

INTEGRATED MARKETS FOR RESILIENT FOOD SYSTEMS: TRADE POLICY AND FOOD AND NUTRITION SECURITY IN AN ERA OF CLIMATE CHANGE¹



June 4, 2024



1. This work is a product of the staff of The World Bank. The findings, interpretations, and conclusions expressed in this work do not necessarily reflect the views of the Executive Directors of The World Bank or the governments they represent. The World Bank does not guarantee the accuracy of the data included in this work. The boundaries, colors, denominations, and other information shown on any map in this work do not imply any judgment on the part of The World Bank concerning the legal status of any territory or the endorsement or acceptance of such boundaries.

© 2024 International Bank for Reconstruction and Development / The World Bank
1818 H Street NW
Washington DC 20433
Telephone: 202-473-1000
Internet: www.worldbank.org

This work is a product of the staff of The World Bank with external contributions. The findings, interpretations, and conclusions expressed in this work do not necessarily reflect the views of The World Bank, its Board of Executive Directors, or the governments they represent.

The World Bank does not guarantee the accuracy, completeness, or currency of the data included in this work and does not assume responsibility for any errors, omissions, or discrepancies in the information, or liability with respect to the use of or failure to use the information, methods, processes, or conclusions set forth. The boundaries, colors, denominations, and other information shown on any map in this work do not imply any judgment on the part of The World Bank concerning the legal status of any territory or the endorsement or acceptance of such boundaries.

Nothing herein shall constitute or be construed or considered to be a limitation upon or waiver of the privileges and immunities of The World Bank, all of which are specifically reserved.

Rights and Permissions

The material in this work is subject to copyright. Because The World Bank encourages dissemination of its knowledge, this work may be reproduced, in whole or in part, for noncommercial purposes as long as full attribution to this work is given.

Any queries on rights and licenses, including subsidiary rights, should be addressed to World Bank Publications, The World Bank Group, 1818 H Street NW, Washington, DC 20433, USA; fax: 202-522-2625; e-mail: pubrights@worldbank.org.

This work is a product of the staff of The World Bank. The findings, interpretations, and conclusions expressed in this work do not necessarily reflect the views of the Executive Directors of The World Bank or the governments they represent. The World Bank does not guarantee the accuracy of the data included in this work. The boundaries, colors, denominations, and other information shown on any map in this work do not imply any judgment on the part of The World Bank concerning the legal status of any territory or the endorsement or acceptance of such boundaries.

Design: Cover, Veronica Gadea; Accesibility and Template, Will Kemp, GCS, World Bank Group

CONTENTS

Acknowledgments	vi
Abbreviations	vii
Overview	ix
1 Setting the Stage: Trends in FNS, Climate Change, Trade, and Price Volatility	2
1.1. Shocks' Impacts on FNS	2
1.2. Climate Change's Impacts on Agriculture and FNS	8
1.3. Benefits of Food Trade	12
1.4. Trends in Food Price Volatility	16
2 Learning from the Past: The Impacts on Food Markets from Russia's Invasion of Ukraine and Policy Responses	22
2.1. The Invasion's Impacts on Food Markets	22
2.2. The Response of Food Markets	25
2.3. The Invasion's Impacts on Fertilizer Markets	27
2.4. The Invasion's Impacts on Agrifood Logistics	35
2.5. The Invasion's Indirect and Household-Level Effects	39
3 Navigating Policy: Price Insulation's Impacts on Food Price Volatility	50
3.1. Price Insulation's Role in Managing Food Price Volatility	50
3.2. The Political Economy of Price Insulation	57
3.3. Price Insulation's impacts on Food Price Stability	59
3.4. The Impacts from Avoiding Price Insulation: The Cases of Chile and Colombia	60
3.5. Implications for the World Trade Organization	64
4 Moving Forward: Conclusions and Recommendations	68
4.1. Conclusions	68

Annex 1: References	75
Annex 2: Sources and Determinants of Volatility in Agricultural Commodities	83
Annex 3: Modeling General Equilibrium and the Indirect Effects of Russia's Invasion of Ukraine	85
Annex 4: Smooth Transition Model to Explain Asymmetric Price Insulation	87
Annex 5: ECM to Explain Tradeoffs Faced by Policymakers	95

Boxes

Box 1	Composition of food imports by country income levels	5
Box 2	Fertilizer import tariffs are low, but with a few exceptions	31
Box 3	The WTO and Agriculture	65

Figures

Figure O.1	The invasion led to a large jump in trade policy measures	x
Figure O.2	Non-Tariff Measures on fertilizer trade have proliferated	xi
Figure O.3	Freight rates increased after the invasion but then returned to normal	xii
Figure O.4	No regions saw long-term declines in wheat imports	xii
Figure O.5	Most countries have higher downside variability of food availability, meaning they are vulnerable to food supply losses when trade is restricted	xiv
Figure 1	Countries' vulnerability to global food price shocks depends on their food import dependency and share of household expenditures on food	4
Figure 2	Cereals are the highest food imports for lower-income countries, 2021	5
Figure 3	Cereals are the greatest source of dietary energy supply (kcal/capita/day) in most countries, but especially in developing countries, 2021	6
Figure 4	Developing countries typically have higher dependency and vulnerability to concentrated sources of imports	7
Figure 5	Many countries will see real incomes decline from climate change	11
Figure 6	Agricultural Prices have fluctuated greatly	16
Figure 7	Volatility differs across commodities, 1970–2022	18
Figure 8	The invasion led to a large jump in trade policy measures	24
Figure 9	No regions saw long-term declines in wheat imports	26
Figure 10	A small number of countries produce most of the world's fertilizer (averages from 2012 to 2021)	28
Figure 11	There is a close relationship among international commodity prices (2007M1=100)	28

Figure 12	International fertilizer prices climbed as Russia's invasion of Ukraine started (2019M1=100).....	29
Figure 13	The trend of increasing fertilizer trade reversed after the invasion.....	30
Figure 14	Non-Tariff Measures on fertilizer trade have proliferated.....	30
Figure 15	Technical Barriers to Trade (TBT) are the most common fertilizer NTMs, 2019.....	31
Figure 16	Trade-policy measures affecting fertilizer increased after the invasion.....	34
Figure 17	Most of the trade-policy measures affecting fertilizers were distortive, Aug 31, 2023.....	34
Figure 18	Volume of Global Maritime Wheat Shipments (Metric tons), 2019–23.....	36
Figure 19	Freight rates increased after the invasion according to the Baltic Dry Index (red) and GC-GOFI (green).....	37
Figure 20	The rise in dry bulk freight rates and global grain prices contributed to higher consumer food prices (Percentage Change, 2019).....	38
Figure 21	Energy disruptions in selected countries and regions have a larger negative impact on real incomes than agricultural trade disruptions (decomposed across scenarios).....	42
Figure 22	Trade restrictions had the biggest impact on agricultural exports in most selected countries (decomposing agricultural and food export changes).....	43
Figure 23	All shocks combined have a greater impact on domestic kilocalorie supplies than on imported calorie supplies in the most-affected developing countries and regions.....	44
Figure 24	Nearly all households across countries lost real incomes because of the invasion.....	46
Figure 25	The effectiveness of price insulation policies on rice prices varies.....	53
Figure 26	The effectiveness of price insulation policies on wheat prices varies.....	54
Figures 27–30	Estimated elasticities of the transmission from international to domestic prices vary greatly for grains.....	56
Figure 31	Regional trade stabilization mitigated domestic price increases during the 2022 price shock.....	62
Figure 32	Most countries have higher downside variability of food availability, meaning they are vulnerable to food supply losses when trade is restricted.....	63
Figure A4.1	Asymmetric Price Insultation.....	94
Figure A5.1	The relationship between product prices and protection.....	99

Map

Map 1	Countries in red, including India, Canada, and European countries, have the highest average applied tariffs, while Chile, Peru, and Australia have the lowest, 2021.....	72
--------------	--	----

Tables

Table ES.1	Recommendations to Increase Food and Nutrition Security through Trade Policy... xix
Table 1	Only a few countries have fertilizer tariffs above 10 Percent, 2021..... 31
Table 2	Ad Valorem Equivalent (AVE) Estimates: TBTs (right) increase trade costs more than SPSs (left)..... 33
Table 3	Shock Descriptions..... 40

ACKNOWLEDGMENTS

This report was prepared by the team co-led by Ghada Elabed (Sr. Agriculture Economist, SAGGL), and Alberto Portugal-Perez (Sr. Economist, ETIRI). The team was composed of Sergiy Zorya (Lead Agriculture Economist, SAGGL), Joshua Gill (Agriculture Economist, SAGGL), Md Mansur Ahmed (Sr. Agriculture Economist, SAGGL), John Nash (Consultant, SAGGL), Cordula Rastogui (Sr Transport Specialist, IEAT1), Maryla Maliszewska (Sr. Economist, ETIRI), Israel Osorio-Rodarte (Economist, ETIRI), Erhan Artuc (Sr. Economist, DECTI), John Baffes (Sr. Agriculture Economist, DECPG) and Dawit Mekonnen (Sr. Economist, DECPG). Madhur Gautam (former Lead Agriculture Economist, SAGGL) provided guidance on the design of the study. Maximillian Ashwill (Ed4Dev) edited the report.

A series of background papers used in the study were prepared by Colin Carter (Distinguished Professor, Agricultural, Food and Resource Economics Department, University of California Davis); Sandro Steinbach (Associate Professor, Department of Agribusiness and Applied Economics, North Dakota State University); Stephan von Cramon-Taubadel (Professor, Agricultural Economics, University of Göttingen); Alberto Portugal-Perez; Clemens Hoffmann (Department of Agricultural Economics and Rural Development, University of Göttingen); Lina Kastens (University of Göttingen); Erik von Uexkull (Senior Economist, ELCMU); John Baffes; Jeetendra Khadan (Senior Economist, DECPG); Dawit Mekonnen; Will Martin (Senior Research Fellow, IFPRI); Cordula Rastogi; Daria Ulybina (Data Scientist, ETIRI); Alvaro Espitia (Consultant, ETIRI); Erhan Artuc (Senior Economist, DECTI); Guido Porto; Bob Rijkers (Senior Economist, DECTI); and Maksym Chepeliev (GTAP); Abdullah Mamun (Senior Research Analyst, IFPRI) and Nicholas Minot (Senior Research Fellow, IFPRI).

The overall guidance was provided by Martien van Nieuwkoop (former Director, SAGDR), Mona Haddad (Director, ETIDR), Julian Lampietti (Practice Manager, SAGGL) and Sébastien Dessus (Practice Manager, ETIRI). The report was peer reviewed by Svetlana Edmeades (Lead Agriculture Economist, SMNAG), Jose Signoret (Senior Economist, ETIRI), and Ralph Ossa (Chief Economist, World Trade Organization).

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 Programme
WTO	World Trade Organization

OVERVIEW

This report explores how shocks, food price policies, and food trade affect Food and Nutrition Security (FNS) in an era of changing climate. It aims to guide policy responses to climate change's projected impacts on FNS by examining the relationship between shocks, food trade, and price volatility from other contexts. The report analyzes the food shock related to Russia's invasion of Ukraine to better understand future food security and price shocks driven by climate change. It also assesses the effects of price insulation policies on global and domestic food markets. The report argues that open trade and integrated markets, free from price-distorting policies, offer the greatest benefits for FNS and household welfare in a warming world.

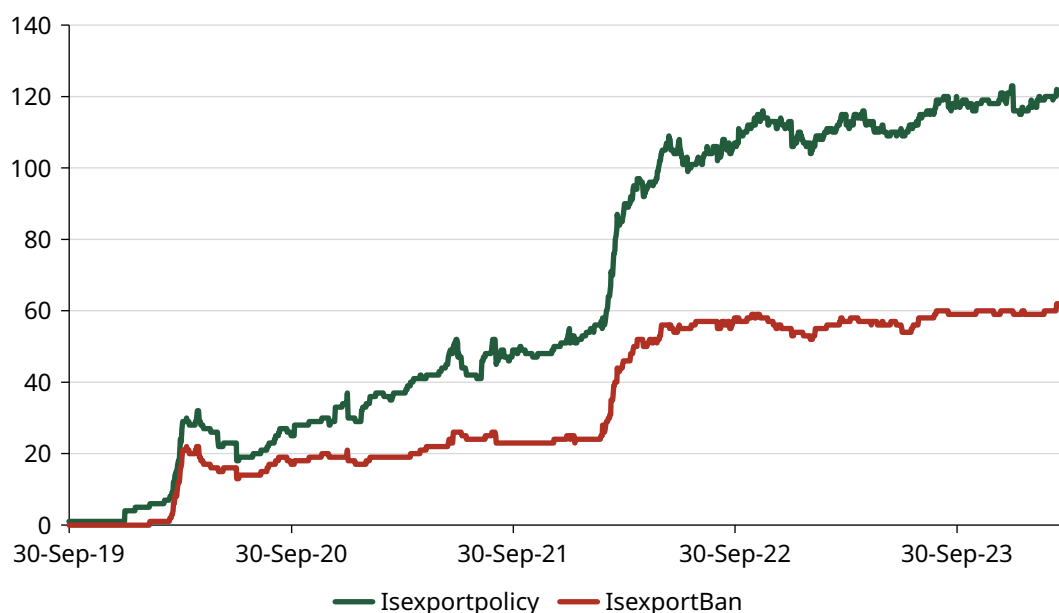
Climate risks are worsening and threaten food and nutrition security and global food markets. Climate change disrupts agricultural production through rising temperatures, shifting rainfall patterns, and more frequent extreme weather events. These factors lead to supply shortages and higher food prices. High temperatures increase food inflation in both high- and low-income countries, with Europe potentially facing a 30–50 percent rise in food inflation by 2035 (Kotz and others, 2024). Modeling by Artuc and others (2024) predicts declining crop yields in most countries, with productivity dropping by nearly 40 percent. Extreme weather events, like droughts, could reduce yields of major crops by over 50 percent by 2050 (Li and others, 2009). Compounding these risks are rising sea levels and shifting pest patterns. Such disruptions strain global food supply chains and worsen food insecurity, particularly in vulnerable regions. In 2021 alone, rising food prices pushed 30 million people in low-income countries into food insecurity (World Bank, 2022).

Russia's invasion of Ukraine shocked food markets and undermined FNS, making it a strong test case for future climate shocks. Together, Russia, Ukraine, and Belarus are major exporters of grains, energy, and fertilizers (UN Comtrade, 2022). The invasion sharply reduced Ukraine's grain production and exports. Grain harvests fell from 85 million tons in 2021 to 55 million tons in 2023 due to lower yields, reduced planting areas, and blocked Black Sea export routes (USDA, 2024). Sanctions on Russia further strained global food supply chains by raising transportation costs and creating financial barriers (TASS, 2022). These disruptions triggered record-high global food prices in March 2022 (CSIS, 2023) and drove food price inflation in many low-income countries to over 15 percent by late 2023, with rates as high as 30 percent in some cases (IFPRI, 2023). Global export restrictions,

such as India's rice export bans, exacerbated these shocks, covering 11 percent of global food trade (Rocha and Espitia, 2023). The invasion's ripple effects pushed 258 million people into acute food insecurity in 2022, the highest number on record (FSIN, 2023). The invasion also exacerbated inequality as the real income gap between poorer and wealthier households grew. This highlights the potential vulnerability of global food markets to global climate shocks.

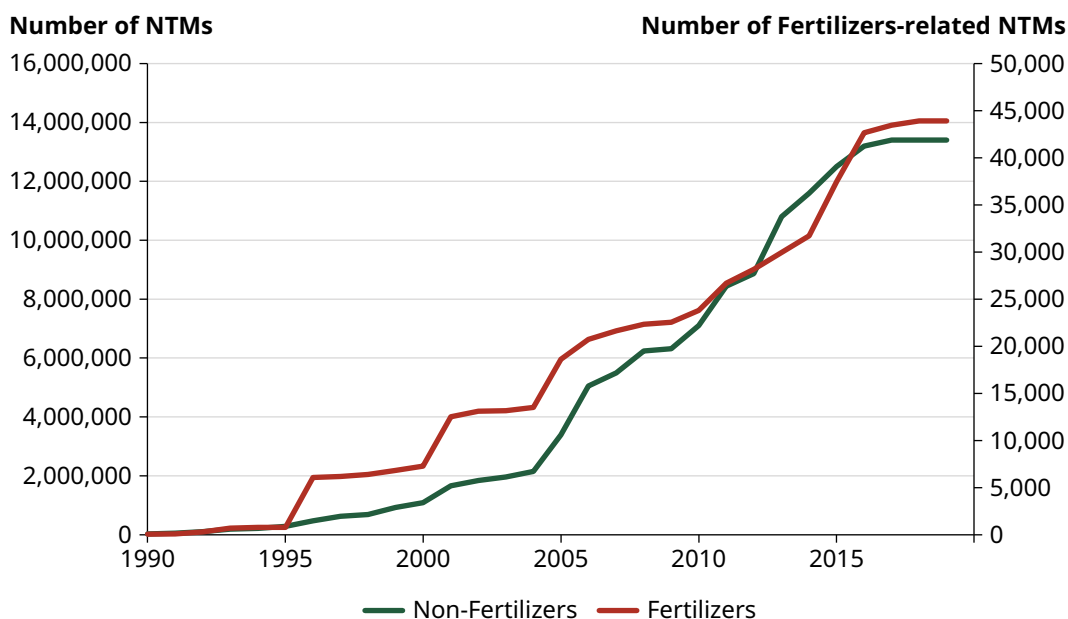
Russia's invasion of Ukraine disrupted the global fertilizer trade and led to a surge in restrictive non-tariff trade measures (NTMs) (Figures O.1 and O.2). Fertilizer prices, already rising due to increasing natural gas costs, spiked as production and exports from key suppliers like Russia and Belarus were interrupted. Fertilizer tariffs tend to be low or zero, but this disruption led to an increase in fertilizer NTMs, which are trade regulations other than tariffs, that countries used to control imports and exports in the face of the invasion's shock. Two specific NTMs became more prevalent: Technical Barriers to Trade (TBTs), such as pre-shipment inspections and import licensing, and Sanitary and Phytosanitary (SPS) measures, which ensure the quality and safety of fertilizers (Portugal-Perez and others, 2025a). TBTs are the most common type of fertilizer NTM, but they can be counterproductive as they increase trade costs and restrict market access for many fertilizers. In contrast, SPS measures had a less negative impact and sometimes facilitated trade by providing valuable information about quality, safety, and compliance to importers, consumers, and regulatory authorities (World Bank, 2019). The lack of coordination in NTMs further exacerbated global fertilizer price volatility.

Figure O.1 The invasion led to a large jump in trade policy measures



Source: Global Trade Alert database

Figure O.2 Non-Tariff Measures on fertilizer trade have proliferated



Source: Global Trade Alert database

Russia's invasion of Ukraine caused global grain shipping prices to spike, but agrifood logistics remained resilient. The invasion caused a near 60 percent increase in dry bulk transport costs, including grains, between February and May 2022 (UNCTAD, 2022). Freight rate increases also contributed to higher consumer food prices, disproportionately impacting middle- and lower-middle-income countries that rely heavily on food imports. These rising costs worsened inefficiencies in agrifood logistics and increased food waste, with nearly one-third of food produced globally—valued at approximately \$1 trillion—lost annually due to poor storage, transportation, and processing infrastructure. Despite these challenges, the global seaborne grain trade showed resilience. Importing countries diversified their sourcing strategies and improved storage and supply chain practices to minimize spoilage and mitigate risks. Freight rates stabilized after the invasion's initial shock (Figure O.3).

The global food system showed remarkable resilience to Russia's invasion of Ukraine, quickly adapting to disruptions in grain markets. Initial fears of severe food shortages did not materialize, largely because of the EU's Solidarity Lanes and the Black Sea Grain Initiative, which helped sustain Ukraine's grain exports (European Council, 2023). Major exporters in Europe and North America compensated for reduced supplies by redirecting food trade to vulnerable regions (CSIS, 2023). Importing countries diversified their suppliers, with West Africa and the Sahel increasing imports from Poland and Lithuania, including re-routed Ukrainian grain. The Middle East and Central Africa sourced more from Argentina and Australia. For example, Morocco replaced Ukrainian wheat imports by rerouting through Türkiye and Romania. Some countries, like Egypt and Türkiye,

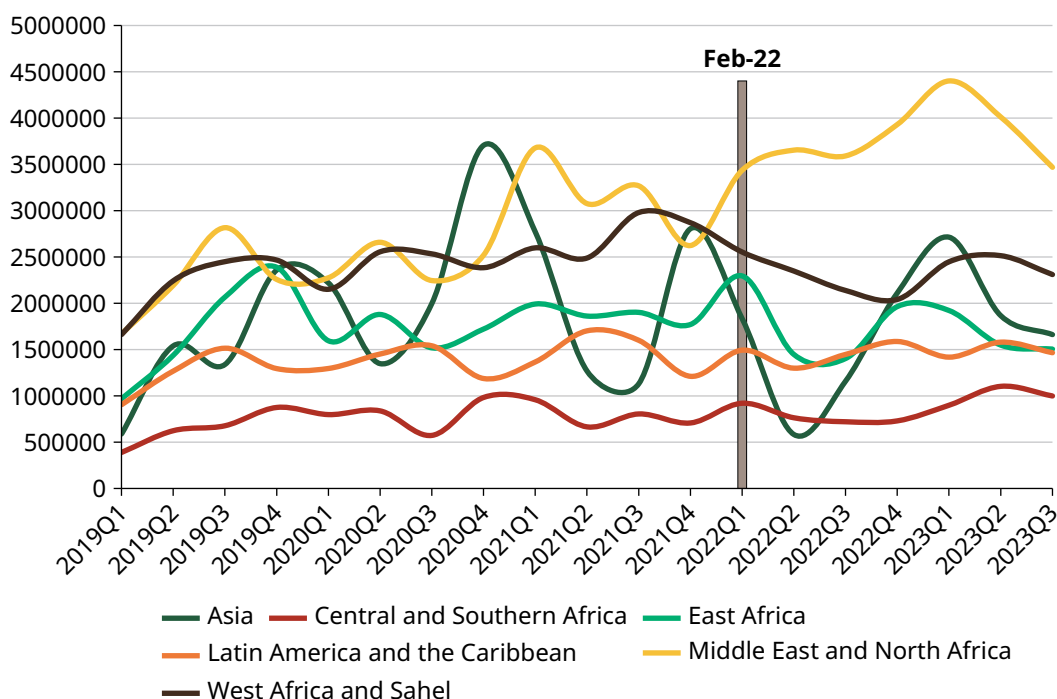
turned to alternative grains when wheat and maize supplies dropped (GRFC, 2023). These swift adaptations ensured food deliveries resumed to regions most at risk of acute food insecurity, highlighting the global food system's capacity to absorb and respond to major shocks, including potential climate-related shocks. No regions saw long term disruptions to wheat imports from the invasion (Figure O.4).

Figure O.3 Freight rates increased after the invasion but then returned to normal



Sources: Baltic Dry Index (in blue) and GC-GOFI (orange)

Figure O.4 No regions saw long-term declines in wheat imports



Source: Cordula Rastogi and Daria Ulybina (2024)

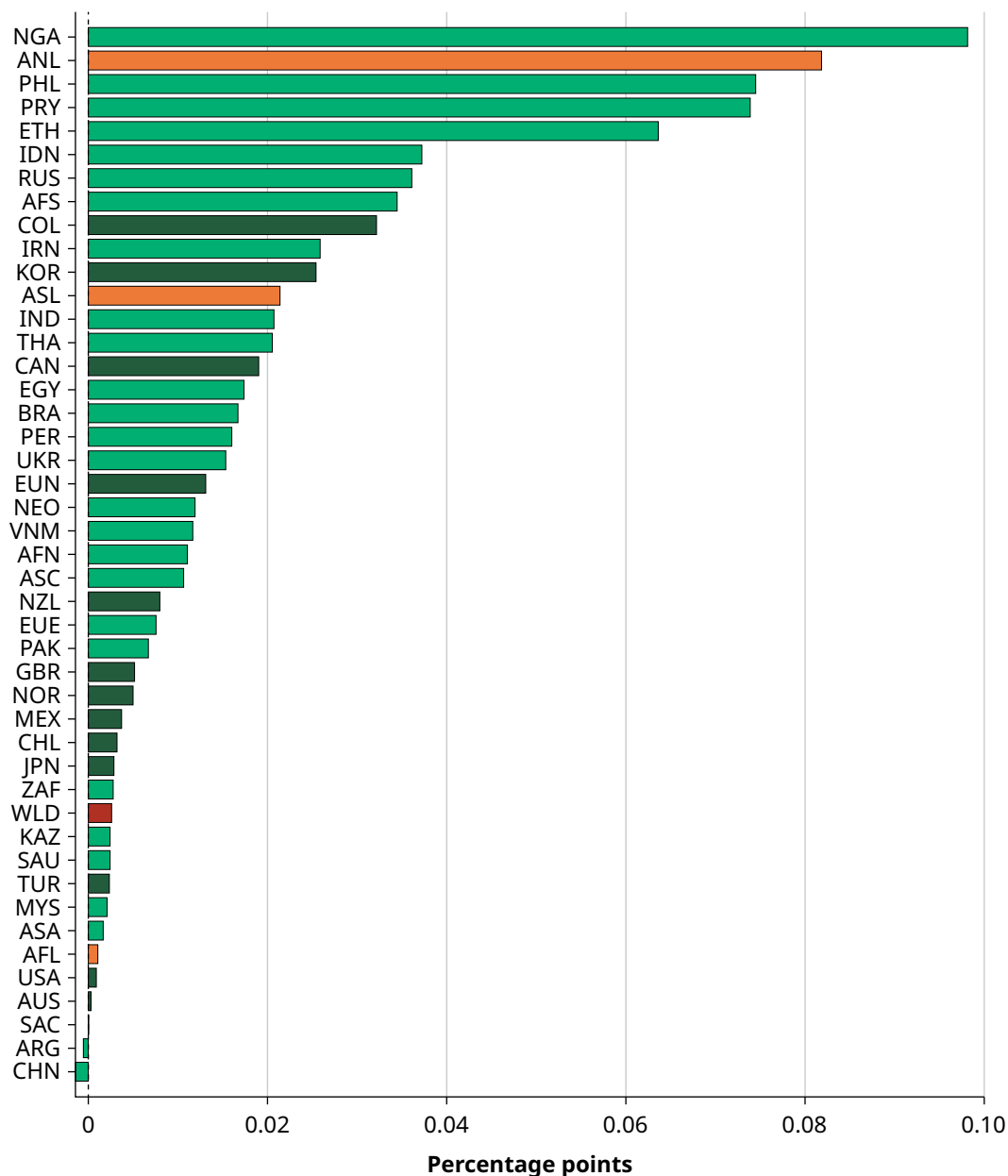
Countries enact price insulation policies ostensibly to shield domestic markets from global food price shocks. These measures stabilize local food prices, support food self-sufficiency, and protect vulnerable populations. For example, Figure O.1 shows price shocks from Russia's invasion of Ukraine in 2022 led to over 100 export restrictions globally, affecting eleven percent of pre-pandemic food trade (Rocha and Espitia, 2023). India, the world's largest rice exporter, implemented export bans and duties that impacted sixty percent of its non-Basmati rice trade (Glauber and Mamun, 2023). Policymakers commonly take measures to shield their markets when food prices reach certain levels, which tend to be \$250–300 per ton for wheat, \$270–280 for yellow maize, or \$260–265 for white maize (Hoffmann and others, 2024).

Policymakers often adjust trade policies and resist subsidy reforms to avoid political costs and balance the competing interests of producers and consumers. Consumers react more negatively to price increases, while producers react more negatively to price drops. This dynamic pressures governments to maintain price insulation policies (Giordani and others, 2016). Such policies can often be popular and politically motivated, complicating reform efforts. For example, Egypt's heavily subsidized bread program serves 70 percent of the population. Most of its population view it as an entitlement and attempts to reform it have led to civil unrest (Bellemare, 2015). Such dynamics pressure governments to maintain subsidies and restrictive trade measures to avoid public backlash. Governments rely on some of these policies as revenue sources and want to retain the flexibility to enact them to respond to shocks or political pressure, even without a strong trade or FNS need. Despite these reasons, these policies can also strain government budgets, worsen global food price volatility, discourage agricultural investment, undermine trade balances, and provoke retaliatory trade actions.

Price insulation policies lead to price instability and worsen food and nutrition security. Policies like import tariffs, non-tariff measures, and export controls often fail to stabilize domestic food prices and instead amplify global price volatility. These measures aim to shield domestic markets from global price shocks by limiting the transmission of international price fluctuations, but their reactive nature also creates unpredictable shocks that frequently destabilize both domestic and global markets. For example, Martin and others (2024) found that insulation policies magnify world price swings by reducing trade volumes, creating thinner markets where production shocks lead to larger price increases. These policies also increase domestic price volatility, as seen in wheat and rice markets, where domestic prices were as unstable or more unstable than international prices in several countries. This instability reduces household access to affordable food, discourages agricultural investment,

and undermines long-term productivity growth, particularly in low-income countries (Jayne, 2012; Minot, 2014). Figure O.5 shows that countries with more restrictive trade policies are more vulnerable to food shortages. The collective action problem of price insulation further compounds these issues. Individual countries' efforts to stabilize their markets collectively exacerbate global price instability, negatively affecting vulnerable populations.

Figure O.5 Most countries have higher downside variability of food availability, meaning they are vulnerable to food supply losses when trade is restricted



Source: Adenauer and others (2023).

