveats. First, the results represent relative price changes with respect to the deflator. Second, an applied model provides a representation of the economic flows annually. As such, observed impacts also reflect annual average implications, which differ from the short-term market volatility impacts. Third, the current assessment focuses on the impacts on key commodity markets—energy, crops, and fertilizers—and only cover select sanctions. The analysis does not capture the potential spillovers from the significant and broad sanctions imposed on the Russian economy and increased market uncertainty. Finally, the current analysis primarily focuses on quantifying the relative impacts across considered channels, highlighting the magnitudes of the implemented shocks and potential policy responses. In this regard, historically observed impacts across selected countries might differ from the results discussed in the paper due to the various interacting channels not explicitly captured in the analysis.

Source: Chepeliev et al. (2024)

45. **In both cases, the average direct effects of the agricultural trade disruption are relatively small compared to the contributions of the other effects**. For real income, the most important impacts came from shocks to the energy market (labeled as "other shocks"), although for some countries, the effects of trade restrictions also played a significant role (Figure 17). At the global level, out of around 0.7 percent reduction in households' income under all shocks combined, only a small share (less than 5 percent) can be attributed to impacts related to agriculture and fertilizers. The rest is largely associated with disruptions in energy markets. Unsurprisingly, the biggest losers are net importers of energy agricultural products. However, in some countries, food imports are very large, and the impacts of direct agricultural trade shocks were much higher; for instance, 41 percent for Togo and 46 percent for Benin.

Figure 17: Change in Real Income in Selected Countries and Regions, Decomposed Across Scenarios (Percent)

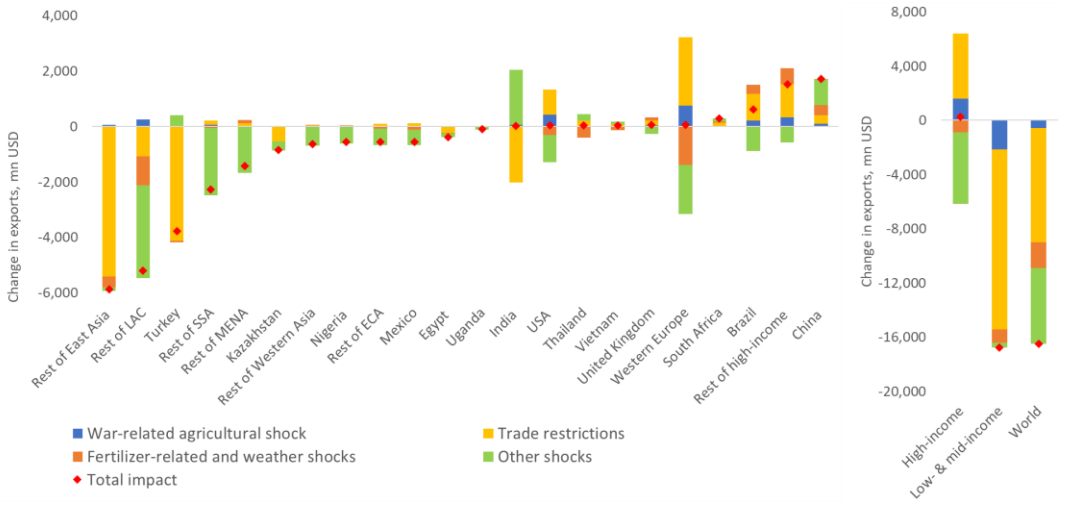


Notes: MENA, Middle East and North Africa; SSA, Sub-Saharan Africa; ECA, Europe and Central Asia; LAC, Latin America and the Caribbean. Net agricultural and energy importers are highlighted for cases when net import values correspond to at least 1 percent of the country's GDP. For reporting purposes, some individual countries included in the model aggregation are combined within aggregate regions on this figure. In particular, the Rest of ECA includes Kyrgyzstan, Tajikistan, ECA, and XSU; Western Europe comprises Western Europe and the United Kingdom. Russia, Belarus, and Ukraine are not reported as individual countries or within composite regions but are included to the low- and middle-income aggregation.

Source: Chepeliev et al. (2024).

46. **Trade restrictions are the primary driver of changes in agricultural exports in most countries, although other energy-related shocks also had a large effect in some countries** (Figure 18). The direct effects of the disruption of agricultural trade only played a major role in a few countries. The results suggest that the direct disruption of the agricultural supply from Ukraine contributes less than 4 percent of the overall decline in global agricultural and food exports. In contrast, trade restrictions on agriculture and fertilizers are responsible for approximately 51 percent of the reduction. Energy-related shocks and sanctions (other shocks) contribute 34 percent, while fertilizer-related and weather shocks account for 11 percent. Regarding distribution, the net effect is negative for most countries, though a substantial number experience a negligible or positive net effect.

Figure 18: Decomposing the Change of Agricultural and Food Exports Across Countries (US$, millions)

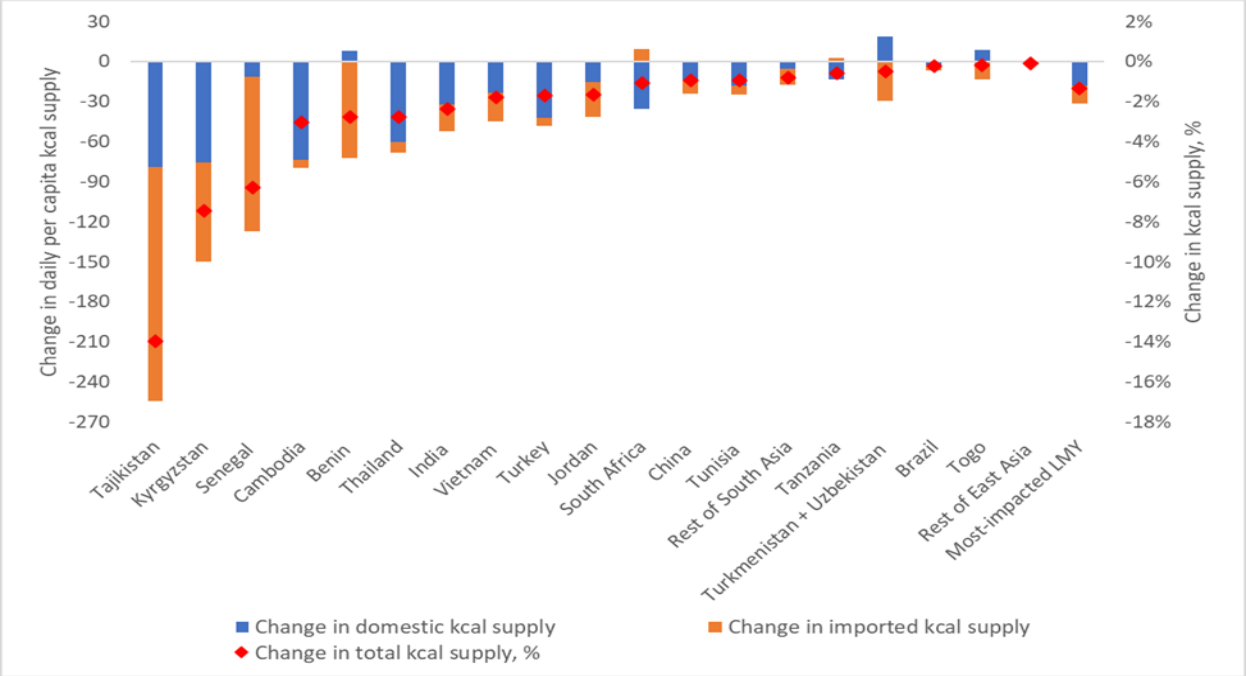


Source: Chepeliev et al. (2024).

Notes: Selected agricultural exporters are reported as individual countries or regions on the figure. Reporting of changes across composite aggregates on the right panel includes all countries/regions represented in the modeling framework.

47. **The decomposition of food consumption changes in individual countries, distinguishing between domestic and imported sources, reveals that domestic reductions predominate (Figure 19).** In the most-impacted developing countries, an average daily per capita food supply reduction is 31 kcal. About 58 percent of this reduction can be attributed to a decline in the supply of domestically produced food, likely due to increased costs for fertilizer and energy, while a reduction in imported food drives the remaining part. This finding further stresses the importance of accounting for spillover channels such as rising prices of energy and fertilizer, as well as changing climate conditions, which greatly exacerbate disruptions of the international trade flows. In relative terms, the model finds that countries in South and Central Asia, as well as Sub-Saharan Africa, are impacted the most adversely in terms of food availability. In most cases, observed reductions in daily per capita kcal supply in these regions are 20–70 kcal per capita per day, equivalent to a reduction of 1–3 percent. The estimated reductions are considerably greater in several countries, including Senegal, Kyrgyz Republic, and Tajikistan, ranging from 6–14 percent.

Figure 19: Changes in Kcal Supply Across Most-Impacted Developing Countries and Regions Under the Combination of All Shocks



Source: Chepeliev et al. (2024).

Notes: "Most-impacted low and middle income (LMY)" includes an aggregation of the 15 countries/regions that observed the most substantial reduction in caloric supply within the considered scenario.

Distributional effects

48. **Considering heterogeneous effects at the household level is crucial for obtaining a more accurate assessment of the overall impacts and understanding the distributional consequences of shocks.** This subsection presents the findings by Artuc et al. (2024), who constructed a general equilibrium trade model of heterogeneous households to estimate the welfare implications of the Russian invasion of Ukraine. The model incorporates household-level survey data[12] from 51 low- and middle-income countries. It simulates heterogeneous household decisions regarding consumption and land and labor allocations, including crop choices, among 20 possible crops. Household data is aggregated into 100 households per country, each representing a percentile of the income distribution.[13]In contrast to other studies that use a single representative household for each country, this study obtains highly granular results of the impacts on income distribution within countries. It also demonstrates that using a single representative household for all these countries—as in other studies—would have underestimated overall welfare losses by about 8 percent on average. This inherent aggregation bias happens because the average welfare impact across heterogeneous households, each making different consumption and production decisions, does not coincide with the welfare impact for a single household characterized by aggregate-level data.[14] Since the shock induced by the Russian invasion of Ukraine has already occurred, the model's goodness of fit is evaluated by assessing whether the price changes predicted by the model correlate with actual food price increases observed in developing countries after the start of the war. Reassuringly, the price changes generated by the model are highly correlated with observed prices.

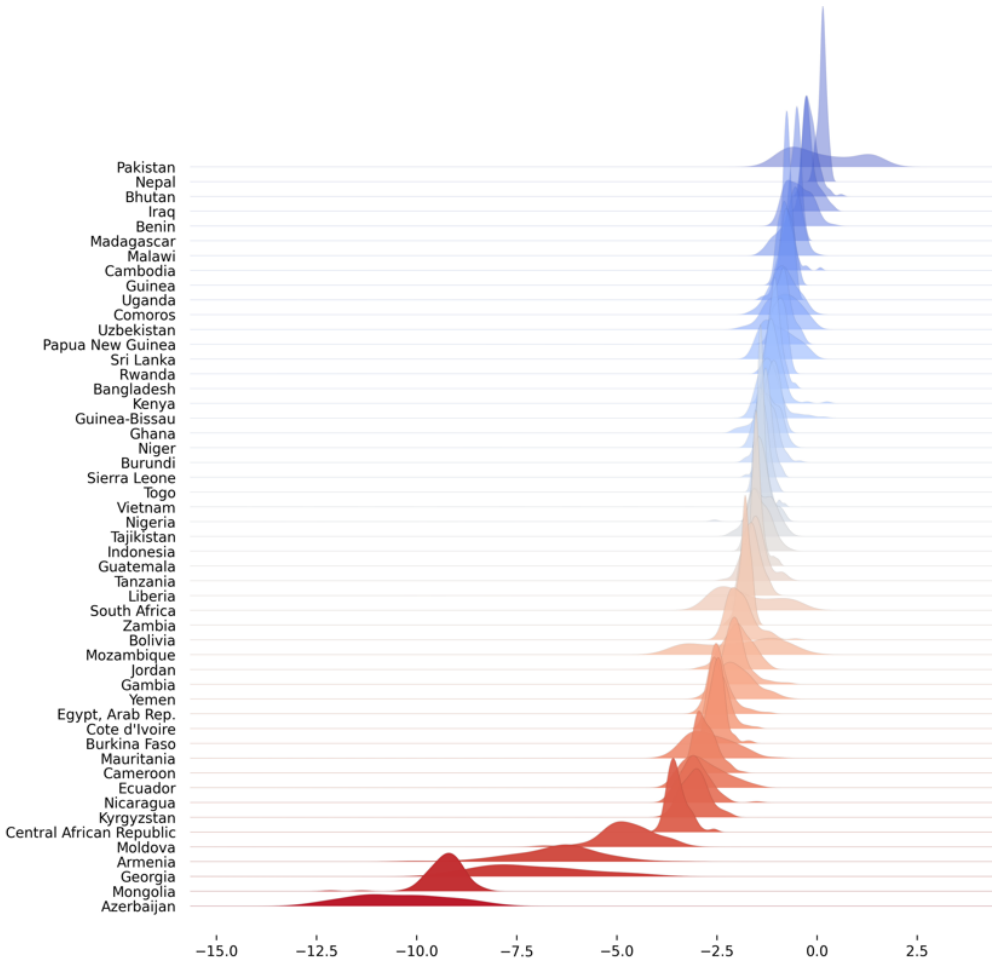
[12] The data is from the Household Impacts of Tariffs database (Artuc, Porto, and Rijkers, 2020).

[13] For the global modelling, a single representative household is used in countries other than these 51 countries.

[14] These findings are in line with literature on heterogenous firms that concluded that microstructure matters for the aggregate gains from trade (Melitz and Reddings, 2015, and Costinot et al 2020, Econometrica).

49. **The Russian invasion of Ukraine led to economic losses that were highly heterogeneous across and within countries**. The simulations assumed that exports and imports of agricultural products and fertilizers to and from Ukraine were completely cut off, and that Russia banned exports of cereals, sugar, oilseeds, and fertilizers.[15] Over 96 percent of households in the sample experienced reduced real incomes because of the war (Figure 20). More than three-quarters of all households experienced losses of 3–10 percent. However, the distribution of losses is skewed and has a large left tail, with the maximum loss incurred by a single household being 12.78 percent and the biggest gain 0.40 percent. The largest losses are incurred by households living in countries located close to Russia, such as Azerbaijan, where average real income decreased by 10.41 percent, Mongolia (-9.31 percent), Georgia (-7.08 percent), and Armenia (-6.51 percent). On the other end of the spectrum, the average income gains in Nepal and Pakistan are positive, albeit very small (0.14 percent).

Figure 20: Distribution of Welfare Effects of the Russian Invasion of Ukraine



Source: simulations by Artuc et al (2024)

50. **The variation within countries is as striking as the large variation in gains across countries.** Most existing trade models based on a single aggregate agent cannot capture this pattern. In Azerbaijan for

[15] As shown in other research, disruption in Ukrainian exports was far from the total, as much of this trade was apparently re-routed through other countries or carried out under the Solidarity Lanes or the Black Sea Grain Initiative. That notwithstanding, the price effects predicted by the simulations in this section were close to those observed.

instance, all households lost from the war, but the losses range from 8.07 percent to 12.78 percent. In Togo, all households lost, too, but the losses range from 1.64 percent to 0.97 percent. By contrast, in Pakistan, impacts are mixed. Over half of the population (52 percent) lost real income, but the remainder gained because of the war; impacts ranged from -1.07 percent to 1.60 percent.

51. **At the country level, the greatest losses (in percentage terms) tend to be in the countries with higher incomes in the sample of low- and middle-income countries. In contrast, within countries, the highest (percentage) losses are in poorer households**. On average, households at the bottom of the income distribution suffered larger losses than households at the top. The losses for the bottom 25 percent of households (-2.2 percent on average) are 23 percent higher than those for the top 25 percent (-1.8 percent on average), implying an increase in income inequality. Although the effects of the war on income from labor and land prices are complex, the rise in food prices is the most dominant effect, which affects the poor disproportionately as they spend a higher share of their income on food.

To summarize, this chapter suggests that a large part of the negative impact of Russia's invasion of Ukraine on FNS is through global markets (and large spillovers), not directly via the local market. In addition, these impacts vary across income distributions, with poorer households bearing the brunt of the costs.