International trade in more integrated markets is the best solution for managing shocks to food markets and FNS. Short-term price swings for food are common, but long-term trends drive major price changes. As such, trade restrictions do little to mitigate the biggest drivers of price changes. Evidence from Chile and Colombia during the 2022 price shock highlights the benefits global price changes passing through to local markets. Chile's less-insulated wheat market experienced a 17 percent increase in import costs, significantly lower than Colombia's more insulated market. In Colombia, price insulation increased demand and raised import costs, creating a trade balance deficit (von Uexkull, 2024). By reducing reliance on insulation policies, Chile encouraged consumers to adjust demand and incentivized domestic production, promoting self-sufficiency without distorting trade. Regional market integration also mitigates the impact of price shocks. In Colombia, reliance on regional imports limited price increases for maize and wheat. A study by Adenauer and others (2023) supports this, showing that integrated trade systems reduce food supply instability during climate-induced shocks. Countries with open trade systems enjoy more stable food availability and fewer disruptions, demonstrating that trade integration is critical for managing food price volatility and enhancing global FNS.

Yet, the world seems to be moving away from stronger trade integration, with trade restrictions expanding and multilateral negotiations stalling in recent years. In 2023, nearly 3,000 trade restrictions were imposed globally, a fivefold increase since 2015. This rise exacerbates the negative effects of economic shocks on global food systems (Rocha and Espitia, 2023). That said, many countries continue to impose high agricultural tariffs, with averages exceeding 12 percent globally and much higher in certain nations, such as Türkiye (42 percent) and India (33 percent). Despite efforts by the WTO to address trade distortions, such as converting quotas into tariffs and capping variable levies during the Uruguay Round, progress on key reforms has stagnated. At the World Trade Organization's (WTO) 13th Ministerial Conference, members failed to agree on critical issues like lowering import barriers and increasing the transparency of export restrictions (Brenton and others, 2022). Advances in public finance, digital technologies, and safety nets could offer alternatives to trade-policy instruments, but reaching consensus on global reforms remains elusive. As a result, the global food trade system stays fragmented and vulnerable to future climate shocks.

Recommendations

Revitalize International Trade Governance

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

-  **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.
-  **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 ones. Also, collecting comprehensive information on stocks remains difficult. Therefore, continued efforts to address these issues are needed.
-  **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.

Multilateral action will produce the biggest benefits for all. Yet, even in its absence, countries must take independent actions to address food and nutrition security challenges, as discussed below.

Enhance National Crisis Preparedness

In the short-run, timely responses during crises can save lives and prevent economic losses. In the medium-term, countries could improve and implement 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.

Improved Policy Responses

In the medium term, policy actions should include:

- **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 local 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.

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 losses.** 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.

Implement Long-Term Structural Reforms for Resilient Food Systems

Over the long term, countries should focus on policies that enhance agricultural productivity, mitigate climate risks, improve economic sustainability, and facilitate trade integration. Governments 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.²
- **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.

2 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.

Advance Research to Address Food Security Challenges

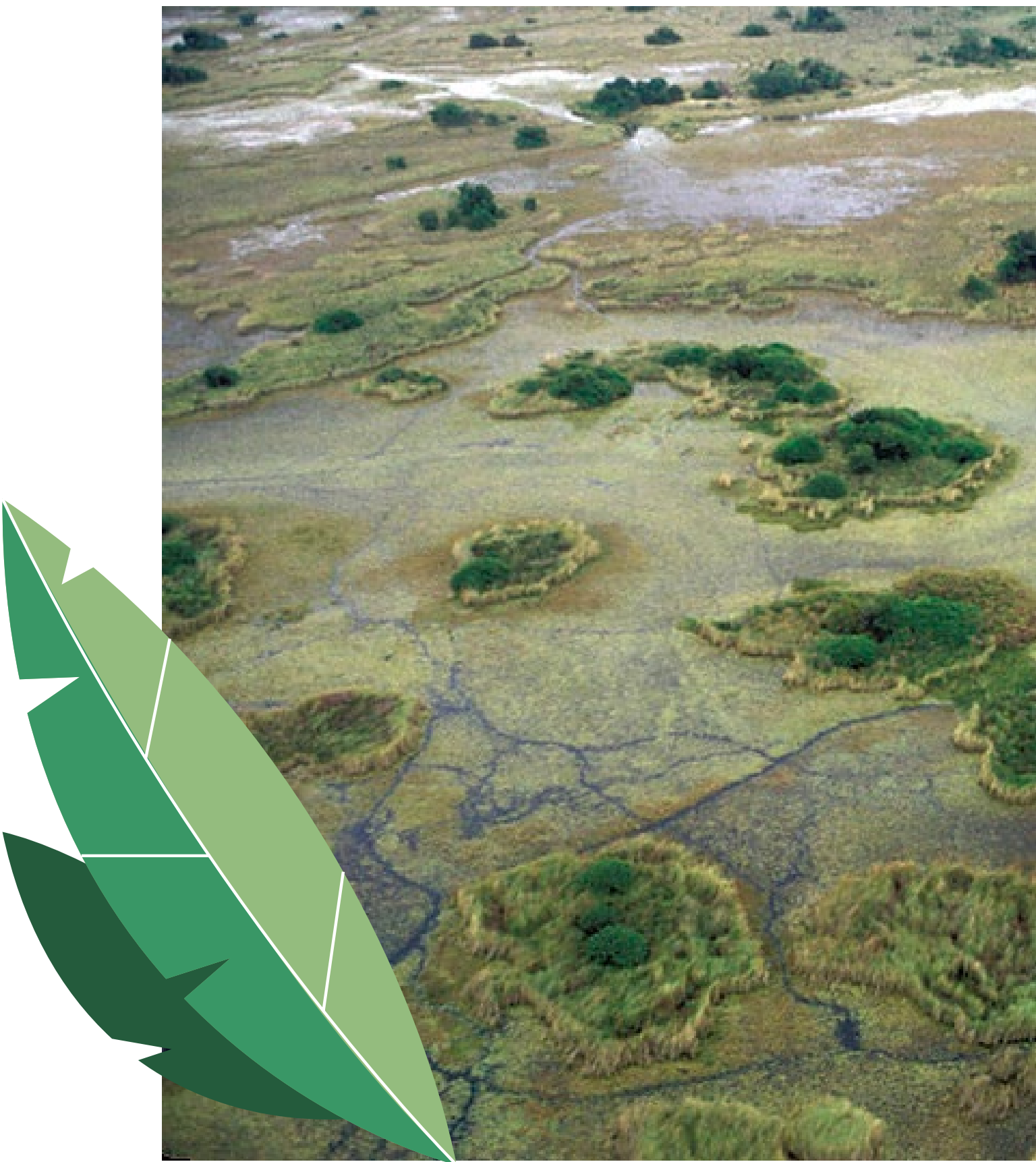
Future research must focus on understanding the broader impacts of food security shocks and identifying effective policy interventions. Research institutions and governments should:

- **Address aggregation bias in welfare analysis:** Economic research should include household-level data to accurately capture distributional impacts. Studies show that the poorest populations are disproportionately affected by climate shocks and food price surges.
- **Evaluate general equilibrium effects:** Incorporate indirect and ripple effects of shocks to better estimate overall welfare losses and policy impacts.
- **Support innovations in agricultural technologies:** Invest more in agricultural research to accelerate the development of climate-resilient crops and sustainable farming methods.

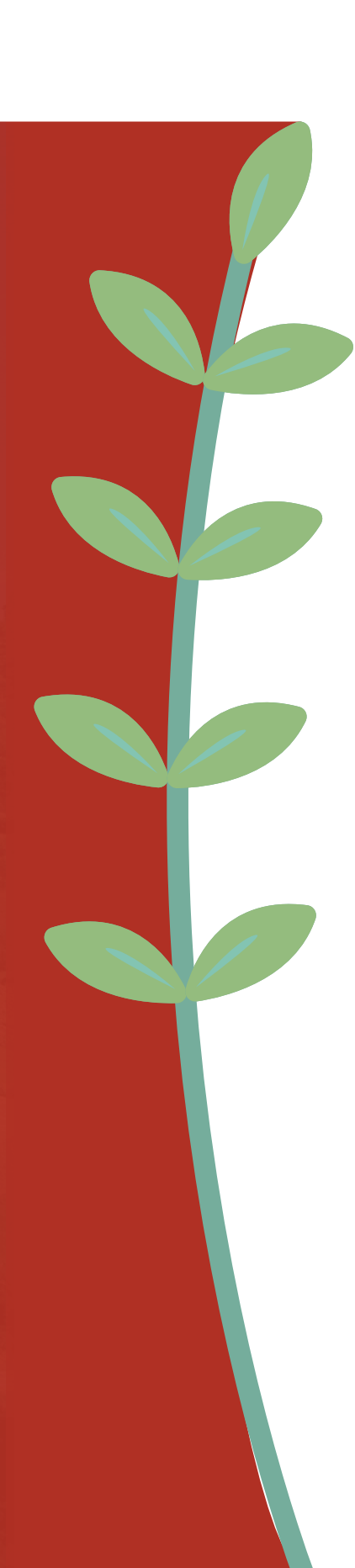
Table ES.1 Recommendations to Increase Food and Nutrition Security through Trade Policy

Recommendations	Timeframe
	Short
	Medium Long
MULTILATERAL ACTIONS	
1. Better disciplines in WTO commitments.	Short
2. Continued progress in monitoring and early warning systems for food production and trade.	Medium
3. Enhanced assistance to developing countries to upgrade infrastructure for trade in food and agricultural inputs and technologies.	Long
COUNTRY LEVEL ACTIONS	
4. Improve preparedness to crisis by:	
• Preparing and implementing crisis preparedness plans.	Short
• Strengthening early warning systems.	Medium
5. 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

Recommendations	Timeframe
	Short
	Medium
	Long
6. Strengthen Social protection by:	
• Strengthening and scaling up safety nets.	Medium
• Substituting targeted safety nets for universal food subsidies.	Long
7. 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







1 SETTING THE STAGE: TRENDS IN FNS, CLIMATE CHANGE, TRADE, AND PRICE VOLATILITY

This report examines the impacts of shocks, food price policies, and food trade on Food and Nutrition Security (FNS). It aims to inform food and trade policy responses to adverse shocks, including climate change's projected impacts. Chapter 1 describes the impacts that shocks and climate change have on FNS, the purpose of food trade, and the trends in food price volatility. Chapter 2 analyzes the food shocks resulting from Russia's invasion of Ukraine to assess potential food security and price shocks from climate change. Chapter 3 investigates the effects of food price policies, particularly the presence or absence of price insulation, on international and domestic food markets. Chapter 4 concludes with key messages and recommendations. The report argues that open food trade and closer market integration, without distorting price insulation policies, will provide the greatest benefits for FNS and household welfare in the era of climate change.

1.1. Shocks' Impacts on FNS

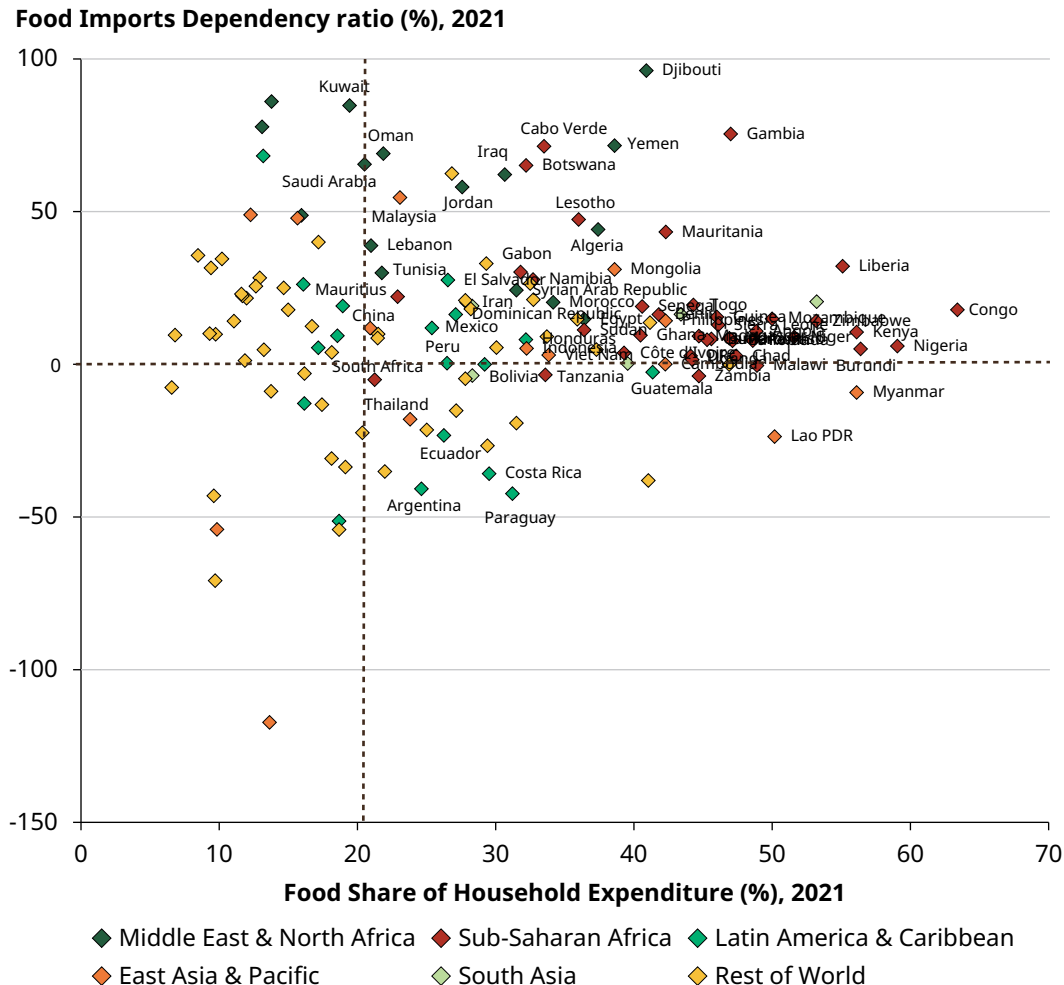
The world's understanding of FNS and its solutions has evolved. Many governments once believed FNS meant domestic self-sufficiency in food production. This belief led to public policies that protected domestic production from international competition. Today, FNS is recognized as a multi-dimensional concept, but some governments still base their policies on outdated views. The 1996 World Food Summit defined FNS as "when all people, at all times, have physical and economic access to sufficient safe and nutritious food that meets their dietary needs and food preferences for an active and healthy lives". Now, FNS definitions have evolved to comprise four dimensions: (a) availability, (b) economic and physical access, (c) utilization for good health and nutrition, and (d) stability to ensure resilience to shocks. Box 1 shows the composition of food imports sources for different country income groups.

The world faces its third food and nutrition security crisis in less than two decades. Food and nutrition insecurity is at its highest level since 2016 and is expected to worsen without immediate action. Currently, 258 million people in 58 countries are acutely food insecure, creating significant challenges in regions already struggling with food access. Hunger and starvation result from extreme poverty, with women and children most affected. Globally, 148 million children are stunted, and 1.2 billion women suffer from major micronutrient deficiencies. Climate extremes and geopolitical tensions, such as Russia's invasion of Ukraine and the situation in the Middle East, harm food systems, contributing to the global FNS crisis. Weather-related events displace populations, which causes food insecurity. The World Food Programme estimates that climatic shocks displaced 31.8 million people in 2022. Furthermore, economic mismanagement and conflicts often turn temporary disruptions into famines and social unrest. The future of FNS appears challenging. As the world's population is projected to grow from roughly 8 billion to 10 billion by 2060, global food systems will face increasing pressure. Most of this growth will occur in the developing world.

Short-term and long-term shocks have contributed to recent food and nutrition security crises. The COVID-19 pandemic disrupted production and supply chains, decreased demand for commodity exports, and affected local labor and food markets. Russia's invasion of Ukraine increased uncertainty, especially in markets where both countries supply key agricultural products, fertilizers, and energy. This worsened food insecurity and inflation. These shocks coincided with an increase in extreme weather events due to climate change, affecting major agricultural producers like Argentina, Brazil, India, and the United States.

Shocks to global food and fertilizer markets increase prices and volatility, affecting countries differently. Countries that rely heavily on food imports, such as those in the Middle East, North Africa, and West Africa, allocate more of their national budgets to imports. This reduces fiscal space and heightens vulnerability to global price fluctuations, especially for key food commodities like rice and wheat (World Bank 2012). Higher food prices raised the import bills of the 48 most-import-dependent countries by around US\$9 billion in 2022/23 (IMF, 2022). The cost of government programs to protect vulnerable households is estimated at US\$5 billion to \$7 billion globally (IMF, 2022). Shocks disproportionately affect poor households that spend a larger portion of their budgets on food, which is common in many African and Asian countries. In contrast, net exporting countries in Latin America, Eastern Europe, and Central Asia benefit from increased international prices (Figure 1).

Figure 1 Countries' vulnerability to global food price shocks depends on their food import dependency and share of household expenditures on food



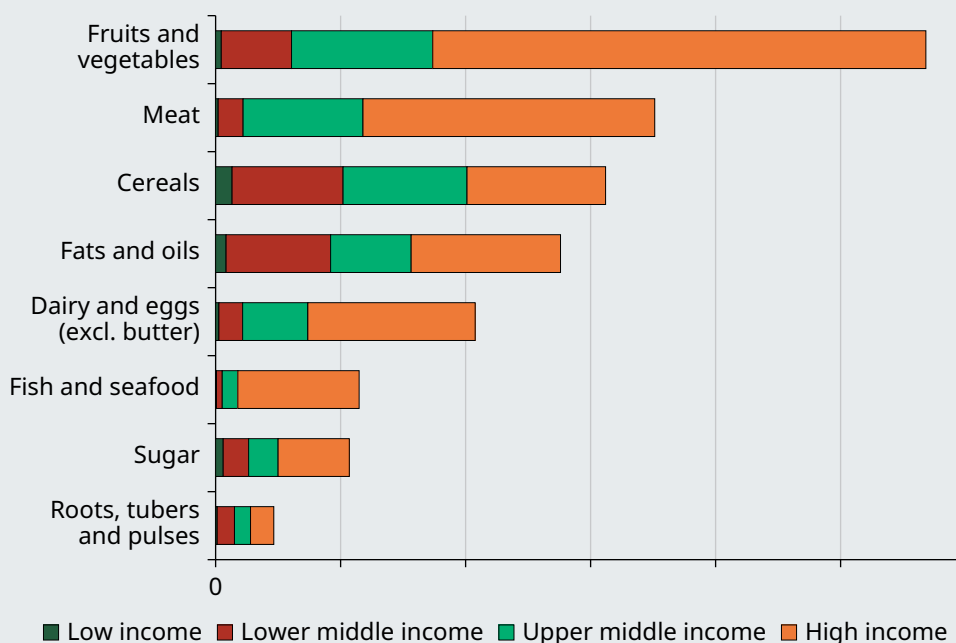
Note: The indicator of food imports dependency is computed as the ratio: (total food imports – total food exports)/(total food production + total food imports – total food exports). It only assumes values ≤ 100 . Negative values indicate that the country is a net food exporter. The two dimensions reflected in the above figure are important contributors to vulnerability, but other factors include whether a country has a safety net program 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.

Box 1 Composition of food imports by country income levels

Cereals are the most traded food category for low-income and lower-middle-income countries and serve as their main source of dietary energy. (Figure 2 and Figure 3). In 2021, cereals made up about 34 percent of the value of total food imports in low-income countries, 29 percent in lower-middle-income countries, and 21 percent in upper-middle-income countries. In upper-middle-income countries, cereal imports rank second to fruits and vegetables. Cereals provide slightly 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 drops to 27 percent in high-income countries but remains the primary source of dietary energy there. Wheat, rice, and maize are the most important cereals traded on commodity exchanges. The concentration of cereal imports varies by country. Developing countries that rely heavily on cereal imports and have higher supplier concentration should diversify their import sources (Figure 4).

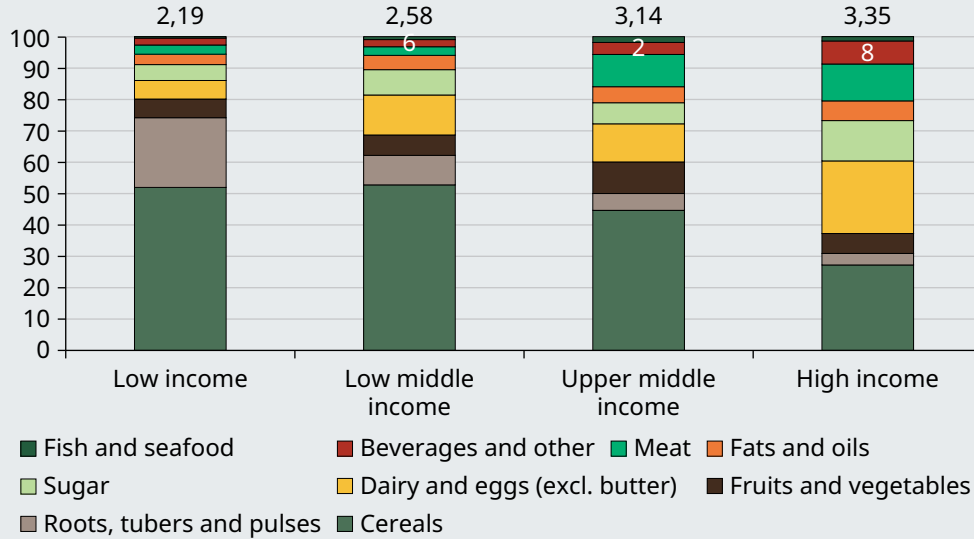
Figure 2 Cereals are the highest food imports for lower-income countries, 2021



Source: Portugal -Perez and others (2025b) with data from BACI

Figure 3 Cereals are the greatest source of dietary energy supply (kcal/capita/day) in most countries, but especially in developing countries, 2021

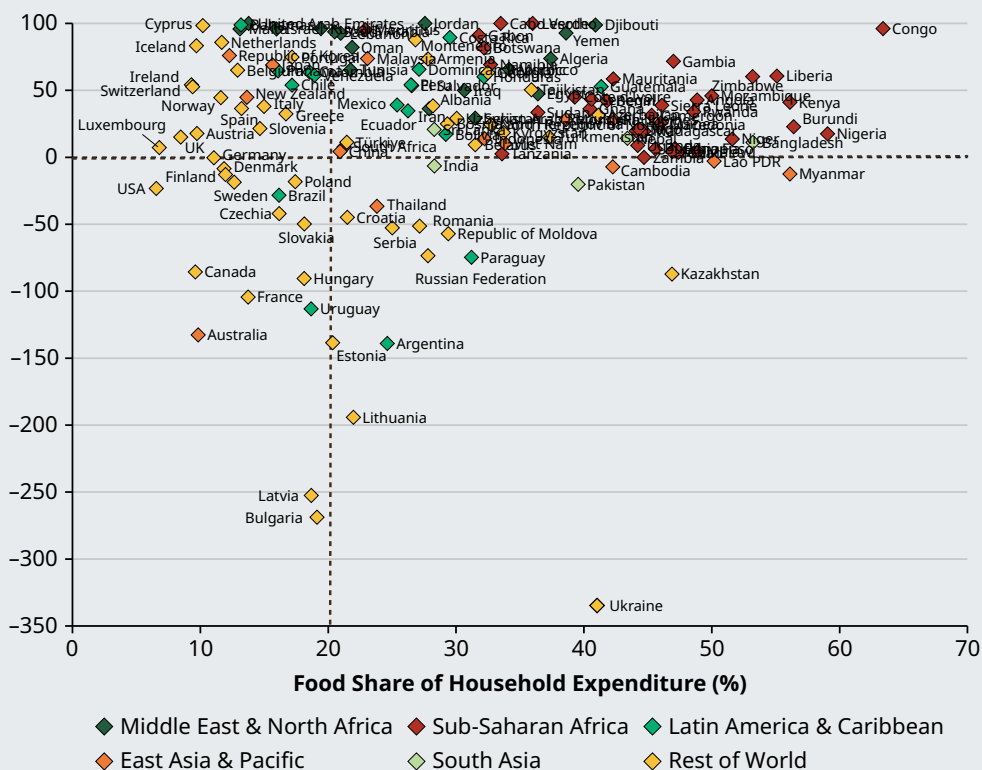
Change in average import price, 2022 vs 2021



Source: Portugal-Perez and others (2025b) with data from FAOSTAT

Figure 4 Developing countries typically have higher dependency and vulnerability to concentrated sources of imports

Cereal Imports Dependency



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

1.2. Climate Change's Impacts on Agriculture and FNS

Global warming and associated climate change will directly impact agriculture.

This is largely because of crop and livestock production's close dependence on weather. A recent study by NASA concluded that under some scenarios, the adverse effects of climate change will intensify in the early 2030s, earlier than previously thought. The study predicts even more severe impacts later in the century, including a 24 percent decline in average maize yields. However, focusing on average effects obscures the highly localized nature of impacts. Some areas may become unsuitable for certain crops, while others may become more suitable. For example, NASA's study suggests that a 2°C temperature increase in the mid-latitudes could boost wheat production by nearly 10 percent, while the same increase in low latitudes could reduce yields by almost the same amount.

Climate change is causing other weather and atmospheric impacts that will impact agricultural productivity in specific ways:³

- a. **Changes in the mean climate will have mixed impacts on agricultural productivity.** Warmer temperatures will reduce productivity in some already warm regions and increase it in typically colder regions. Changes in average rainfall and the timing of rainy seasons will have different effects depending on the area. Regions that rely on glacial and snow-fed water during the growing season could suffer as warmer temperatures prevent snow and ice accumulation in winter. Traditional farming patterns in some areas may become less viable because of changes in temperature and rainfall.
- b. **Climate change will influence the frequency and severity of extreme weather events, including heatwaves, abnormally low or high precipitation, and storms.** Modeling the productivity impacts of these short-term events is more challenging than that of long-term changes in average temperature and precipitation. However, the net impact of extreme events on productivity may be even more important than that of average changes. For example, Li and others (2009) estimated that drought-related crop yield reductions could increase by more than 50 percent by 2050 for major crops.

³ Refer, for instance, to [Gornall and others \(2010\)](#).

- c. **The underlying cause of climate change, particularly carbon dioxide in the atmosphere, may also affect productivity.** Higher concentrations of carbon dioxide can enhance photosynthetic activity in some major food crops, but this effect varies because of differences in photosynthetic pathways. As a result, there is considerable debate over the net impact on food crop yields.
- d. **Other climate changes will also affect agricultural production.** These include sea level rise, which may render some coastal areas unsuitable for agriculture, and shifting patterns of pest infestations.

Methods Note #1:

This section relies on the general equilibrium trade model by Artuc and others (2024), which estimates the effects of climate change -related agricultural shocks on household welfare. The study uses household-level data from 51 low- and middle-income countries to analyze the impact of climate change on agricultural productivity and income distribution. It incorporates FAO's Global Agro-Ecological Zones (GAEZ) (FAO and IIASA, 2021), a detailed micro-level dataset that employs agronomic models and high-resolution geographic data, including soil, topography, elevation, and climate conditions. GAEZ predicts agricultural yields for various crops worldwide based on climate change scenarios used by the UN's Intergovernmental Panel on Climate Change (IPCC).⁴ The study adjusts land productivity according to FAO GAEZ model predictions, simulates the effects on household income and welfare across the 51 countries, and accounts for international trade. In this model, households adapt to changing conditions by altering crop choices, reallocating labor, and modifying consumption while implicitly engaging in trade. If households do not optimize land and labor allocations, the model estimates that losses would increase by about 28 percent. The Artuc study quantifies the potential impact of climate change by comparing households' real incomes, consumption, and land and labor allocations in this counterfactual scenario with their observed choices.

4 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.

Climate change is expected to have large and variable effects on productivity.

Artuc and others (2024) modeled the impact of climate-related agricultural shocks on household welfare in low- and middle-income countries (Methods Note #1). The model predicts that 39 of the 51 countries in the sample will experience lower crop yields, while 12 will see higher yields. Productivity changes vary widely; Cambodia could see a drop of 63.4 percent, while Mongolia may experience an increase of 259.9 percent. The median productivity change across countries is a 37.8 percent decrease, and the average is a 17.4 percent decrease. These changes in agricultural productivity primarily drive welfare impacts, which affect labor, land income, and consumer prices.

The model reveals that climate change's impacts on household incomes vary widely.

Figure 5 shows the distribution of climate change's welfare effects in different countries. On average, households in the Artuc model's sample experience real income drops of 9.7 percent. However, there is a lot of variation across countries, with a standard deviation of 20 percent. At the household level, impacts range from an 87.4 percent decrease in income to a 76.4 percent increase. Most households suffer income losses from climate change's negative effects on productivity. However, 28 percent of households are expected to gain real income because of increased agricultural yields. That said, the model predicts that, on average, real income will decline in 37 out of 51 countries. Countries near the equator, where average temperatures are already high,⁵ experience average income losses exceeding 30 percent. In contrast, some countries—including Kenya, Rwanda, Kyrgyzstan, Tajikistan, Madagascar, and Mongolia—see income gains exceeding 10 percent. Income effects also vary greatly within countries, with an average range of 16.9 percent between the smallest and largest variations.⁶ The model also finds that climate change will have much larger and more varied impacts on global welfare than the Russia's invasion of Ukraine. This is because climate change affects a broader set of products and has sizable productivity effects that differ across countries.

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

6 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 5 Many countries will see real incomes decline from climate change



Source: estimates by Artuc and others (2024).

Climate change will also affect income distribution differently within countries.

Generally, poor producers see the biggest change in productivity from climate change. In countries that experience productivity losses, the poor lose more than the rich in percentage terms, which increases inequality. The opposite is true for countries that experience productivity gains, which decreases inequality. However, since most countries face negative impacts on productivity, the most

common result is an increase in inequality. The model also compared these results to what they would look like if estimations were based on a single “representative” household in each country instead of using disaggregated household-level data. It found that using a representative household would underestimate the average productivity loss, showing a decline of only 8.6 percent, which is 11 percent smaller than the estimate using disaggregated household data.

Climate change will increasingly drive food price volatility and food insecurity.

As we have seen, it has disrupted agricultural production. This will lead to supply shortages and elevated food prices. A 2024 study found that high temperatures increase food inflation in both high- and low-income countries. The study cautioned that global warming could increase food inflation in Europe by 30 to 50 percent by 2035 (Kotz and others, 2024). These climatic shocks diminish crop yields and strain the global food supply chain, exacerbating food and nutrition insecurity, particularly in regions that already suffer from it. The World Bank reported that rising food commodity prices in 2021 helped push approximately 30 million additional people in low-income countries toward food insecurity (World Bank, 2022).