CHAPTER 3: Price Insulation and its Impact on the Volatility of International and Domestic Food Prices

Policy objectives aimed at divorcing prices from world markets have generally not been fulfilled, and the attempt has had adverse impacts. In fact, price insulation magnifies world price shocks, creating a collective action problem and global negative externalities from the policy choices made by individual countries. This is true both of ad hoc adjustment in import tariffs and NTMs in response to world price movements and of use of export taxes and controls. These policies also can actually increase domestic price instability in the countries that use them. This collective action problem is not addressed effectively through current global institutions.

3.1. Evidence of Price Insulation

52. **Food price volatility is a key concern for policymakers.** Chapter 1 shows that volatility was pronounced during the 2009–23 multi-shock period and was mainly caused by macroeconomic variables. This volatility is detrimental to the welfare of poor and vulnerable households. High food prices put the FNS of vulnerable net buyers of food at risk, while low prices may impoverish farmers reliant on food production and sale for their incomes. In addition, political stability is threatened by food price volatility, particularly in urban areas (for example, see Bellemare et al. 2015).

53. **In response to food price volatility, governments tend to insulate their domestic markets.** As has long been clear, many governments tend to respond to price shocks in ways that insulate their domestic economies to ensure that local prices fluctuate less than world prices. Another way of expressing this is that the policies prevent the full "transmission" of fluctuations in world prices. For example, when world prices fall, countries sometimes raise import tariffs or use export subsidies to avoid declines in domestic prices (Martin and Anderson, 2011). When world prices of food staples such as wheat rise, exporters frequently introduce export restrictions, while importers often reduce their import barriers to avoid having their domestic prices rise in line with world prices (Giordani et al., 2016). Both measures are intended to prevent domestic prices from rising commensurate with global market prices.

54. **Price insulation is present in rice and wheat markets**. Martin et al. (2024) use annual data on producer and external reference prices for rice and wheat for 29 economies from the Agricultural Incentives (Anderson 2008) and AgIncentives databases up to 2021. These annual data are designed to measure the level of protection per country and commodity.[16] The analysis of price transmission by Martin et al. (2024) indicates that, for most countries, policies aim to reduce the extent to which domestic prices change in response to changes in external prices. The following describes the results.

55. **Price insulation in the rice market.** Figure ***21*** shows prices received by producers and the reference prices that producers would have received in the absence of trade-policy interventions. These price data highlight sharp differences between domestic and external prices in many countries while showing the close correspondence between the two series in other countries. Even in countries where the two series diverge for extended periods, the domestic series appear to respond to international prices somewhat. For example, the producer and reference prices in India begin and end in a similar proportion to each other. The graphs reveal that the domestic prices are not necessarily less volatile than the external prices, despite the strong emphasis on price stabilization in many trade-policy discussions for food staples (Timmer, 2010).

[16] The annual price data are designed to measure the level of protection by choosing comparable commodities, using producer prices as a proxy for domestic prices, setting external reference prices as work prices adjusted for transport and marketing costs and degree of processing. Therefore, the only differences between producers and reference prices are due to policy.

Figure 21: Producer and Reference Prices for Rice at the Farm Gate, by Country Code (US$/MT)

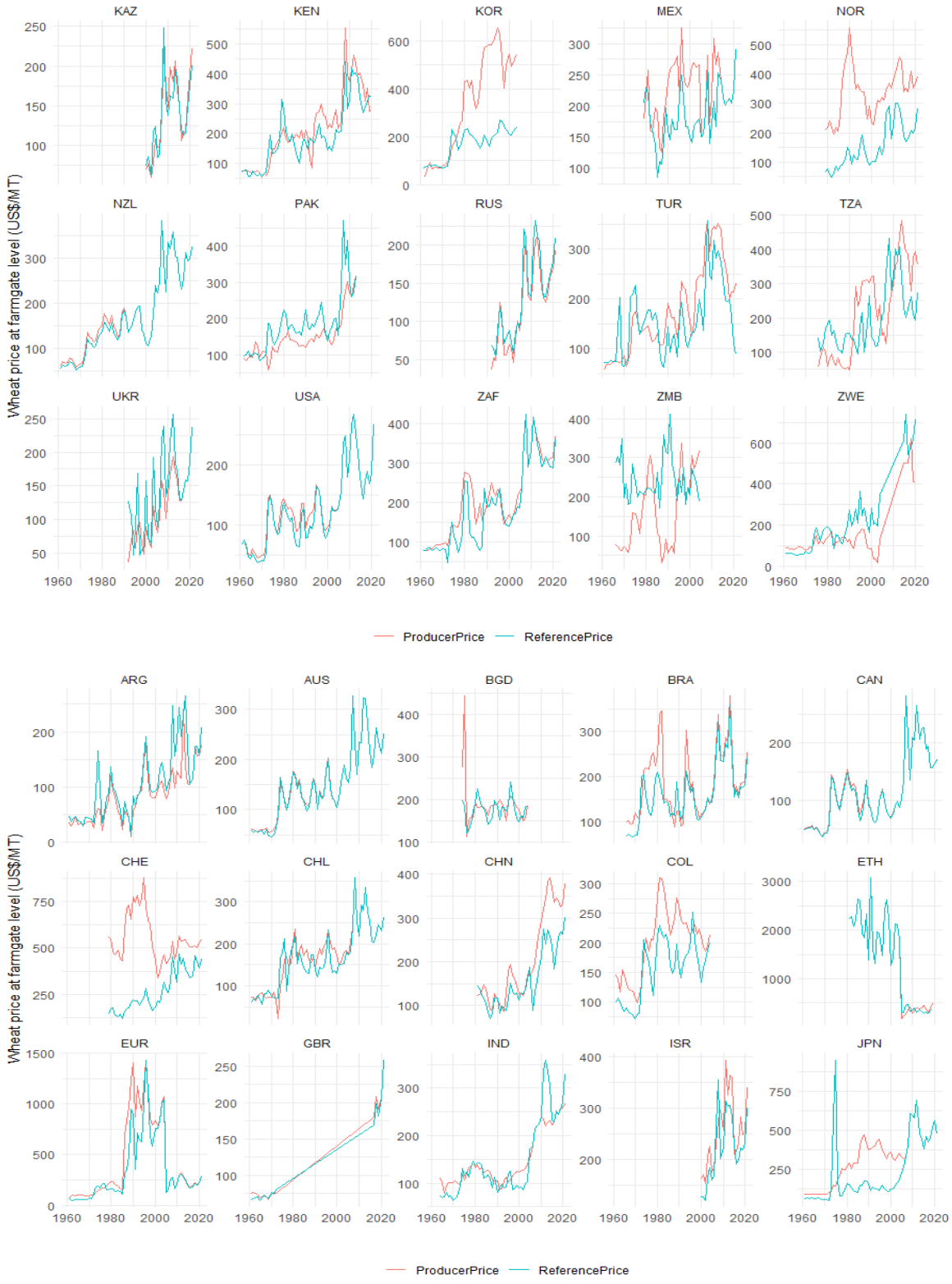
Source: Martin et al. *(2024)*

56. **Price insulation in the wheat market**. Figure ***22*** presents data for wheat prices on the same basis as those for rice in Figure ***21***. In some countries, like Argentina, the differences between the two prices are intermittent, being sizable in some periods and very small in others. In other countries, such as Australia and Canada, the differences have been quite small in most periods and essentially zero in recent years. In several countries, like Bangladesh, Europe, Japan, Switzerland, and the United States, there appear to have been structural breaks in the trade regime, with the relationship between the two prices changing sharply during the sample period. In a few countries, like India, the producer price is much more stable than the reference price, but this pattern is surprisingly rare given the widespread use of price insulation. In many other countries, such as Switzerland, Colombia, and Norway, the domestic price appears to be at least as volatile as—or perhaps more volatile than—the external reference price.

57. **Statistical models applied to the data in Figures 16 and 17 confirm that policymakers in many countries pass through only part of any change in world prices**. On average, only about half of any annual change in world prices of rice or wheat is passed through into domestic prices. Policymakers subsequently adjust their policies to return to an equilibrium level of protection or taxation. This behavior is consistent with policymakers seeking to avoid the high political costs of making sharp changes in domestic prices and deviating too far from the rate of protection or taxation that balances the political pressure from producers and consumers.

58. **Within this general framework, however, there is considerable heterogeneity between countries**. In some countries—frequently high-income exporters—there is little resistance to passing through price changes. Elsewhere, especially in countries where food expenses are an important share of household budgets, policymakers strongly insulate domestic markets from changes in world prices.

Figure 22. Producer and Reference Prices for Wheat at the Farm Gate, by Country Code (US$/MT)



Source: Martin et al. (2024)

59. **Even using a different methodology, Hoffman et al. (2023) find that price transmission is imperfect in grain markets.** While the Martin, Mamun, and Minot (2024) study examines annual price changes, the Hoffman et al. study (2023) examines monthly price changes on a shorter time horizon**.** Monthly price data for wheat, yellow maize, white maize, and rice was obtained from the Food and Agriculture Organization's Global Information and Early Warning System (GIEWS, FAO, 2022). These data were used to estimate a smooth transmission model of price transmission from international to domestic markets and to investigate whether passthrough decreases when international prices increase. Methodology and data sources are explained in Annex 3. As in the previous study, this study finds significant heterogeneity in responses. The heterogeneity appears to be particularly pronounced for yellow maize. For wheat, it seems that when world prices are low, domestic markets have relatively little insulation on average, a result not shared in the yellow maize market. However, even for wheat, when prices are high, the insulation effect is generally quite strong.

60. **Wheat.** As shown in Figure 23 the elasticity for wheat falls for most countries and on average during episodes of high international wheat prices such as in 2007/08 and 2022/23 the mid-point of the transition from the low- to the high-price regimes ranges from US$250–300 per ton for most countries.

61. **Yellow maize.** The elasticities for yellow maize are lower than for wheat on average; the median elasticity mostly moves between 0.3 and 0.5 when international prices are low and falls to roughly 0.2 when international prices peak. Again, we see considerably more heterogeneity than was the case for wheat. Some elasticities drop sharply in the high-price regime and become negative, while others increase. The mid-point of the transition from the low- to the high-price regimes for yellow maize lies between roughly US$270–280 per ton for most countries, corresponding to the major price peaks experienced in the last two decades.

62. **White maize.** For white maize, elasticities mostly move between 0.3 and 0.5 but fall sharply to values approaching -1 when international prices increase; this occurred in 2011/12, 2016, and 2022. Note that we only analyzed 11 white maize price series, of which six are prices from different market locations in Togo. The price series for which elasticity is higher rather than lower in the high-price regime is a retail price from Maputo in Mozambique. In most countries, the transition between the low- and the high-price regimes occurs when international prices reach US$260–265 per ton, which is somewhat lower than the transition trigger for yellow maize.

63. The median elasticity for rice is generally higher than for maize and typically equals 0.5 or more. However, when international rice prices increase, the median elasticity falls to 0.2–0.3. This effect was seen in 2008, 2011/12, and briefly in 2020 and early 2021. As rice prices did not peak as strongly as wheat and maize prices in 2022, there is no evidence of increased insulation for this important staple following Russia's attack on Ukraine. The mid-point of the transition between the low- and the high-price regimes averages around US$550 per ton.

Figures 20–23: Estimated Elasticities of Transmission from International to Domestic Prices

Figure 23: Wheat

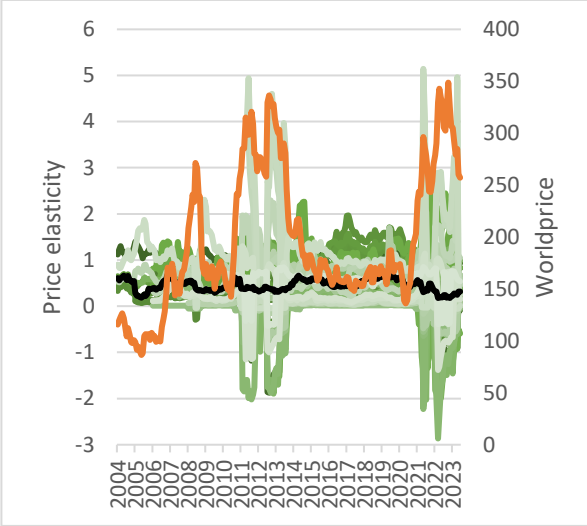


Figure 24: Yellow maize

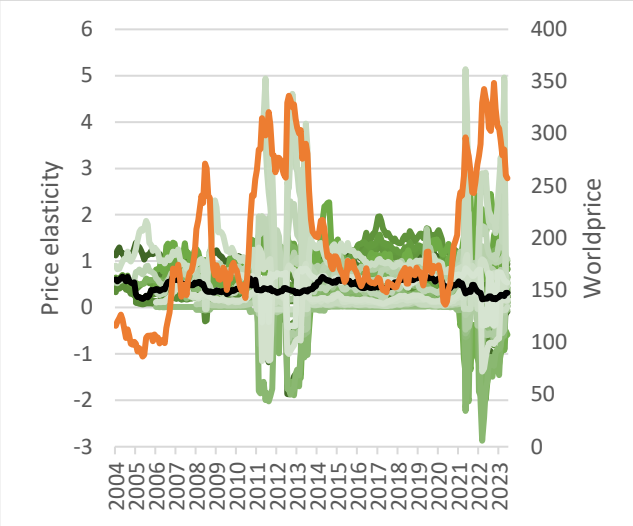


Figure 25: White maize

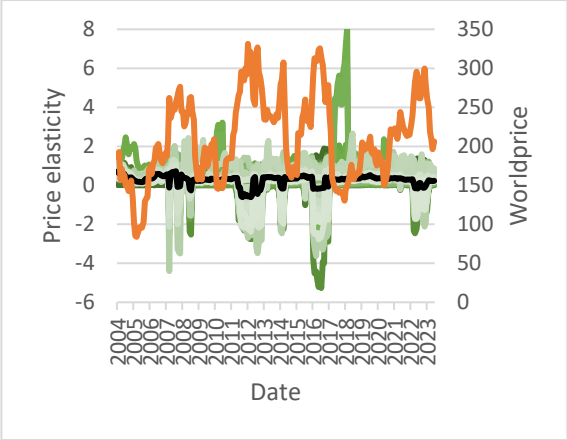
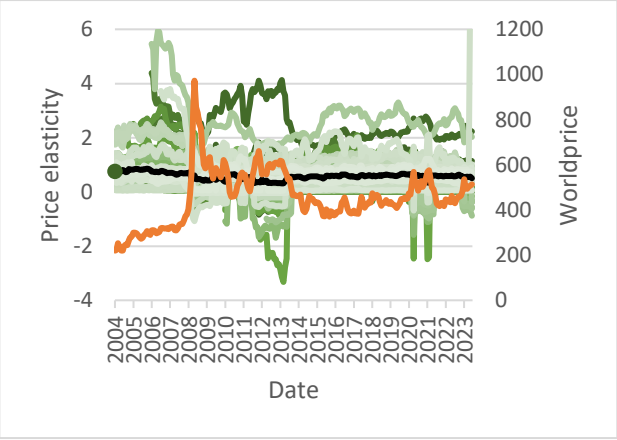


Figure 26: Rice



International price in red, individual elasticities in green, median elasticity in ***black****.*

Source: Hoffman et al. *(2024).*

3.2. The Political Economy of Price Insulation

64. **Price insulation and the associated adjustments in food prices can be politically costly.** So, it is important to understand the motivation of policymakers. Giordani, Rocha, and Ruta (2016) point to loss aversion models whereby consumers losing from higher prices react more strongly than producers, and producers losing from lower prices react more strongly than consumers. But there is also a political-economy equilibrium to be respected, as emphasized by Grossman and Helpman (1994): if protection rates change when world prices change, this disturbs the political-economy balance that underlies the tendency for protection to be systematically positive in some countries and negative in others when prices are stable.

65. **The report models policymakers' decision-making as a trade-off between short- and long-term policies for trade in two key staples: rice and wheat**. Based on the model developed in Martin et al

(2024), resisting price changes upsets the political-economy equilibrium. Protection falls if world price rises, but the domestic price does not. However, deviations from the political-economy equilibrium are costly. Policymakers' decisions regarding the levels of internal versus border prices result from two forces. First, there is some equilibrium level of protection, which results from internal political considerations, among which are the inherent tradeoffs between the interests of food producers in maintaining high prices and those of consumers in keeping prices low. Second, political costs are incurred when domestic prices are adjusted to return to equilibrium in response to world price movements and idiosyncratic shocks to local supply or demand that cause deviations from the equilibrium rate of protection. Depending on the relative magnitude of these two costs, governments may move quickly or more slowly, resulting in lower or higher average deviations of internal prices from world prices. The paper estimates a parameter measuring this adjustment speed for individual economies and finds a range of values among countries. The model is estimated using newly available data on the price of staple food. As these data measure protection rates, they eliminate many non-policy influences, such as additive margins or changes in the direction of trade that cause conventional measures of world and domestic prices to respond differently to shocks. Annex 4 explains the methodology.