1.3. Benefits of Food Trade

International trade contributes to economic growth, development, and poverty reduction. Openness to trade boosts national GDPs by encouraging countries to efficiently exploit their comparative advantages (World Bank and WTO, 2018). Trade facilitates access to advanced technology, driving innovation that increases productivity and enhances human capital development. It provides consumers access to a wider variety of goods and services, often at lower prices, improving living standards and reducing poverty. Producers also gain access to a broader range of cheaper, high-quality inputs, some of which are unavailable domestically. This reduces production costs and enables product diversification, raising productivity.⁷ The reduction of trade costs 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 enhances a nation’s FNS by increasing consumers’ purchasing power.

7 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 ratio at US\$2.15 a day decreased from 37.9 to 9 percent of the global population.

Agricultural trade and productivity improvements create rural jobs and boost rural incomes. Globally, agriculture contributes four percent to GDP, and accounts for over 25 percent in some developing countries (World Bank, 2024). About 79 percent of the world's poorest people live in rural areas, where agriculture is their primary livelihood (World Bank, 2018). Lowering barriers to agricultural trade helps rural producers sell their goods in external markets, fostering employment. Removing export barriers can increase prices for producers, stimulating production and income growth. Meanwhile, liberalizing agricultural trade lowers the prices of imported goods, which can boost real incomes (Loayza and Raddatz, 2010). Studies show that agricultural trade reduces food and nutrition insecurity by improving access to food and consumer goods and providing livelihoods for farmers and food system workers (Martin 2017). Additionally, income from agricultural trade supports growth when farmers reinvest profits into production. Increased agricultural productivity lowers the cost of staple foods, which constitute a large portion of poor people's and farmers' expenditures (Ivanic and Martin, 2016).

International agricultural trade with minimal barriers and affordable logistics supports FNS. Agricultural trade increases the variety of food available, providing essential nutrients that may not be locally sourced. Diversifying food production beyond local sources reduces the volatility of staple food supplies and lowers the risk of food and nutrition insecurity (Burgess and Donaldson, 2010). Open international trade allows countries to export surplus food and import needed products at competitive prices. Imports are crucial for ensuring food security in countries where domestic production cannot meet demand or is less stable and cost-effective than global supply. High local production costs and trade barriers that block cheaper imports drive up food prices, making food less affordable for consumers. This situation reduces food security and increases the risk of hunger.

Countries enact food trade barriers for a variety of reasons, including to protect against shocks, maintain food self-sufficiency, and keep domestic food prices low. In food-importing countries, there is a common belief that a population's FNS is proportional 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. Indeed, 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).

Surges in food prices and reactive trade policies often occur in times of rising world prices, including in response to recent shocks like Russia’s invasion of Ukraine. The invasion caused a food price shock, prompting countries to implement food trade restrictions. Data from the World Bank and the Global Trade Alert revealed that 101 export restrictions—such as quotas, licenses, and outright bans—remained in effect a year after the invasion, indicating that many restrictions were not temporary. In 2022, these restrictions encompassed more than 11 percent of pre-COVID food trade. Export bans, the most severe export restrictions, accounted for up to 3.8 percent of global food trade. Map 1 shows the countries with highest and lowest trade barriers. 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.

Some literature has advocated these protectionist trade barriers for developing countries. One well-known idea is the “Prebisch-Singer” hypothesis (Prebisch, 1950; Singer, 1950). It predicts that developing countries, which mostly export food and import manufactured goods, will see a long-term decline in their terms of trade. To counter this, the hypothesis suggests that these countries should adopt interventionist policies. This idea was popular from the 1950s through the 1980s and influenced development policies in many developing countries. However, most empirical research has not found clear evidence of these policies benefitting the countries that implement them.

This report shows that trade barriers harm FNS, leading to higher costs, natural resource exploitation, and lost benefits from efficient global trade. Countries often change trade policies in response to shocks, then remove them, which contributes to volatility and uncertainty in global food prices. A balance of local production and imports is often the most effective approach. Export restrictions hurt local farmers by preventing them from selling their products at higher international prices, making their countries less reliable suppliers. This prompts importers to seek alternatives. For importing countries, these restrictions reduce global food availability, driving up prices and making it harder to secure enough food for their populations. Export taxes can also raise global food prices by reducing the available supply for trade while increasing demand from importing countries. Higher food prices can trigger more export restrictions, worsening the situation. This cycle contributed to the 2011 food crisis (Giordani, Rocha, Ruta, 2016). Import restrictions further undermine food security by blocking affordable food imports from reaching local populations in need.

Food self-sufficiency can incur high costs for countries that strive for it. Martin and others (2024) report that trade distortions to wheat cost these countries

approximately US\$12 billion per year. This amount represents 6.8 percent of the value of wheat production at world prices. The total cost of trade distortions to rice in these countries reaches US\$33 billion annually at average prices from 2010 to 2021, exceeding 10 percent of the value of rice production at world prices. In addition, this policy objective offers minimal benefits if global shocks are unlikely to seriously disrupt food supplies from abroad.

International efforts aim to improve food market data and transparency.

Governments often respond cautiously to opening their food markets due to insufficient information on the costs and benefits. In 2011, the G20 acknowledged the need for better food market data and launched the Agricultural Market Information System (AMIS).⁸ The G20 countries agreed to provide timely and accurate data on food stocks, production, and consumption. International organizations committed to enhancing monitoring, reporting, and analysis of market conditions and improving national and regional food systems. AMIS has made high-quality market data more accessible, but it has limitations. Many countries, especially in Africa, still do not provide data. Additionally, gathering comprehensive information on national food stocks remains inherently difficult, making this data a “weak link” in the AMIS.

Social safety nets and early warning systems are effective at mitigating the impacts from short-term spikes in food prices. These measures help reduce the immediate impact of price volatility on vulnerable populations while fostering long-term food security. For example, conditional cash transfer programs, like in countries like Brazil, Mexico, and others have successfully reduced poverty and improved food security by providing financial assistance to low-income households, contingent upon meeting education and health goals (World Bank, 2020; 2014). Likewise, strengthening early warning systems enables governments to predict and respond proactively to food crises by monitoring global food supply and demand trends (FAO, 2024).

Buffer stocks can be problematic for managing food supply shocks. Small-scale, well-designed strategic grain reserves can help net food-importing countries manage food price spikes more efficiently and avoid trade policies that hinder trade. Historically, many countries used large grain reserves, or buffer stocks, to stabilize domestic prices, but these efforts often resulted in high costs with minimal benefits. One problem is that a lot of price variability is long-term cyclical or permanent, causing buffer stock schemes to eventually run out of either stocks or storage capacity. Another issue is that successful schemes that reduce price swings often crowd out private storage activities, which may not increase the country’s total storage capacity. Limited food emergency and safety net reserves may be

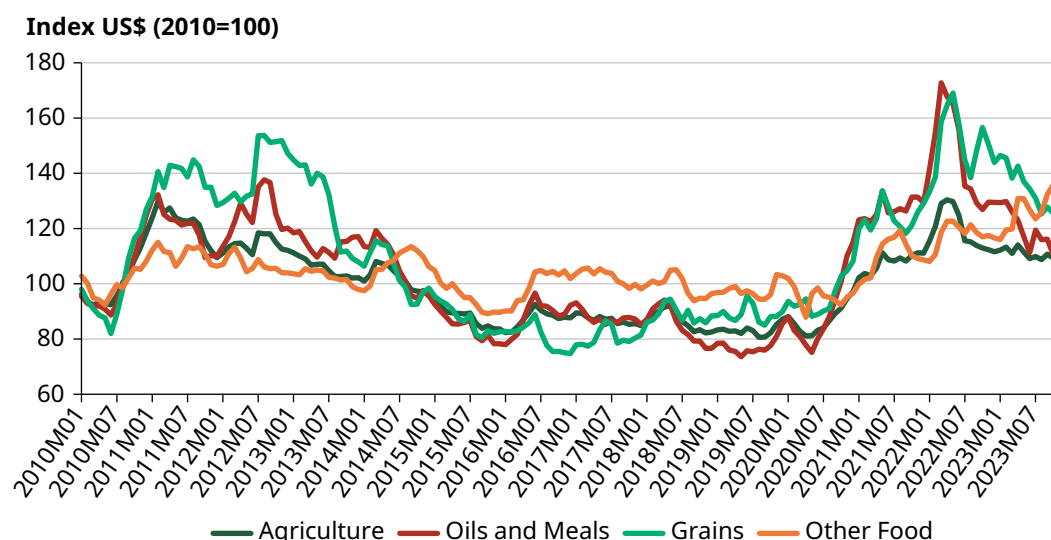
⁸ [Improving global governance for food security AMIS.pdf](#)

a more practical strategy for achieving FNS. An upcoming World Bank report will examine strategic food reserves, including considerations for their adoption, design, and operation.⁹

1.4. Trends in Food Price Volatility

Food price volatility has been common but especially pronounced since 2009. Global agricultural commodity markets experienced many ups and downs over the last two-and-a-half decades (Figure 6). From 2009 to 2023, food price volatility was particularly pronounced. These fluctuations reverberate through external trade, exchange rate movements, and inflation rates, influencing the stability and growth of national economies. Consequently, it is essential to understand the nature and causes of this volatility in order to improve agricultural and trade policymaking.

Figure 6 Agricultural Prices have fluctuated greatly



Source: World Bank data.

There have been at least three commodity price changes that lasted several decades but each was unique in nature. These long-term changes, called “supercycles,” included one for metal prices ([Cuddington and Jerrett, 2008](#); [Jerrett and Cuddington, 2008](#)) and the rest for commodity prices (Erten and Ocampo, 2012; [Jacks, 2019](#); Ojeda-Joya and others, 2019). Research on the supercycles shows that two of them, one in the 1970s and another in the 2000s, did not share the same patterns, implying that they are affected by idiosyncratic rather than common, long-term factors (Baffes and Kabundi, 2024). Recent studies

⁹ The World Bank and World Food Programme are preparing a report on using strategic grain reserves to improve FNS. It will be published in the first quarter of 2025.

suggest that the commodity supercycles were much shorter than previous literature typically assumes (Baffes and Kabundi, 2024). Our decomposition analysis used monthly data from 1970 to 2022 to identify medium-term cycles lasting eight to ten 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.

Many factors cause short-term shocks to commodity prices. Transitory, or short-term, demand-side shocks can originate from recessions, such as the 1997 East Asian financial crisis and the 2008 global financial crisis, which affected various commodities (Kabundi and others, 2022b). Trade tensions, like those between China and the United States in 2018 and 2019, also impact metal and soybean prices. Policy measures, such as export bans by several countries on grain between 2007 and 2011, can create short-term price shocks. Likewise, certain political policies, such as trade restrictions after Russia's invasion of Ukraine in 2022, can lead to sudden price changes (World Bank, 2022). Adverse weather conditions, such as El Niño and La Niña, or recurrent droughts, cause agricultural production shortfalls, as seen with grain in 1995 and coffee in 1975 and 1985. Supply chain disruptions, like those from the COVID-19 pandemic or Russia's invasion of Ukraine, also trigger transitory shocks.

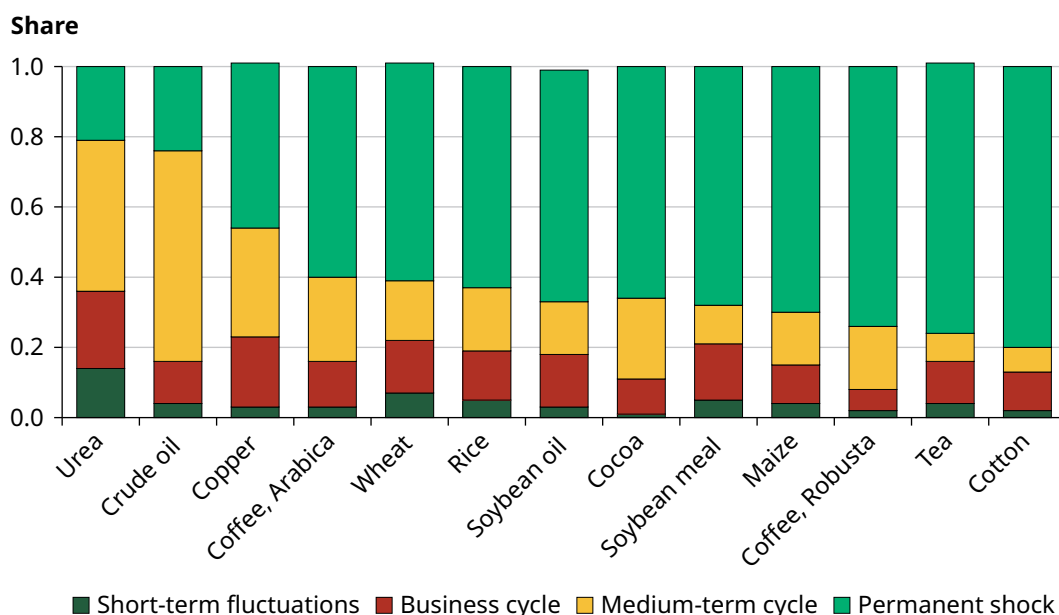
Shocks in related markets, particularly energy markets, can spill over into food markets. Energy price booms raise food production costs through higher fertilizer and fuel prices (Baffes and others, 2022a). These shocks can also trigger policy changes that affect the food market. For example, the oil price shocks of 1972 and 1979 led to policies promoting coal, nuclear power, renewable energy, and fuel-saving technologies. Similarly, the oil price boom of the early 2000s contributed to government policies that promoted biofuel production, which requires large-scale agricultural expansion (Baffes, 2013).

Research shows that certain market conditions cause short-term swings in food price. For example, prices are more volatile when futures contracts near expiration or when food inventories are low. There is debate about whether financial markets, like futures and derivatives, increase food price volatility. Some studies attribute food price spikes, such as those in 2007 and 2008, to these markets and call for stricter regulations. However, most research does not establish a clear link between trading in these markets and price volatility in agriculture (Boyd, Harris, and Li, 2018; Hamilton and Wu, 2014; Aulerich, Irwin, and Garcia, 2014; Brunetti, Büyüksahin, and Harris, 2016; Capelle-Blancard and Coulibaly, 2011; Irwin and Sanders, 2012; Stoll and Whaley, 2010). In fact, some studies, including Peck (1981), suggest that increased trading can lower price swings by mitigating risks. Our research for this report shows that speculative trading did not worsen the price spikes caused by Russia's invasion of Ukraine.

Other types of shocks can affect commodity markets more permanently. These shocks include technological innovations, government policies, or changes to food demand from growing populations, shifting consumer preferences, or other factors. For example, advances in biotechnology during the 1990s increased crop productivity by more than 20 percent (Klümper and Qaim, 2014). As mentioned above, policies that encouraged biofuel production shifted as much as 4 percent of global land from food to biofuel production (Rulli and others, 2016). Other agricultural policies, including measures to support domestic production, have pushed down global agricultural prices for many years (Aksoy and Beghin, 2004).

Volatility differs across commodities, but short-term fluctuations generally contribute less to overall price volatility compared to cyclical and permanent shocks. Figure 7 breaks down global price volatility for 13 commodities into four components: short-term fluctuations, business cycles, medium-term cycles, and permanent shocks. The data reveal that the relative importance of these components varies by commodity. Nonetheless, short-term price swings consistently represent a smaller proportion of total volatility, with cyclical components and permanent shocks accounting for the majority.

Figure 7 Volatility differs across commodities, 1970–2022



Source: Baffes, Khadan, and Mekonne (2024).

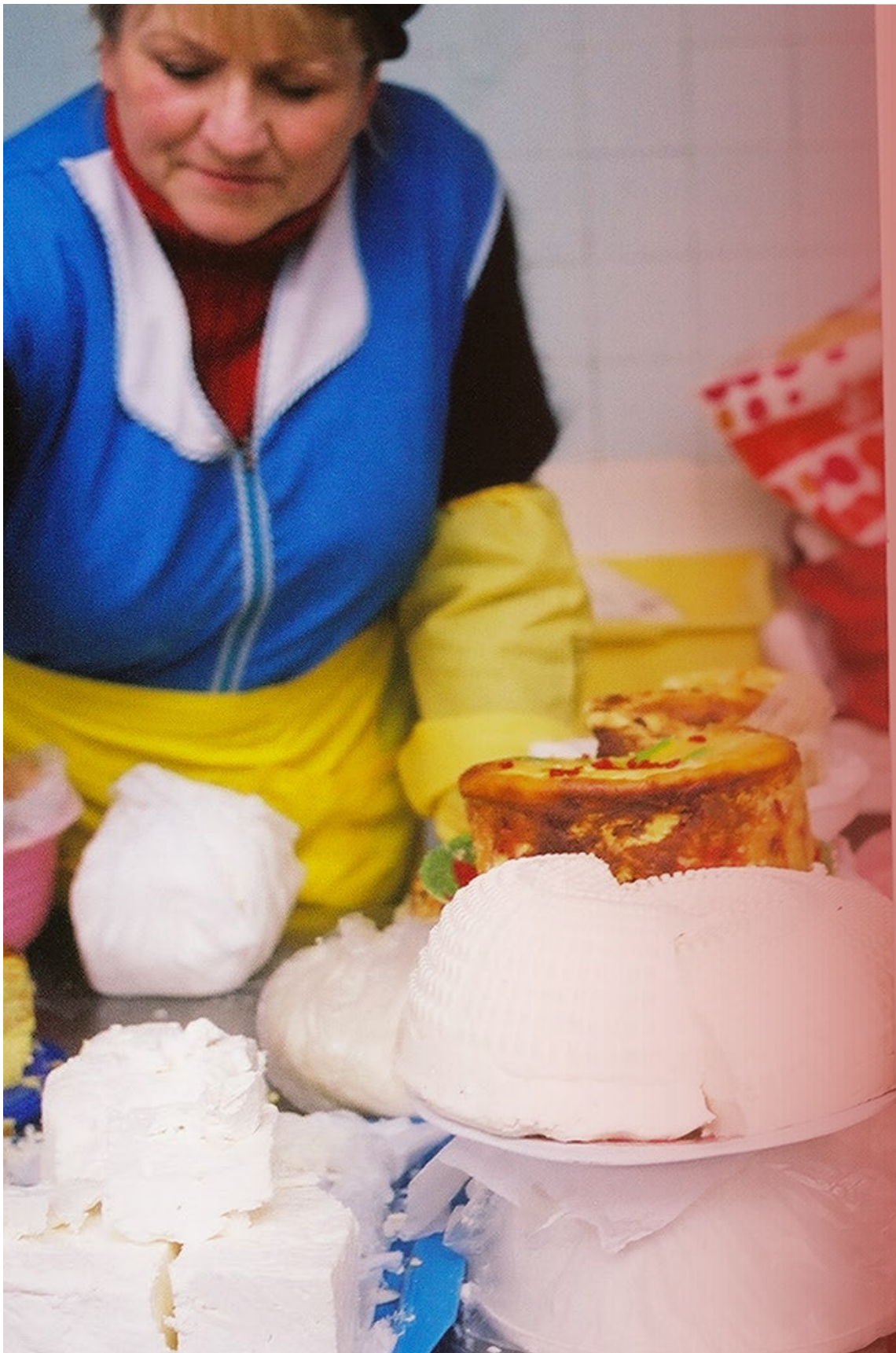
Macroeconomic variables influence price volatility. This report analyzed the price movements of nine agricultural commodities over different periods.¹⁰ The findings show that variables such as the equity index, crude oil prices, and the US dollar exchange rate strongly influence price volatility for most commodities. From 2002 to 2023, multiple shocks occurred, including the 2008 global financial crisis, the 2015 oil price collapse, the 2020 COVID-19 pandemic, and Russia's Invasion of Ukraine in 2022. During this multi-shock period, macroeconomic factors were prominent in driving commodity prices. The equity index and the US dollar exchange rate showed statistical significance for most commodity prices. Price volatility was also more persistent during the commodity boom (2002–2008) and the multi-shock period compared to the pre-boom era (1985–2001). These findings show that macroeconomic conditions strongly shape agricultural commodity prices, especially during times of economic uncertainty.

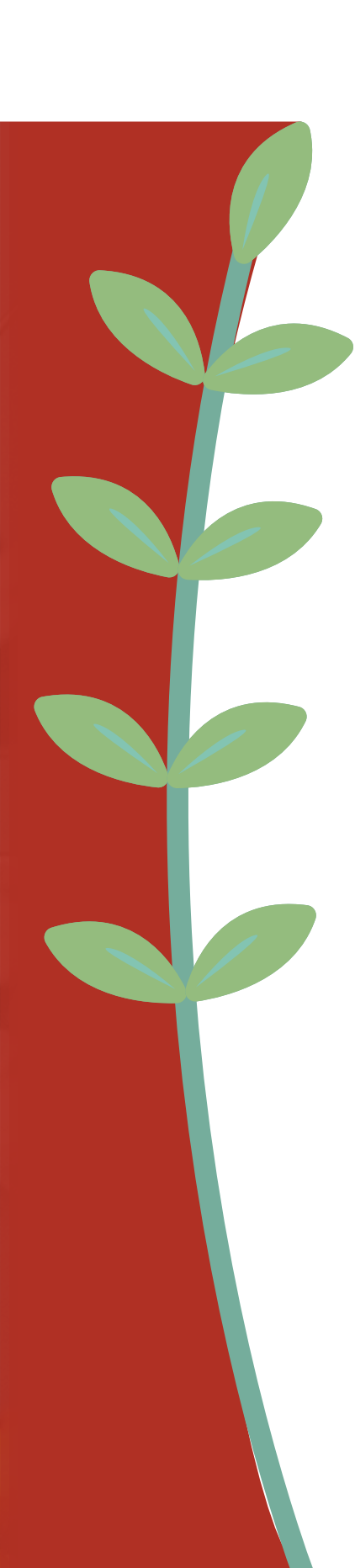
Authors' section lessons:

This discussion shows that long-term trends are the main drivers of price changes for most food commodities. This means that trade protection will do little to lower long-term food prices and could actually undermine FNS. Trade remains important for smoothing out sudden spikes in food prices, which have become more common recently. However, investments in social safety nets and early warning and FNS response systems are more effective in mitigating the impacts of short-term price fluctuations.

¹⁰ This report employed a Generalized AutoRegressive Conditional Heteroskedasticity (GARCH) statistical model with daily data from the past two decades. GARCH models analyze time series where 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.







2

LEARNING FROM THE PAST: THE IMPACTS ON FOOD MARKETS FROM RUSSIA'S INVASION OF UKRAINE AND POLICY RESPONSES

This chapter examines the impacts of Russia's invasion of Ukraine on food and fertilizer markets and how those markets responded to the shock. In February 2022, Russia's invasion of Ukraine set off a security crisis that persists to this day. It is a real-world example of a shock that affected global food markets and, as such, it is a test case of what could happen as climate change worsens and its impact threaten the international food production and trading system. This experience has implications for how the world can respond during the climate crisis to global food shocks and FNS challenges. The chapter begins by analyzing the invasion's impacts on food markets. Next, it examines the response of food markets before assessing the invasion's impacts on fertilizer markets and agrifood logistics. The chapter concludes by discussing the invasion's indirect impacts and direct welfare impacts on households. Overall, the chapter finds that the invasion initially caused disruptions in food and fertilizer markets, leading to a surge in trade restrictions aimed at limiting spillover effects. But, food markets showed remarkable resilience and trade and price volatility stabilized. However, many trade restrictions remained in place despite the receding threats to domestic food markets. These restrictions proved counterproductive in many cases. The invasion also increased income inequality as the poorest households bore the brunt of the negative impacts.

2.1. The Invasion's Impacts on Food Markets

Russia, Belarus, and Ukraine - the countries most directly involved in the conflict - are major suppliers of food products

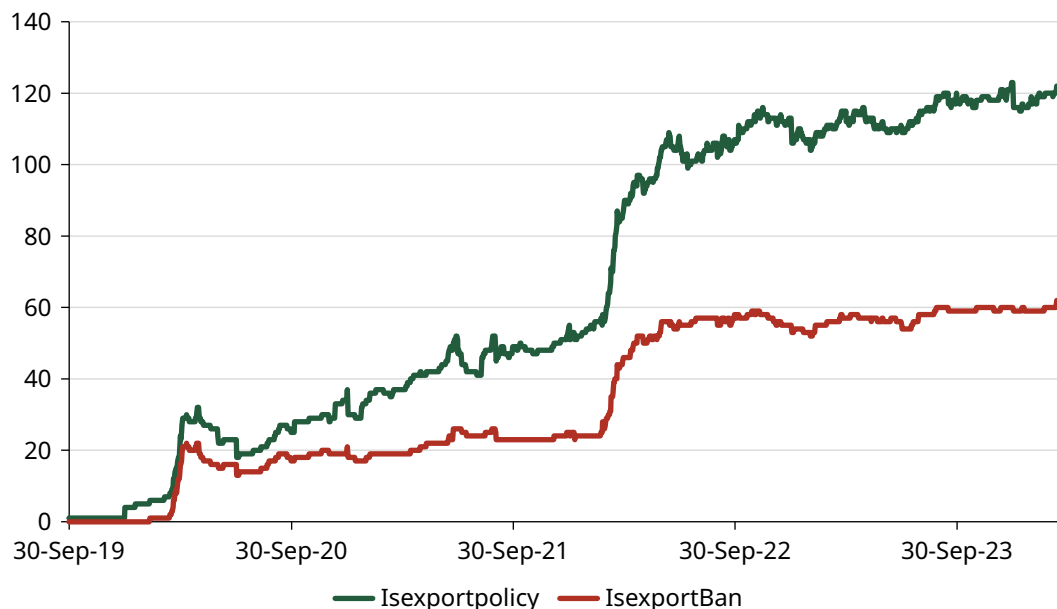
and production inputs. These include cereals, fertilizers, and energy. Russia and Ukraine rank among the top seven global producers and exporters of wheat, corn, barley, sunflower seed, and sunflower oil. Ukraine alone accounts for over half of the world's sunflower oil production. In 2019, Russia and Ukraine accounted for 25 percent of global wheat exports and 14 percent of global corn exports (UN Comtrade, 2022). Russia and Belarus are the world's second and third-largest potash fertilizer producers. Russia produces around 13 percent of the world's crude petroleum and is the second-largest crude petroleum exporter. Russia also exports 10 percent of the world's refined petroleum products and 9 percent of the world's natural gas. These commodities account for over half of the cost of producing ammonia fertilizer. Clearly, any disruption to food production or transport in these countries can have big ripple effects.

The invasion disrupted Russia and Ukraine's agricultural production and exports. Russia blocked Ukrainian ports in the Black Sea, which are located along grain export routes, since the invasion began. In July 2022, the United Nations and Türkiye brokered a deal between Kyiv and Moscow to unblock the ports (UN, 2022). However, a year later, in July 2023, Russia announced it would terminate the deal, known as the Black Sea Grain Initiative (European Council, 2023). Ukraine's grain harvests also diminished because of lower yields and Russia's occupation of Ukraineian territories, harvesting only 55 million tons of grain (wheat, corn, and barley) compared to 85 million tons in 2021. The conflict also reduced the area planted with grain by 4 million hectares, falling from 11.62 million hectares (USDA, 2024). In Russia, most food disruptions stemmed from sanctions imposed by the US, the EU, and their allies. These sanctions did not directly target food and agricultural commodities but led to higher transportation costs, reputational risks, and financial restrictions for countries trading with Russia. Moreover, Russia restricted grain and sugar exports from March to August 2022 to protect its domestic food supplies (TASS, 2022).

The invasion's impacts on food markets spilled over to countries around the world. This shock sent global food prices to record highs in March 2022 and triggered ripple effects across food, fertilizer, and energy markets (CSIS, 2023). By January 2024, global food prices fell to their lowest level in three years, but local food prices in many low-income and lower-middle-income countries (LICs and LMICs) continued to rise. By late 2023, over a third of these countries experienced food price inflation above 15 percent, with LICs seeing rates as high as 30 percent (IFPRI, 2023). In 2022, 258 million people faced acute food insecurity—the highest number on record—partly due to these disruptions (FSIN, 2023). Meanwhile, Russia expanded its wheat exports to a record 51 million metric tons in the 2023–2024 season, 30 percent higher than in 2020–2021 (USDA, 2024). Russia used low-cost or free grain deliveries to food-import-dependent nations, particularly in sub-Saharan Africa, to maintain its geopolitical influence.

The food supply disruptions led some food-exporting countries to restrict their own exports to protect domestic food supplies, but this just exacerbated the global disruptions (Laborde and Mamun, 2022). Figure 8 shows that the invasion triggered a large jump in export bans and restrictions. In 2022, export restrictions covered 11 percent of the pre-pandemic global food trade (Rocha and Espitia, 2023). India, the world's leading rice exporter, which represents around 40 percent of the global rice trade, imposed an export ban on broken rice and a 20 percent export duty on non-Basmati rice in September 2022. This covered around 60 percent of the country's non-Basmati rice exports (Good, 2022). India introduced a new rice export ban in July 2023 (Glauber and Mamun, 2023). Many export bans, including India's, remain in place despite declines in international food prices. Governments hesitate to lift these restrictions because of ongoing uncertainties in global food supply chains. These restrictions have several known costs. They disadvantage domestic producers who cannot capitalize on higher international food prices. They can deter investment in the agri-food system and diminish the inflow of foreign currency from exports. These measures can also strain international trade relations and provoke retaliatory actions from other countries.

Figure 8 The invasion led to a large jump in trade policy measures



Source: Global Trade Alert database.

2.2. The Response of Food Markets

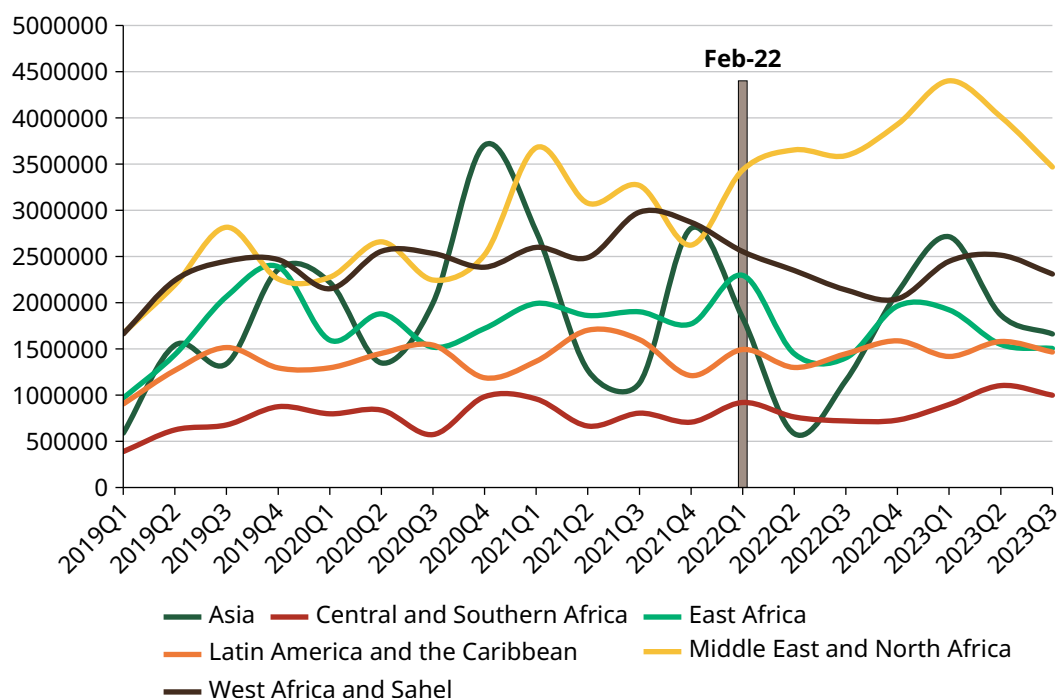
The global food trade system proved resilient to COVID-19 and Russia's invasion of Ukraine. Both events caused supply chain disruptions and temporary food shortages, but the effects were not as severe as many feared.¹¹ Comparing predicted trade flows during the invasion to actual trade flows revealed that, apart from the initial shocks, the invasion had only modest impacts on global trade in grain and oilseed markets. This was largely because the EU's Solidarity Lanes, which gave Ukraine access to European trade routes and ports, and the Black Sea Grain Initiative helped keep grain flowing out of Ukraine. Other exporters, particularly in North America and Europe, also helped pick up the slack by diverting food trade, avoiding major shortages.

The international grain trade quickly adapted to the invasion's disruptions in deliveries to countries in need. These countries are identified by the Global Report on Food Crises (GRFC) as most at risk of "acute food insecurity."¹² After the initial shock, the seasonal schedule for food deliveries to at-risk countries resumed. Wheat imports declined for several months in countries at risk of acute food insecurity across different regions after Russia's invasion of Ukraine, but no regions experienced long-lasting drops in imports (Figure 9). When grain exports from Ukraine fell to almost nothing, importing countries diversified their import sources to maintain food supplies, according to our composition analysis. That said, different regions diversified their food sources in different ways. For example, West Africa and the Sahel increased shipments from Poland and Lithuania, likely including Ukrainian wheat re-routed through Europe. Regions like MENA and Central Africa also increased imports from EU countries, but also from other major exporters, including Argentina and Australia. For example, after the invasion, Morocco's wheat imports from Ukraine fell dramatically, yet the country's total food import volumes did not decline because they rerouted Ukrainian grain shipments through Türkiye and Romania. Besides sourcing food from more countries, importing countries also changed the types of food products they brought in. The invasion disrupted maize and wheat imports the most. In response, major grain-producing regions expanded exports of non-wheat grains to compensate for the fall in global wheat supplies. For instance, Egypt and Türkiye turned to other types of grain imports when exports from Ukraine and Russia dropped.

11 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>

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

Figure 9 No regions saw long-term declines in wheat imports



Source: Cordula Rastogi and Daria Ulybina (2024).

Note: Regions are as listed in the GRFC (WFP 2023) and include countries at risk of acute food insecurity.

Authors' section lessons:

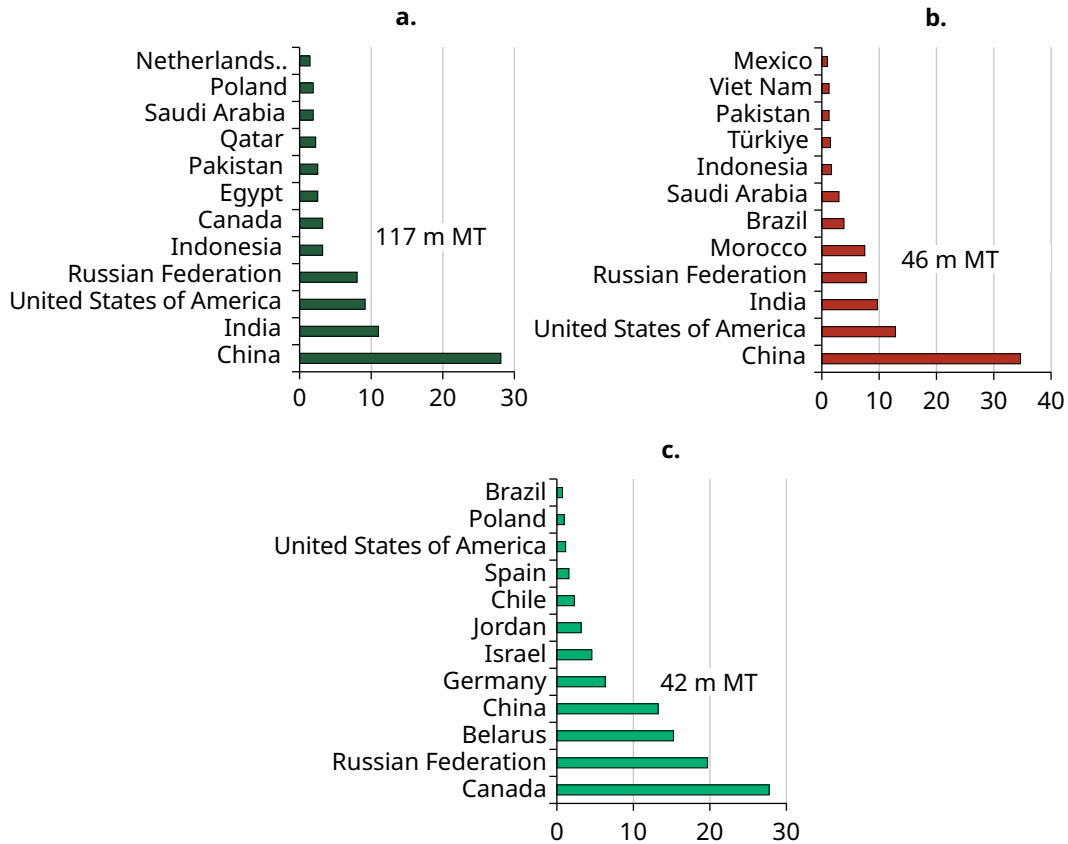
The global food trade system functioned during Russia's invasion of Ukraine, but it revealed vulnerabilities that could be exploited by more frequent or severe shocks, such as those from climate change. This evidence of the trade system's resilience argues against using national self-sufficiency to achieve FNS. Pursuing self-sufficiency is costly for countries and offers minimal benefits if global shocks are unlikely to seriously disrupt food supplies from abroad.

2.3. The Invasion's Impacts on Fertilizer Markets

The availability of synthetic fertilizers contributes to global FNS. Synthetic fertilizers, a group of chemical fertilizers, provide essential nutrients such as nitrogen, phosphorus, and potassium to soils, which are often depleted during intensive farming. Replenishing these nutrients promotes crop growth, increases yields, and improves harvest quality. Synthetic fertilizers enable farmers to maximize food production on existing arable land. Estimates indicate that foods grown with nitrogen fertilizers feed 40 to 50 percent of the world's population (Hannah, 2017). A recent World Bank study (Ghose and others, 2023) examined Sri Lanka's abrupt ban on chemical fertilizer imports in May 2021. The study analyzed high-frequency firm-level trade data and agricultural production data to assess the ban's impacts. It found that the ban caused dramatic declines in fertilizer imports, agricultural production, and fertilizer-dependent crop exports. The study estimated that the ban's average welfare effects were equivalent to a 4.35 percent reduction in income, with disproportionate losses for farmers, estate workers, and the regions that cultivate fertilizer-intensive crops, negatively impacting FNS.

The international fertilizer trade is uniquely vulnerable to supply chain disruptions. Most fertilizer is produced by a small number of countries (Figure 10). The top four suppliers of nitrogen fertilizer—China, India, the United States, and Russia—account for half of the global supply. Canada, Russia, and Belarus supply two-thirds of potassium fertilizer, while China produces over a third of phosphorus fertilizer. The top five producers of phosphorus fertilizer supply over 75 percent of it. Disruptions in any of these countries can have important ripple effects in the fertilizer market. Nitrogen fertilizer manufacturing depends heavily on natural gas. Ammonia, an essential ingredient in nitrogen-based fertilizers, is primarily synthesized through the Haber-Bosch process, which combines nitrogen from the air with hydrogen from natural gas. This process requires large amounts of natural gas as a feedstock. As a result, variations in natural gas production, availability, and prices can greatly impact the costs and supplies of nitrogen fertilizers. Figure 11 shows the close relationship between fertilizer prices and natural gas prices.

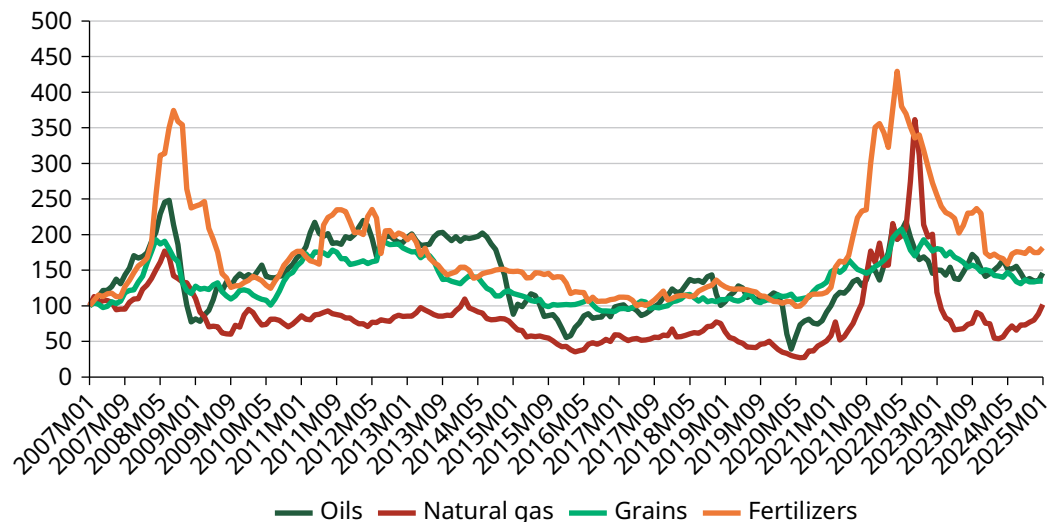
Figure 10 A small number of countries produce most of the world's fertilizer (averages from 2012 to 2021)



Source: FAOSTAT (April 25, 2024).

Note: Figures in millions of metric tons.

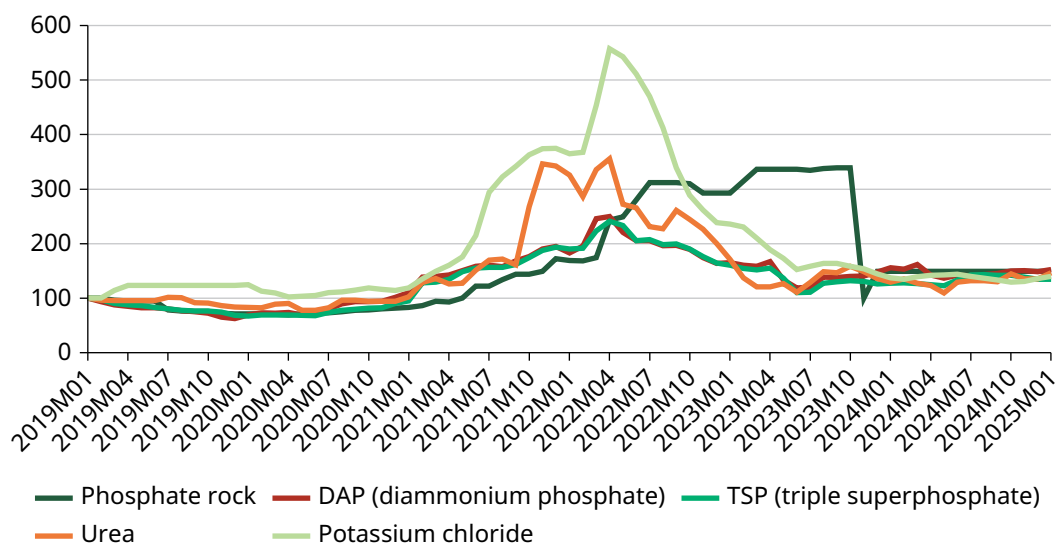
Figure 11 There is a close relationship among international commodity prices (2007M1=100)



Source: Portugal-Perez and others (2025a) using data from the World Bank Pink sheet monthly prices.

Russia's invasion of Ukraine exacerbated the rise in natural gas and fertilizer prices that began before the invasion but disrupted fertilizer trade. Russia is a major supplier of natural gas and fertilizers, especially nitrogen and potassium. Figure 12 shows that fertilizer prices were already rising by early 2021 but spiked in early 2022 as Russia prepared to invade Ukraine. A rise in natural gas prices in mid-2021, particularly in Europe, decreased global ammonia production. Concurrently, rising coal prices in China prompted fertilizer production facilities to ration electricity and cut back production. This drop led China to impose limits on fertilizer exports, especially phosphates, until June 2022, citing the need to safeguard domestic supplies and protect FNS. These measures drastically reduced the global fertilizer supply and raised prices. In addition, since several Sub-Saharan African countries have subsidies to fertilizers to incentivize its use, higher prices will have an impact on fiscal expenditure of these countries which already have limited fiscal space. Production declines and disruptions from the invasion reversed the steady acceleration of fertilizer trade over the last decade (Figure 13). This suggests that future agricultural production, which relies on these fertilizers, could fall short of its potential and fail to capitalize on relatively high food prices. Simulations show that lower domestic food production and fertilizer use created a greater nutritional deficit in food-insecure countries than did lower food imports. It would take closer monitoring of the downturn in fertilizer trade to determine whether it is a temporary issue or a longer-term problem.

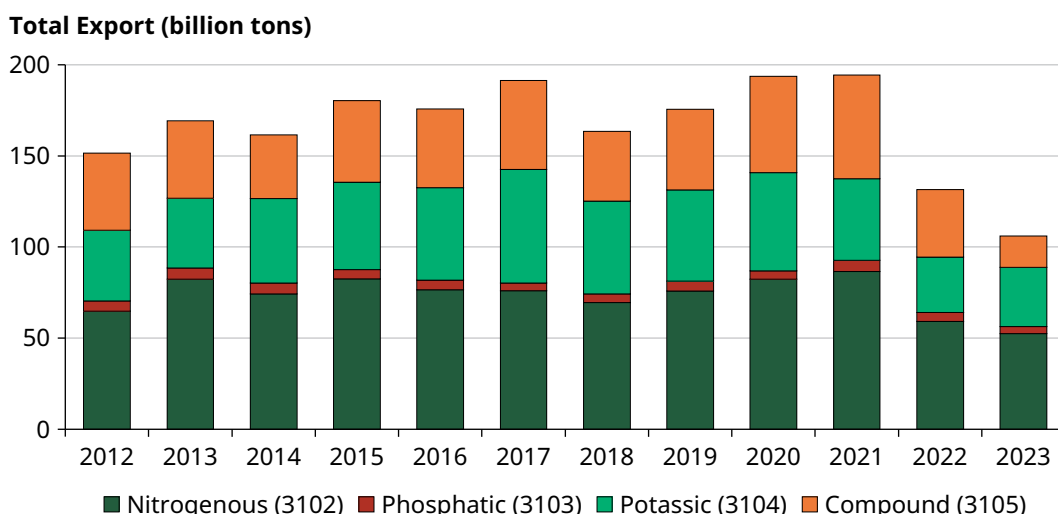
Figure 12 International fertilizer prices climbed as Russia's invasion of Ukraine (2019M1=100)



Source: Portugal-Perez and others (2025a) using data from the World Bank Pink sheet monthly prices.

Note: 2019M1=100, fertilizer prices are indexed to their values in January 2019, with the baseline value set at 100.

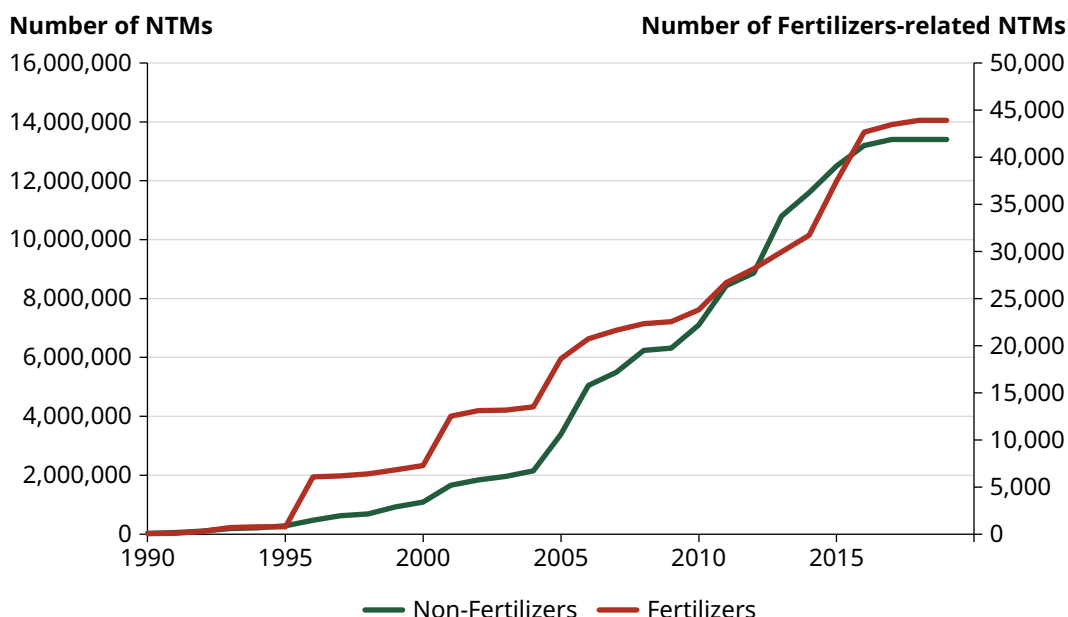
Figure 13 The trend of increasing fertilizer trade reversed after the invasion



Source: Portugal-Perez and others (2025a) using data from COMTRADE.

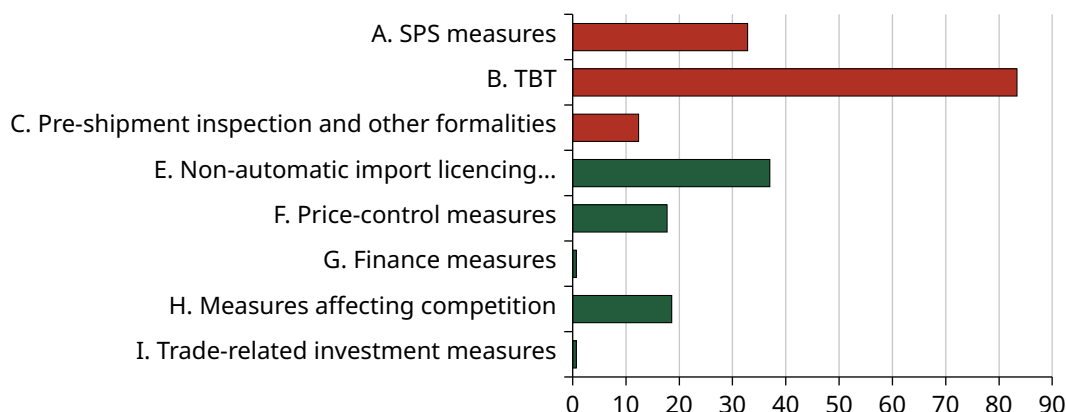
The fertilizer trade has seen a rapid rise in Non-Tariff Measures (NTMs) over the last two decades. Tariffs on fertilizer imports are relatively uncommon or low, with some notable exceptions in certain countries (see Box 2). That said, a large and growing proportion of the global fertilizer trade is covered by NTMs. This had been true for other goods as well, but Figure 14 shows that NTMs have proliferated rapidly in the fertilizer trade. The most common NTMs for fertilizers are Technical Barriers to Trade (TBTs), non-automatic import licensing, and Sanitary and Phytosanitary SPS measures (Figure 15).

Figure 14 Non-Tariff Measures on fertilizer trade have proliferated



Source: Data from UNCTAD.

Figure 15 Technical Barriers to Trade (TBT) are the most common fertilizer NTMs, 2019



Source: Data from UNCTAD.

Box 2 Fertilizer import tariffs are low, but with a few exceptions

Tariffs on fertilizers have been falling for years and are currently absent in most countries. However, some countries still impose tariffs of 10 percent or higher on fertilizers. Governments may use these tariffs to raise revenue or protect domestic production. Table 1 shows the countries with the highest fertilizer tariffs. These tariffs impose the same kinds of costs on domestic food producers and consumers as other protectionist tariffs.

Table 1 Only a few countries have 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

Importer	Type of Fertilizer	Product	Ad Valorem Tariff
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.

Methods Note #2:

This section uses estimates of the ad valorem equivalent (AVE) of the restrictiveness of certain NTMs applied to fertilizer imports. AVEs represent the additional costs imposed by NTMs on imports. They can be seen as the uniform tariff that would have the same impact on imports as the specific NTM applied. The bilateral annual AVE estimates of NTMs update those by Adarov and Mahdi (2023). Data on NTMs come from the WTO I-TIP notifications database, focusing on (a) sanitary and phytosanitary (SPS)¹³ measures and (b) technical barriers to trade (TBTs)¹⁴, which are two prevalent NTMs in fertilizers. The methodology follows Kee and others' (2008 and 2009) approach and uses a three-step framework: (i) estimate bilateral import demand elasticities, (ii) estimate the impact of TBTs and SPS measures on trade quantity for each HS-6-digit product per year, and (iii) use the estimated elasticities from the first step and NTM impacts from the second step to calculate the annual bilateral AVEs for each type of NTM.

13 SPS measures are regulations and procedures aimed at protecting human, animal, and plant life or health from risks arising from the entry, establishment, or spread of pests, diseases, contaminants, toxins, or disease-causing organisms. These measures include food safety standards, animal and plant health regulations, and import restrictions related to health concerns. SPS measures are designed to ensure that food is safe for consumers and to prevent the spread of diseases and pests among animals and plants. SPS measures can become trade barriers if they are not based on scientific evidence, are applied in a discriminatory manner, or are not efficiently designed.

14 TBTs refer to regulations, standards, testing, and certification procedures that countries use to ensure the quality and safety of products, protect human, animal, and plant life or health, and prevent deceptive practices. These measures can include labeling requirements, product standards, technical specification, as well as other technical regulations and procedures of assessment of conformity with technical regulations. While TBTs are intended to serve legitimate objectives, they can sometimes act as barriers to trade if they are overly restrictive or discriminatory.

Our estimates confirm that SPS measures have a less negative impact on fertilizer trade than TBT measures. We estimated ad valorem equivalents (AVE) for these two types of NTMs to assess how restrictive they are on fertilizer imports (Methods Note #2). AVEs represent the additional costs of importing fertilizer when NTMs are imposed. Negative AVEs for some NTMs suggest that they are effectively reducing the costs of trade, which can occur, for instance, when they lead to improvements in efficiency, quality or safety that outweigh the costs of compliance, thereby increasing trade. The median AVE for SPS measures is close to zero, and in some cases, it is negative. This means these measures reduce the costs of trade, especially for nitrogenous and potassic fertilizers. In contrast, the median AVE for TBTs is positive, indicating they generally increase trade costs and reduce trade, except for TBTs related to phosphatic fertilizer. The AVEs for SPS measures are more tightly grouped, with many negative values and none exceeding 5 percent (Table 2). Many AVEs for TBTs are above 5 percent, showing they significantly increase trade costs. Some countries' negative AVEs for SPS measures may result from the useful information these measures provide on the quality and safety of fertilizers, which outweighs compliance costs. This effect simplifies trade. TBTs protect consumers by offering valuable information, but they can sometimes lead to higher costs than benefits. As the WTO I-TIP database is restricted to SPS and NTM measures, AVE estimates do not include restrictiveness costs of other NTMs, such as pre-shipment inspections and non-automatic licensing, which can further increase costs and enable corruption in the regulatory system. For example, a World Bank (2019) report shows that non-automatic fertilizer import licenses in Cambodia led officials to demand bribes from importers, raising fertilizer prices and harming farmers.

Table 2 Ad Valorem Equivalent (AVE) Estimates: TBTs (right) increase trade costs more than SPSs (left)

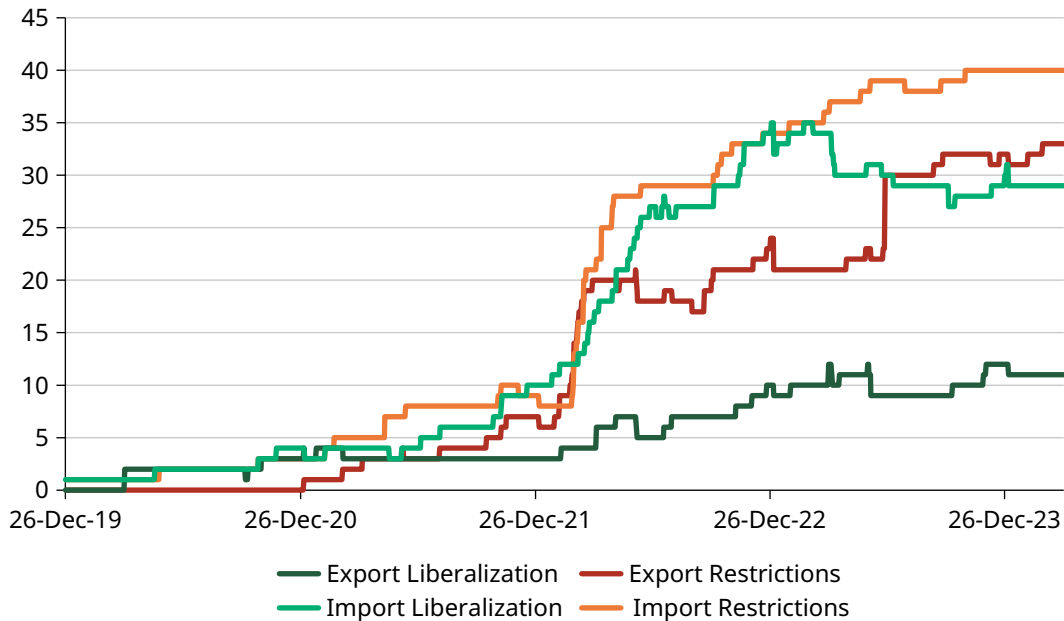
Fertilizer product	Number of Importer-Product Pairs by range of AVEs for SPS measures						Number of Importer-Product Pairs by range of AVEs for TBT measures					
	<0	0	0-5	5-10	10-15	>15	<0	0	0-5	5-10	10-15	>15
Nitrogenous	392	408	283	0	0	0	0	834	14	20	73	142
Phosphatic	2	282	0	0	0	0	0	185	8	3	2	86
Potassic	249	164	2	0	0	0	1	173	67	58	12	104
Compound	5	605	477	0	0	0	2	633	49	92	41	270
Total	648	1459	762	0	0	0	3	1825	138	173	128	602

Source: Estimates from Portugal-Perez and others (2025a).

Russia's invasion of Ukraine led to a surge in restrictive fertilizer trade policies, worsening price volatility. The number of trade policies affecting fertilizers increased dramatically following the invasion (Figure 16), with exporters increasing barriers to export—frequently in the form of export bans—while many importers reduced tariffs and taxes. Both of these actions were designed to insulate domestic

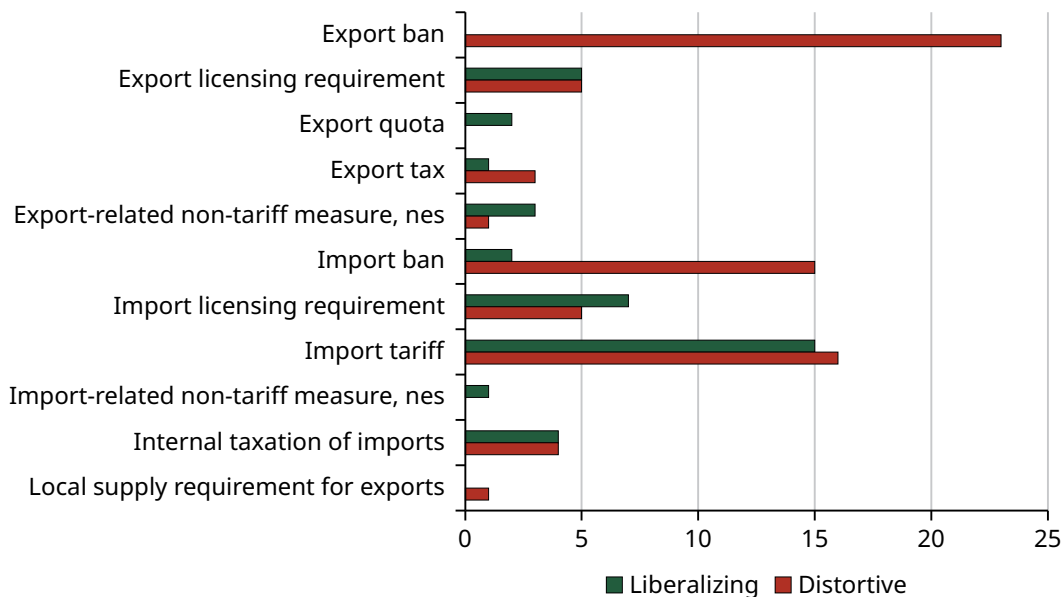
markets from the impacts of higher world fertilizer prices. They both share the problem that, following any shock to world prices, they further increase the world price of fertilizers. Export restrictions do this by restricting supply to world markets, while tariff reductions increase demand for fertilizer on world markets.