66. **Although there are differences between countries, in almost all cases, the estimates fall within a range consistent with the political-economy decision-making model. This provides strong confirmation of the model.**

67. **Results for rice.** In all but a few countries, results for rice are consistent with the political-economy interpretation described above**.** In nearly all cases, the coefficient on the change in world prices, δ—showing the extent to which the domestic price is adjusted in response to changes in the world price—is positive and lies between zero and unity. In nearly all cases, the error-correction term, θ—capturing the speed of adjustment toward long-term political-economy equilibrium—is negative and between zero and one. These results imply that deviations from the political-economy equilibrium are reduced in subsequent periods. The size of the price adjustment term provides insights into policymakers' aversion to price adjustment, while the weight on error correction provides insights into the relative magnitudes of their aversion to changing prices and to being away from the political-economy equilibrium.

68. For results consistent with the model, the impact effect of a change in world prices on domestic prices (δ) ranges from 0.94 in Australia through 0.75 in Europe, 0.73 in the USA, 0.42 in China, 0.14 in Japan to 0.02 in Korea and 0.01 in Bangladesh. Several countries that might seem strongly averse to transmitting changes in world prices—such as India (0.8) and Indonesia (0.6)—have quite high initial passthrough. The impact effect is inconsistent with the theory in only two countries, Kenya and Türkiye, and the estimates are not statistically significant. The error-correction terms, θ, have an important economic interpretation, indicating how much of the gap between the domestic and world price is made up in the period following an initial shock. These coefficients range from -0.71 in Brazil to -0.01 in Bangladesh. The absolute value of this parameter generally appears to be smaller than for the δ coefficient, although the absolute values of the two coefficients appear to be positively correlated.

69. **Results for wheat**. There is a significant heterogeneity between countries. The short-run adjustment coefficients are close to one for traditional exporters such as Argentina, Australia, Canada, and the USA. Major exporters, Europe and Russia, also have high short-run rates of price transmission. The result for Europe—an aggregate with membership expanding over time—is somewhat surprising given the high levels of support and apparent price insulation. Another set of countries has short-term price transmission rates below 0.9 but above 0.3, including Bangladesh (0.75), Brazil (0.75), Israel (0.71), Kazakhstan (0.73), Korea (0.49), Mexico (0.65), Ukraine (0.51), Switzerland (0.33), China (0.39), Kenya (0.38), Colombia (0.33) and South Africa (0.34). A third set of countries, including Türkiye (0.27), Norway (0.29), India (0.13), and Japan (0.10), has small, but generally still statistically significant, δ values. Unsurprisingly, the second and third groups of countries include many with

relatively low incomes, where staples are likely to make up large shares of consumer expenditures, and sharp price increases are likely to generate hostile responses. However, these groups also include higher-income countries such as Japan and Norway. The results for Japan are strongly influenced by the regime in place before 2007, when protection was high and variable, rather than the zero-protection regime that has been prevalent since.

70. In a small group of countries, including Pakistan (0.01), Tanzania (-0.05), and Zambia (-0.17), the price transmission coefficients are close to zero and not statistically significant. Policymakers in these countries are likely particularly interested in insulating domestic markets from shocks to world markets. This result may reflect a strong aversion to adjusting prices for this important staple in Pakistan. For Tanzania and Zambia, wheat may not be important enough for policymakers to take the political pressure associated with adjusting prices when world prices change. Tanzania and Zambia experience significant idiosyncratic policy shock terms, which leads to domestic price volatility that is much higher than the volatility of the external wheat prices they face.

71. **Case studies of Egypt and Morocco consider a politically popular food pricing policy—the use of generalized food subsidies—and provide a cautionary tale relevant to many other countries**. Egypt has a long-standing policy of heavily subsidizing bread to the general population, with limited means of testing or targeting. The program now provides subsidized bread for about 70 percent of the population. The population has come to view this as an entitlement, and all past efforts to reform the program have been abandoned in the face of fierce resistance and civil unrest. Consequently, when a shock raises international wheat prices, as with Russia's invasion of Ukraine, the government has little choice but to increase the already huge subsidies and undertake other measures, such as releasing stocks and restricting exports. In Morocco, bread is an important component of the national diet: Moroccans consume 175 kg per year per capita, compared to 120 kg in France and 150 kg in Egypt. A shock to world prices can have a significant fiscal impact in both Egypt and Morocco. The lesson is clear: countries that do not already have generalized food subsidies should not start them. Many models are available for targeted safety net programs that reach the poor at a much more affordable cost and which can be scaled up when needed, e.g., when food prices surge. Countries with generalized subsidies should aim to maintain them at modest levels to avoid them becoming expensive entitlements that are difficult to reform. In the medium term, they should attempt to phase out general subsidies and transition to targeted safety nets.

3.3. Implications for World and Domestic Price Stability

72. **Price insulation magnifies swings in world prices**. Anderson (2014), for example, makes the point that this occurs in two ways. First, long-term trade protectionism (import tariffs and restrictions) and export taxes and controls reduce trade volume in food products, making markets "thinner". Any given shock (e.g., a production shortfall) results in a larger price swing in a "thin" global market than in one with a larger trade volume. Second, reactions to short-term shocks amplify the magnitude of the resulting price fluctuation, as described above. Anderson (2014) estimates the contribution of policy reactions in rice, wheat, and maize during the 2006–08 food price spike and concluded that this magnification effect on world prices was so large that it mostly offset whatever insulating effects these policies had on internal markets. In other words, the actual increases in domestic prices in most countries were no (or very little) smaller than they would have been if all countries had refrained from attempting to insulate their own markets. This once again illustrates the collective action nature of the problem.

73. **This report finds that the magnitude of world price fluctuations can be roughly doubled by many countries' price insulation, using recent price data for rice and wheat**. Martin et al. (2024) estimated a "magnification factor" of 1.57 for rice and 1.91 for wheat. The latter is very close to the

estimated price magnification effect during the 2022 wheat price shock (Martin and Minot, 2022), lending it additional credibility.

74. **While policies can often successfully de-link domestic prices from world prices in the short term, this does not necessarily lead to the underlying policy goal of significantly stabilizing domestic prices.** The analysis reveals many cases where the opposite occurs. In the rice market, the domestic price volatility (measured by standard deviation) is 0.27, which is very close to the world price volatility of 0.29. Domestic price volatility exceeds world price volatility in 7 of 29 cases analyzed, and the two are equal in one other country. In 9 of 29 countries, the volatility of domestic wheat prices exceeds that of world prices. In another three countries, the two prices are equal. Previous studies have documented the frequency with which interventionist trade regimes for African staples actually increase price volatility (Jayne, 2012; Minot, 2014). This study suggests that policy failures of this type are much more widespread, at least in world markets for rice and wheat.

75. **There could be many reasons for failing to achieve the policy goal of stabilizing domestic prices.** Domestic prices are affected by both world price movements and "idiosyncratic" (country-specific) shocks in individual countries. These idiosyncratic shocks, even when aggregated, will not significantly affect world prices as long as they are not correlated across countries since they will tend to cancel each other out. This finding contrasts the systematic policy responses, which are positively correlated since they are responding to the same global price movements, so they *do not* cancel each other out. Some factors that might generate idiosyncratic shocks that would offset or overwhelm systematic policy responses are accounted for in the model. These include domestic supply shocks when quantitative restrictions such as export bans are in effect, the timing and magnitude of adjustments to administered domestic prices, changes in the success of interest groups' framing of policy effects, and/or changes in the influence of key policymakers. For example, schemes that try to fix a local price at an unrealistic level often collapse suddenly under financial pressure, causing rapid price changes. In addition, much anecdotal evidence indicates that when decisions affecting food prices are politicized, actions are often so poorly timed that they have an effect opposite from what was intended. For example, when world prices rise, or there are negative shocks to domestic production, pressure may begin to mount for a reduction in tariffs, an increase in imports by the government-run food agency, or a release of stocks. However, this kind of proposal will meet with political resistance from local producers, delaying the decision. By the time the decision is finally made and implemented, world prices may have fallen or domestic production may have recovered, so the action may actually amplify the internal price decline. This finding—that government attempts to stabilize internal prices often result in the opposite outcome—argues for caution in the discretionary use of trade and other instruments.

3.4. Implications for the WTO

76. **One over-arching conclusion is that the current rules governing the international trading system are ineffective in helping to resolve the "collective action" challenges created by governments' reactions when world food commodity markets undergo significant shocks.** The "collective action" problem arises because when one country insulates its domestic market, it reduces the adjustment that its consumers and producers must make to the higher prices, pushing the adjustment burden onto the world market. This outcome, in turn, means that the world price rises more than it would if individual countries did not insulate their internal markets. So, what seems to mitigate the problem on the level of individual countries exacerbates it globally, making everyone worse off; a classic collective action issue. This collective action problem has its worst effects precisely when it is most harmful, i.e., when world prices are spiking. If all countries acted in the collective interest, they could mitigate the price shock. However, there is no mechanism to organize such a coordinated effort.

Box 3: WTO and Agriculture

Given the importance of agriculture in global trade, a specific agreement on agriculture (the WTO Agreement on Agriculture) was reached as part of the Uruguay Round and became part of the Doha round at the 2001 Doha Ministerial Conference. The Agreement aims to establish a "fair and market-oriented agricultural trading system" and governs domestic support, export competition, and market access. Progress has been made on these three components during the Ministerial Conferences (the highest decision-making body at the WTO, which takes place every two years) in 2013, 2015, and, most recently, 2022. For example, Ministerial Conferences in 2013 and 2015 delivered a decision to eliminate agricultural export subsidies, the most important reform of international trade rules in agriculture in the history of WTO. In 2022, the 12th Ministerial Conference agreed to exempt humanitarian food aid purchases of the World Food Programme from export restrictions and issued a declaration on food security.

However, progress has not been achieved in important negotiation topics. In the most recent 13th Ministerial Conference, members did not reach an agreement on important topics, including adopting a framework for reducing trade-distorting domestic support; reducing protection through reduction of import barriers to improve market access; enhancing the transparency and predictability of export prohibitions and restrictions; reducing market access barriers for cotton-producing and exporting LDCs; and adopting a permanent solution on the issue of public stockholding for food security purposes.

77. **While current WTO rules are not a complete solution to the problem, they play an important role.** Before the Uruguay Round agreement in 1994, trade distortions in agriculture were essentially not subject to international disciplines. The Uruguay Round agreement began implementing rules by converting NTMs, such as quotas, into tariffs and limiting (binding) the extent to which they could be raised. It also restricted the use of variable import levies that some rich countries had previously used to insulate their markets and make world markets thinner and more volatile (Hathaway and Ingco 1995). Tariff bindings in many developing countries ruled out the highest and most costly events of protection (Francois and Martin 2004).

78. **However, there are several areas where WTO rules could be improved.** One is that WTO rules do not effectively discipline export taxes and controls. Export restrictions on foodstuffs are still allowed, with notification requirements, even though quantitative restrictions are generally banned. In addition, developing countries, especially, have very little discipline under WTO rules regarding tariff levels**.** Many developing country agricultural tariffs are "bound" (i.e., have ceilings under WTO commitments) at quite high levels. This means governments can maintain high tariffs, resulting in the "market thinning" described above. Agricultural tariffs, in general, are higher than those on non-agricultural products. Worldwide, tariffs on agricultural products average more than 12 percent, compared to 8 percent for other goods (Brenton et al., 2022). In several important countries, tariffs on food products are much higher: for example, 42 percent in Türkiye; 33 percent in India, 29 percent in Morocco, and 25 percent in Kenya. With bound tariffs so high, governments have great scope to raise or lower the actual tariff rates ad hoc, thus insulating domestic markets.

79. **More effective disciplines in WTO commitments on (a) export taxes/controls, (b) ad hoc import tariff adjustments, and (c) levels of bound tariffs could help resolve these issues. However, negotiating such rules would undoubtedly be contentious**. Proposals to incorporate more effective restraints on export restrictions and taxes have not so far gained traction in the Doha Development Agenda negotiations (Anderson, 2014). In the early 2000s, for example, Japan and Jordan tabled proposals with this objective but these were opposed by a group of food-exporting countries led by Argentina, which frequently uses export taxes and restrictions. Reforming these policies has been politically difficult in Argentina, partly because export and import taxes represent a sizable part of government revenue and one not shared with the provinces.

80. **Any proposals to place more binding constraints on the level of tariffs used by developing countries and on ad hoc adjustment have been opposed.** Opposition was based on (a) the ostensible need to protect domestic producers, (b) the reliance of some governments on tariffs as a source of revenue, and (c) the need to protect consumers by adjusting tariffs downward when world prices spike. Recent developments in public finance make it much easier for countries to switch to a value-added tax (VAT) as a more efficient source of revenue than tariffs, as several developing countries have done. Recent developments in digital technologies and especially advances in safety net mechanisms should alleviate some of these concerns and may make it easier for countries to agree to forego the use of trade-policy instruments. Digital technologies also make it less challenging to rely on electronically administered targeted income supplements, such as conditional cash transfers, to assist poor consumers in times of high food prices.

81. **It is critical to recognize that current policy measures based on price insulation are largely ineffective in stabilizing prices**. While countries often reduce the extent to which world prices directly influence their prices, many of the policies they use—such as export restrictions—generate a great deal of domestic price instability. This fact creates a strong case for reforming domestic policies toward less costly and more predictable measures. Such reformed policies would likely make it easier to agree on global trade rules than the discretionary policies that are currently widely used.

82. **One important conclusion from this discussion is that reform of agricultural trade policies should be given prominence in any multilateral negotiations, notwithstanding the difficulties**. Brenton et al. (2022) propose a "grand bargain" in negotiations, whereby exporter countries agree to forego restrictions, and importing countries agree to reduce tariffs and keep them stable. An effective agreement could greatly benefit global FNS by reducing volatility and increasing overall food trade. Chepeliev et al. (2023)explores the benefits of an overall reduction of agricultural tariffs and shows these would be large – perhaps sufficient to offset the impacts of recent negative shocks. Yet, this is not an easy task, as shown by the lack of agreement to advance agriculture reform at the WTO 13th Ministerial Conference (MC-13), including on public stockholding and export restrictions.

CHAPTER 4: The Role of International Trade in Building Resilience to Shocks in Food Markets

The chapter describes insights from an analysis that used detailed transaction-level customs data from Chile and Colombia. It shows that when policy does not prevent higher prices from being transmitted to domestic markets, the impacts on the balance of payments are mitigated. The chapter also underlines the role of regional markets in helping to build resilience to shocks. It then discusses the role of agrifood logistics, highlighted by the COVID-19 pandemic and the ongoing Russian invasion of Ukraine. Ensuring efficient, secure, low-cost international movement of foodstuffs is critically important for FNS (FNS), especially in the face of the increased frequency of extreme events and volatility. Finally, the chapter discusses how climate change will affect agricultural productivity, which will also have implications for the inequality of income distribution across and within countries.

4.1. Insights from Custom Data from Chile and Colombia

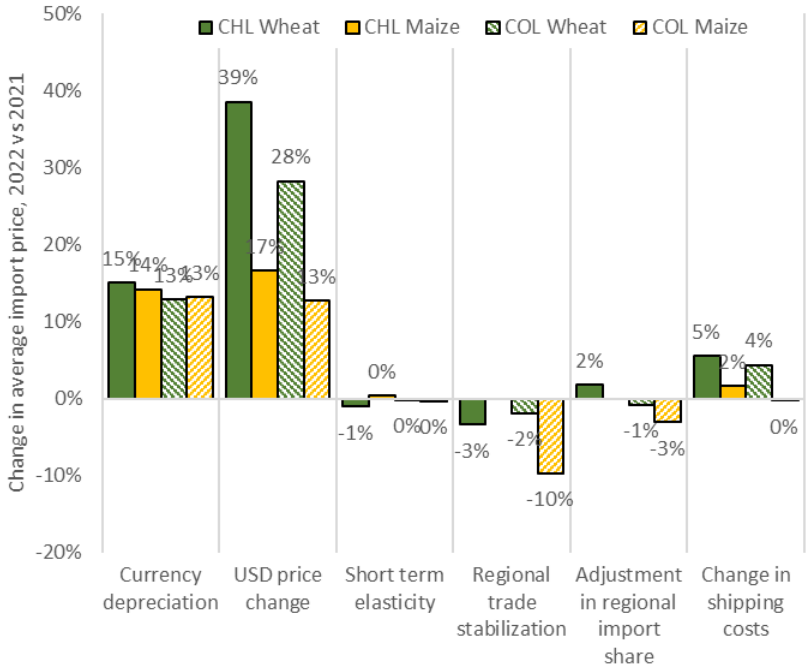
83. **This section analyzes the detailed transaction-level customs data from Chile and Colombia to provide insights into how world price shocks are transmitted to the domestic economy.** The relationship between the world market and import prices is complex and depends on several interacting factors, some of which might be susceptible to policy intervention. Global market prices typically reflect spot transactions at major commodity exchanges. However, commodity imports may follow different pricing arrangements, for instance, through longer-term supply contracts or futures transactions. In addition, price transmission differs in terms of lead times from the world market to import prices, as well as by origin, quality of the product, importer-exporter relationships, and trade costs. Transaction-level customs data, which is published by a few countries, including Chile and Colombia, makes it possible to assess and quantify the role of these factors. This section demonstrates some insights from von Uexkull (2024) in the form of stylized facts, focusing on the experience of Chile and Colombia during the 2022 food price shock. Since the analysis considered only these two countries, some results are idiosyncratic and may not be generalizable to other economies. However, the results demonstrate strategies and policies that can be helpful to other countries, at least under some circumstances.