Figure 16 Trade-policy measures affecting fertilizer increased after the invasion



Source: Data from Global Trade Alert.

Figure 17 Most of the trade-policy measures affecting fertilizers were distortive, Aug 31, 2023



Source: Data from Global Trade Alert.

As NTMs can restrict fertilizer trade and increase prices, an individual review of NTMs suspected of being NTBs should be conducted in more detail to determine whether they should be removed or how to streamline them. The problems involved in making NTMs more efficient, including less trade distorting, are essentially problems of better regulation, which are like those encountered in the improvement of domestic regulations. The role of the private sector in such a process is key as they can help identify and flag issues with non-tariff barriers and potentially contribute to their removal or reform. A process of regulatory improvement also covering the flow of new ones, to prevent having to start streamlining efforts all over again when poorly designed new measures keep on appearing. The Government should put in place adequate structures to make streamlining NTMs an owned and sustained effort to lower fertilizer prices.

Authors' section lessons:

Russia's invasion of Ukraine highlighted the importance of fertilizers for food security as key inputs for food production. Although tariffs on fertilizer trade are usually low, a large and growing share of global fertilizer trade is subject to NTMs. TBTs often restrict trade, though exceptions exist in the phosphatic fertilizer market. SPS measures have a less negative impact on fertilizer trade than TBT measures. Other NTMs, such as pre-shipment inspections, non-automatic licensing, and quantity and price control measures, can increase further trade costs. Therefore, analyzing specific NTMs is crucial to identify opportunities for streamlining or removing them to reduce trade costs while still achieving their intended goals. Harmonizing and mutually recognizing certain NTMs can also lower trade costs.

2.4. The Invasion's Impacts on Agrifood Logistics

The global grain trade is vulnerable to shipment delays and supply chain inefficiencies. Grains have unique logistics requirements compared to many industrial goods. Harvest schedules, shipping times, and storage limits create tight trade calendar windows that require reliable logistics networks. Shipping delays, port congestion, infrastructure issues, or external shocks can cause grains to spoil during transport, leading to supply shortages. These disruptions can also result in higher costs and unstable prices. Logistics will become even more important as climate change increasingly alters production and trade patterns.

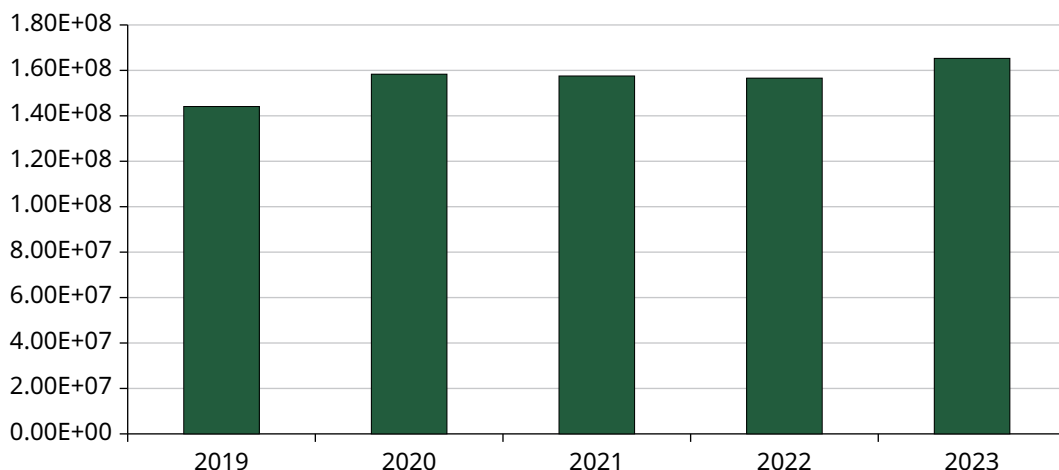
Delays in agrifood logistics contribute to already large amounts of lost or wasted food. Globally, nearly one-third of food produced for human consumption is lost or

wasted, totaling about 1 billion tons per year, worth around US\$1 trillion. This food could feed 1.3 billion hungry people annually. According to UNEP, if food loss and waste were a country, it would be the third-largest emitter of greenhouse gases, after the US and China. FAO estimates that 30 to 40 percent of total food production in developing countries is lost before reaching the market because of the improper use of inputs and inadequate storage, processing, or transportation facilities. In industrialized countries, more than 40 percent of food is lost and wasted at the retail and consumer levels of the value chain. Inefficiencies in agrifood logistics, such as inadequate storage, poor transportation infrastructure, and processing bottlenecks, worsen food loss by delaying delivery to markets and increasing spoilage risks.

Long-distance movement of grain primarily relies on maritime shipments.

The volume of wheat shipped has steadily increased in recent years, except in 2022, the year the invasion began (Figure 18). Bulk carriers, with capacities ranging from 10,000 to over 300,000 Deadweight Tons, transport much of this grain. These carriers handle about 31 percent of all global grain shipments. Lower-middle-income countries account for 44 percent of global grain shipments, while upper-middle-income countries account for 40 percent. Alternatives to bulk shipping are much more expensive. For example, transporting Ukrainian grain by rail, road, or river through the “solidarity lanes” instead of Black Sea ports added an estimated US\$30 to US\$40 per metric ton (Reuters, 2023).

Figure 18 Volume of Global Maritime Wheat Shipments (Metric tons), 2019–23



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

Maritime bulk shipping is vulnerable to various shocks. Disruptions can arise from climatic events or political disputes at key transit points, including the Suez Canal, Panama Canal, and the Black Sea. Grain terminals, unlike container terminals, cannot operate in the rain, as it compromises cargo quality. Drought conditions can also have negative impacts. For example, droughts near the Panama Canal led to

transit restrictions and higher canal fees. These droughts forced bulk grain carriers transporting crops from the US Gulf Coast to Asia to divert onto longer alternate routes, raising trade costs ([World Grain, 2023](#)).

Russia's invasion of Ukraine caused spikes in global shipping and food prices. An UNCTAD report (2022) noted that between February and May 2022, during the initial stage of the invasion, the cost of transporting dry bulk goods like grains increased by nearly 60 percent. International indices tracking the cost of moving raw materials by sea, including the Baltic Dry Index and the International Grain Council Grains and Oilseeds Freight Index (IGC-GOFI), confirmed this increase. Freight rates increased during the COVID-19 pandemic and again in the first half of 2022, shortly after the invasion. Shipping rates also increased after the July 2023 end of the Black Sea Grain Initiative. UNCTAD's Annual Review of Maritime Transport (2022) estimated that higher grain prices and rising bulk shipping costs led to a 1.2 percent increase in global consumer food prices, with the biggest impact on middle- and lower-middle-income countries. In these countries, the rise in transport costs was much higher than the increase in grain prices (Figure 20). This is because many of these countries rely on food imports, which are typically transported by dry bulk.

Figure 19 Freight rates increased after the invasion according to the Baltic Dry Index (red) and GC-GOFI (green)



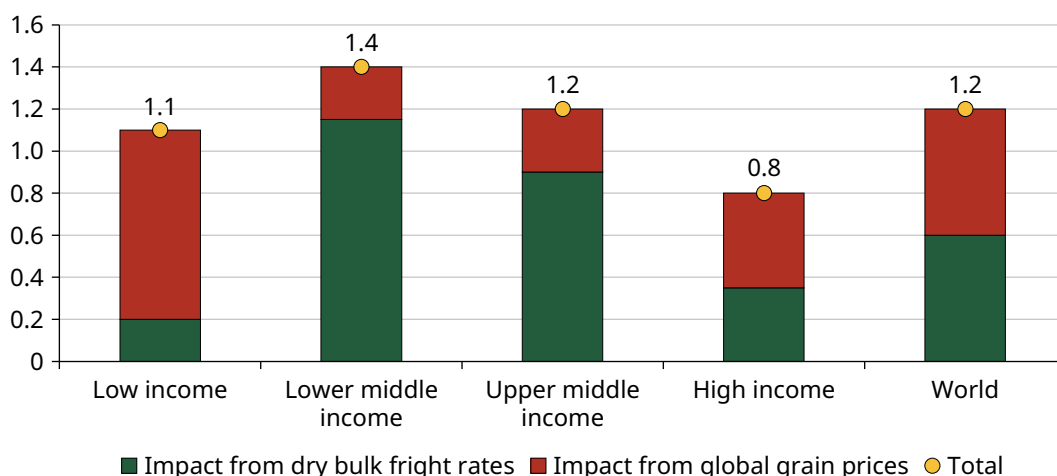
Source: Baltic Dry Index and GCC, 2023.

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

The global seaborne wheat trade has proven resilient to the invasion's impacts as countries diversified sources and improved supply management. Importers in dependent countries adjusting their sourcing strategies played an important role.

They diversified both origins and products, shifting from wheat and corn to yams, maize, millet, buckwheat, sorghum, cassava, and other local or traditional crops. Countries implemented advanced supply and storage management practices to minimize spillage and spoilage, reduce supply risks, and extend the storage duration of imported grains. Overall, global wheat trade has demonstrated remarkable resilience, with countries quickly adapting their sourcing strategies in response to market shocks caused by the invasion.

Figure 20 The rise in dry bulk freight rates and global grain prices contributed to higher consumer food prices (Percentage Change, 2019)



Source: UNCTAD (2022).

Authors' Section Lessons:

Russia's invasion of Ukraine exposed inefficiencies in agri-food logistics. As such, there are opportunities to further strengthen the resilience of agrifood logistics against future global shocks, including those from climate change. Key improvements include adopting digital technologies, upgrading market infrastructure, and expanding storage facilities such as cold chains and warehouses. Public investments and private sector involvement can streamline supply chains, reduce food waste, and support smallholder farmers and small and medium-sized enterprises. Successful innovations include single windows for customs, ePhyto certificates, blockchain-enabled platforms, solar-powered cold storage in Nigeria that reduces spoilage by up to 80 percent, and digital platforms in Kenya that optimize logistics and payments.

2.5. The Invasion's Indirect and Household-Level Effects

Russia's invasion of Ukraine had direct household impacts and indirect impacts from other countries' policy responses, primarily in fertilizer and energy markets. Some responses, like sanctions on Russia, were intentionally disruptive, while others, such as import tariff reductions or export restrictions, were not. In the first subsection below on *indirect impacts*, we applied an economy-wide modeling framework, or general equilibrium analysis (Methods Note #3), to four core impacts of the invasion: war-related agricultural shocks, trade restriction shocks, fertilizer-related and weather shocks, and energy-related shocks and sanctions. This approach allowed us to compare different sources of direct and indirect impacts from the invasion and concurrent weather events (Chepeliev and others, 2023). In the second subsection on distributional impacts, we present findings from Artuc and others' (2024) general equilibrium analysis of trade impacts on different households. This analysis estimates the welfare implications of Russia's invasion of Ukraine (Methods Note #4). The results suggest that a large part of the invasion's negative impact on FNS occurs through global markets and large spillovers, rather than directly through local markets. Additionally, these impacts vary across income distributions, with poorer households bearing the brunt of the costs.

Indirect impacts

Methods Note #3:

We used an economy-wide modeling framework to explore the impacts of Russia's invasion of Ukraine on global agricultural trade and value chains. We linked a global Multi-Region Input Output (MRIO) database with the Environmental Impact and Sustainability Applied General Equilibrium (ENVISAGE) computable general equilibrium (CGE) model. This model distinguishes agent-based demand for imports by region of origin (Chepeliev and others, 2022b). We also incorporated a recently developed GTAP nutritional module into the assessment framework, following Chepeliev (2022). The model represents the global economy with 39 aggregate regions or countries and 33 sectors. The 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
Conflict-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

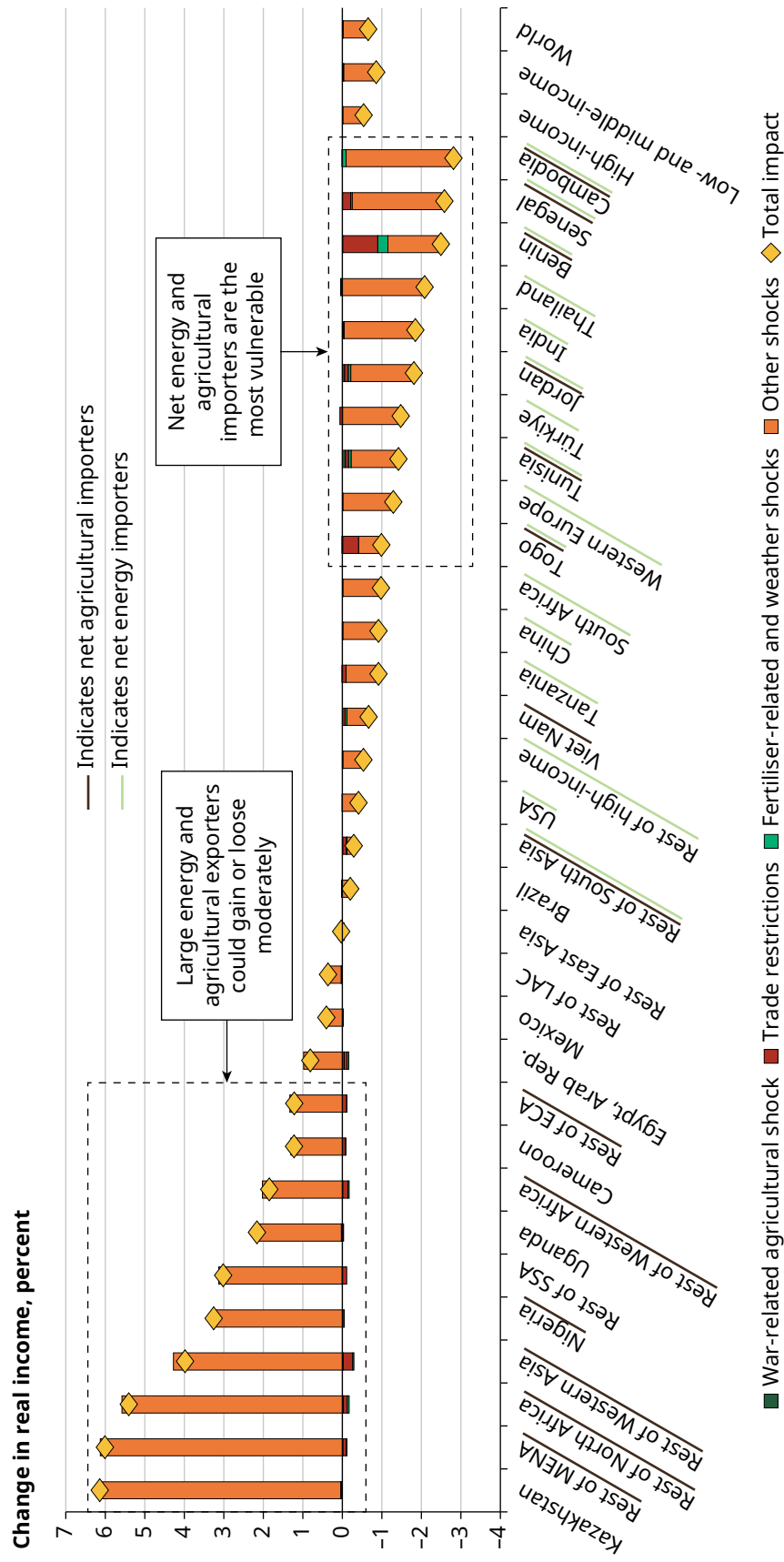
The analysis has four caveats. First, the results show relative price changes in relation to the deflator. Second, an applied model represents annual economic flows. Consequently, observed impacts reflect annual averages, which differ from short-term market volatility. Third, this assessment focuses on impacts in key commodity markets—energy, crops, and fertilizers—and covers only select sanctions. It does not capture potential spillovers from the broad sanctions imposed on the Russian economy and the resulting market uncertainty. Fourth, the analysis primarily quantifies relative impacts across the considered channels, emphasizing the magnitude of implemented shocks and potential policy responses. Historically observed impacts in selected countries may differ from the results discussed here because of the various interacting channels not explicitly captured in the analysis.

Source: Chepeliev and others (2024)

Agricultural trade disruptions have a smaller negative impact on incomes than energy disruptions. Our model shows that energy market shocks, labeled as “other shocks” (green) have the greatest effect on real incomes (Figure 21). In some countries, trade restrictions (yellow) strongly influenced incomes; for example, trade restrictions accounted for 41 percent of income losses in Togo and 46 percent in Benin. Overall, all shocks combined caused a net reduction of 0.7 percent in household incomes worldwide. Less than 5 percent of this reduction is attributed to conflict-related agriculture (blue) and fertilizer (orange) shocks. The remaining 95 percent is linked to energy market disruptions. Consequently, the largest income losses occur in net importer countries of energy products. However, the direct impacts of agricultural trade shocks on incomes were much higher in countries with substantial food imports.

Trade restrictions had the biggest impact on agricultural exports in most countries, while energy-related disruptions also played a significant role (Figure 22). Direct disruptions to agricultural trade were a key factor in only a few countries. The reduction in agricultural exports from Ukraine accounts for less than four percent of the overall drop in global agricultural and food exports. In comparison, trade restrictions on agriculture and fertilizers make up about 51 percent of the decline. Energy-related disruptions and sanctions contribute 34 percent, while fertilizer issues and weather-related shocks account for 11 percent. Most countries are negatively affected, but some see little or even positive impacts overall.

Figure 21 Energy disruptions in selected countries and regions have a larger negative impact on real incomes than agricultural trade disruptions (decomposed across scenarios)

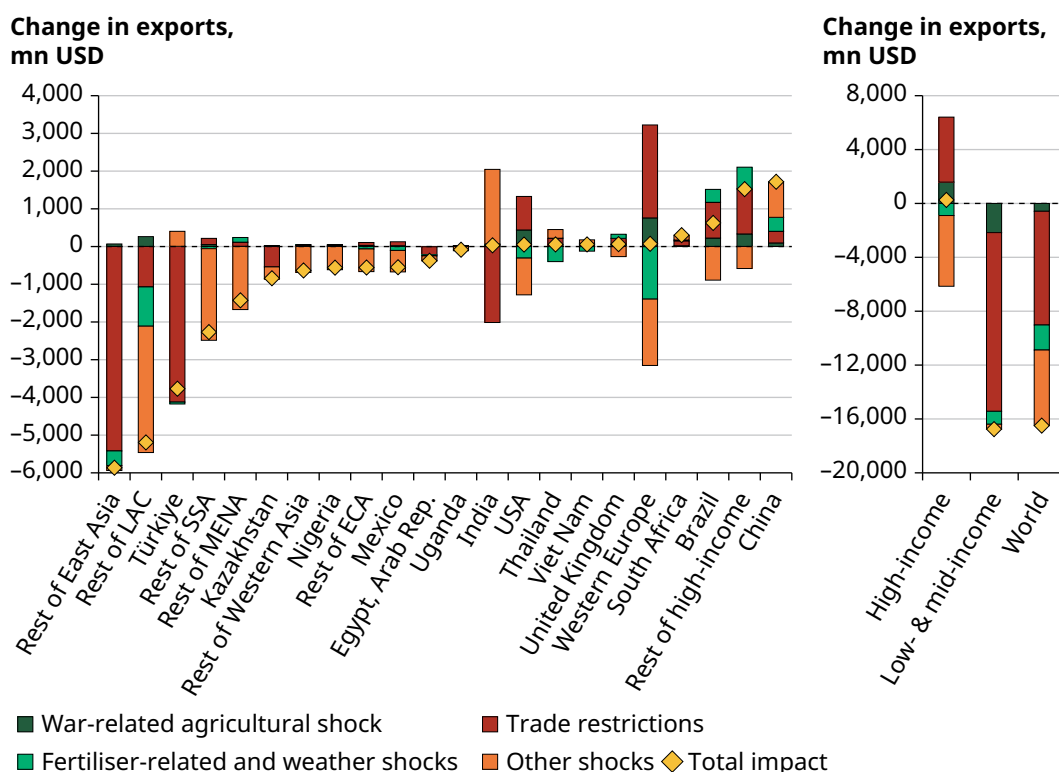


Notes: MENA, Middle East and North Africa; SSA, Sub-Saharan Africa; ECA, Europe and Central Asia; LAC, Latin America and the Caribbean. Net agricultural and energy importers are highlighted for cases when net import values correspond to at least 1 percent of the country's GDP. For reporting purposes, 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 and others (2024).

Shocks have a greater impact on domestic calorie supplies than imported calorie supplies (Figure 23). Domestic calorie supplies are produced locally, while imported calorie supplies come from abroad. Shocks reduce calorie availability by 31 kilocalories per person per day in the most affected developing countries. About 58 percent of this reduction results from declines in domestic food production, likely because of higher energy and fertilizer costs. The remainder stems from reduced food imports. This suggests that spillover impacts from energy and fertilizer disruptions greatly disrupt international food trade. Our model finds that countries in South and Central Asia and Sub-Saharan Africa have the largest reductions in food availability from shocks. In these regions, daily calorie supplies drop by 20 to 70 kilocalories per capita per day, reflecting a reduction of one to three percent. In some countries—such as Senegal, Kyrgyz Republic, and Tajikistan—reductions are even larger, ranging from six to fourteen percent.

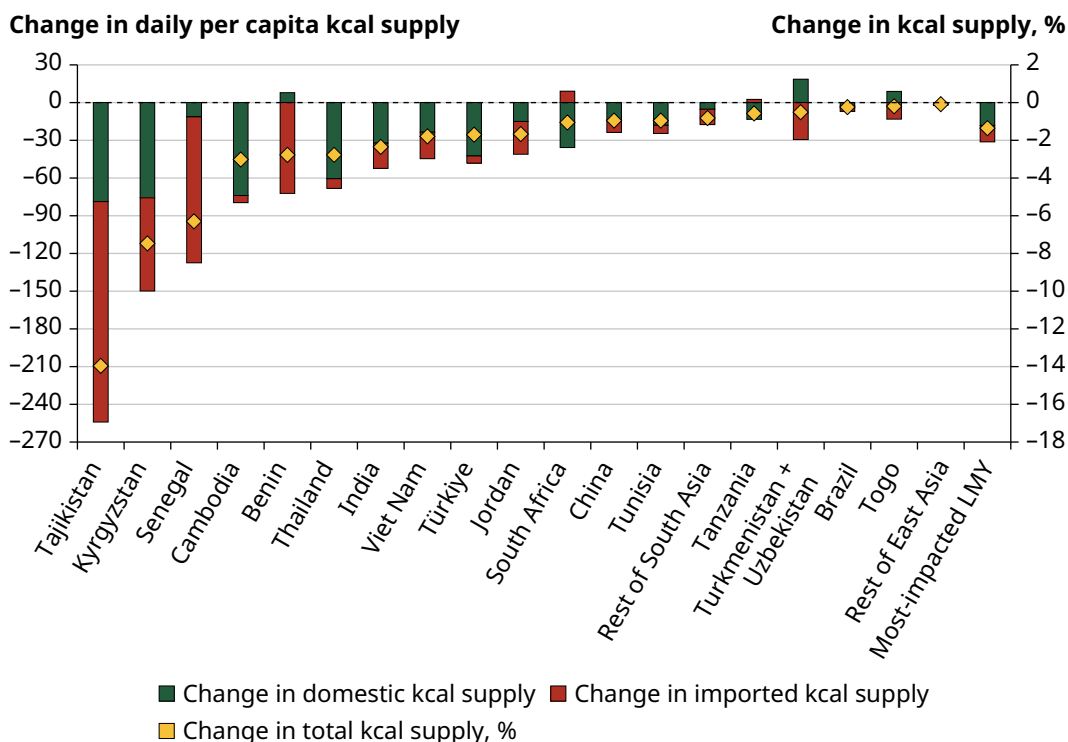
Figure 22 Trade restrictions had the biggest impact on agricultural exports in most selected countries (decomposing agricultural and food export changes)



Source: Chepeliev and others (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.

Figure 23 All shocks combined have a greater impact on domestic kilocalorie supplies than on imported calorie supplies in the most-affected developing countries and regions



Source: Chepeliev and others (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.

Household impacts

Methods Note #4:

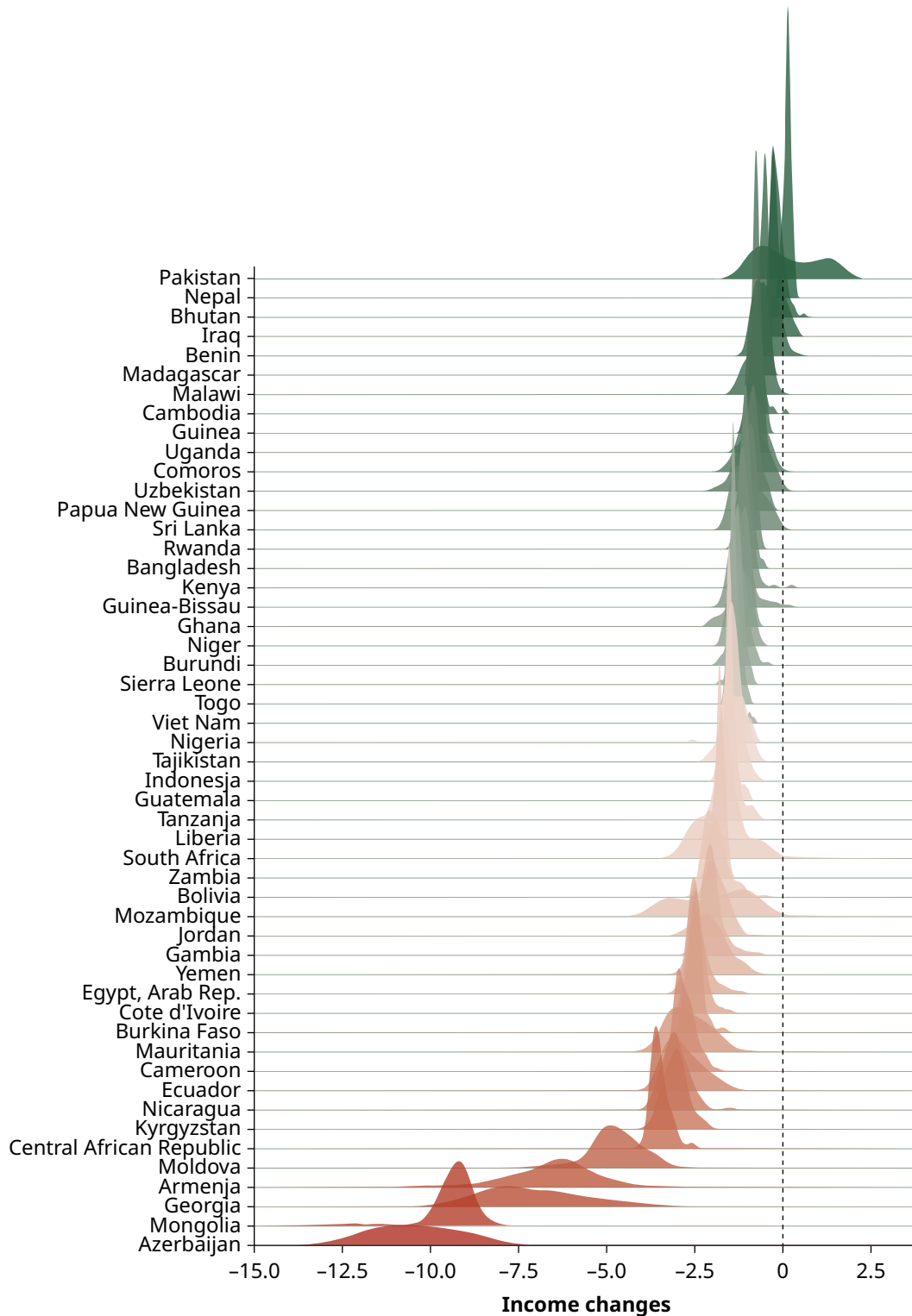
This section relies on Artuc and others (2024) who constructed a general equilibrium trade model of heterogeneous households to estimate the welfare implications of the Russia's invasion of Ukraine. The model uses household-level survey data from 51 low- and middle-income countries. It incorporates FAO's Global Agro-Ecological Zones (GAEZ) (FAO and IIASA, 2021), a detailed micro-level dataset that employs agronomic models and high-resolution geographic data. The model simulates household decisions on consumption and land and labor allocations, including choices among 20 crops. The model aggregates household data into 100 households per country, each representing a percentile of the income distribution.

Unlike other studies that use a single representative household for each country, this study obtains highly granular results on income distribution impacts within countries. It shows that using a single representative household would have underestimated overall welfare losses by about eight percent on average. This aggregation bias occurs because the average welfare impact across heterogeneous households does not match the welfare impact for a single household based on aggregate-level data. Since the shock from Russia's invasion of Ukraine has already occurred, the model's accuracy is evaluated by comparing the price changes it predicts with actual food price increases observed in developing countries after the invasion began. The price changes generated by the model are highly correlated with observed prices.