84. **One lesson is that when policy allows internal demand to respond to the higher prices during shocks, the impacts on the balance of payments are mitigated.** When wheat prices spiked, demand in Chile declined, so the import bill only rose by 17 percent. This figure accounted for roughly half the rise in Colombia's import bill since demand in the country actually increased imports in that period. For this adjustment in internal demand to take place in response to movements in border prices, those movements must be passed through to domestic markets. This action encourages consumers to reduce their consumption by substituting for lower-priced products while also providing incentives to increase domestic supply. In the short run, this is achieved by drawing down privately held stocks and, in the longer term, by increasing production. Both actions reduce import demand. This illustrates why it is a wise policy for governments to avoid trying to insulate their markets by stabilizing domestic prices.

85. **A second lesson is that integration in—and reliance on—regional markets can sometimes help mitigate the effects of price shocks, especially when shocks originate outside the region.** For both countries, reliance on imports within the region resulted in opportunities for considerable potential savings. For Chile and Colombia, the price increases on regional imports were smaller than those for imports from the rest of the world. The differences are significant: The ability to rely on regional imports reduced the potential increase in prices by 3 percentage points for wheat in Chile, 2 percentage points for wheat in Colombia, and 10 percentage points for maize in Colombia compared to a scenario where regional import prices increased in line with the rest of the world (Figure 24). Both countries took advantage of the lower regional prices in the maize market. For Colombia, the share of maize

imports from within the region increased from 22 percent to 52 percent. Chile's increase was from 90 percent to close to 100 percent. In the wheat market, Colombia increased its regional share, while Chile reduced it, for reasons which could not be explored in this paper. So, for Colombia, the actual rise in average import price was limited to 3 percentage points for maize and 1 percentage point for wheat. For Chile, the actual average import price for wheat increased by an additional 2 percentage points. This may have happened because the negative shock originated outside of the region and price transmission into the region takes longer and may be incomplete. Trade costs are likely to be smaller between countries in the same region.

Figure 27: Customs Data Explains Some of the Observed Differences in Transmission from Global Prices to Import Prices



Source: von Uexkull (2024) using custom data

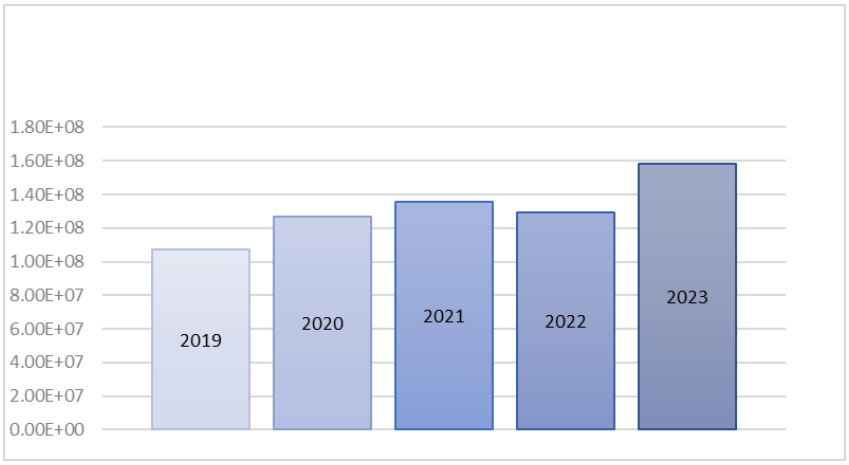
4.2. The Role of Agrifood Logistics

86. **Compared to less time-sensitive cargoes, the global trade of wheat (and other grains) is particularly vulnerable to shipment delays and supply chain inefficiencies**. Grains have unique logistics requirements compared to many industrial goods. Factors such as crop harvest schedules, cargo shipment lead times, and storage lifespan create narrow windows that require reliable logistics networks. Disruptions caused by shipping delays, port congestion, infrastructure issues, or other external shocks can easily cause spoilage, quality deterioration, or supply shortages. These disruptions may create ripple effects of post-harvest loss, higher costs, and price instability. These are important considerations now and will be even more important in the future as climate change results in new production patterns, requiring more and different trade patterns. This chapter dealt specifically with the wheat trade, but many of its conclusions are also broadly relevant for other grains.

87. **Long-distance movement of grain is primarily by maritime shipments.** The volume of wheat shipped has increased steadily in recent years, except for 2022 (Figure 28). Much of this is done by

bulk carriers with capacities ranging from 10,000 to over 300,000 DWT. Such bulk carriers account for about 31 percent of all grain shipments globally. They are especially important for lower-middle-income and upper-middle-income countries, where they account for 44 percent and 40 percent of global grain shipments, respectively. Alternatives to bulk shipping add considerably to the cost. Shipment of Ukrainian grain by rail, road, or river as part of the Solidarity Lane initiative to circumvent the blockage of Black Sea ports is estimated to have added US$30–40 per MT (Reuters, 2023).

Figure 28: Volume of Global Maritime Wheat Shipments (Metric tons), 2019–23

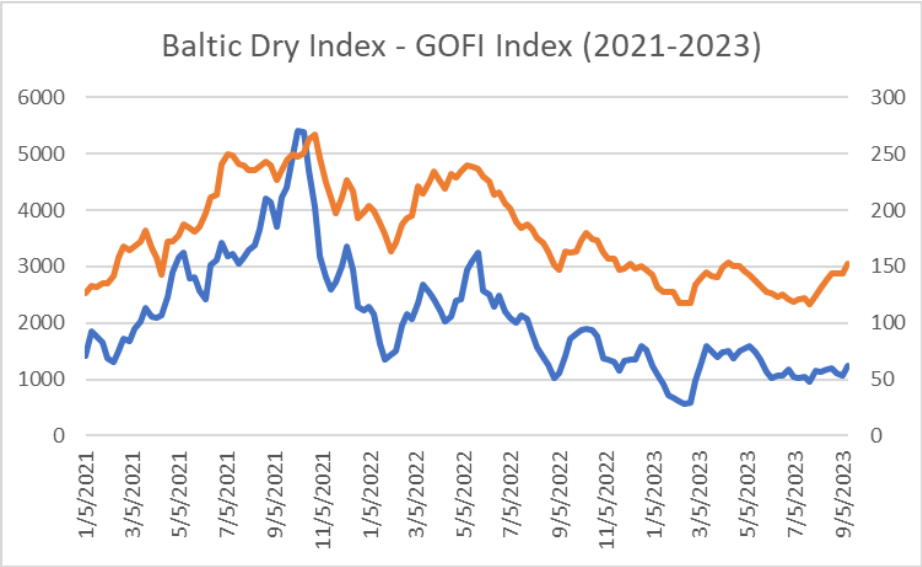


Source: *Rastogi and Ulybna (2024), based on Alphaliner data*

88. **Given the above, the ability of the maritime bulk shipping network to withstand disruptions, whether from natural disasters, geopolitical tensions, or market fluctuations, is paramount to FNS. However, it is highly vulnerable to shocks from multiple sources**. This includes disruptions at key transit points, such as the Suez and Panama Canals and the Black Sea, as well as inefficiencies and/or other disruptions affecting the loading/unloading at ports, e.g., weather events. Unlike container terminals, grain terminals cannot operate in the rain since it compromises the quality of the cargo being loaded onto the vessel. Furthermore, the effects of drought conditions on the operation of the Panama Canal cannot be underestimated due to its impact on transit restrictions and increased fees. For example, bulk grain carriers transporting crop shipments from the US Gulf Coast region to Asia had to divert onto longer alternate routes due to drought conditions, raising trade costs (World Grain, 2023). The Russian invasion of Ukraine is another obvious example, the effects of which are discussed in Chapter 2.

89. **While freight rates have been rising since the COVID-19 pandemic, Russia's invasion of Ukraine has exacerbated this trend and reversed a temporary decline in shipping prices.** A report by UNCTAD (2022) noted that between February and May 2022, the price paid for transporting dry bulk goods such as grains increased by nearly 60 percent. International indices have confirmed this increase, including the Baltic Dry Index, a price benchmark for moving major raw materials by sea, and the International Grain Council Grains and Oilseeds Freight Index (IGC-GOFI). In the grains and oilseeds markets, for example, the July 2023 cessation of the Black Sea Grain Initiative– the four-way agreement that enabled shipments from Ukraine's deep seaports – appears to have negatively impacted freight rates (Figure 29).

Figure 29: Baltic Dry Index (in blue) and GC-GOFI (orange), 2021–23

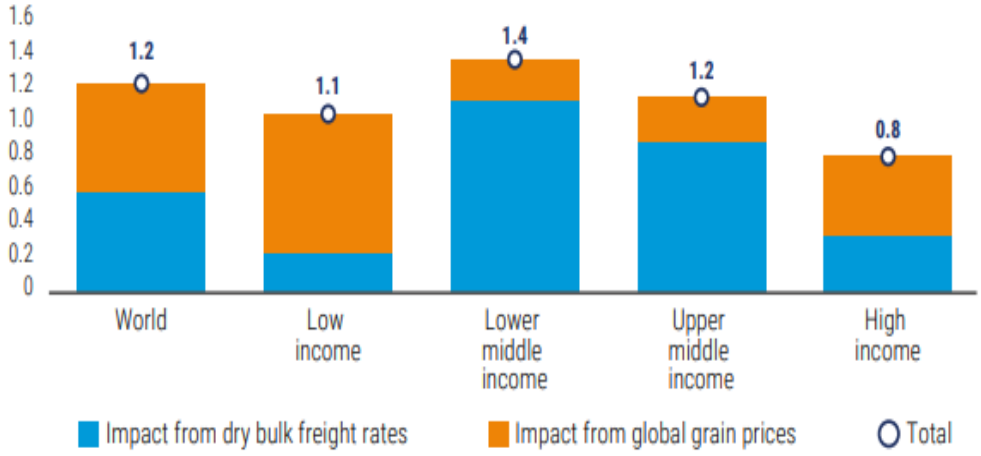


Source: Baltic Dry Index and GCC, 2023.

Note: GC-GOFI, International Grain Council Grains and Oilseeds Freight Index.

90. **According to a simulation conducted by UNCTAD as part of its Annual Review of Maritime Transport (2022), elevated grain prices combined with rising bulk shipping freight rates are estimated to have produced a 1.2 percent increase worldwide in consumer food prices, with the highest impacts on middle- and lower-middle-income countries.** For these countries, the increase in transport costs far outweighed the increase in the cost of the grains (Figure 30). The reason is that these groups include countries that depend on food imports, typically transported by dry bulk. Further research is needed to examine the supply and demand of bulk carriers, vessel hire, fuel costs, distance, and other determinants and components of freight rates to understand their impact on consumer prices.

Figure 30: Impact of Higher Dry Bulk Freight Rates and Global Grain Prices on Consumer Food Prices, by Selected Country Groups, 2019 (Percentage Change)



Source: *UNCTAD (2022)*.

91. **As discussed in Chapter 2, the global seaborne wheat trade has proved to be resilient despite major disruptions, partly due to adjustments in sourcing strategies by importers in dependent countries.** Countries typically adapted through origin and product diversification strategies, switching from wheat and corn to millet, buckwheat, maize, sorghum, cassavas, yams, and other local/traditional crops. Advanced preparations were made for efficient supply and storage management, which prevented spillage and spoilage of food imports, reduced supply risks, and allowed for the grains to be stored for longer periods. Overall, the world trade in wheat has proved relatively resilient. Countries promptly adapted their sourcing strategies following market shocks from the Russian war in Ukraine.

92. **Improving the efficiency of agri-logistics is necessary**. Solutions include digital technologies, improvements to market infrastructure, collection centers, and warehouse or cold chain storage centers. Public sector investments are needed, together with operation models that encourage private investment to scale up agri-logistics investment, improve supply chain transactions and food movement, and improve local value addition to producer associations and SMEs.

93. **Strengthening FNS to improve the efficiency and reliability of the food supply chain logistics to reduce food waste and loss can be done by leveraging technological innovations.** Globally, nearly one-third of food produced for human consumption is lost or wasted, amounting to about 1 billion tons per year worth about US$1 trillion. This amount of food could feed 1.3 billion hungry people every year.[17] According to the UNEP, if food loss and waste were a country, it would be the third-highest GHG-emitting nation behind the US and China.[18] The FAO estimates that 30–40 percent of total production in developing countries can be lost before it reaches the market, due to problems ranging from improper use of inputs to lack of proper post-harvest storage, processing or transportation facilities. In industrialized countries, more than 40 percent of food is lost and wasted at the retail and consumer levels. Technological innovations in logistics have been targeting food waste throughout the food supply chain of developing countries. For instance, single windows simplify and expedite customs procedures and promote comprehensive digitalization of trade procedures, which lowers trade costs. Better systems to exchange key trade information- including food safety standards and phytosanitary regulations- can broaden smallholder farmers' access to international food markets, thereby increasing the food supply and improving food safety. For instance, using electronic phytosanitary certificates, called ePhyto, instead of traditional physical certificates enables agents to exchange certificates quickly, accurately, and at a lower cost. In Nigeria, solar-powered cold storage infrastructure has been used to store perishable food, like tomatoes, reducing spoilage by up to 80 percent. A blockchain-enabled mobile platform has been used to coordinate supply logistics between farmers and vendors in Kenya. The platform is combined with payments finance to encourage smallholder participation.

4.3. Agriculture Trade and Climate Change

94. **Global warming and associated climate change will affect virtually all economic activities. However, it will have the most direct impact on agriculture due to the close dependence of crop and livestock production on weather, thus affecting FNS.** A recent study by a NASA team[19] concluded that under some scenarios, the adverse effects of climate change will become more important in the early 2030s than previously thought. The study predicts much more severe impacts later in the century, including a 24 percent decline in average maize yields. Looking at the average effects obscures the highly localized nature of the impacts, as some areas become completely unsuitable for the

[17] According to FAO's State of Food and Agriculture (2019) report, around 14 percent of the world's food continues to be lost after it is harvested and before it reaches the shops; while UNEP's Food Waste Index Report shows that a further 17 percent of our food ends up being wasted in retail and by consumers, particularly in households.

[18] Food waste that ends up in landfills releases methane (CH4), a GHG with a global warming potential approximately 28–36 times higher than carbon dioxide (CO2).

[19] Jägermeyr et al (2021). A non-technical summary can be found at "Global Climate Change Impact on Crops Expected Within 10 Years, NASA Study Finds – Climate Change: Vital Signs of the Planet"..

cultivation of particular crops while others become more amenable. For example, according to the NASA study, a local warming of 2°C in the mid-latitudes could increase wheat production by almost 10 percent, whereas at low latitudes, the same 2°C warming could decrease yields by almost the same amount.