Russia's invasion of Ukraine caused uneven economic losses across and within countries. Artuc and others (2024) used data from the Household Impacts of Tariffs database (Artuc, Porto, and Rijkers, 2020) to create a general equilibrium trade model that estimates the household welfare implications of the invasion (Methods Note #4). The simulations assumed a complete cutoff of agricultural and fertilizer trade with Ukraine and that Russia ceased exporting sugar, oilseeds, cereals, and fertilizers.¹⁵ Under this scenario, over 96 percent of households in the sample saw their real incomes decrease because of the invasion (Figure 24). More than three-quarters of these households experienced income losses of 3 to 10 percent. The losses were not evenly distributed; one household lost 12.8 percent, while the largest gain was 0.4 percent. The hardest-hit households were in countries close to Russia. In Azerbaijan, average real incomes dropped by 10.4 percent; in Mongolia, by 9.3 percent; in Georgia, by 7.1 percent; and in Armenia, by 6.5 percent. Conversely, average income gains in Nepal and Pakistan were positive but minimal at 0.14 percent. Income losses within countries varied significantly. In Azerbaijan, all households lost income, with losses ranging from 8.1 percent to 12.8 percent. In Togo, all households also faced losses, but those losses ranged from 1.6 percent to 0.97 percent. In Pakistan, the impacts were mixed; over half the population (52 percent) lost real income, while the rest gained. Real income changes ranged from -1.1 percent to 1.6 percent.

15 Research shows that disruption in Ukrainian exports was not total. Much of this trade was re-routed through other countries or carried out under the Solidarity Lanes or Black Sea Grain Initiative. Nevertheless, the price effects predicted by the simulations in this section closely matched those observations.

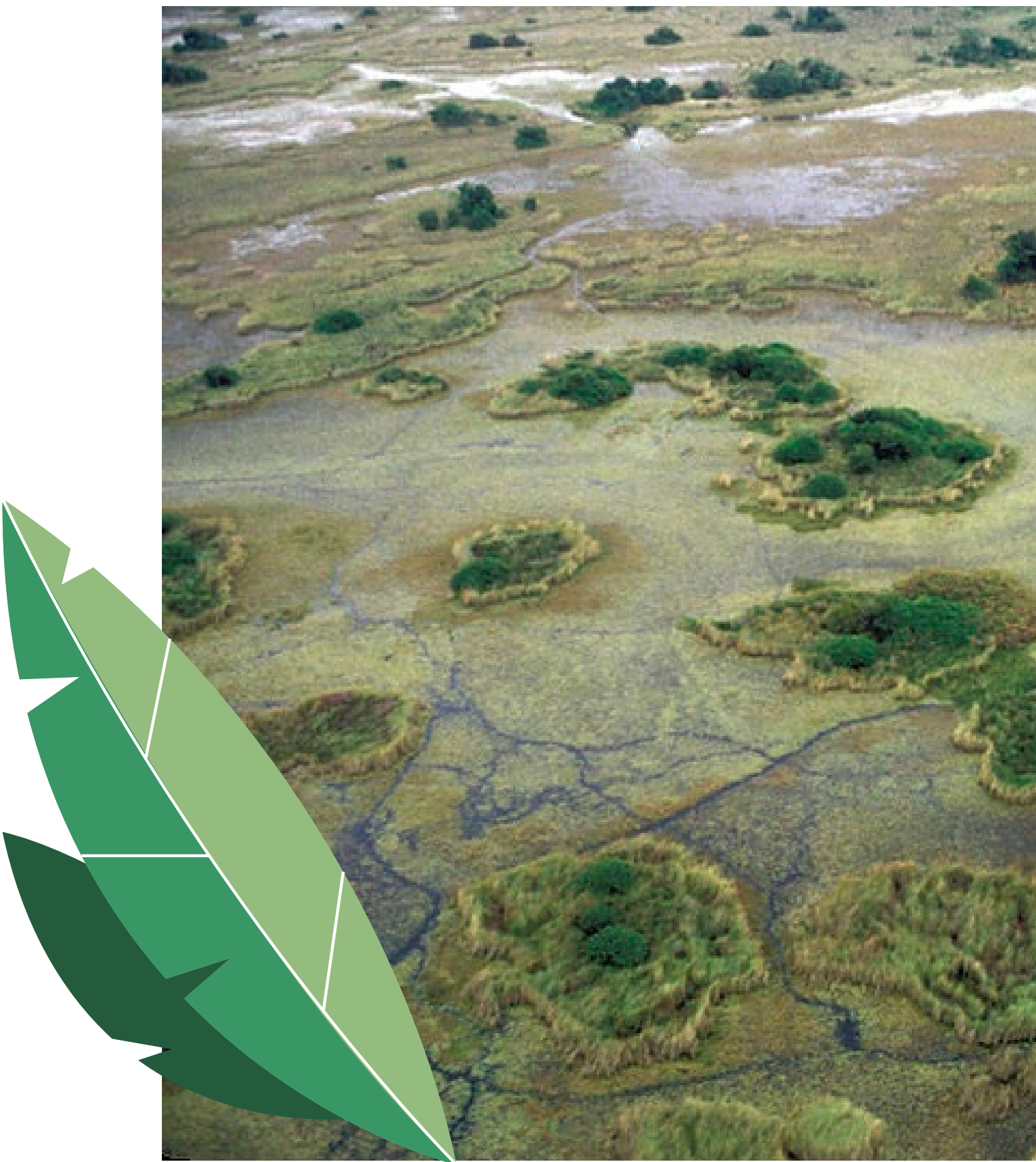
Figure 24 Nearly all households across countries lost real incomes because of the invasion

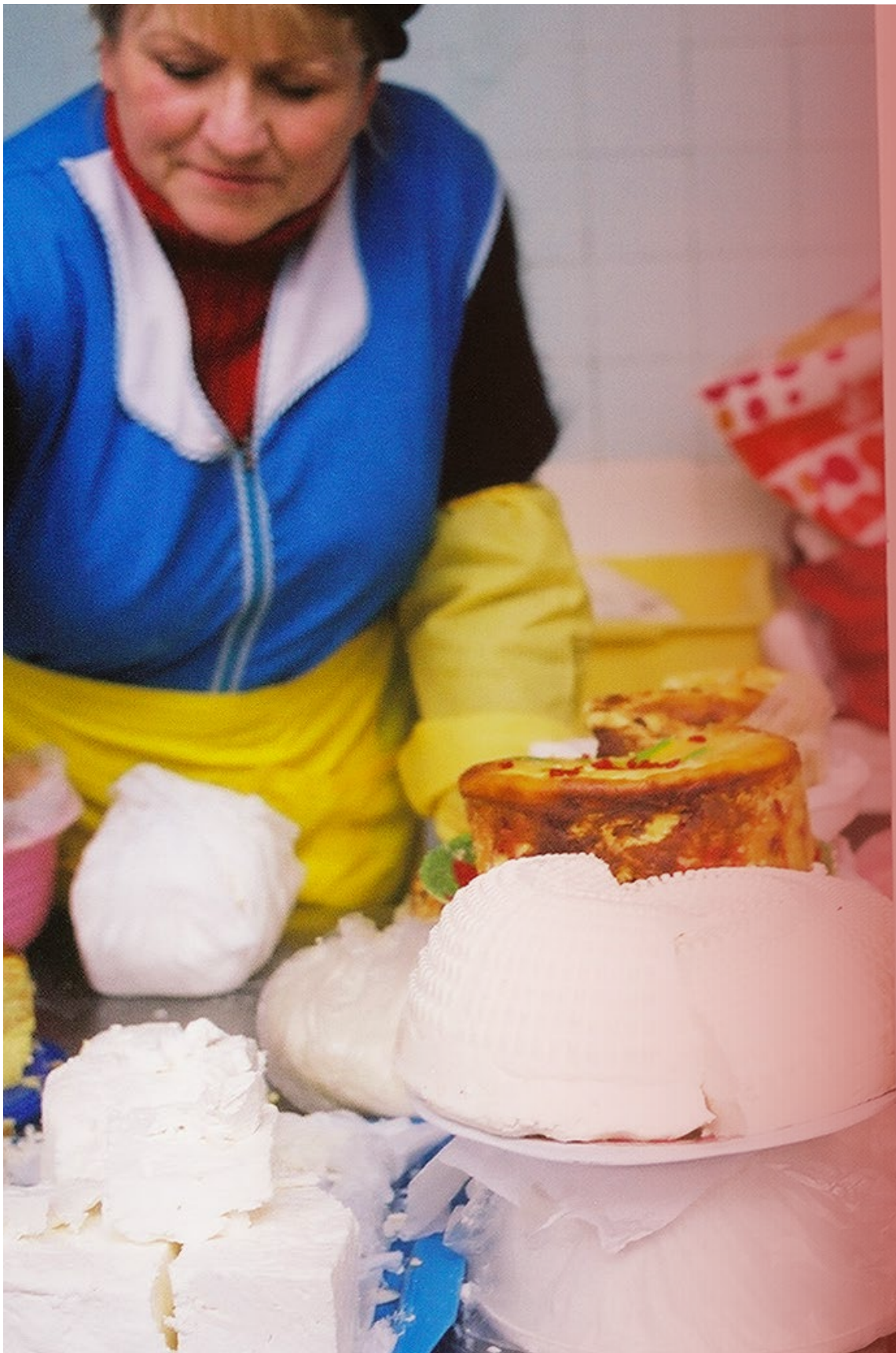


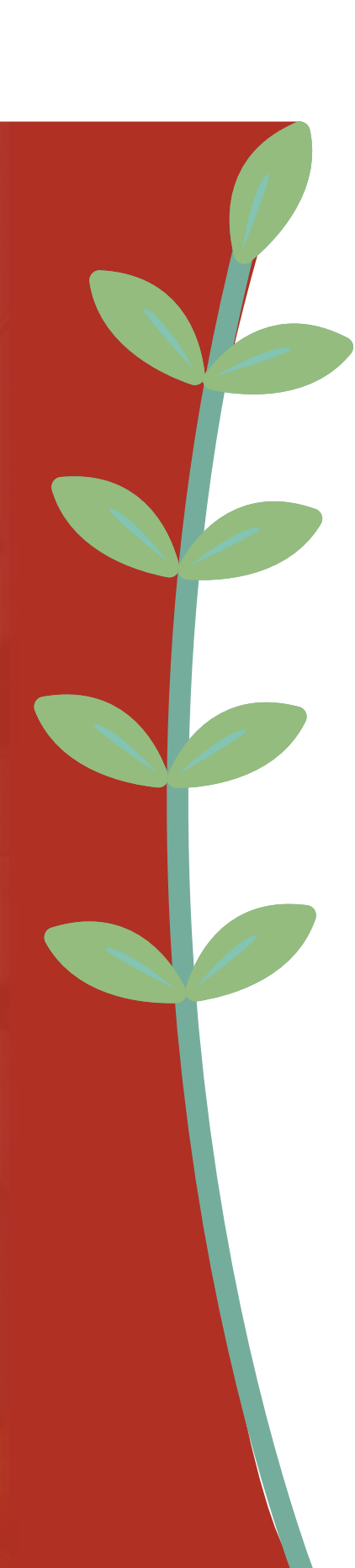
Source: simulations by Artuc and others (2024)

The poorest households suffered the largest income losses from the invasion.

The biggest income losses were in the highest-income countries within the sample of low- and middle-income countries. That said, within each country, poor households suffered the highest income losses. On average, households at the bottom of the income distribution experienced larger losses than households at the top. The bottom 25 percent of households lost 2.2 percent of their income, which is 23 percent more than the top 25 percent, who lost an average of negative 1.8 percent, or gained income. This dynamic increased income inequality. The invasion's impacts on income from labor and land prices are complex, but rising food prices is the main impact, hitting the poor the hardest since those households spend a higher share of their income on food.







3

NAVIGATING POLICY: PRICE INSULATION'S IMPACTS ON FOOD PRICE VOLATILITY

The chapter examines price insulation policies' impact on food price volatility, effectiveness in stabilizing prices, and implications for trade. Price insulation policies aim to protect domestic food prices from global price shocks. The chapter's first section discusses the role of price insulation policies in managing food price volatility. The second section addresses the political economy issues surrounding these policies. The third section evaluates their impacts on food prices. The third section provides lessons from Chile and Colombia on the impacts from greater market integration. The final section explores the implications for international trade, particularly for the World Trade Organization (WTO). The chapter finds that policies aimed at insulating domestic food prices from international volatility are politically important but have generally failed to stabilize world food prices and, in some cases, have actually magnified global price shocks. This creates a collective action problem: each country's individual attempt to shield its economy collectively amplifies global price instability, negatively affecting all nations. This issue arises from reactive adjustments in import tariffs and non-tariff measures in response to global price movements. That said, current global institutions are not effectively addressing this collective action problem. There is also evidence that these measures can increase domestic price instability in the countries that implement them, contrary to their intended purpose.

3.1. Price Insulation's Role in Managing Food Price Volatility

Food price volatility disrupts household welfare, destabilizes incomes, and undermines FNS, making it a critical concern for policymakers. Chapter 1 shows that food price volatility was pronounced during the 2009–2023 multi-shock period,

primarily due to macroeconomic variables. Chapter 2 highlights that raising prices particularly harms poor households, which spend a large share of their income on food. Moreover, high food prices reduce access and affordability, worsening FNS for vulnerable populations. Low prices, on the other hand, undermine farmers' and producers' ability to invest in future production, leading to longer-term supply shortages. This instability discourages investment in the agricultural sector, reducing innovation and productivity growth. Raising food prices can also threaten political stability, especially in urban areas, where sudden price spikes have been linked to protests and civil unrest. (see Bellemare and others, 2015). These factors make price volatility a pressing policy issue with far-reaching implications for poverty, inequality, and global food systems.

Governments often try to insulate their domestic markets from food price volatility. Their objective is to keep local food prices stable compared to world prices. For example, when world food prices fall, countries may raise import tariffs or use export subsidies to prevent domestic prices from dropping (Martin and Anderson, 2011). Conversely, when world food prices rise, exporters may impose export restrictions, while importers may lower import barriers (Giordani and others, 2016). These measures are meant to prevent domestic prices from rising in line with global market prices. Martin and others (2024) show that most countries design policies to limit how much domestic prices change in response to external price fluctuations.

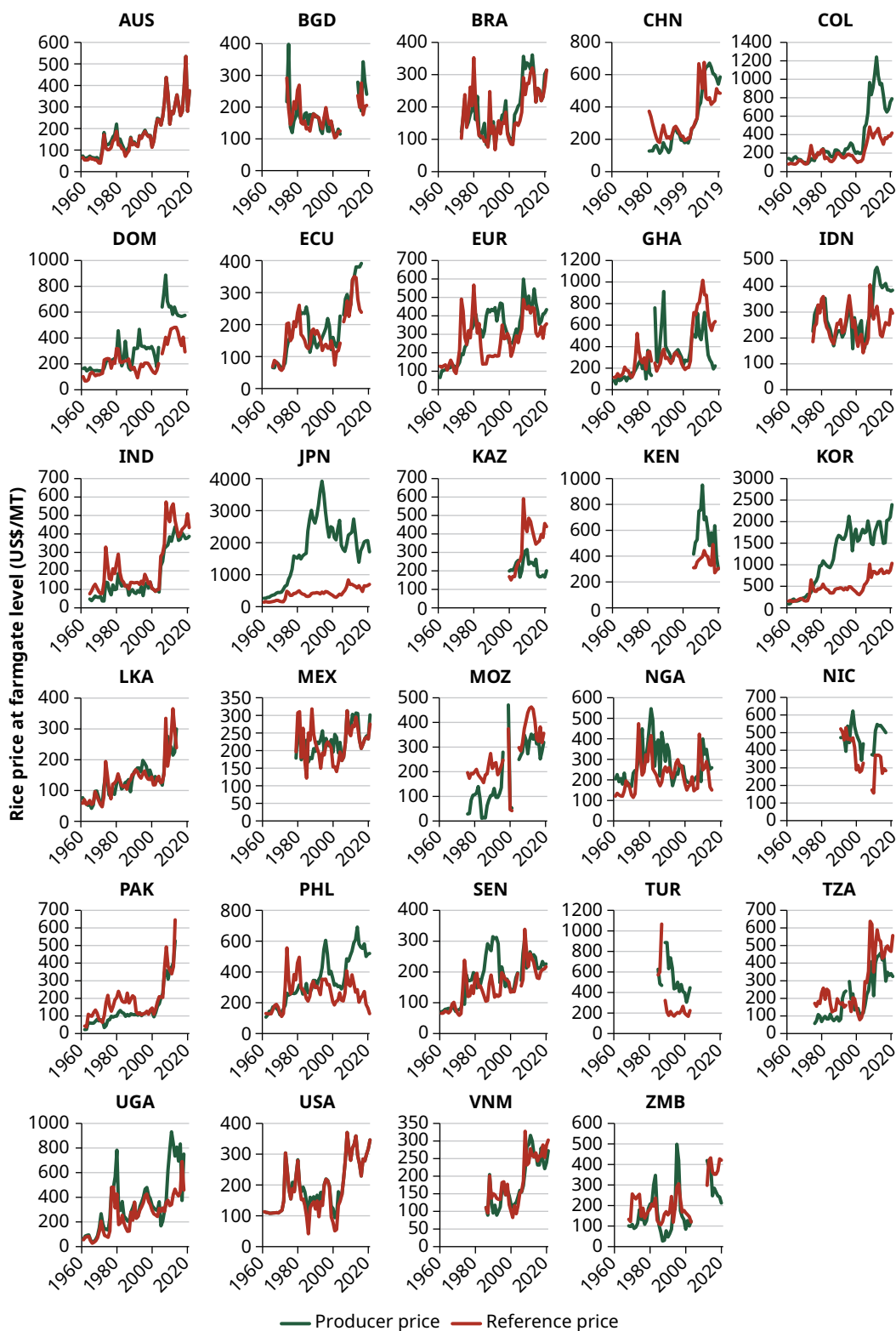
Methods Note #5:

The first part of this section relies heavily on Martin and others (2024), a background paper for this report. The study uses annual data on producer and external reference prices for rice and wheat from 29 economies, based on the Agricultural Incentives (Anderson 2008) and AgIncentives databases through 2021. This data measures the level of protection for each country and commodity. The annual price data is designed to assess protection levels by selecting comparable commodities, using producer prices as a proxy for domestic prices, and setting external reference prices as world prices adjusted for transport, marketing costs, and processing degree. Therefore, differences between producer and reference prices result solely from policy.

Price insulation policies can limit domestic price changes, but their effectiveness varies, with domestic food prices often remaining as unstable as international prices. Martin and others (2024) analyze how much these policies limit domestic price changes compared to external prices (see Methods Note #5 for details). Figure 25 shows the rice prices producers receive and the reference prices they would have received without trade-policy interventions. The data reveal sharp differences between domestic and external prices in some countries, while other countries show strong similarities. Even in countries where the two series diverge for extended periods, the domestic series responds somewhat to international prices. For example, the producer and reference prices in India are similar. The graphs indicate that domestic rice prices can be just as unstable as international prices, despite trade policies aimed at keeping food prices (Timmer, 2010).

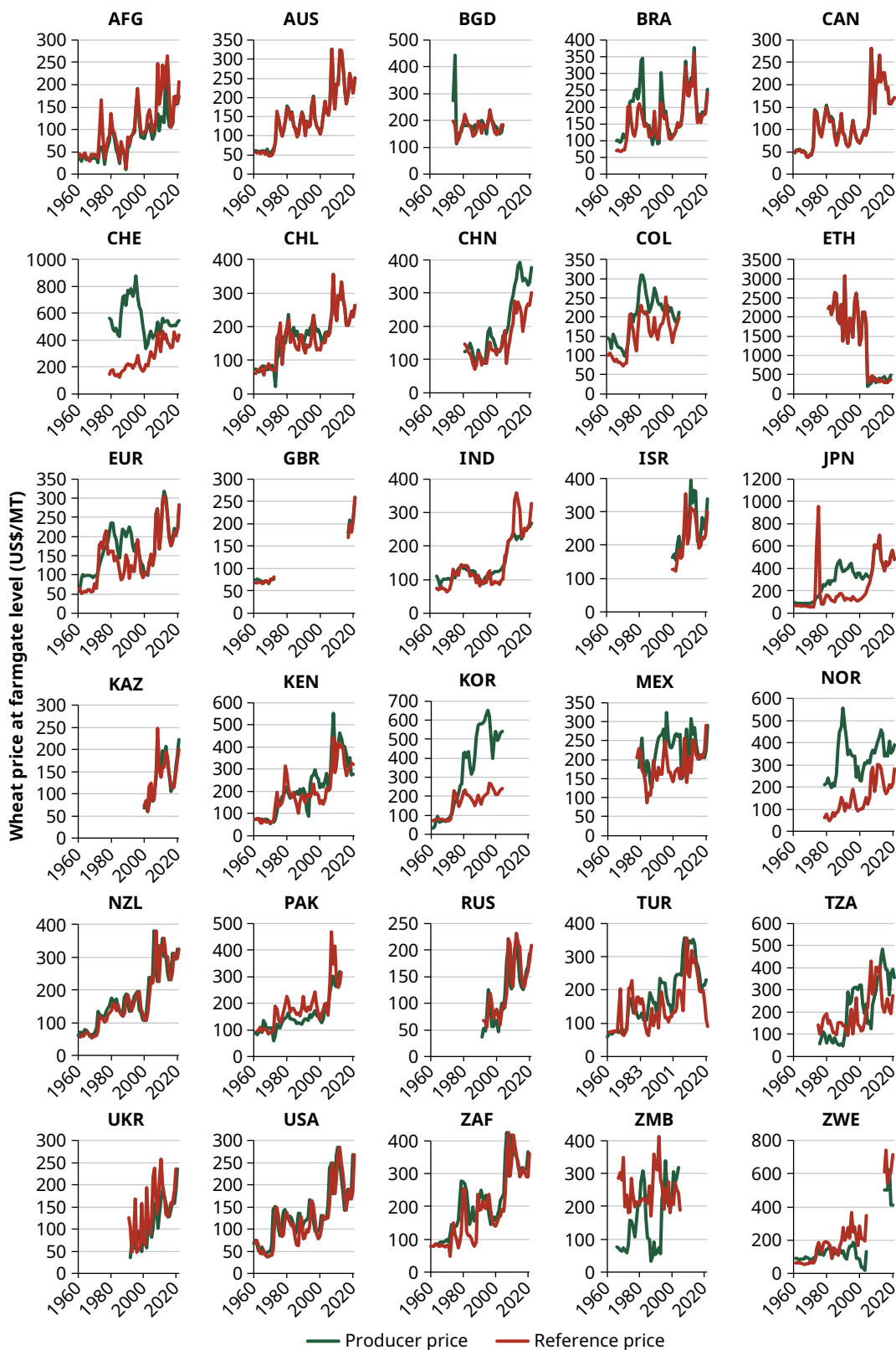
The success of price insulation policies in wheat markets differs across countries, with domestic prices can being less, equal to, or more unstable than international prices. Figure 26 shows wheat price differences between domestic prices and international reference prices. In some places, like Argentina, the price gap fluctuates, being large at times and small at others. In countries like Australia and Canada, the gap has typically been small and nearly disappeared in recent years. In Bangladesh, Europe, Japan, Switzerland, and the U.S., major changes in trade policies have caused sharp shifts in the relationship between the two prices. In some countries, like India, domestic prices are much steadier than international prices; however, this pattern is surprisingly rare given the widespread use of price insulation in India. In many other countries, including Norway, Colombia, and Switzerland, domestic prices are at least as unstable, if not more so, than international prices. The estimates in Figure 25 and Figure 26 suggest that food trade policies prevent half of annual world food price changes, on average, from passing onto domestic prices.

Figure 25 The effectiveness of price insulation policies on rice prices varies



Source: Martin and others (2024)

Figure 26 The effectiveness of price insulation policies on wheat prices varies



Source: Martin and others (2024)

Price transmission in grain markets varies widely. Hoffmann and others (2023) found that price transmission, which refers to the extent to which changes in international prices are reflected in domestic markets, is incomplete. Their methodology differed from the Martin study, which analyzed annual price changes. Instead, Hoffmann focused on higher-frequency monthly price changes using data from the Food and Agriculture Organization's Global Information and Early Warning System (GIEWS, FAO, 2022) for wheat, yellow maize, white maize, and rice. The researchers applied a smooth transmission model to analyze how changes in international prices affect domestic markets and whether price passthrough weakens during periods of high international prices. Annex 3 provides details on the methodology and data. The study found wide heterogeneity in price transmission across products and countries. Yet, when prices are high, the insulation effect is generally quite strong. The heterogeneity appears to be particularly pronounced for yellow maize. Domestic markets for wheat closely reflect international price changes when global prices are low, but this pattern does not completely hold for yellow maize. When international wheat prices rise, domestic markets generally show stronger insulation. Figure 27 through Figure 30 show the results from the Hoffmann study with main takeaways for each grain in the following bullets.

- **Wheat markets show stronger price insulation during spikes** (Figure 27). When international wheat prices rise sharply, most countries experience a drop in price transmission. This was evident during the major price spikes in 2007/08 and 2022/23. Estimates find that the turning point between low and high price regimes typically occurs when international prices reach US\$250 to US\$300 per ton.
- **Yellow maize markets are more volatile and unpredictable** (Figure 28). Price transmission elasticities for yellow maize markets are more heterogeneous than for wheat. When international prices are low, transmission elasticities typically range from 0.3 to 0.5, but they drop to around 0.2 during price peaks. Some markets experience even bigger changes, with elasticities turning negative or rising sharply. For most countries, the shift from low- to high-price regimes are estimated to happen when prices reach US\$270–280 per ton.
- **White maize markets experience sharp drops in price transmission** (Figure 29). White maize markets are more unstable when international prices rise. Elasticities usually range from 0.3 to 0.5 but can drop as low as –1 during price spikes, such as in 2011/12, 2016, and 2022. Data from 11 white maize markets, mostly in Togo, show this pattern, except for one market in Maputo, Mozambique, where prices behaved differently. The switch to high-price regimes typically occurs when international prices are US\$260–265 per ton, slightly lower than for yellow maize.
- **Rice markets showed weaker insulation in recent crises** (Figure 30). Price transmission in rice markets tend to be more stable, with elasticities usually above 0.5. However, during international price spikes, elasticities fall to around 0.2–0.3, as seen in 2008, 2011/12, and briefly in 2020–2021. Unlike wheat and maize, rice prices did not surge in 2022, so there is no evidence that insulation increased after Russia's invasion of Ukraine. The shift from low- to high-price regimes usually occurs when prices reach about US\$550 per ton.

Figures 27–30 Estimated elasticities of the transmission from international to domestic prices vary greatly for grains

Figure 27: Wheat

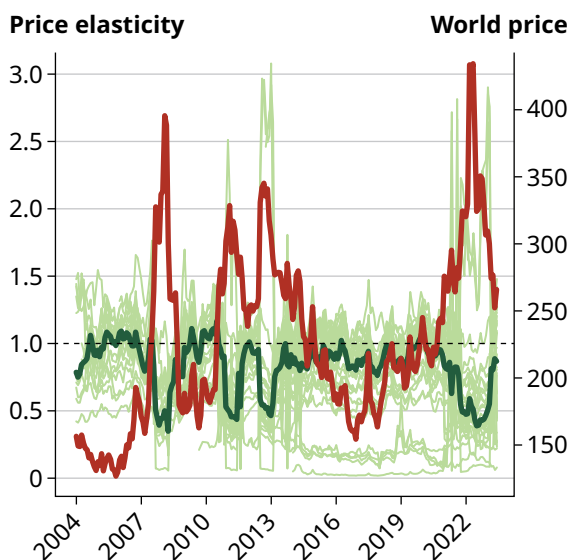


Figure 28: Wheat

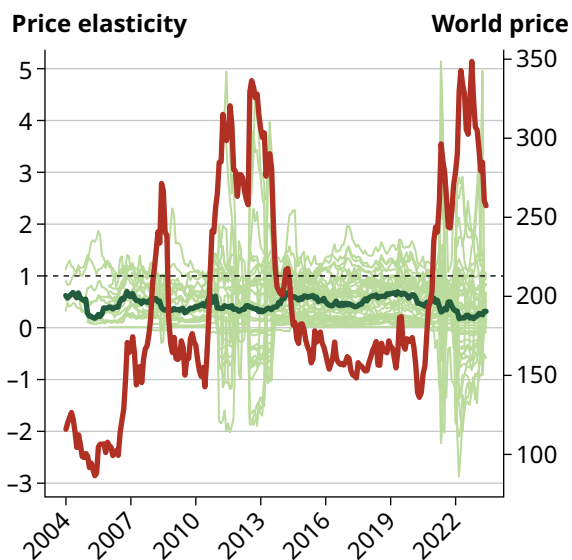


Figure 29: White maize

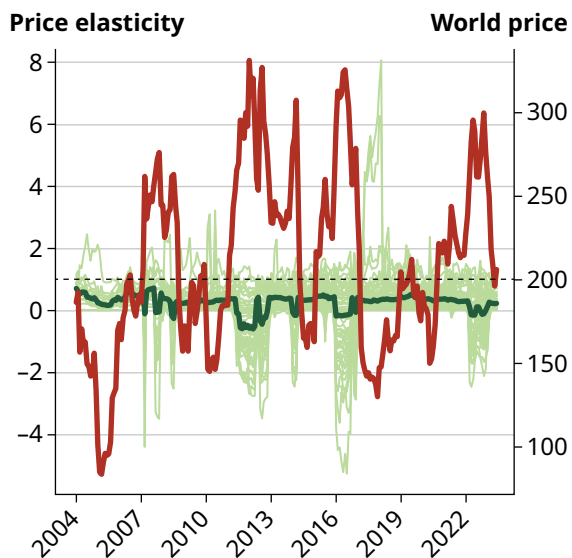
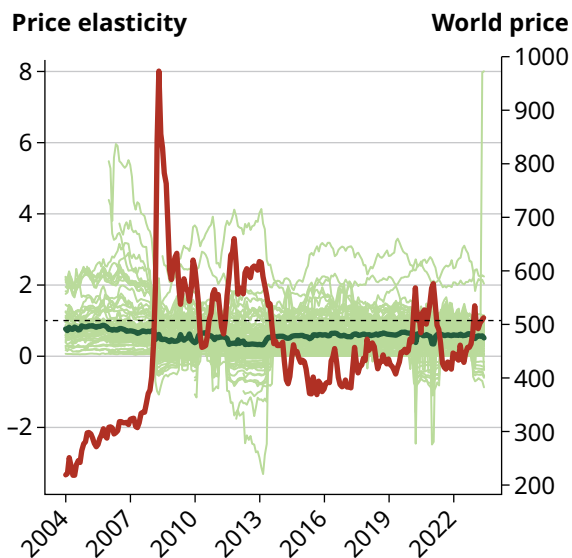


Figure 30: Rice



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

Source: Hoffmann and others (2024)

3.2. The Political Economy of Price Insulation

Price insulation policies and the resulting changes in food prices can be politically costly. Giordani, Rocha, and Ruta (2016) suggest that consumers react more strongly to price increases than producers do to drops, and vice versa. Grossman and Helpman (1994) emphasize that policymakers must maintain a balance between these producer and consumer interests. If policy measures 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.