95. **The impact of climate change on agricultural productivity will play out through multiple channels:**[20]

    a) *Changes in the mean climate*. Warmer temperatures will make some areas (generally warm regions in today's world) less productive and others (generally cold regions) more productive. Changes in average precipitation and its seasonality will have variable effects. Some areas that rely on glacial and snow-fed runoff in the growing season may be hit hard as warmer temperatures prevent the accumulation of ice and snow in winter. Traditional cropping patterns in some or many areas may become non-optimal or wholly unviable due to the changes in both temperature and precipitation.

    b) *Changes in severity and frequency of extreme events*. Climate change is also expected to influence the frequency and severity of short-term extreme weather events, including heatwaves, abnormally low or high precipitation, and storms. While it is more difficult to model the productivity impacts of this kind of effect than that of long-term changes in average temperature and precipitation, the net impact for the extreme events in terms of productivity may be even more important than for the changes in the average. For example, Li *et al.* (2009) estimated that drought-related yield reductions could increase by more than 50 percent by 2050 for the major crops.

    c) *Carbon dioxide fertilization*. The underlying causes of climate change, specifically carbon dioxide concentration in the atmosphere, may affect productivity in addition to climate change itself. While higher concentrations of carbon dioxide will increase the rates of photosynthetic activity for some major food crops, this effect is not universal due to differences in the photosynthetic pathways. As a result, there is considerable controversy surrounding the net effect on overall food crop yields.

    d) *Other effects of climate change*. These changes include sea level rise, which will make some coastal areas unsuitable for agricultural production and changing patterns of pest infestations.

95. **The general equilibrium trade model by Artuc et al. (2024) is used to estimate the effects of agricultural shocks due to climate change on households' welfare**. The study uses household-level data for low- and middle-income countries to draw highly granular conclusions regarding the effects of climate change on agriculture productivity and income distribution in 51 low- and middle-income countries, unlike much other research on this topic. It also uses the FAO's Global Agro-Ecological Zones (GAEZ).[21] GAEZ is a rich micro-level dataset that uses agronomic models and high-resolution geographic data, such as soil, topography, elevation, and climate conditions. GAEZ can be used to predict agricultural yields for various crops worldwide based on a climate change scenario used by the UN's Intergovernmental Panel on Climate Change (IPCC).[22] The study adjusts the productivity of land based on the predictions of the FAO GAEZ model and simulates its impact on household income and welfare across 51 developing countries, taking into account international trade. Households in this model adapt to changed conditions by changing their labor allocations, crop choices, and consumption and implicitly engaging in trade.[23] The study can quantify the likely impact of climate change by

[20] Refer for instance to Gornall et al (2010).
[21] FAO and IIASA (2021).
[22] The estimates are based on the FAO GAEZ Hadley CM3 A1FI model. The A1FI scenario describes a future world of rapid economic growth, global population that peaks around midcentury and declines thereafter, and the rapid introduction of new and more efficient fossil-intensive technologies.
[23] If households are not allowed to optimize land and labor allocations in the model, estimated losses are about 28 percent higher.

comparing households' real incomes, consumption, and land and labor allocations in this counterfactual scenario with their observed choices.

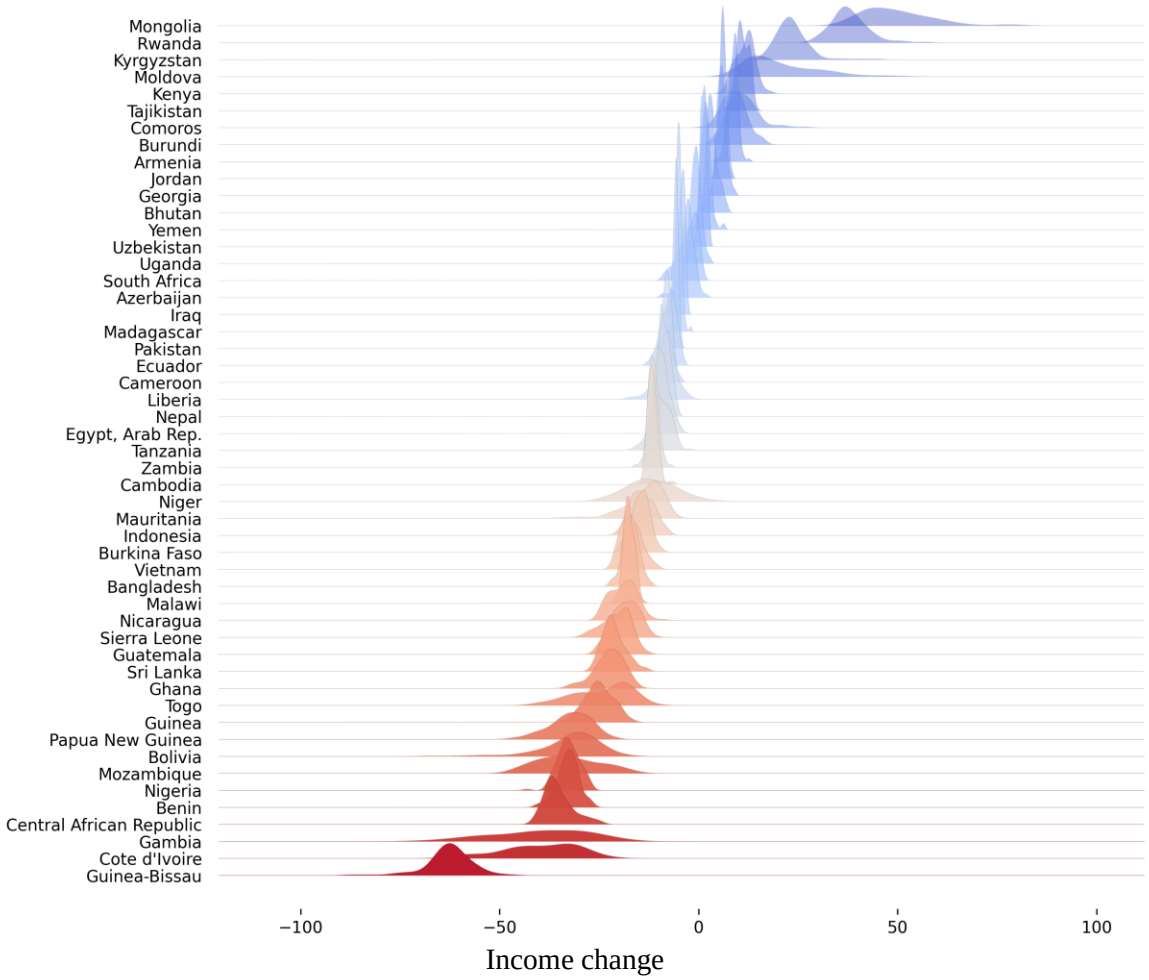
96. **In this model, climate change is expected to have large and variable effects on productivity.** Of the 51 countries in the sample, 39 are projected to have substantially lower yields, while the remaining 12 are projected to have higher yields. Productivity changes vary considerably across space, ranging from a minimum of -63.4 percent in Cambodia to a maximum of 259.9 percent in Mongolia. The median productivity change across countries is -37.8 percent, while the average is -17.4 percent. These climate-change-related changes in agricultural productivity are the main drivers of welfare impacts, which affect labor, land income, and consumer prices.

97. **The impacts of climate change on household real incomes are heterogeneous and significant (**Figure 31). On average, households in the sample see their real incomes decline by 9.7 percent. However, the standard deviation of the estimated average effects across countries is large, notably 20 percent. At the household level, the range is from a minimum of –87.4 percent to a maximum of 76.4 percent. Most households suffer very sizable losses due to negative productivity shocks. However, a striking 28 percent of households are expected to gain real income because of increased agricultural yields. The average real income gains are negative in 37 out of 51 countries. Countries near the equator, where average temperatures are already high,[24] experience average losses exceeding 30 percent. By contrast, average gains in some countries—mostly those not near the equator, including Kenya, Tajikistan, Madagascar, Kyrgyzstan, Rwanda, and Mongolia—exceed 10 percent. Within countries, the effects also vary greatly. The average range between the smallest and largest variation within a country is 16.9 percent.[25] Having used the same general equilibrium trade model to estimate the impact of the Russian invasion of Ukraine described in Chapter 2, Artuc et al. (2024) find that climate change will have much larger and much more variable effects on welfare than the war in Ukraine. This is because it impacts a broader set of products and has sizable productivity effects that cut in different directions in different countries.

[24] Such countries include Guinea Bissau, the Gambia, Cote d'Ivoire, Central African Republic, Nigeria, Mozambique, Bolivia and Papua New Guinea.

[25] To illustrate the wide disparities, note the cases of Guinea-Bissau and the Gambia where all household lose from climate change, with losses ranging from -87.4 percent to -46.8 percent and -72.4 percent to -16.3 percent, respectively. In Bangladesh, there are widespread losses, but they are less dispersed, ranging from -22.11 percent to -12.06 percent of real household income. By contrast, all households gain in Mongolia, with real income growth rates ranging from 35.38 percent to 76.47 percent. In Kenya, everybody gains, but with less dispersed welfare effects, with income gains ranging from 5.9 percent to 18.8 percent. In places like Uzbekistan or Yemen, there are both winners and losers from climate change. Within-country heterogeneity in the impact of climate change is thus of first order importance.

Figure 31: Distribution of Welfare Effects of Climate Change by Country



Source: estimates by Artuc et al (2024)

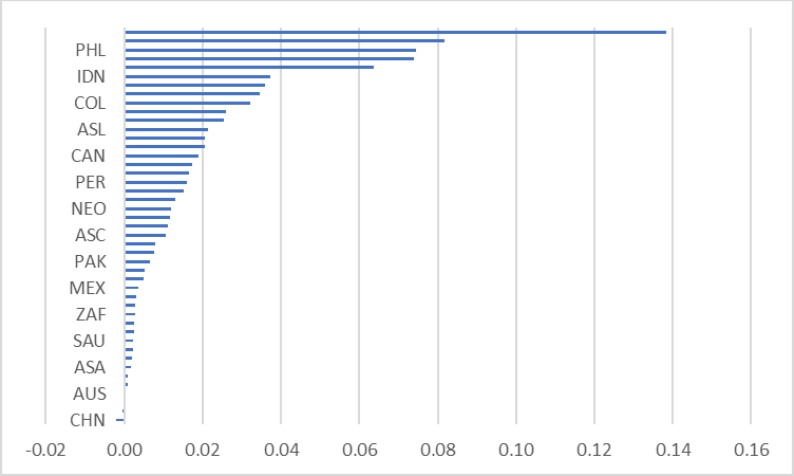
98. **Climate change will also affect income distribution within countries, with heterogeneous effects across countries**. In general, for countries that suffer from loss of productivity, the poor lose more than the rich in percentage terms, increasing inequality. The converse is true for countries that benefit from a positive effect on productivity, so inequality is reduced. However, since most countries experience a negative impact on productivity, the overall result is an increase in inequality. The study also looked at how much these aggregate results would differ if estimations were based on one single "representative" household per country instead of using disaggregated household-level data. It turned out that the average loss under the "single representative household" estimation would be underestimated and would be only -8.6 percent, over 11 percent smaller than the estimate using disaggregated household data. Finally, income losses will be greater if agricultural product and fertilizer trade restrictions were to be implemented.

CHAPTER 5: Conclusions and Recommendations: Enhancing Future FNS in a Riskier World

99. **The global trade system, particularly food trade, has recently been tested by important shocks, notably a major pandemic and the outbreak of a war in a crucial region for food and energy production.** While these events, especially the pandemic, produced significant hardship in food insecurity in some areas of the world, they did not lead to the catastrophic outcomes many had anticipated, demonstrating the system's resilience.

100. **Nonetheless, the demands of an increasingly populated world, coupled with persistent risks and the exacerbation of climate-related events, necessitate a more integrated trade system.** Global warming is poised to negatively affect the global food supply and alter production patterns across nations, requiring corresponding changes in food trade patterns. In addition, it is critical to facilitate the movement of production inputs and technologies (some of them embodied in inputs) across borders with ease and affordability to facilitate adaptation to climate change. The future world requires a level of integration surpassing that of today. Research by Adenauer et al. (2023) has shown that a well-integrated food trade system, as opposed to a restricted one, significantly reduces the risk of food insecurity for nearly all countries, with the most profound benefits for the LDCs and emerging economies. This was demonstrated using simulations of food availability during climate-induced extreme weather events (Figure 32).

Figure 32: Downside Variability of National Food Availability (Difference Between the Restricted Trade and Integrated Trade Scenarios)



Source: Adenauer et al. (2023).
Notes: The figure uses the lower semi-variation coefficient of average food availability across the time horizon 2022-2040. Semi-variation is obtained by dividing the square root of the semi-variance by the mean of the distribution. Semi-variance is the variance of all observations above or below the mean of the distribution. Positive values indicate higher vulnerability under the restricted trade scenario.

101. **Yet, the current trend seems to be moving away from stronger integration, with multilateral negotiations stalling in recent years.** This project's findings highlight the general increase in NTMs that hinder trade, including those affecting fertilizer (as detailed in Chapter 2) and food trade. In 2023, nearly 3,000 trade restrictions were enacted worldwide, a fivefold increase from 2015. Countries are employing tariffs and NTMs on imports and exports in ways that often amplify the adverse global impacts of economic shocks. While food safety and environmental regulations are well-intentioned, they can also act as trade barriers, especially when poorly designed. Additionally, the recent emphasis on reporting GHG emissions within agrifood supply chains, as noted by the OECD (2024), threatens to

generate unnecessary trade costs with possible adverse consequences, particularly for small-scale producers in developing countries. Harmonization and coherence across different reporting platforms are essential to mitigate such risks.

102. **Decisive multilateral action is necessary to strengthen the international trade governance system and reinvigorate the momentum toward greater integration.** Doha Development Agenda began with ambitious goals, many of which have not been met. Negotiations have now largely stagnated. More recently, the 13th Ministerial Conference of the WTO has ended without agreeing on a way forward for trade in agriculture and food. It is crucial to rekindle these negotiations with a focus on the issues highlighted in this report and encourage other international organizations beyond the WTO to facilitate necessary negotiations and actions. This report emphasizes the following priority areas for action:

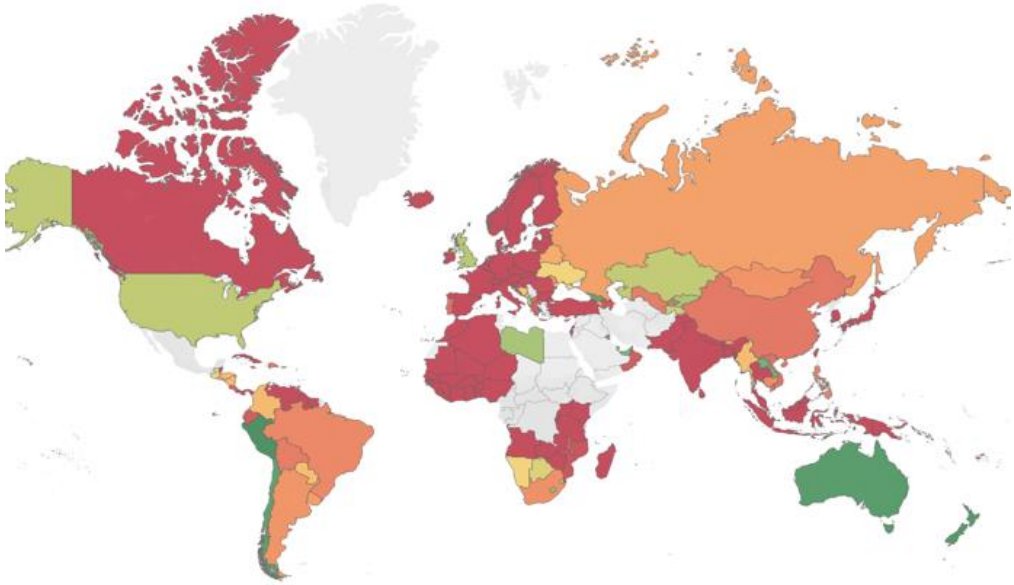
a. Implement better disciplines in WTO commitments that focus on constraining the kind of "beggar-thy-neighbor" ad hoc import and export policies that have been demonstrated to exacerbate price swings and food shortages in times of crisis.

b. Harmonizing regulations and reporting requirements related to environmental and other issues, which threaten to obstruct trade in food and fertilizer.

c. Continue progress in monitoring and early warning systems for food production and trade (particularly improving monitoring of stocks and expanding the number of included countries). Doing so can help policymakers avoid making panicky decisions based on limited and poor-quality information.

d. Provide enhanced assistance to developing countries to upgrade infrastructure for trade in food and agricultural inputs and technologies. This includes hard infrastructure and "soft" infrastructure, such as reformed domestic regulatory frameworks to encourage technological "spill-ins" from abroad.

Figure 33: Average Applied Tariffs Across Countries, 2021



Source : Portugal-Perez et al. 2024b

103. **Action should also be taken at the national level.** Multilateral action will produce the biggest benefits for all. However, even in its absence, individual countries have incentives to undertake reforms**. In the short run**, when an FNS crisis take place, timely response is key to avoid economic and human

losses. As crises preparedness is critical, countries could improve their preparedness to crisis by preparing and implementing crisis preparedness plans, such as those supported by the World Bank —in close partnership with humanitarian and development actors under GAFS, Global Network Against Food Crises (GNAFC), national governments, United Nations (UN) agencies, and donor partners**.** These plans are living contingency plans to deal with the impacts of acute shocks. They articulate operational arrangements for how crisis risks are monitored and identified, how risk information is channeled to decision-makers to inform financing of response activities, criteria for identifying populations targeted for support, and coordination mechanisms (such as dedicated inter-ministerial bodies and stakeholder forums) to ensure a coherent, adequate, and early response to emerging shocks.

In the medium term, actions are context specific:

- Tariffs applied to food and fertilizers imports are high in several developing countries (Figure 33) and **reduced tariffs** in those countries should diminish the food and fertilizer prices and have a positive net welfare impact for the country and benefit poor households.
- **Reforming NTMs on food and fertilizers.** Fertilizers importers with high trade costs due to restrictive NTMs should streamline them or even remove some NTMs if some other regulations fulfill the legitimate goals the NTMs to be removed supposedly pursue. *An in-depth analysis of specific NTMs* applied on food and fertilizers is required to determine how they can be streamlined and, some of them, removed while their legitimate objectives —such as consumer, health, and environment protection— are pursued. Harmonization and mutual recognition of some NTMs can also reduce associated trade costs.
- **Streamline customs procedures and improving trade facilitation.** Initiatives, such as single windows, promoting comprehensive digitalization of trade procedures, electronic phytosanitary certificates can reduce the time and cost of trading food and lower food waste in different parts of the supply chain. Countries with cumbersome customs procedures are to gain most of these reforms.
- **Increase agriculture productivity and resilience to climate change**. Countries should focus on policies that promote sustainable agricultural practices and ensure that the benefits of food production and exports, contribute to overall economic development. This could involve investing in "public inputs" such as agricultural research and development, improving infrastructure for agricultural production, disseminating climate smart agriculture technologies that improve input use efficiency and reduce the environmental footprint of food production, promoting trade agreements that support fair and equitable food exports.

104. Other policy priorities are based on a country's food imports dependency (i.e., share of net imports in domestic food consumption), and its share of food in households 'expenditure. **Countries with high food share in household expenditure** need to protect the most vulnerable members of the population and help them cope with a surge in food prices by strengthening and scaling up safety net programs. **Countries with high food import dependency** need to prioritize the following:

- **Strengthen early warning systems**. Countries should actively participate in both national, regional, and global early warning networks that monitor hydro-meteorological events and other significant food security shocks. Countries need to also strengthen their national capabilities to track food prices in real-time and disseminate market information.

Strengthen management of strategic grain reserves and upgrade existing storage to reduce losses. Countries need to improve how they manage their strategic grain reserves to mitigate sudden increases in food prices and address short term food security risks. Options include investing in modern storage infrastructure, improving public procurement of imported food by adopting rule-based procurement and release policies to minimize fiscal impacts and food loss and waste from excessive stock build up**.** Where needed, support the technical upgrading of existing storage facilities for strategic reserves to reduce food losses from pests, heat, humidity, and disease.

- **Review agriculture policies to remove any potential bias towards domestic food production.** Countries need to review their local policies to ensure that they do not disproportionately favor food imports over domestic production, and to promote a more balanced approach to food security.
- **Avoid ad hoc reactions such as putting in place import subsidies to prop up domestic supplies.**

105. Countries with low (or negative) food import dependency can do the following:

Avoid export restrictions. Governments in food exporting countries must be strongly advised to avoid export restrictions on essential goods. Such ad hoc policies, which would bring relief for the imposing countries only in the short run, further reduce supplies and push up global prices.

106. **In the long term**, *countries need to undertake adjustments to their trade policies. First, they should desist from the use of ad hoc changes in trade policies that attempt to insulate their economies from world price movements*. In addition to the adverse effects of such policies on other countries, these policies have costs for the countries that use them. Border prices of imports or exports indicate the true economic value of products consumed or produced in a country. So, when domestic prices do not reflect the border prices, domestic consumption and production are inefficiently high or low, wasting the country's productive resources. This outcome is one reason why protectionism—or export taxes and restrictions—are suboptimal policies in the long term.

107. *Second, countries should repurpose agricultural policies and support toward sustainable and resilient food systems by* moving away from quantitative restrictions and policies that have proven expensive and ineffective, including minimum price support and other forms of subsidies to inputs or outputs. In their place, agricultural support payments should be focused on providing key public goods like improved research and extension services and infrastructure and crowding in private sector investments. Gautam (2023) shows that repurposing a portion of distortive government support on agriculture each year towards climate-smart innovations that boost agricultural productivity while curbing greenhouse gas emissions could slash overall emissions from agriculture by over 40 percent. This investment could also lead to the restoration of 105 million hectares of agricultural land to natural habitats. Moreover, it has the potential to lower the cost of nutritious foods, thereby improving nutritional outcomes. Countries *can also benefit from reforms in their domestic FNS policies*. Substituting targeted safety nets for universal food subsidies will realize great fiscal savings and provide more effective cushioning for the poor during high food prices. Using limited strategic grain reserves, following the guidelines cited in this report, will prove much more realistic and less costly than trying to stabilize internal prices through large buffer stocks or trade policy.

108. *Third, a key ingredient in mitigating GHG emissions and adapting to a warmer world with more climatic shocks will be the accelerated progress in agricultural production technologies to meet the requirements of the new climate patterns.* Such progress will require investments in local and global agricultural research. It will also require reforms in current domestic regulatory policies, which obstruct both the international flow and local development of technologies embedded in improved seeds and other inputs in some countries.

109. **In addition to policy recommendations, this project has provided valuable insights for future research.** One key takeaway is the importance of including general equilibrium, indirect, and household-level effects in the analysis of shock events to avoid misleading conclusions. For instance, the research has shown that the indirect effects and general equilibrium "ripple" effects can cause more damage than the initial direct impacts. Moreover, estimates of welfare losses due to adverse shocks, such as the Russian invasion of Ukraine and long-term climate change, are significantly lower when based on models that include one single "representative household" per country, rather than on models using multiple households with actual household data. Artuc et al. (2024) estimated that welfare losses are, on average, 7.7 percent greater for the Russian invasion of Ukraine and 11.1 percent greater for the long-term effects of climate change when incorporating heterogeneous households in the model instead of the single representative household. This inherent aggregation bias occurs because the average welfare impact across various

households that make different consumption and production decisions does not match the welfare impact for an individual household characterized by aggregate-level data.[26] It is crucial to conduct household-level analysis to evaluate the distributive effects of shocks, as this highlights that climate change threatens overall FNS. The poorest are expected to be disproportionately affected by climate change.

[26] These findings are in line with literature on heterogenous firms that concluded that microstructure matters for the aggregate gains from trade (Melitz and Reddings, 2015, and Costinot et al 2020, Econometrica).

ANNEXES

Annex 1: References

Papers and presentations that are part of this project.

"Grains on the Move: The Logistics of Food and Nutrition Security" by Cordula Rastogi and Daria Ulybina, Draft February 13, 2024

"Market and Policy Response to a Global Food Crisis: A Case Study of the Russia- Ukraine War", by Colin Carter and Sandro Steinbach, September 16, 2023

"Price Volatility, Cycles, and Trends in Global Food Markets: Implications for FNS and Trade" by John Baffes, Jeetendra Khadan, and Dawit Mekonnen, March 2024

"Trade policies and the transmission of international to domestic prices" by Clemens Hoffmann, Lina Kastens, Alberto Portugal-Perez and Stephan von Cramon-Taubadel, January, 2024

"Trade Policy in Fertilizer in Fertilizer Markets", by Alberto Portugal-Perez, Esteban Ferro and Alvaro Espitia, April, 2024a

"Trade Policy in Food Markets: Hunger Hotspots and LDCs" PowerPoint presentation by Alberto Portugal-Perez, Alvaro Espitia, Achim Vogt and Esteban Ferro, April 2024 b

"Trade Policy Measures Could Mitigate the Negative Impacts of the War in Ukraine on Food Markets" by Maksym Chepeliev, Maryla Maliszewska, and Maria Filipa Seara e Pereira, 2023

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Annex 2: Sources and Determinants of Volatility in Agricultural Commodities

Author(s)	Main Conclusion	Methods	Data	Commodity
Tadesse et al. 2014	Financial crisis increases food price volatility, confirming the increasing link between financial and commodity markets.	OLS and FGLS	1986-2009 (monthly)	Wheat, maize, soybeans, cattle, hogs, cocoa, cotton, coffee, and sugar
Geman and Nguyen 2005	Price volatility increases with decreasing inventory.	OLS	1974-2001 (monthly)	Soybeans
Roache 2010	Volatility in US inflation and the US dollar partly explain the rise in low-frequency food price volatility since the mid-1990s.	spline-GARCH	1875-2009 (annual)	Maize, palm oil, rice, soybeans, sugar, and wheat
Rude and An 2015	Export restrictions (2006 to 2011) increased price volatility for wheat and rice but not maize and soybean. The variability of crude oil prices and real interest rates affect commodity price variability.	GMM	1994-2012 (monthly)	Maize, wheat, rice, and soybeans
Brümmer et al. 2016	Volatility in the US dollar drives up the price volatility of oilseeds and vegetable oils. The financialization of commodity markets does not increase volatility.	GARCH and VAR	1990-2012 (monthly)	Soybeans, rapeseed, palm oil, soybean oil, rapeseed oil, sunflower oil, and biodiesel
Gardebroek and Hernandez 2013	There is no evidence that volatility in energy markets stimulates price volatility in the US maize market.	MGARCH	1997-2011 (weekly)	Maize
Irwin and Sanders 2012	There is little evidence to suggest that index positions influence returns or volatility in commodity markets.	Regression tests	2007-2011 (quarterly)	19 commodities in agriculture, energy, and metals
Karali and Thurman 2010	As the maturity date approaches, volatility increases. There is also strong seasonality in volatility patterns, peaking in the summer months before harvest times.	GLS	1986-2007 (daily)	Maize, soybeans, wheat, and oats
Karali, Dorfman, and Thurman 2010	Price volatilities are affected by inventories, time to delivery, and the crop progress period. They are also higher before the harvest starts than during planting.	Smoothed Bayesian estimator	1987-2004 (daily)	Maize, soybeans, and oats
Karali and Power 2013	Low-frequency volatility is affected by changes in inflation, industrial production, inventories, and the long-term and short-term interest rate spread.	spline-GARCH	1990-2009 (daily)	Corn, soybeans, wheat, cattle, hogs, crude oil, natural gas, heating oil, gold, silver, and copper
Prokopczuk, Stancu, and Symeonidis 2019	Variables associated with credit risk, funding liquidity, equity and bond market stress, and fluctuations in real business conditions bear significant predictive power over commodity market volatility.	Multivariate regression	1970-2015 (daily)	25 commodities in agriculture, energy, and metals
Streeter and Tomek 1992	Seasonality and market structures, such as the volume of open interest and relative positions of speculation and hedging, are key determinants of price volatility.	GLS, SUR	1976-1986 (daily)	Soybeans
Tomek and Peterson 2001	Implied volatility for corn and soybeans is high during the growing season and low	Review paper		

	during the storage season. For wheat, it is the highest near harvest and lowest during November through March.			
Samuelson 1965	Futures prices exhibit increased volatility as they approach their maturity.	Theoretical paper		Wheat
Anderson 1985	Seasonality of production is the primary factor affecting the volatility of prices, followed by the time to maturity.	OLS	1966-1980 (daily)	Wheat, corn, oats, soybeans, soybean oil, live cattle, silver, and cocoa
Garcia and Leuthold 2004	Seasonality, maturity effects, and market characteristics such as volume and trader compositions can explain volatility in futures prices.	Review paper		
Karali, Power, and Ishdorj 2011	Volatility increases the closer the time to delivery for soybeans and wheat, but decreases for maize.	Bayesian SUR	1987-2007 (weekly)	Maize, wheat, and soybeans
Symeonidis et al. 2012	Price volatility is a decreasing function of inventory.	OLS	1993-2011 (daily)	21 different commodities
Kenyon et al. 1987	Previous month volatility explains 38 to 62 percent of the variance in futures prices.	OLS	1974-1983 (daily)	Maize, wheat, soybeans, live cattle, and hogs
Chatrath, Adrangi, and Dhanda 2002	There is evidence for Samuelson's hypothesis of a maturity effect in futures prices.	GARCH	1969-1995 (daily)	Maize, wheat, soybeans, and cotton
Goodwin and Schnepf 2000	Crop-growing conditions, seasonality, stocks-to-use ratio, and the structure of the futures markets are significant determinants of the volatility in futures prices.	VAR, ARCH, GARCH	1986-1997 (weekly)	Maize and wheat

Annex 3: Modeling General Equilibrium and the Indirect Effects of Russia's Invasion of Ukraine

The modeling framework used by Chepeliev et al. (2023) relies on three inputs:

3.1. GTAP MRIO Database

As a key data input to the modeling framework, the GTAP 10A MRIO database with the 2014 reference year is used (Carrico et al., 2020; Aguiar et al., 2019). A particular feature of this database is distinguishing bilateral trade and tariff flows by agents or so-called end users, namely firms, private households, government, and investors. GTAP 10A MRIO is one of the few global databases that uses concordances between products and end-uses to differentiate sourcing of imports across agents and tariff rates across end users. Most other global MRIO databases assume proportional sourcing of imports across agents (e.g., Lenzen et al., 2013; Peters et al., 2011; Stadler et al., 2018).

An original GTAP 10A MRIO database, which contains 141 regions and 65 sectors, is aggregated to 33 sectors and 39 regions for simulation purposes.

3.2. GTAP Nutritional Module

Following Chepeliev (2022), the developed modeling framework incorporates nutritional accounts to trace the quantities of food, calories, fats, proteins, and carbohydrates along the value chains. This approach tracks changes in key nutritional indicators across different use categories, including food, feed, seed, and non-food purposes. It differentiates between domestic and imported sources of supply across key agricultural and food sectors, considering the regions of origin. One distinct feature of the approach, developed by Gatto and Chepeliev (2023), is the representation of the out-of-home food supply, including restaurants, hotels, schools, etc. The nutritional module explicitly represents global food loss and waste flows across various stages of the global supply chains. This allows us to distinguish between gross and net food supply to the final users, which is important for properly representing the food availability trends.

3.3. ENVISAGE Model

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

The report expanded the modeling framework by incorporating an MRIO module to allow for the agent-based demand for imports by region of origin. Selected manufacturing sectors in the ENVISAGE model are represented using the MRIO specification. All other sectors use the standard Armington assumption, treating imports as imperfect substitutes with domestically produced commodities, and sourcing is done at the national level.

The core strength of global CGE models, like ENVISAGE, is their consistent representation of interdependencies between sectors, agents and markets within the economy and across countries. By capturing both the supply and demand sides, the model represents adjustments in quantities and prices

reacting to policy shocks. For instance, if wheat supply is restricted/disrupted in the Black Sea region, global wheat prices increase, reducing wheat demand and stimulating substitution toward alternative food commodities, such as other grains and rice.

Annex 4: Smooth Transition Model to Explain Asymmetric Price Insulation

Methodology

1. The background paper by Hoffman et al. (2024XXX) shows that countries tend to respond to increasing international prices by increasing the insulation of their domestic markets. The high-price regime is characterized by greater insulation than the low-price regime. The degree of insulation is measured by the slope of the line showing the relationship between world and domestic prices; the lower the slope, the greater the insulation.

2. This annex describes the methodology used.

3. The paper uses the ST model to describe the relationship between the domestic price of a commodity, such as wheat, and its corresponding international price to show how policy changes and other factors affect this relationship. Consider a country importing a food commodity that applies a combination of ad valorem (v) and specific (s) tariffs on it. The domestic price in this country (p^D) will equal:

$$p^D = p^I(1+v) + s + TC + OTC \quad (1)$$

where p^I is the international price, and TC measures transport costs between the locations at which p^I and p^D are reported. OTC are trade costs other than transport costs. The first two terms on the right-hand-side of equation (1) ($p^I(1+v)+s$) capture the effects of border policies in the importing country. TC captures the physical and other costs of trade as well as traders' margins.[27]

Under these conditions, the elasticity of international to domestic price transmission (ε) equals:

$$\varepsilon = \frac{p^I(1+v)}{p^I(1+v)+s+TC+\mathrm{OTC}} \quad (2)$$

It is immediately apparent that $0 < \varepsilon \leq 1$, with $\varepsilon = 1$ occurring when $s = TC = OTC = 0$.