Many examples show that it is politically difficult for countries to remove popular food subsidies. Egypt heavily subsidizes bread for its population without targeting specific groups. Currently, about 70 percent of the population receives subsidized bread. The public views this subsidy as an entitlement, and the government has abandoned efforts to reform the program because of strong civil resistance and social unrest. As a result, when international wheat prices rise, such as during Russia's invasion of Ukraine, the government has little choice but to increase the already large subsidies and take other actions, such as releasing wheat stocks and restricting grain exports. In Morocco, bread is an even more important staple. Each Moroccan consumes 175 kilograms of bread per year, compared to 120 kilograms in France and 150 kilograms in Egypt. Any shock to world grain prices will inevitably lead to major fiscal costs in bread-loving and bread-subsidizing countries like Egypt and Morocco.

Policymakers often adjust trade policies to avoid political costs and balance producer and consumer interests. Maintaining a stable level of protection or taxation is typically aimed at minimizing sharp domestic price changes, which can provoke public backlash, particularly in urban areas where food prices are politically sensitive. For example, food price spikes have triggered protests and political instability in several countries, as seen during the 2007–2008 food crisis (Bellemare, 2015). High-income exporters, such as Australia and Canada, often allow global price changes to pass through to domestic markets, reflecting their lower political and economic need for insulation (Martin and others, 2024). Conversely, countries where food expenses represent a significant share of household budgets strongly insulate their domestic markets to protect vulnerable populations from global price fluctuations. This disparity underscores the trade-off between stabilizing domestic markets and fostering global market integration. There is also a trade-off between producers and consumers, as policymakers balance the needs of farmers seeking higher prices with those of consumers wanting lower prices.

A model by Martin and others (2024) shows that policies that resist price changes can upset the political balance. If world prices rise but domestic prices do not, protection from rising global food prices weakens for food producers. However,

as mentioned, changing the political economy balance can be costly. Depending on these political costs, governments may adjust prices quickly or slowly, creating smaller or larger gaps between domestic and world prices. The Martin study measures how quickly countries adjust their prices, revealing wide differences. It also uses new data on staple food prices to calculate how much price insulation comes from these policies, excluding other factors affecting price comparisons. Methods Note #5 provides a summary and Annex 4 has the details. Key findings from the model are presented in the following bullets.

- **Rice price adjustments align with the model in most countries.** In nearly all countries, domestic rice prices adjust in ways consistent with the political-economy model. The coefficient on the change in world prices (δ), which measures how much domestic prices adjust to global prices, is positive and falls between zero and one in most cases. This means domestic prices partially follow world prices. The error-correction term (θ), which shows how quickly domestic prices return to a long-term balance, is negative and between zero and one, meaning deviations from equilibrium are reduced over time. These findings suggest that policymakers' reluctance to adjust prices and their aversion to deviating from balance influence price behavior.
- **Countries differ in how strongly domestic prices respond to global price changes.** The impact of global price changes on domestic prices (δ) varies widely, from 0.94 in Australia to 0.01 in Bangladesh. Surprisingly, countries like India (0.8) and Indonesia (0.6), often seen as resistant to global price transmission, show high passthrough rates. Kenya and Türkiye are exceptions; their results do not align with the model, and their estimates lack statistical significance. The error-correction terms (θ) indicate how much of the gap between domestic and world prices is closed after an initial shock. The speed of adjustment varies from -0.71 in Brazil to -0.01 in Bangladesh, demonstrating how quickly countries close the gap between domestic and world prices. Generally, higher δ values correlate with larger adjustments, but these measures vary by country.
- **Wheat price adjustments vary widely between countries.** Domestic wheat prices respond to global price changes at different rates. Traditional exporters like Argentina, Australia, Canada, and the USA show strong short-term price transmission, with coefficients near one. Major exporters like Europe and Russia also show high rates, despite Europe's apparent price insulation. Other countries have intermediate rates, 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 group, including Türkiye (0.27), Norway (0.29), India (0.13), and Japan (0.10), shows much weaker transmission, likely due to policies that protect consumers from price shocks. Unsurprisingly, the second and third groups mainly consist

of lower-income countries where staples represent large shares of consumer expenditures, making sharp price increases likely to provoke backlash. However, these groups also include higher-income countries like Japan and Norway. Japan's results are influenced by the high and variable protection regime in place before 2007, rather than the zero-protection regime prevalent since then.

- **Some countries show minimal wheat price transmission.** A few countries, including Pakistan (0.01), Tanzania (−0.05), and Zambia (−0.17), have very low or no significant price transmission. Policymakers in these countries appear focused on insulating domestic markets from global price shocks. In Pakistan, this likely reflects their strong reluctance to adjust prices for an important staple. For Tanzania and Zambia, wheat may not be important enough to justify the political risks of price adjustments. Both countries also experience unpredictable idiosyncratic policy shocks, leading to domestic price volatility that is far higher than global wheat price volatility.

Authors' section lessons:

The lesson is clear: countries without generalized food subsidies should not start them. There are many models to follow for developing targeted safety net programs that reach the poor at a much lower cost and can be scaled up when necessary, such as during food price surges. Countries that already have generalized subsidies should keep them at modest levels to prevent them from becoming expensive entitlements that are difficult to reform. In the medium term, they should phase out general subsidies and transition to targeted safety net programs.

3.3. Price Insulation's impacts on Food Price Stability

Price insulation magnifies swings in world food prices. Anderson (2014) argues that this occurs in two ways. First, long-term trade protectionism, such as import tariffs and export restrictions, reduces food trade and creates "thinner" markets. As a result, any production shortfall due to shocks leads to larger price swings in these markets compared to those with "thicker" trade volumes. Second, government responses to short-term shocks can amplify global price fluctuations. Anderson (2014) estimates that policy responses to the 2006-2008 global price spikes in rice, wheat, and maize magnified price increases to the point that these policies did not lower net prices in internal markets. In essence, domestic price increases would have been similar if countries had not insulated their markets at all. Our calculations using recent data

on rice and wheat prices indicate that world price fluctuations can double from price insulation policies. Martin and others (2024) estimated a “magnification factor” of 2.0 for rice and 1.91 for wheat. This aligns with the estimated magnification effect during the 2022 wheat price shock reported by Martin and Minot (2022).

Our model shows that domestic food price volatility often equals or exceeds global levels, suggesting widespread failures in trade insulation policies. In the rice market, we estimate that the domestic price volatility, measured by standard deviation, is 0.27, close to the world price volatility of 0.29. In fact, our analysis found that domestic volatility was higher in many cases. Specifically, domestic price volatility exceeded world price volatility in seven of the 29 case study countries, and domestic and international price volatility were equal in one country. In the wheat market, nine of the 29 countries had greater domestic volatility than world volatility, while in three countries, the two prices were equal. Other studies have shown that trade insulation policies often increase domestic price volatility in some African countries (Jayne, 2012; Minot, 2014). This report suggests that these policy failures are more widespread, at least in the global markets for rice and wheat.

There are several reasons that price insulation policies fail to stabilize domestic prices. First, systematic policy responses to global price changes are often positively correlated, meaning they react to the same global price movements, amplifying the instability of global prices rather than mitigating it. Second, domestic supply shocks, such as those occurring in the presence of export bans, can counteract or worsen the intended effects of insulation policies. Third, poorly timed and inconsistent adjustments to domestic prices frequently undermine stability. For example, efforts to keep local prices artificially low often become financially unsustainable, forcing abrupt policy changes that lead to sharp price spikes. Fourth, politicized food pricing decisions, such as lowering tariffs or releasing reserves, are often delayed because of resistance from local producers. By the time governments act, global prices may have already fallen, or domestic production may have recovered, exacerbating price drops.

3.4. The Impacts from Avoiding Price Insulation: The Cases of Chile and Colombia

Methods Note #6:

This section analyzes transaction-level customs data from Chile and Colombia to show how world price shocks affect the domestic economy. The relationship between world market prices and import prices is complex and influenced by

several factors, some of which may be susceptible to policy intervention. Global market prices typically reflect spot transactions at major commodity exchanges. However, commodity imports may follow different pricing arrangements, such as longer-term supply contracts or futures transactions. In addition, price transmission differs in lead times from the world market to import prices, as well as by origin, product quality, importer-exporter relationships, and trade costs. Transaction-level customs data, published by a few countries, including Chile and Colombia, makes it possible to assess and quantify these factors. This section highlights insights from von Uexkull (2024), focusing on Chile and Colombia's experience during the 2022 food price shock. The analysis focuses on these two countries, making some results idiosyncratic and potentially not generalizable to other economies. However, the findings demonstrate strategies and policies that may benefit other countries under certain circumstances.

Allowing global price shocks to pass through to local markets helps countries manage import costs and ease balance of payments deficits. When global wheat prices spiked, demand for wheat declined in Chile because the local market was not insulated from the shock.¹⁶ As a result, the country's import costs increased by 17 percent, as less wheat was imported to meet lower demand (see Methods Note #6). In contrast, Colombia's import cost increases were roughly twice those of Chile. The reason is that its domestic wheat market was more insulated from international price shocks, leading to increased wheat demand during the shock and imports. In Chile, internal demand adjusted to changes in border prices because they passed through to domestic markets. This encouraged consumers to reduce consumption by substituting for lower-priced products and provided incentives to increase domestic supply. In the short run, countries can achieve this by drawing down privately held food stocks. In the longer term, they can increase production. Both actions reduce import demand and help countries move toward food self-sufficiency without relying on distortive policies.

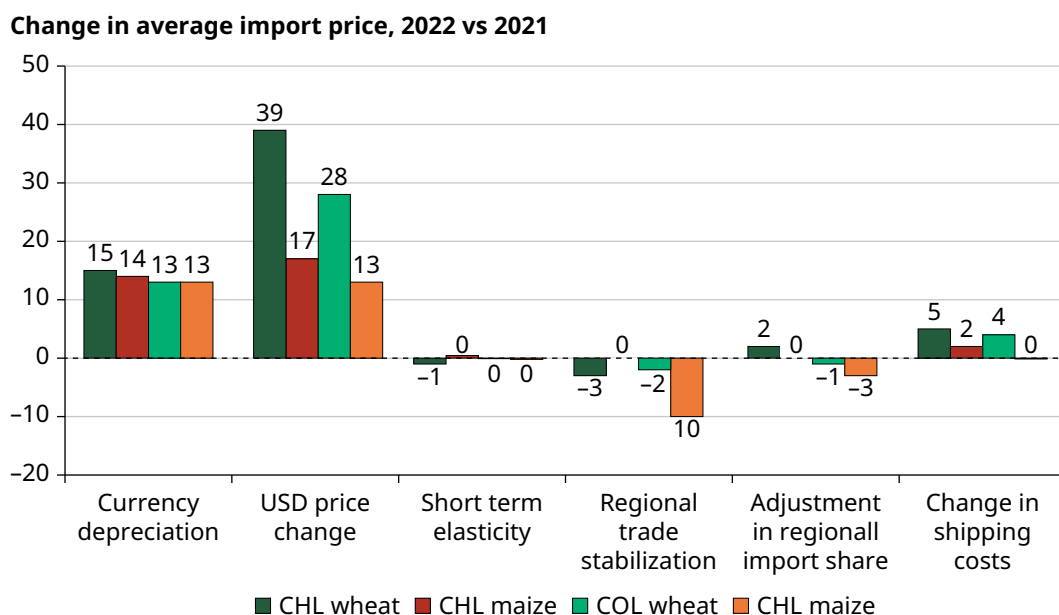
Chile and Colombia relied on regional imports instead of global ones during the shock, limiting domestic grain price increases. This reliance created opportunities for considerable savings. For Chile and Colombia, the price increases on regional imports were smaller than those for imports from the rest of the world. The differences are notable. Relying on regional imports reduced the potential price increase by three percentage points for wheat in Chile, two percentage points for wheat in Colombia, and ten percentage points for maize in Colombia compared to if regional import prices had increased in line with global prices (Figure 31).

16 Refer back to Map 1 in Chapter 1, which shows that Chile has some of the lowest trade barriers (applied tariffs) in the world.

Both countries took advantage of lower regional prices in the maize market. In Colombia, the share of maize imports from within the region rose from 22 percent to 52 percent. Chile's share increased from 90 percent to nearly 100 percent. In the wheat market, Colombia increased its regional share, while Chile decreased it, for reasons not explored in this paper. Consequently, Colombia's average import price rose by three percentage points for maize and one percentage point for wheat. Chile's average import price for wheat increased by an additional two percentage points. Figure 31 shows that price changes were the primary driver of import price increases for wheat and maize, while regional trade stabilization and adjustments in regional import shares helped offset some of these increases, especially in Colombia.

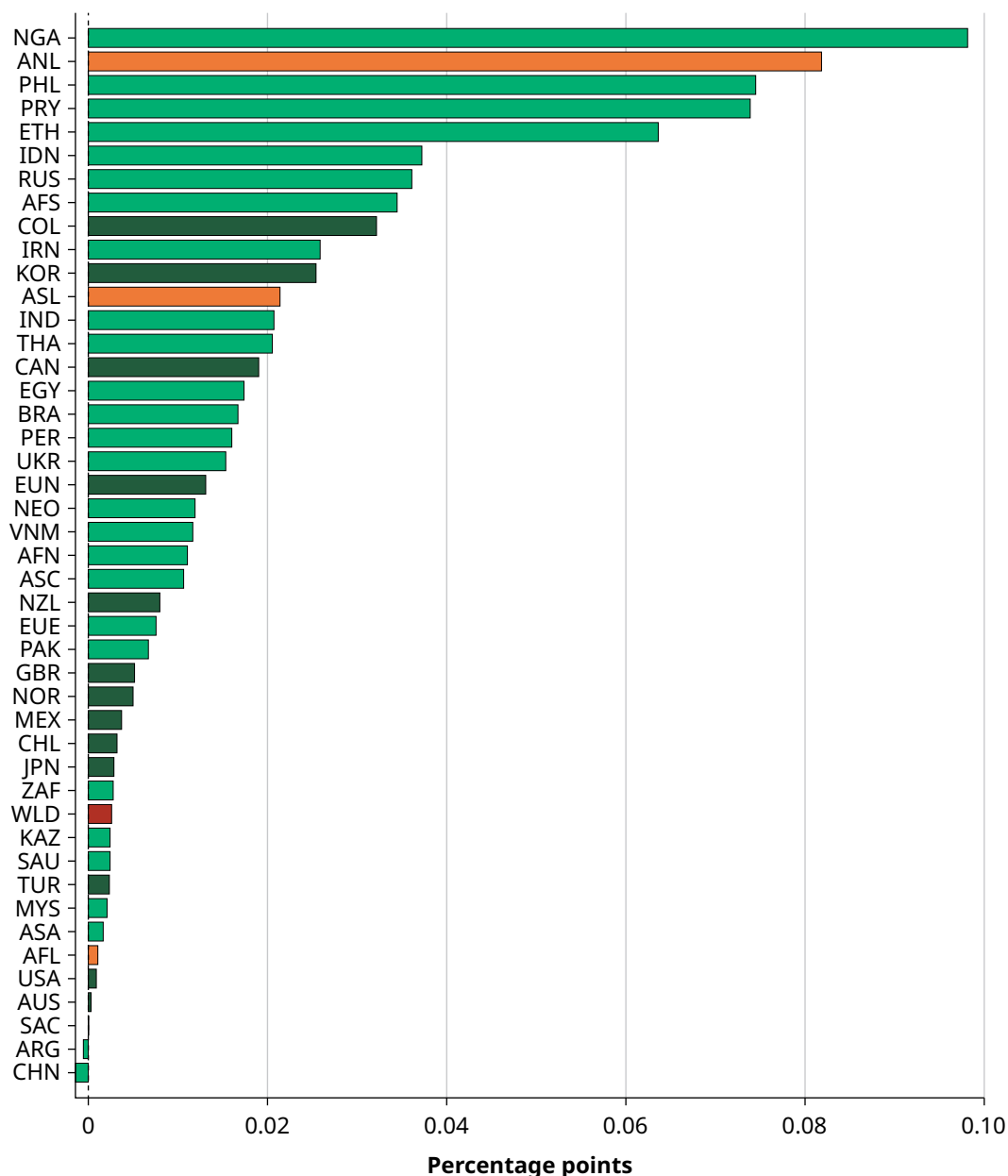
A separate study shows that greater food market integration contributes to FNS. Adenauer and others (2023) simulate food availability during climate-induced extreme weather events. Figure 32 shows the study's results. It displays the downside semi-variation coefficient of average food availability, which measures the instability of food supply under different trade scenarios. Higher values indicate greater vulnerability to food shortages when trade is restricted compared to when trade is integrated. Lower or negative values suggest that countries experience more stable food availability when trade is integrated. Overall, the figure shows that a well-integrated food trade system reduces the risk of food insecurity for nearly all countries, with the most profound benefits for the LDCs and emerging economies. For example, Colombia has one of the highest levels of downside variability, indicating that its food availability is much more unstable under trade restrictions.

Figure 31 Regional trade stabilization mitigated domestic price increases during the 2022 price shock



Source: von Uexkull (2024) using custom data.

Figure 32 Most countries have higher downside variability of food availability, meaning they are vulnerable to food supply losses when trade is restricted



Source: Adenauer and others (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.

Authors' Section Lessons:

Evidence from Chile and Colombia shows that avoid insulating domestic prices during shocks may yield more benefits than reactive protectionist policies. Those examples show that allowing global price shocks to affect local markets helps countries manage import costs and reduce pressure on the country's balance of payments. This approach can reduce import demand and promote food self-sufficiency without relying on distorting policies. Likewise, we see that Integration with regional markets can also mitigate the effects of price shocks, especially when shocks originate outside the region.

3.5. Implications for the World Trade Organization

The “collective action” problem arises when individual governments insulate domestic food prices in isolation. The “collective action” problem occurs when individual countries insulate their domestic markets. This insulation reduces the adjustments that consumers and producers must make to higher prices, shifting the burden onto the world market. As a result, world prices rise more than they would if individual countries did not insulate their internal markets. In essence, what benefits individual countries worsens the problem globally, leaving everyone worse off. This collective action problem is most damaging when world prices spike. If all countries acted in the collective interest, they could mitigate the price shock, but there is no mechanism in place to coordinate such efforts.

The WTO took positive steps to address trade distortion problems. Before the WTO's Uruguay Round agreement in 1994, agricultural trade distortions were largely unchecked by international rules. The Uruguay Round agreement changed that by converting NTMs, such as quotas, into tariffs and capping how much they could be raised. It also restricted variable import levies that some wealthy countries used to insulate their markets, reducing trade and increasing volatility in world markets (Hathaway and Ingco 1995). In many developing countries, tariff bindings—commitments to cap the maximum tariff rates on specific goods—prevented the most extreme and costly forms of food price protection by ensuring that tariffs could not be raised unpredictably to unsustainable levels (Francois and Martin 2004). These efforts align with the goals of the WTO Agreement on Agriculture, which aims to create a fair and market-oriented agricultural trading system (see Box 3).

Box 3 The WTO and Agriculture

The World Trade Organization (WTO) is the main global organization regulating and facilitating international trade. The WTO Agreement on Agriculture was established at the 2001 Doha Ministerial Conference to create a “fair and market-oriented agricultural trading system.” It governs market access, domestic support, and export competition. At the 2013 and 2015 Ministerial Conferences, WTO members agreed to eliminate agricultural export subsidies, marking the most significant reform of agricultural trade rules in WTO history. In 2022, the 12th Ministerial Conference agreed to exempt World Food Programme humanitarian food aid purchases from export restrictions and issued a declaration that underscores the critical role of trade in enhancing global food security. However, progress has stalled on key negotiation topics. At the recent 13th Ministerial Conference, members failed to agree on actions such as lowering import barriers, reducing trade-distorting domestic support, increasing transparency and predictability of export restrictions, easing market access barriers for cotton-producing and exporting LDCs, and establishing lasting rules for government food stockpiles to support food security efforts.

There are several areas where WTO rules could improve. WTO rules do not effectively manage export taxes and controls. They allow export restrictions on foodstuffs with notification requirements despite a general ban on such quantitative restrictions. The rules also lack strict limits on tariff levels. This flexibility has allowed developing countries, in particular, to impose high tariffs. As a result, many of these countries have set high ceilings on agricultural tariffs under WTO commitments. This allows governments to maintain elevated tariffs, leading to the previously mentioned “market thinning” effect. Agricultural tariffs are generally higher than those on non-agricultural products. Globally, agricultural tariffs average over 12 percent, compared to eight percent for other goods (Brenton and others, 2022). In some countries, food tariffs are much higher: for example, 42 percent in Türkiye, 33 percent in India, 29 percent in Morocco, and 25 percent in Kenya. High tariff ceilings give governments considerable leeway to adjust actual tariff rates, insulating their domestic markets.

Negotiating rules on taxes and export restrictions has been difficult.

Proposals to limit these measures did not gain much support in the WTO’s Doha Development Agenda negotiations (Anderson, 2014). In the early 2000s, Japan and Jordan proposed such measures, but a group of food-exporting countries led by Argentina opposed them. Argentina frequently uses export taxes and restrictions.

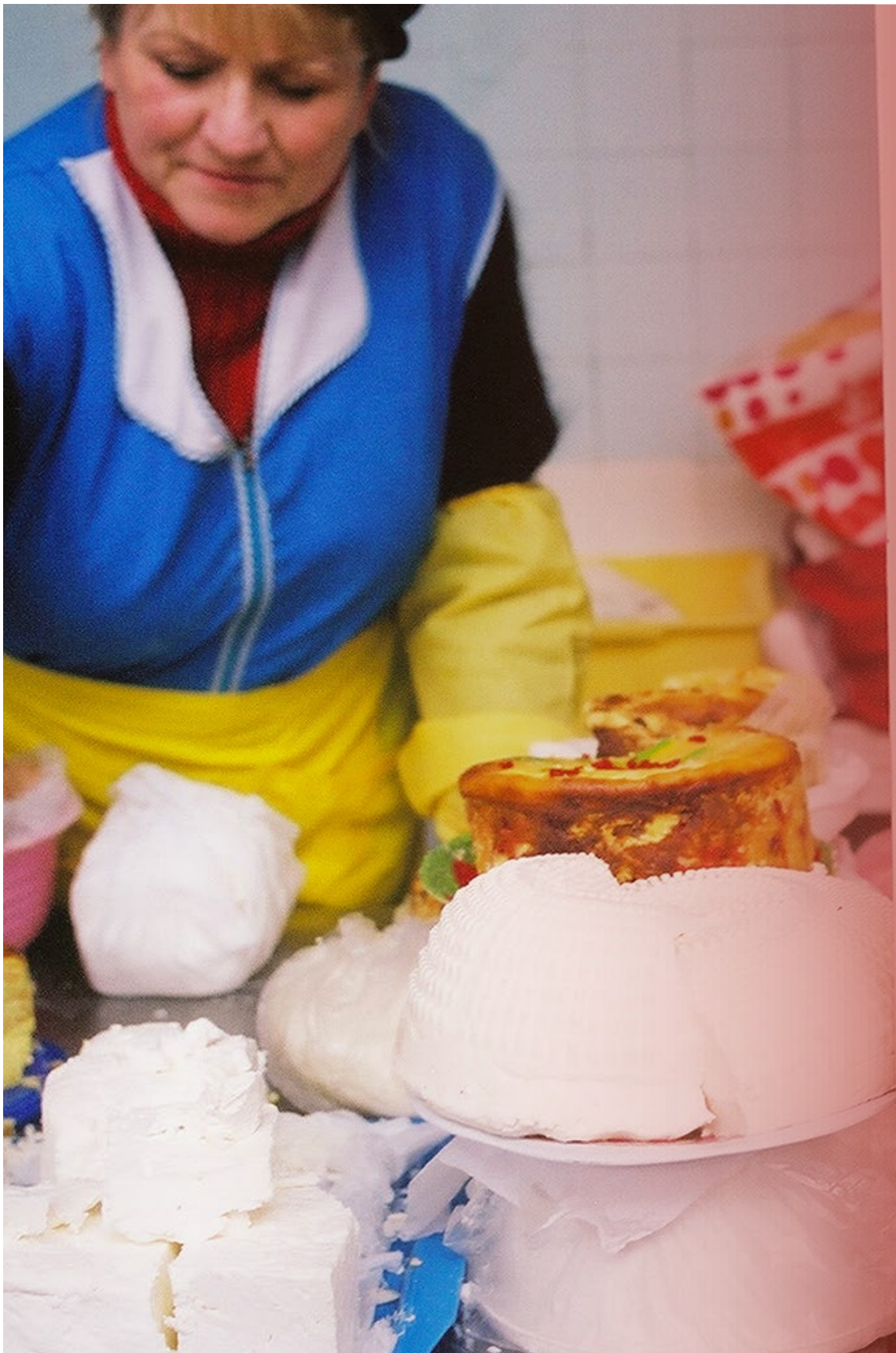
Reforming these policies has been politically challenging in Argentina because import and export taxes account for a sizable portion of government revenue. More generally, opposition to tariff limits stems from (a) the ostensible need to protect domestic producers, (b) the reliance of some governments on tariffs as a revenue source, and (c) the desire to retain flexibility in adjusting tariffs as world prices rise or fall.

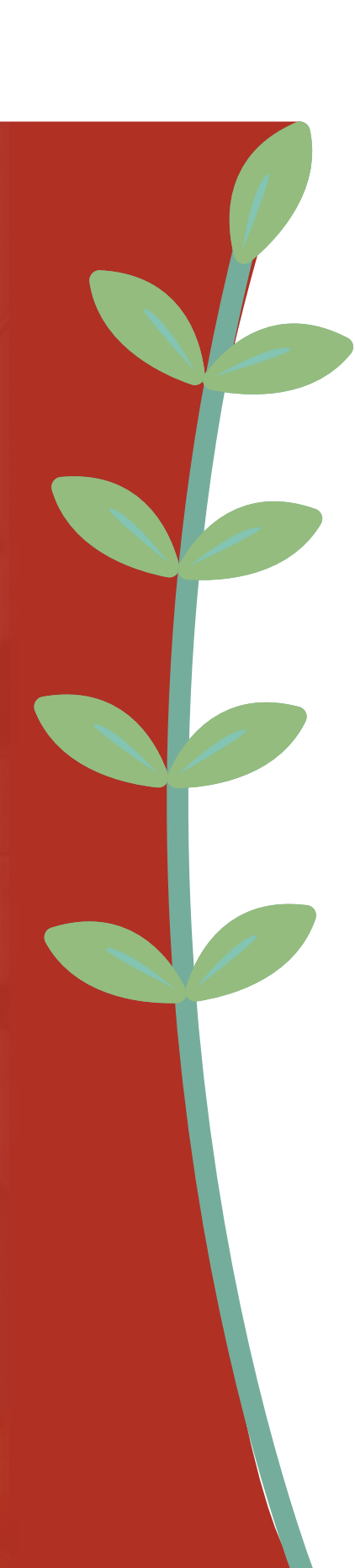
Certain developments may make it easier for countries agree on limits to price insulation policies. Recent changes in public finance allow countries to adopt value-added tax (VAT) instead of tariffs as a more efficient revenue source, as several developing countries have already done. Likewise, advances in digital technologies and safety net mechanisms may also enable countries to forego trade-policy instruments. Digital technologies simplify the implementation and targeting of conditional cash transfer programs, especially during periods of high food prices.

Authors' section lessons:

Current policy measures that rely on price insulation are ineffective at stabilizing prices. Countries often try to shield domestic markets from global price fluctuations, but tools like export restrictions can increase domestic price instability. This highlights the need to reform domestic policies by adopting less costly and more predictable approaches. Such reforms would improve domestic price stability and facilitate agreements on global trade rules. However, discretionary government policies undermine trust and predictability in international trade, making it harder for countries to commit to and uphold global agreements.

Agricultural trade policy reform should be a focus of multilateral trade negotiations, despite the inherent challenges. Brenton and others (2022) propose a "grand bargain," where exporting countries commit to removing restrictions and importing countries agree to lower tariffs to maintain trade stability. Such an agreement could enhance global FNS by reducing price volatility and expanding food trade. Chepeliev and others (2023) show that reducing agricultural tariffs could offset the impacts of recent economic shocks. However, progress remains difficult because of the lack of consensus on agricultural reforms at the WTO 13th Ministerial Conference (MC-13), particularly on public food stockholding and export restrictions





4 MOVING FORWARD: CONCLUSIONS AND RECOMMENDATIONS

4.1. Conclusions

Climate risks are worsening and threaten food and nutrition security and global food markets. Chapter 1 showed that climate change disrupts agricultural production through rising temperatures, shifting rainfall patterns, and more frequent extreme weather events. These factors lead to supply shortages and higher food prices. High temperatures increase food inflation in both high- and low-income countries, with Europe potentially facing a 30–50 percent rise in food inflation by 2035 (Kotz and others, 2024). Modeling by Artuc and others (2024) predicts declining crop yields in most countries, with productivity dropping by nearly 40 percent. Extreme weather events, like droughts, could reduce yields of major crops by over 50 percent by 2050 (Li and others, 2009). Compounding these risks are rising sea levels and shifting pest patterns. Such disruptions strain global food supply chains and worsen food insecurity, particularly in vulnerable regions. In 2021 alone, rising food prices pushed 30 million people in low-income countries into food insecurity (World Bank, 2022).