Equation (2) can be used to derive the following results:

$$\frac{\partial \varepsilon}{\partial p^I} = \frac{\varepsilon}{p^I}(1-\varepsilon) > 0, \quad (3)$$

$$\frac{\partial \varepsilon}{\partial v} = \frac{\varepsilon}{(1+v)}(1-\varepsilon) > 0, \text{ and} \quad (4)$$

[27] In the case of an exporting country, TC will be negative, as will v and s if export taxes are applied. This has no effect on the following derivations.

$$\frac{\partial \varepsilon}{\partial s} = \frac{\partial \varepsilon}{\partial TC} = \frac{-\varepsilon}{p^I(1+v)+s+TC+OTC} < 0. \quad (5)$$

4. Equation (3) shows that the elasticity of international to domestic price transmission (ε) is an increasing function of the international price. Intuitively, this is because, as p^I increases, the price difference $p^D - p^I$ that is due to a given s and TC becomes smaller relative to the price level, and ε asymptotically approaches 1. Equation (4) shows that if the importing country reduces its *ad valorem* tariff v, ε will decrease. However, if $\varepsilon = 1$, then changes in p^I and v in equations (3) and (4) do not affect ε. Finally, equation (5) shows that if a country reduces its specific tariff s, or if its trade costs *TC* decrease, ε will increase.

5. Although equations (3), (4) and (5) describe partial changes to elasticities driven by p^I, v, s, and TC, the *ceteris paribus* condition will rarely hold in reality; changes in p^I, v, s, TC, and OTC will be contemporaneous and interrelated. Indeed, the hypothesis underlying our analysis is that changes in p^I prompt countries to adjust policies such as tariffs. In other words, t and s are functions of p^I. In addition, since energy costs are an important component of TC, and agricultural and energy commodity prices co-move (Pindyck and Rotemberg, 1990; Baffes and Haniotis, 2016), $\partial TC/\partial p^I \neq 0$. If we assume, for illustration, that p^I and TC increase by the same amount ($dp^I = dTC = x$), then we can derive the total derivative:

$$d\varepsilon = \left[\frac{\varepsilon}{p^I(1+v)}\left(1 + v - \varepsilon(2+v)\right)\right] x \quad (6)$$

The derivative will be negative or positive depending on the relative magnitudes of v and ε. Yet, in reality, it is unlikely that p^I and TC will change by the same amount, and that this change will not trigger any changes in v and s. When p^I, v, s, and TC change simultaneously, the resulting total change in the elasticity of international to domestic price transmission will be a different, more complex combination of the reactions in equations (3), (4), and (5).

6. Governments can use other policy tools in addition to import tariffs to influence their domestic prices. These policy tools include price and margin controls, sales and value-added taxes, subsidies, manipulation of exchange rates, public stockholding, and export restrictions such as export taxes and bans in exporting countries. The effects of some of these policy tools can be expressed as tariff equivalents. Depending on how and when such policy tools are implemented, ε might even appear to be negative over a period. If, for example, in response to increasing international prices, the government of an importing country releases public stocks on its domestic market, or the government of an exporting country imposes an export ban, then international and domestic prices might move in opposite directions for a period, leading to $\varepsilon < 0$.

7. Finally, the relationship between international and domestic prices can also be influenced by the market power of traders and other businesses along the supply chain, such as harbor facilities and other critical infrastructure, logistics, or testing and certification procedures. Such businesses might, for example, attempt to take advantage of the uncertainty and confusion created by an agricultural price crisis to inflate their prices and margins, provided they have market power. In this case, the domestic prices might increase more rapidly than international prices over time. If p^D is not a border price but is instead measured further along the supply chain (for example, at the retail level), TC will include additional marketing costs. These

costs will render the price transmission mechanism more complex and, depending on the market structure in processing and retailing, will increase the scope for non-competitive pricing. Therefore, increasing trade costs and non-competitive pricing behavior could cause domestic prices to grow faster than international prices, in which case we might observe $\varepsilon > 1$ over a period.

8. Considering all these factors, it is difficult to predict *a priori* how the relationship between international and a domestic price for an agricultural commodity will change when international prices increase rapidly. While we can be quite certain that this relationship will change, the nature of this change will depend on a wide range of country- and product-specific factors. It is reasonable to expect that when international prices increase sharply, most governments will attempt to insulate domestic markets for political reasons, thus reducing ε, and perhaps even making it negative over certain periods. However, increases in marketing costs and non-competitive pricing behavior in the value chain could cause domestic prices to grow more than international prices, leading to periods in which $\varepsilon > 1$.

9. To analyze the varying relationships between domestic and international prices econometrically, we use a simple specification of the long-term relationship between prices:

$$p_t^D = \beta_0 + \beta_1 p_t^I + \beta_2 TC_t + u_t \qquad (7)$$

where the subscript t is an index of time and u is a stochastic error term. In equation (7), β_1 captures the term $(1 + v)$ in equation (1), β_0 captures $s + OTC$, and the elasticity of international to domestic price transmission is given by:

$$\varepsilon = \frac{\beta_1 p^I}{\beta_1 p^I + \beta_0 + \beta_2 TC_t} \qquad (8)$$

10. A country seeking to insulate its domestic market from a surge in international prices would typically take steps that aim at reducing β_1, for example, by reducing its ad valorem tariff v. At the same time, if trade costs increase, say, because of a rise in fuel prices, which often occurs in conjunction with rising agricultural prices, $\beta_2 TC_t$ will increase, unless compensated by reductions in any specific tariff s. The combined effect of decreasing β_1 and increasing $\beta_2 TC_t$ would be to reduce ε in equation (8), but since increasing international prices (p_t^I) have the opposite effect, the total effect on ε is ambiguous.

11. Moving from comparative statics to econometrics, if v, s, TC, and/or OTC are changing over time, then equation (7) is misspecified and estimates of β_0, β_1 and thus ε will be biased. This omitted-variable bias in purely price-based estimates of price transmission relationships has been identified by many studies (e.g., Barrett, 1996; Kinnucan, 2022). Given complete information on the evolution of v, s, TC, and/or OTC— and any other policy measures that affect price determination—over time, the ideal solution to this problem would be to specify a structural model of the relationship between p^D and p^I. Since complete information on all of these factors is rarely available, especially on other trade costs, an alternative solution is to use flexible forms for the specification in equation (7) that allow the variation of parameters β_0 and β_1 over time. Several flexible models have been proposed and applied in the price transmission literature that allow for structural breaks, threshold effects, asymmetry, non-parametric variation, and other non-linear characteristics in the relationship between variables. This solution is less than ideal because it is unlikely that a chosen flexible model will exactly mimic the changes in unobserved factors that cause β_0 and β_1 to

vary over time. Nevertheless, models that allow for changes in parameters can enable us to at least search for plausible patterns in price data and accumulate evidence, if not rigorously test hypotheses.

12. The Error Correction Model (ECM) has been the dominant model used in price transmission analysis since the mid-1990s.[28] The ECM combines the estimation of the long-term relationship between two variables with the estimation of the short-run dynamic reaction to shocks. Doing so ensures that this relationship is restored when disturbed and thus holds in the long term. The ECM for the relationship between a domestic price and an international price is:

$$\Delta p_t^D = \alpha(p_t^D - \beta_0 - \beta_1 p_t^I - \beta_2 TC_t) + \sum_{i=1}^{k} \delta_i \Delta p_{t-i}^D + \sum_{j=1}^{l} \varphi_j \Delta p_{t-j}^I + u_t \qquad (9)$$

13. In equation (9), the first term on the right-hand-side $(p_t^D - \beta_0 - \beta_1 p_t^I - \beta_2 TC_t)$ measures deviations from the long-term relationship between p^D and p^I in equation (7). α is the so-called adjustment parameter that describes the speed at which changes in the domestic price correct deviations from this long-term relationship ('errors'), hence the term ECM. The δ and the φ are parameters that capture short-run dynamic responses in the system. The ECM is an appropriate specification for non-stationary variables (the technical term is "integrated") but co-move so that the deviations from their long-term relationship are stationary; this co-movement is referred to as "cointegration". Hence, before estimating an ECM, one first tests whether the variables are integrated (often the case with price series) and cointegrated. Variables that are not cointegrated do not share a common long-term relationship, in which case there can be no error correction process that restores such a relationship and, hence, no ECM. In our setting, lack of cointegration, i.e., the lack of a long-term relationship between a domestic and the corresponding international price suggests complete insulation of the domestic market.[29] Otherwise, if the domestic price is cointegrated with the international price, we expect to see the parameters of the long-term relationship change in a manner consistent with increasing insulation, as outlined above, when international prices increase sharply.

14. Martin and Minot (2022) estimated the ECM in equation (9) for 46 domestic wheat price series, using US No. 2 SRW fob Gulf as a representative international price.[30] They found evidence for cointegration between 37 of these domestic price series and the international price. For those 37 series, they estimate an average elasticity of price transmission of 0.765.[31] Since complete price transmission would be reflected in cointegration with an elasticity close to 1, Martin and Minot (2022) interpret their results—the lack of cointegration in some cases, and elasticities of price transmission lower than 1 in others—as evidence that countries are, to varying degrees, insulating their domestic market from international markets.

[28] Von Cramon-Taubadel and Goodwin (2021) offer a recent survey of the price transmission literature.

[29] As we discuss below, we might fail to find that two prices are cointegrated because we do not use an appropriately specified test that accounts for possible non-linear relationship between them.

[30] Of the 46 domestic prices analysed by Martin and Minot (2022), 17 are for wheat grain, 18 for wheat flour, and 11 for bread. Domestic flour and bread prices are not only spatially separated from the international wheat price by TC in equation (1), they are also vertically separated in the food chain because they include varying degrees of processing. To account for this, equation (1) could be modified to include an additional term PC (for processing costs). Changes in PC over time will cause additional bias in estimates of price transmission coefficients such as β_1 that are based solely on price data (Kinnucan, 2022). Hence, estimates of wheat-to-flour and wheat-to-bread price transmission are not directly comparable with estimates of wheat-to-wheat price transmission. To avoid this additional complication, we only analyse prices for unprocessed grains.

[31] Since Martin and Minot (2022) estimate using the logarithms of prices, their estimates of β_1 can be directly interpreted as elasticities.

In the second step of their analysis, Martin and Minot (2022) modeled the effects of this insulation on how international prices respond to shocks.

15. As outlined above, we hypothesize that countries will respond to increasing international prices with policy changes that, depending on previous policies, either introduce or increase pre-existing insulation. If this hypothesis is true, then β_0 and β_1 in equation (7) will not be constant over time. To test this hypothesis, we used two modified versions of the ECM in equation (9), a smooth transition model and a time-varying parameter ECM.

The smooth transition model

16. Intuitively, governments may well be willing to live without intervening in the case of small fluctuations in world prices of food, allowing them to be fully transmitted to the local economy, but not when fluctuations are large. The modification of the ECM that we use is a so-called smooth transition (ST) model. ST models assume that the relationship between two or more variables switches smoothly between two regimes depending on the value of a transition function. The transition function is bound between 0 and 1: for values of 0, the relationship between the variables being modeled follows one regime entirely; for values of 1, it follows the second regime entirely; for values between 0 and 1, it follows a correspondingly weighted mixture of the two regimes.

17. A variety of ST models have been proposed and implemented in the literature. We use the following specification, proposed by Saikkonen and Choi (2004) and implemented in agricultural price transmission, for example, by Götz et al. (2016). This specification allows for a smooth transition in the long-term relationship between a domestic and international price:

$$p_t^D = \beta_0^L + \beta_1^L p_t^I + (\beta_0^H + \beta_1^H p_t^I) * g(p_t^I) + \beta_2 TC_t + u_t \quad (10)$$

where the superscripts L and H refer to low- and high-price regimes, respectively, and

$$g(p_t^I) = (1 + e^{\left(-\gamma(p_t^I - c)\right)})^{-1} \quad (11)$$

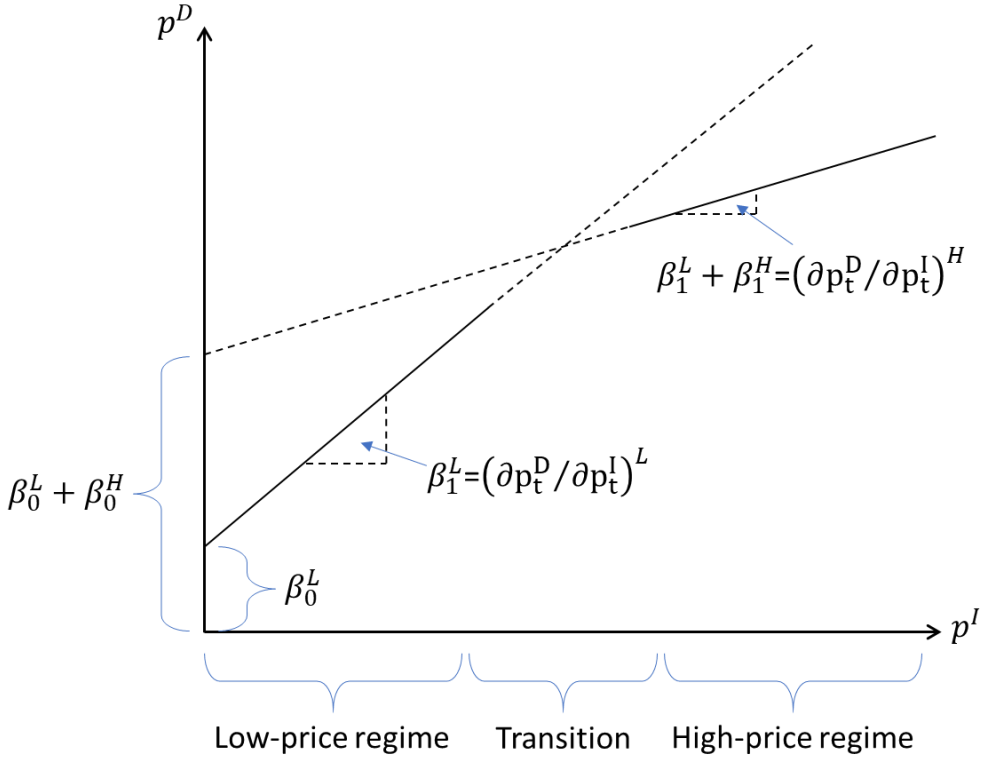
18. In equation (10), the function $g(\cdot)$ ranges from 0 for low values of p_t^I to 1 for high values. When $g(\cdot) = 0$, the long-term relationship between p_t^I and p_t^D is $p_t^D = \beta_0^L - \beta_1^L p_t^I$, which we refer to as the low-price regime. When $g(\cdot) = 1$, the long-term relationship is $p_t^D = (\beta_0^L + \beta_0^H) + (\beta_1^L + \beta_1^H) p_t^I$, which we refer to as the high-price regime. The coefficient c marks the mid-point of the transition between the regimes where $g(\cdot) = 0.5$, and the relationship between p_t^I and p_t^D is an equally-weighted mixture of the low- and the high-price regimes. The coefficient γ determines the speed with which $g(\cdot)$ transitions from 0 to 1 as p_t^I increases. As $\gamma \to \infty$ the transition function $g(\cdot)$ approaches a step function, and the transition from the low- to the high-price regime becomes increasingly abrupt at $p_t^I = c$. This ST model is estimated using maximum likelihood techniques.

19. Based on the theoretical framework outlined above we derive two expectations for the results of estimating the ST model. First, the specification of $g(\cdot)$ in equation (11) assumes that the transition between regimes is driven by the international price level (hence the terms 'low-price' and 'high-price' regime). We expect the transition from the low- to high-price regime to occur when international prices reach what are

perceived to be critical levels. These critical levels will vary by commodity and vary among countries depending above all on their trade situation (especially import dependence), food (in)security, and fiscal situations. International wheat prices, for example, have typically ranged between US$150–200 per ton in recent decades, interrupted by 'agricultural price crises' such as in 2007/08 and 2022, when they increased rapidly and peaked at over US$300 per ton. Hence, we expect many countries will implement policy changes and thus trigger the transition from the low-price to the high-price regime for wheat when international wheat prices climb above US$200 per ton and reach levels of US$250 per ton and above.

20. Second, if countries respond to increasing international prices by increasing the insulation of their domestic markets, then the high-price regime will be characterized by a higher degree of insulation than the low-price regime. Figure A4.1 depicts what we might expect for a typical importing country. For low international prices, the low-price regime $p_t^D = \beta_0^L - \beta_1^L p_t^I$ holds. The coefficients β_0^L and $\beta_1^L = (\partial p_t^D / \partial p_t^I)^L$ will vary among countries depending on their trade costs (e.g., whether they are landlocked, the efficiency of port infrastructure) and the policy measures they implement (e.g., their import tariffs, internal price controls, etc.). For high international prices, the high-price regime holds, and we expect that increased insulation in this regime will be reflected in a reduction in the responsiveness of domestic to international prices, i.e., $(\beta_1^L + \beta_1^H) = (\partial p_t^D / \partial p_t^I)^H < (\partial p_t^D / \partial p_t^I)^L = \beta_1^L$, and therefore $\beta_1^H < 0$. In addition, we expect that $(\beta_0^L + \beta_0^H) > \beta_0^L$ and therefore $\beta_0^H > 0$. As discussed above, an importing country might respond to increasing international prices by reducing specific tariffs, which would shift the price relationship downward, implying that $\beta_0^H < 0$ and $(\beta_0^L + \beta_0^H) < \beta_0^L$. However, the constant term β_0 also includes the costs of trade, especially transport (fuel), which typically increase when agricultural prices and general commodity prices increase.

Figure A4.1: Asymmetric Price Insultation



Annex 5: ECM to Explain Tradeoffs Faced by Policymakers

This annex presents the model developed in the background paper by Martin et al (2024).

As long as a country participates in trade for a particular standardized commodity, the domestic price can be linked to the world price using a tariff equivalent $(1+t)$ that summarizes the protective effect of trade measures such as tariffs and/or quotas. In levels, this may be written:

(1) $$P = (1+t)\cdot P^w$$

where P is the domestic price and P^w is the external price for the same commodity, expressed at a common point in the marketing chain.

If we follow the logic of the seminal Grossman and Helpman paper (1994, p842), political-economy bargaining between interest groups and the government determines a desired proportional tariff equivalent, t^*, that depends on generally stable parameters. These parameters include the elasticity of import demand/export supply, the share of domestic production in total consumption, and the extent to which producers and consumers of the commodity are organized to pursue their interests. The terms of trade explanation for trade policy proposed by Bagwell and Staiger (2002) postulates that trade barriers are determined by similarly stable parameters such as the elasticities of foreign demand for exports and foreign supply of imports. In general, we would expect that small deviations from the desired levels of protection would result in modest political costs, while larger deviations are likely to result in greater costs as the more powerful interest groups supporting the policy equilibrium become concerned that their preferences are not being reflected in policy outcomes.

In logs, equation (1) yields an expression for the desired value of the log of the domestic price:

(2) $$p^* = \tau^* + \cdot p^w$$

Where p^* is the log of the equilibrium level of domestic prices, τ^* is the log of $(1+t^*)$, capturing the effects of political-economy and market elasticities,[32] and p^w is the log of the world price. That the coefficient on p^w is unity in this relationship, as specified by the Grossman-Helpman and/or Bagwell-Staiger models, is a testable hypothesis.

[32] For small values of the tariff, $\tau = \ln(1+t^*)$ is approximately equal to t^*.

If these models were a complete representation of trade policy, then the log of the domestic price, p^d, would equal p^* at all times. As such, the ratios of domestic and world prices would be constant, and changes in the log of the domestic price would be given by:

$$\Delta p_t = 1 \cdot \Delta p_t^w \quad (3)$$

Using models from behavioral economics, Freund and Özden (2008) point to a range of world prices over which the price transmission coefficient should be zero, with policymakers fully compensating losers from price increases or decreases by adjusting rates of protection. This study uses an encompassing model in which domestic prices are adjusted by a coefficient δ, where $0 \leq \delta < 1$. This encompasses both this perfect insulation case where $\delta=0$; intermediate values of δ involving partial insulation; and the case of full price transmission where $\delta=1$.

The formulation used in this paper implies that policymakers have two goals that are conflicting to some degree. They seek to avoid sharp price changes, which reduce the welfare of one group, such as net food buyers or sellers, from their initial reference levels and can generate intense political reactions. However, maintaining the political-economy equilibrium implies maintaining a stable relationship between domestic and world prices. In this situation, if the economy begins at a stable political-economy equilibrium and world prices rise, the loss aversion model requires a reduction in protection levels to blunt the increase in domestic prices. However, this changes the protection rate away from the political-economy equilibrium. Interest groups that had sought and obtained positive or negative protection in the initial equilibrium are likely to become dissatisfied at a new situation in which they receive lower rates of protection, resulting in pressure to return to this equilibrium.

The Error Correction Model and Trade Policy

Much of the extensive literature on price transmission in agricultural markets focuses on situations where competition can be expected to ultimately result in price differentials that equal the costs of transport or product transformation (Von Cramon-Taubadel & Goodwin, 2021). In this situation, deviations from those equilibria are due to factors such as market frictions, asymmetric information, or behavioral responses. Many of these studies use the ECM to capture the dynamics of adjustment and deal with the statistical properties of the data series used (Engle & Granger, 1987). An important question is whether ECM models might be used to capture policy responses to changes in world food prices in markets for sensitive food products.

Nickell (1985) provides a derivation of an ECM for situations where decision-makers minimize a weighted average of the costs associated with adjusting domestic prices and those from being away from a desired long-term target. The resulting objective function for our problem is:

(4) $C_t = \sum_{s=0}^{\infty} \alpha^s \left[\left(p_t^d - p_{t-1}^d\right)^2 + a\left(p_t^d - p_t^*\right)^2\right]$

where α is a discount factor (0< α ≤ 1); the quadratic function $\left(p_t^d - p_{t-1}^d\right)^2$ represents the costs of changing domestic prices and $a\left(p_t^d - p_t^*\right)^2$ represents the costs of deviating from the political-economy equilibrium, where *a* is a weight representing the costs to policymakers of deviations from the political equilibrium relative to those of changing prices.

To make (4) operational, a stochastic process must be specified for future price targets. Nickell shows that a simple model, which characterizes world prices with a unit root and a single lagged price change term, using a simple stochastic process,[33] aligns with the behavior of most of the world price series under study. This results in a simple, parsimonious ECM.

(5) $\Delta p_t = \delta \Delta p_t^w + \phi(p_{t-1} - \tau^* - p_{t-1}^w) +$

where δ is a short-run adjustment coefficient showing the extent to which the domestic price is adjusted in response to change in the world price; the expression in parentheses is the deviation from the long-term political-economy equilibrium tariff level in the previous period; and θ is a coefficient that indicates the speed of adjustment toward this equilibrium. Under this model, the relative magnitudes of δ and θ reflect the relative costs to policymakers of changing domestic prices from their initial levels and of deviations from desired long-term levels of protection. As noted earlier, this model captures the behavior of policymakers who face quadratic costs of adjusting domestic prices as world prices change and deviate from the protection levels associated with the political-economy equilibrium. The derivation of this model shows that the ECM frequently used to analyze linkages between interrelated markets (Von Cramon-Taubadel & Goodwin, 2021) can also have a strong policy interpretation when estimated with suitable data.

While equation (5) focuses on the relationship between domestic and world prices, it can be simply transformed into a relationship between world prices and the rate of protection. If we define the rate of protection in logarithms as $\tau = (p^d - p^w)$, equation (15) can be rewritten as:

(6) $\Delta \tau_t = \alpha + (\delta - 1).\Delta p_t^w + \theta\left(p_{t-1}^d - \tau^* - \beta_1 p_{t-1}^w\right)$

[33] This model, which Nickell (1985, p124) describes as a second-order autoregression with a unit root, can be expressed as $p_t^w = p_{t-1}^w - (1 - \beta).\Delta p_{t-1}^w + \varepsilon_t$ and was used for augmented Dickey-Fuller tests.

When δ less than one, this intuitively implies that an increase in the world price causes the rate of protection to decline, as in equation (5).

Estimation of this model provides important insights into policymakers' relative weights on aversion to sharp price changes and aversion to deviation from the politically optimal relationship between domestic and world prices. The lower the price adjustment coefficient, δ, the greater the political costs of adjusting domestic prices, and the greater the extent to which price instability is exported to the rest of the world. The higher the value of θ, the more rapidly policymakers return protection to its political equilibrium level following a shock to world prices. The long-term equilibrium level of protection, when world prices are stable, is given by τ^*.

A striking feature of the loss aversion model is its range of complete price insulation when prices fall below (rise above) the reservation price of producers (consumers) (Freund & Özden, 2008). This result has enormous potential implications for market stability. If it applied to all countries and a primary shock caused the log of world prices to rise by Δp, then each country would lower the rate of its agricultural distortions (in logs) by Δp. This policy response would raise the world price by a further Δp, setting off another round of reductions in protection. With a price insulation coefficient of unity, this process is clearly explosive, making the world market unstable. Testing whether $\delta = 1$ in equation (5) provides a test of this theoretical prediction together with a maintained hypothesis that the reference price for both producers and consumers is the current price.

If world prices for wheat and rice follow a random path, then the price last period is the best predictor of their price in this period, making it a plausible candidate for the reference price. If they are characterized by the second-order autoregressive process described by Nickell (1985), then this would be the case when the price was the same in the past two periods. Since Tversky and Kahneman (1991) do not specify how reference prices are determined, we cannot be sure how they might be determined in this case. Since world markets for rice and wheat do not appear to be explosive, what matters for both theory and reality is the value of the δ coefficient in equation (5).

Figure A5.1. The relationship between product prices and protection

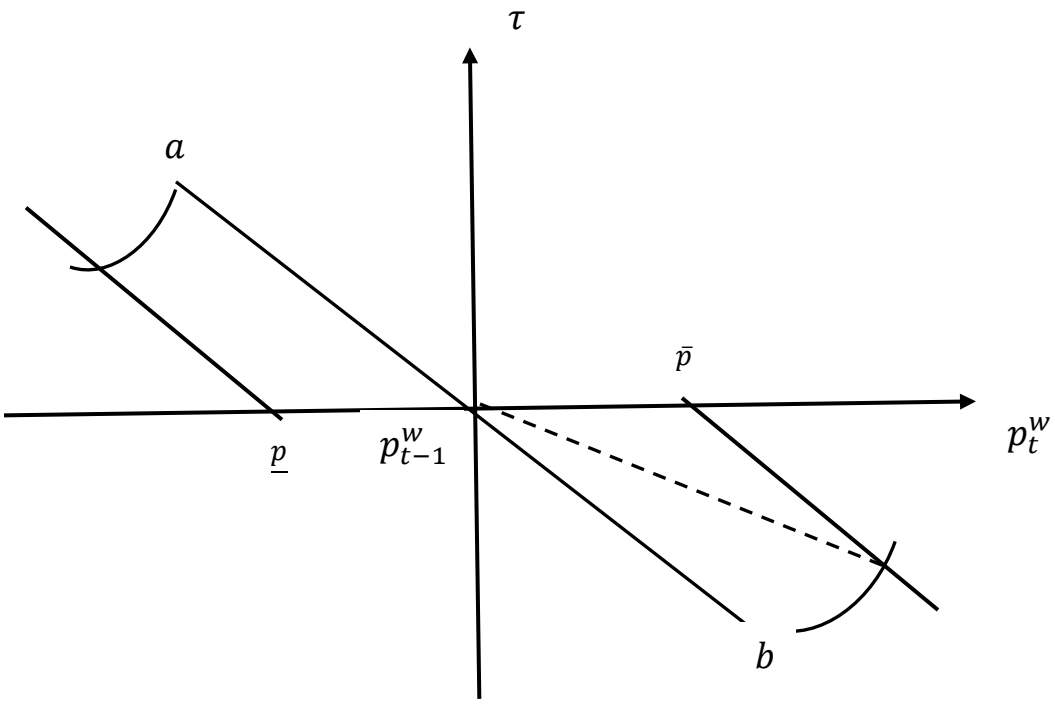


Figure A5.1, drawing on Figure 4 of Freund and Özden (2008) and Figure 3 of Giordani et al. (2016), is useful in identifying at least two ways in which a finding that $\delta < 1$ might be consistent with behavioral theory while avoiding potentially dire implications for market stability. In this figure, the world price is shown on the horizontal axis, and the rate of protection on the vertical axis. The rate of protection begins at zero when the world price equals its level in (t-1). If the reference price equals p_{t-1}^{w} and the world price rises to a level consistent with point *b*, then the rate of protection falls one for one with the world price increase. This action is because the elasticity of price insulation, $(\delta - 1)$ in equation (6), equals -1 or, equivalently, the price transmission elasticity is zero. Freund and Özden show that the protection rate declines in absolute value because of diminishing marginal costs of losses if the world price rises further. In the figure, this response of protection is shown by the upward-sloping curve beginning at point *b*.

Another theory-consistent potential explanation for less than full price insulation is a reference price that differs than p_{t-1}^{w}. If, for instance, the reservation price for consumers is $\overline{p}$, then the compensating reduction in protection associated with a world price increase does not begin until the world price reaches $\overline{p}$. As shown by the dashed line in Figure A5.1, either of these differences could explain less than full compensation of consumers following a rise in the world price, even given the strong internal validity of the theory. Exactly

the same logic would apply in the case where the world price falls and the reference price for producers is $\underline{p}$.

Price Data for Estimation

Ideally, the estimation of the model outlined above would use high-quality data on domestic and external prices adjusted to the same point in the marketing chain so that changes in their relative prices reflect the impacts of trade policy alone, rather than being conflated with non-policy influences such as additive marketing margins, changes in the direction of trade, differences in product quality or lags in price adjustment. Additionally, the data would cover a long period so that the analysis includes several cases of unusually high and low-price periods.

Fortunately, a reasonably long time series of data with these attributes is now available from a combination of the World Bank Distortions to Agricultural Incentives (DAI) project (Anderson, 2009) and the AgIncentives Consortium (Tokgoz et al., 2017). Under these two initiatives, the data on domestic and international prices have been chosen specifically for comparability in terms of product quality, and have been adjusted to the same level of the marketing chain to allow estimation of the level of protection due to trade policies. Measures of the producer prices received for covered commodities and the reference prices that would have applied had there been no interventions such as tariffs, quotas, or other policy measures that create gaps between domestic and external prices are key to measuring the assistance provided. Estimating the level of protection requires that analysts identify price series for important domestic commodities and traded commodities that are similar to domestic commodities. Identifying the rate of protection or taxation provided by trade measures also requires adjusting the prices of externally traded commodities to allow for transport costs and any product transformations (such as between milled and paddy rice). The data are annual, allowing time for prices to adjust following shocks.

Price data for producer prices and external prices adjusted to farm gate level were obtained from the DAI database for years up to 2004 and from the AgIncentives database for subsequent years. Combining data from the two initiatives provides samples from 1955 or 1961 to 2021 in many cases, although we must use shorter series for transition economies such as China and Russia and for a range of other countries with shorter time series. These datasets provided data on rice prices for 29 economies (with the EU treated as one). We excluded United Kingdom due to the structural changes associated with its accession to, and exit from, the EU. We obtained similar data for wheat for a slightly different set of 29 economies.

For our objective of making inferences about trade policies, these data are much better than standard food price series, such as those from FAO-GIEWs used by Martin and Minot (2022) or FAOSTAT data on producer price indexes. The data from studies of agricultural incentives have been chosen and harmonized

to estimate *ad valorem* equivalents of trade distortions. To do this, analysts undertake many quality control steps, such as identifying domestic and foreign products that are as similar as possible; making adjustments for any remaining quality differences; identifying the direction of trade (moving, for example, from FOB prices for exports to CIF prices for imports as the direction of trade changes); and adjusting for internal transport and marketing margins between the farm gate and the border (OECD, 2016). A small number of missing observations were replaced by linear interpolation of the logged values, as per Martin and Minot (2022), because some of the algorithms used, such as those for augmented Dickey-Fuller tests, cannot handle missing values.

A key question is whether to conduct the analysis using nominal or real price series. The nominal price series has the advantage of transparency and avoids introducing irrelevant variation. If the US CPI is used as a deflator, irrelevant variation from the point of view of other countries is introduced whenever the US real exchange rate changes. Deflating by national CPI measures makes it difficult to compare across countries and introduces real exchange rate changes as apparent sources of changes in both domestic and international prices. Given our focus on the arbitrage condition between domestic and international prices, we used nominal price data throughout the analysis. To allay potential concerns that our findings might be different had we used deflated data, we calculated the volatility of the first-differenced series following deflation by the US CPI – we found that the results were essentially the same.