Russia's invasion of Ukraine shocked food markets and undermined FNS, making it a strong test case of future climate shocks. Together, Russia, Ukraine, and Belarus are major exporters of grains, energy, and fertilizers (UN Comtrade, 2022). Chapter 2 showed that invasion sharply reduced Ukraine's grain production and exports. Grain harvests fell from 85 million tons in 2021 to 55 million tons in 2023 due to lower yields, reduced planting areas, and blocked Black Sea export routes (USDA, 2024). Sanctions on Russia further strained global food supply chains by raising transportation costs and creating financial barriers (TASS, 2022). These disruptions triggered record-high global food prices in March 2022 (CSIS, 2023) and drove food price inflation in many low-income countries to over 15 percent by late 2023, with rates as high as 30 percent in

some cases (IFPRI, 2023). Global export restrictions, such as India's rice export bans, exacerbated these shocks, covering 11 percent of global food trade (Rocha and Espitia, 2023). The invasion's ripple effects pushed 258 million people into acute food insecurity in 2022, the highest number on record (FSIN, 2023). This highlights the potential vulnerability of global food markets to global climate shocks.

The global food system showed remarkable resilience to Russia's invasion of Ukraine, quickly adapting to disruptions in grain markets. Initial fears of severe food shortages did not materialize, largely because of the EU's Solidarity Lanes and the Black Sea Grain Initiative, which helped sustain Ukraine's grain exports (European Council, 2023). Major exporters in Europe and North America compensated for reduced supplies by redirecting food trade to vulnerable regions (CSIS, 2023). Importing countries diversified their suppliers, with West Africa and the Sahel increasing imports from Poland and Lithuania, including re-routed Ukrainian grain. The Middle East and Central Africa sourced more from Argentina and Australia. For example, Morocco replaced Ukrainian wheat imports by rerouting through Türkiye and Romania. Some countries, like Egypt and Türkiye, turned to alternative grains when wheat and maize supplies dropped (GRFC, 2023). These swift adaptations ensured food deliveries resumed to regions most at risk of acute food insecurity, highlighting the global food system's capacity to absorb and respond to major shocks, including potential climate-related shocks.

Countries enact price insulation policies to shield domestic markets from global food price shocks and address political pressures. These measures stabilize local food prices, support food self-sufficiency, and protect vulnerable populations. For example, Chapter 2 shows that the price shocks from Russia's invasion of Ukraine in 2022 led to over 100 export restrictions globally, affecting eleven percent of pre-pandemic food trade (Rocha and Espitia, 2023). India, the world's largest rice exporter, implemented export bans and duties that impacted sixty percent of its non-Basmati rice trade (Glauber and Mamun, 2023). These policies are often popular and politically driven, making reform efforts difficult. For instance, Egypt's heavily subsidized bread program, which covers 70 percent of the population, is viewed as an entitlement by most of its population, and attempts to reform it have led to civil unrest (Bellemare, 2015). This pressure forces governments to maintain subsidies to avoid public backlash. Governments also rely on these policies as a revenue source and want the freedom to enact them to respond to economic and political shocks even when there is no strong trade or FNS need. Despite these reasons, such policies can strain government budgets, worsen global food price volatility, discourage agricultural investment, undermine trade balances, and provoke retaliatory trade actions.

Price insulation policies lead to price instability and worsen food and nutrition security. Policies like import tariffs, non-tariff measures, and export controls often fail to stabilize domestic food prices and instead amplify global price volatility. These measures aim to shield domestic markets from global price shocks by limiting the transmission of international price fluctuations, but their reactive nature frequently

destabilizes both domestic and global markets. For example, Martin and others (2024) found that insulation policies magnify world price swings by reducing trade volumes, creating thinner markets where production shocks lead to larger price increases. These policies also increase domestic price volatility, as seen in wheat and rice markets, where domestic prices were as unstable or more unstable than international prices in several countries. This instability reduces household access to affordable food, discourages agricultural investment, and undermines long-term productivity growth, particularly in low-income countries (Jayne, 2012; Minot, 2014). The collective action problem of price insulation further compounds these issues. Individual countries' efforts to stabilize their markets collectively exacerbate global price instability, negatively affecting vulnerable populations.

Integrated trade that limits barriers is the best solution for managing shocks to food markets and FNS. Evidence from Chile and Colombia during the 2022 price shock highlights the benefits of allowing global price changes to pass through to local markets. Chile's less-insulated wheat market experienced a 17 percent increase in import costs, significantly lower than Colombia's more insulated market. In Colombia, price insulation led to increased demand and higher import costs (von Uexkull, 2024). By reducing reliance on insulation policies, Chile encouraged consumers to adjust demand and incentivized domestic production, promoting self-sufficiency without distorting trade. Regional market integration also mitigates the impact of price shocks. In Colombia, reliance on regional imports limited price increases for maize and wheat. A study by Adenauer and others (2023) supports this, showing that integrated trade systems reduce food supply instability during climate-induced shocks. Countries with open trade systems enjoy more stable food availability and fewer disruptions, demonstrating that trade integration is critical for managing food price volatility and enhancing global FNS.

Yet, the world seems to be moving away from stronger trade integration, with trade restrictions expanding and multilateral negotiations stalling in recent years. In 2023, nearly 3,000 trade restrictions were imposed globally, a fivefold increase since 2015. This rise exacerbates the negative effects of economic shocks on global food systems (Rocha and Espitia, 2023). Moreover, many countries continue to impose high agricultural tariffs, with averages exceeding 12 percent globally and much higher in certain nations, such as Türkiye (42 percent) and India (33 percent). Despite efforts by the WTO to address trade distortions, such as converting quotas into tariffs and capping variable levies during the Uruguay Round, progress on key reforms has stagnated. At the WTO's 13th Ministerial Conference, members failed to agree on critical issues like lowering import barriers and increasing the transparency of export restrictions (Brenton and others, 2022). Advances in public finance, digital technologies, and safety nets could offer alternatives to trade-policy instruments, but reaching consensus on global reforms remains elusive. As a result, the global food trade system stays fragmented and vulnerable to future climate shocks.

Recommendations

Revitalize International Trade Governance

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

- **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.
- **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 ones. Also, collecting comprehensive information on stocks remains difficult. Therefore, continued efforts to address these issues are needed.
- **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.

Multilateral action will produce the biggest benefits for all. Yet, even in its absence, countries must take independent actions to address food and nutrition security challenges, as discussed below.

Enhance National Crisis Preparedness

In the short-run, timely responses during crises can save lives and prevent economic losses. In the medium-term, countries could improve and implement 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

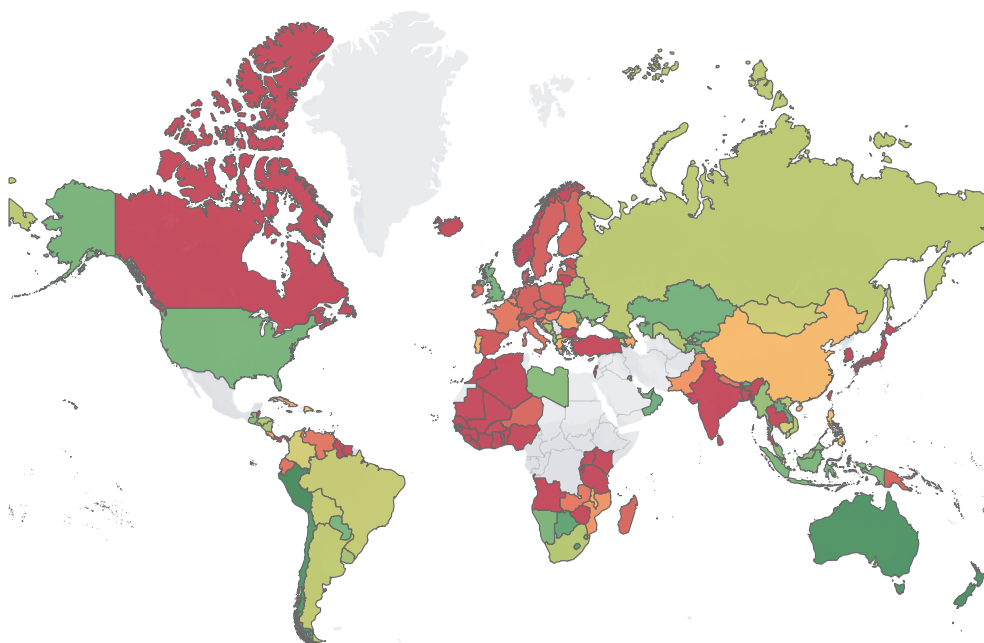
operational arrangements for monitoring and identifying crisis risks, disseminating risk information to decision-makers, financing response activities, identifying populations targeted for support, and coordinating response efforts effectively.

Improved Policy Responses

In the medium term, policy actions should include:

- **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 local 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.

Map 1 Countries in red, including India, Canada, and European countries, have the highest average applied tariffs, while Chile, Peru, and Australia have the lowest, 2021



Source: Portugal-Perez and others (2025b)

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 losses.** 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.

Implement Long-Term Structural Reforms for Resilient Food Systems

Over the long term, countries should focus on policies that enhance agricultural productivity, mitigate climate risks, improve economic sustainability, and facilitate trade integration. Governments 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.¹⁷

- **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.

Advance Research to Address Food Security Challenges

Future research must focus on understanding the broader impacts of food security shocks and identifying effective policy interventions. Research institutions and governments should:

- **Address aggregation bias in welfare analysis:** Economic research should include household-level data to accurately capture distributional impacts. Studies show that the poorest populations are disproportionately affected by climate shocks and food price surges.
- **Evaluate general equilibrium effects:** Incorporate indirect and ripple effects of shocks to better estimate overall welfare losses and policy impacts.
- **Support innovations in agricultural technologies:** Invest more in agricultural research to accelerate the development of climate-resilient crops and sustainable farming methods.

17 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.

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

“Price Peaks and Policy Shifts: Do Governments Increase the Insulation of their Food Markets?” by Clemens Hoffmann, Lina Kastens, Alberto Portugal-Perez and Stephan von Cramon-Taubadel, October 2024

“Trade Policy in Fertilizer in Fertilizer Markets”, by Alberto Portugal-Perez, Esteban Ferro and Alvaro Espitia, April, 2025a

“Trade Policy in Food Markets: Hunger Hotspots and LDCs” PowerPoint presentation by Alberto Portugal-Perez, Alvaro Espitia, Achim Vogt and Esteban Ferro, April 2025 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

“Food Trade Policy and Food Price Volatility” by Will Martin, Abdullah Mamun, and Nicholas Minot, 13 November 2023

Erhan Artuc, Guido Porto, Bob Rijkers. March 3, 2024 “Crops, Conflict and Climate Change” Preliminary and incomplete

Other references cited in this report for which links are not embedded in the text: Adenäuer, M., Frezal, C. and Chatzopoulos, T., 2023. Mitigating the impact of extreme weather events on agricultural markets through trade.

Aguiar, A., Chepeliev, M., Corong, E.L., McDougall, R., and van der Mensbrugghe, D. 2019. The GTAP Data Base: Version 10. *Journal of Global Economic Analysis* 4 (1): 1–27. <https://doi.org/10.21642/jgea.040101af>

Aksoy, M. A., & Beghin, J. C. (Eds.). (2004). *Global agricultural trade and developing countries*. World Bank Publications.

- Anderson, K. (2014). The intersection of trade policy, price volatility, and food and nutrition security. *Annu. Rev. Resour. Econ.*, 6(1), 513-532.
- Anderson, K. (2009). Political Economy of Distortions to Agricultural Incentives: Introduction and Summary.
- Anderson, K., & Martin, W. J. (2008). Distortions to Agricultural Incentives in China and Southeast Asia.
- Aulerich, N. M., Irwin, S. H., & Garcia, P. (2014). Bubbles, food prices, and speculation: evidence from the CFTC's daily large trader data files. In *The economics of food price volatility* (pp. 211-253). University of Chicago Press.
- Baffes, J. (2013). A framework for analyzing the interplay among food, fuels, and biofuels. *Global FNS*, 2(2), 110-116.
- Baffes, J., & Kabundi, A. (2024). Do supercycles dominate commodity price movements?. *Economics Letters*, 237, 111646.
- Baffes, J., A. Kabundi, and P. Nagle. 2022. "The Role of Income and Substitution in Commodity Demand." *Oxford Economic Papers* 74(2): 498-522.
- Bagwell, Kyle and Robert W. Staiger (2002), *The Economics of the World Trading System*, The MIT Press, Cambridge, MA.
- Barret CB, 1996. Market analysis methods: Are our enriched toolkits well suited to enliven the markets? *American Journal of Agricultural Economics* 78(3): 825-9.
- Bellemare, Marc F. "Rising food prices, food price volatility, and social unrest." *American Journal of agricultural economics* 97, no. 1 (2015): 1-21.
- Boyd, N. E., Harris, J. H., & Li, B. (2018). An update on speculation and financialization in commodity markets. *Journal of Commodity Markets*, 10, 91-104.
- Brenton, P., Chemutai, V., & Pangestu, M. (2022). Trade and food and nutrition security in a climate change-impacted world. *Agricultural Economics*, 53(4), 580-591.
- Brunetti, C., Büyükkahin, B., & Harris, J. H. (2016). Speculators, prices, and market volatility. *Journal of Financial and Quantitative Analysis*, 51(5), 1545-1574.
- Burgess, R., & Donaldson, D. (2010). Can openness mitigate the effects of weather shocks? Evidence from India's famine era. *American Economic Review*, 100(2), 449-453.
- Capelle-Blancard, G., & Coulibaly, D. (2011). Index trading and agricultural commodity prices: A panel Granger causality analysis. *International Economics*, 126, 51-71.
- Carrico, C., Corong, E., and van der Mensbrugghe, D. 2020. The GTAP version 10A Multi-Region Input Output (MRIO) Data Base. GTAP Memorandum 34. Center for Global Trade Analysis, Purdue University. <https://www.gtap.agecon.purdue.edu/resources/download/10043.pdf>

- Chepeliev, M. 2022. Incorporating Nutritional Accounts to the GTAP Data Base. *Journal of Global Economic Analysis*, 7(1), 1–43. <https://doi.org/10.21642/JGEA.070101AF>
- CSIS (2023). Russia, Ukraine, and global food security: A two-year assessment. Center for Strategic and International Studies (CSIS). Caitlin Welsh. February 27. <https://www.csis.org/analysis/russia-ukraine-and-global-food-security-two-year-assessment>
- Cuddington, J. T., & Jerrett, D. (2008). Super cycles in real metals prices?. *IMF staff Papers*, 55(4), 541-565.
- Dwyer, Orla (2024). *Five charts: How climate change is driving up food prices around the world*. Carbon Brief. August 24. Retrieved from <https://www.carbonbrief.org/five-charts-how-climate-change-is-driving-up-food-prices-around-the-world/>
- Erten, B., & Ocampo, J. A. (2012). Building a stable and equitable global monetary system.
- European Council. (2023). “Ukrainian grain exports explained” <https://www.consilium.europa.eu/en/infographics/ukrainian-grain-exports-explained/>
- Food and Agriculture Organization of the United Nations (FAO) (2024). *Background - Global Information and Early Warning System (GIEWS)*. Retrieved from <https://www.fao.org/giews/background/en/>
- FAO and IIASA. (2021). Global Agro-Ecological Zones (GAEZ v4) - Data Portal user’s guide. FAO and IIASA. <https://doi.org/10.4060/cb5167en>
- Farrokhi, F., & Pellegrina, H. S. (2023). Trade, technology, and agricultural productivity. *Journal of Political Economy*, 131(9), 2509-2555.
- Freund, C., & Özden, Ç. (2008). Trade policy and loss aversion. *American Economic Review*, 98(4), 1675-1691.
- FSIN (2023). Global report on food crises 2023. Food Security Information Network. <https://www.fsinplatform.org/report/global-report-food-crises-2023/>
- Gatto, A., and Chepeliev, M. 2023. Mounting Nutritional and Environmental Pressures of the Global Food Loss and Waste Call for Urgent Policy Action. Research Square; 2023. DOI:10.21203/rs.3.rs-2761872/v1
- GIEWS, FAO.(2022) <https://fpma.fao.org/giews/fpmat4/#/dashboard/home>
- Gautam, Madhur; Mamun, Abdullah; Martin, Will; Vos, Rob. 2022. Repurposing Agricultural Policies and Support: Options to Transform Agriculture and Food Systems to Better Serve the Health of People, Economies, and the Planet. © World Bank, Washington, DC. <http://hdl.handle.net/10986/36875>
License: CC BY 3.0 IGO.

- Ghose, Devaki, Eduardo Fraga, and Ana Fernandes. Fertilizer Import Bans, Agricultural Exports, and Welfare: Evidence from Sri Lanka. Policy Research Working Paper No. 10642. The World Bank, 2023.
- Giordani, P. E., Rocha, N., & Ruta, M. (2016). Food prices and the multiplier effect of trade policy. *Journal of International economics*, 101, 102-122.
- Glauber, J., & Mamun, A. (2023). India's new ban on rice exports: potential threats to global supply, prices, and FNS'. *International Food Policy Research Institute* (<https://www.ifpri.org/blog/indias-new-ban-rice-exportspotential-threats-global-supply-prices-and-food-security>).
- Global Network Against Food Crisis and Food Security Information Network, 2023 *Global Report on Food Crises*
- Good, P. (2022). *The East India Company in Persia: Trade and Cultural Exchange in the Eighteenth Century*. Bloomsbury Publishing.
- Gornall J, Betts R, Burke E, Clark R, Camp J, Willett K, Wiltshire A. (2010) Implications of climate change for agricultural productivity in the early twenty-first century. *Philosophical Transactions of the Royal Society of London*. Sep 27;365(1554):2973-89
- Götz, L., Djuric, I., & Nivievskyi, O. (2016). Regional price effects of extreme weather events and wheat export controls in Russia and Ukraine. *Journal of Agricultural Economics*, 67(3), 741-763.
- Grossman Gene, Elhanan Helpman (1994). "Protection for sale." *American Economic Review* 84(4): 833-50.
- Hathaway, D. and Ingco, M. (1996), "Agricultural liberalization and the Uruguay Round" in Martin, W. and Winters, L.A. eds *The Uruguay Round and the Developing Countries*, Cambridge University Press, Cambridge.
- Hamilton, J. D., & Wu, J. C. (2014). Risk premia in crude oil futures prices. *Journal of International Money and Finance*, 42, 9-37.
- Hannah Ritchie (2017) - "How many people does synthetic fertilizer feed?" Published online at [OurWorldInData.org](https://ourworldindata.org/how-many-people-does-synthetic-fertilizer-feed). Retrieved from: '<https://ourworldindata.org/how-many-people-does-synthetic-fertilizer-feed>' [Online Resource]
- Headey, D. and Fan, S., 2010. *Reflections on the global food crisis: How did it happen? How has it hurt? And how can we prevent the next one?* (Vol. 165). Intl Food Policy Res Inst.
- IFPRI (2023). Despite improved global market conditions, high food price inflation persists. Vos, R., Glauber, J., Kim, S., & Martin, W. International Food Policy Research Institute (IFPRI). December 4. <https://www.ifpri.org/blog/despite-improved-global-market-conditions-high-food-price-inflation-persists/>

- Independent Evaluation Group, 2013. "The World Bank Group and the Global Food Crisis". Retried from: 'https://ieg.worldbankgroup.org/sites/default/files/Data/reports/food_crisis_eval_1.pdf'
- IMF. 2022. "Tackling the Global Food Crisis: Impact, Policy Response, and the Role of the IMF". IMF Note 2022/004
- Irwin, S. H., & Sanders, D. R. (2012). Financialization and Structural Change in Commodity Futures Markets. *Journal of agricultural and applied economics*, 44(3), 371-396.
- Jacks, D. S. (2019). From boom to bust: A typology of real commodity prices in the long run. *Cliometrica*, 13(2), 201-220.
- Jägermeyr, J., Müller, C., Ruane, A.C. and others. Climate impacts on global agriculture emerge earlier in new generation of climate and crop models. *Nature Food* 2, 873–885 (2021).
- Jayne, T. S. (2012). Managing food price instability in East and Southern Africa. *Global FNS*, 1(2), 143-149.
- Jerrett, D., & Cuddington, J. T. (2008). Broadening the statistical search for metal price super cycles to steel and related metals. *Resources Policy*, 33(4), 188-195.
- Kabundi, A., Mlachila, M., & Yao, J. (2022). How persistent are climate-related price shocks? Implications for monetary policy.
- Kee, Hiau Looi, Alessandro Nicita, and Marcelo Olarreaga (2008), Import Demand Elasticities and Trade Distortions, *The Review of Economics and Statistics* 90(4), 666-682.
- Kee, Hiau Looi, Alessandro Nicita, and Marcelo Olarreaga (2009), Estimating Trade Restrictiveness Indices, *The Economic Journal* 119, 172-199.
- Kinnucan, H. W. (2022). A note on the correspondence between horizontal and vertical price transmission. *Journal of Agricultural Economics*, 73(3), 654-665.
- Klümper, W., & Qaim, M. (2014). A meta-analysis of the impacts of genetically modified crops. *PloS one*, 9(11), e111629.
- Kotz, M., Kuik, F., Lis, E. and others. Global warming and heat extremes to enhance inflationary pressures. *Commun Earth Environ* 5, 116 (2024). <https://doi.org/10.1038/s43247-023-01173-x>
- Laborde Debucquet, D., & Mamun, A. (2022). *Documentation for Food and Fertilizers Export Restriction Tracker: Tracking export policy responses affecting global food markets during crisis* (Vol. 2). Intl Food Policy Res Inst.
- Lenzen, M., Moran, D., Kanemoto K., Geschke, A. 2013. Building Eora: a global multi-region input-output database at high country and sector resolution. *Econ Syst Res* 25(1):20–49. <https://doi.org/10.1080/09535314.2013.769938>

- Li, Y., Ye, W., Wang, M., & Yan, X. (2009). Climate change and drought: a risk assessment of crop-yield impacts. *Climate research*, 39(1), 31-46.
- Loayza, N. V., & Raddatz, C. (2010). The composition of growth matters for poverty alleviation. *Journal of development economics*, 93(1), 137-151.
- Martin, W. (2017). *Agricultural trade and food and nutrition security* (No. 664). ADBI Working Paper.
- Martin, W., & Anderson, K. (2012). Export restrictions and price insulation during commodity price booms. *American Journal of Agricultural Economics*, 94(2), 422-427.
- Martin, W., & Ivanic, M. (2016). Food price changes, price insulation, and their impacts on global and domestic poverty. *Food price volatility and its implications for FNS and policy*, 101-113.
- Martin, Will & Mamun, Abdullah & Minot, Nicholas. (2024). Food Trade Policy and Food Price Volatility. 10.13140/RG.2.2.27235.12329.
- Martin, W., & Minot, N. (2022). The impacts of price insulation on world wheat markets during the 2022 food price crisis. *Australian Journal of Agricultural and Resource Economics*, 66(4), 753-774.
- Minot, N. (2014). Food price volatility in sub-Saharan Africa: Has it really increased?. *Food Policy*, 45, 45-56.
- Moritz, S., & Bartz-Beielstein, T. (2017). imputeTS: time series missing value imputation in R. *R Journal*, 9(1).
- Nickell, S. (1985) Error correction, partial adjustment and all that: an expository note, *Oxford Bulletin of Economics and Statistics*, 47, 119-29.
- Ojeda-Joya, J. N., & Guzman, O. E. (2019). The size of fiscal multipliers and the stance of monetary policy in developing economies. *Contemporary Economic Policy*, 37(4), 621-640.
- Peck, Anne E. (1981), "The Adequacy of Speculation on the Wheat, Corn, and Soybean Futures Markets." *Research in Domestic and International Agribusiness Management*, 2: 17-29.
- Prebisch, Raúl (1950), "The Economic Development of Latin America and its Principal Problems", reprinted in *Economic Bulletin for Latin America*, Vol. 7, No. 1, 1962, 1-22.
- Reuters. (2023) "Ukraine boosts grain deliveries to Black Sea ports as new export route working" <https://www.reuters.com/world/europe/ukraine-boosts-grain-deliveries-black-sea-ports-new-export-route-working-2023-10-30/>
- Rocha, N., & Espitia, A. (2023). One year after Ukraine invasion, food export curbs have subsided, but concerns remain. *World Bank*. <https://blogs.worldbank.org/trade/one-year-after-ukraine-invasion-food-export-curbs-have-subsidedconcerns-remain>.

- Rulli, M. C., Bellomi, D., Cazzoli, A., De Carolis, G., & D'Odorico, P. (2016). The water-land-food nexus of first-generation biofuels. *Scientific reports*, 6(1), 22521.
- Saikkonen, P., & Choi, I. (2004). Cointegrating smooth transition regressions. *Econometric theory*, 20(2), 301-340.
- Singer, H. W. (1950), "U.S. Foreign Investment in Underdeveloped Areas: The Distribution of Gains Between Investing and Borrowing Countries," *American Economic Review, Papers and Proceedings*, 40, 473-485.
- Stadler, K., Wood, R., Bulavskaya, T., and others. 2018. EXIOBASE 3: Developing a time series of detailed environmentally extended multi-regional input-output tables. *J. Ind. Ecol.* 22, 502–515 (2018).
- Stoll, H. R., & Whaley, R. (2010). Commodity index investing and commodity futures prices. *Journal of Applied Finance (Formerly Financial Practice and Education)*, 20(1).
- TASS. (2022) <https://tass.com/economy/1422097>
- Timmer, C. P. (2010). Reflections on food crises past. *Food policy*, 35(1), 1-11.
- Tokgoz, S., Laborde, D., Lallemand, T., Majeed, F., & Martin, W. (2017). Introducing the Agincentives Consortium and Database. In *20th Annual Conference on Global Economic Analysis, West Lafayette, IN*.
- UN Comtrade data base, 2022, <https://comtrade.un.org/>
- UNCTAD. (2022). Review of maritime transport. United Nations Conference for Trade and Development, United Nations, Geneva
- USDA (2024). World Agricultural Supply and Demand Estimates. U.S. Department of Agriculture. January. <https://www.usda.gov/oce/commodity/wasde/wasde-0125.pdf>
- van der Mensbrugghe, D. 2019. The Environmental Impact and Sustainability Applied General Equilibrium (ENVISAGE) Model. Version 10.01. Center for Global Trade Analysis, Purdue University. <https://mygeohub.org/groups/gtap/envisage-docs>
- Von Cramon-Taubadel, S., & Goodwin, B. K. (2021). Price transmission in agricultural markets. *Annual Review of Resource Economics*, 13, 65-84.
- World Bank. 2012. Using Public Foodgrain Stocks to Enhance FNS. REPORT NUMBER 71280-GLB
- World Bank. 2012. Responding to Higher and More Volatile World Food Prices. REPORT NUMBER 68420-GLB
- World Bank. 2013. "Global Food Crisis Response Program." <https://www.worldbank.org/en/results/2013/04/11/global-food-crisis-response-program-results-profile#:~:text=In%20mid%2D2008%2C%20the%20world,compared%20to%20the%20mid%2D2007>.

- World Bank (2014). *Un modelo de México para el mundo*. Feature Story. November 19. Retrieved from <https://www.worldbank.org/en/news/feature/2014/11/19/un-modelo-de-mexico-para-el-mundo>
- World Bank (2020). *Strengthening conditional cash transfers and the single registry in Brazil*. Results Briefs. April 22. Retrieved from <https://www.worldbank.org/en/results/2020/04/22/strengthening-conditional-cash-transfers-and-the-single-registry-in-brazil>
- World Bank (2022). *What you need to know about food security and climate change*. Interview with William Sutton. Retrieved from <https://www.worldbank.org/en/news/feature/2022/10/17/what-you-need-to-know-about-food-security-and-climate-change>
- World Bank (2024). Agriculture and Food. <https://www.worldbank.org/en/topic/agriculture/overview>
- World Grain. (2023) Panama Canal drought slowing grain shipments. <https://www.world-grain.com/articles/19383-panama-canal-drought-slowing-grain-shipments>

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

Author(s)	Main Conclusion	Methods	Data	Commodity
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 during the storage season. For wheat, it is the highest near harvest and lowest during November through March.	Review paper		
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:

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.

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.

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

The background paper by Hoffmann et al. (2024) 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.

This annex describes the methodology used.

The paper uses the smooth transition 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.¹⁸

18 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.

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

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

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:

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

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

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

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 ν , ε will decrease. However, if $\varepsilon = 1$, then changes in p^I and ν 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.

Equations (3), (4) and (5) describe partial changes to elasticities driven by p^I , ν , s , and TC . However, the *ceteris paribus* condition will rarely hold in reality; changes in p^I , ν , 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, ν 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:

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

This derivative will be negative or positive depending on the relative magnitudes of ν 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 ν and s . When p^I , ν , 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).

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 $\varepsilon < 0$.

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.

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 $\varepsilon > 1$.

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

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

where the subscript t is an index of time and u is a stochastic error term.

In equation (7), β_1 captures the term $(1+\nu)$ in equation (1), β_0 captures $s + OTC$, and the elasticity of international to domestic price transmission is given by:

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

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 ν . 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.

Moving from comparative statics to econometrics, if ν , 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 ν , 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.

The Error Correction Model (ECM) has been the dominant model used in price transmission analysis since the mid-1990s.¹⁹ 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:

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

In equation (9), the first term on the right-hand-side $\left(p_{t-1}^D - \beta_0 - \beta_1 p_{t-1}^I - \beta_2 TC_{t-1} \right)$ 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.²⁰ 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.

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.²¹ They found evidence for cointegration between 37 of these domestic price series

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

20 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.

21 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.

and the international price. For those 37 series, they estimate an average elasticity of price transmission of 0.765.²² 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. In the second step of their analysis, Martin and Minot (2022) modeled the effects of this insulation on how international prices respond to shocks.

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

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.

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:

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

²² Since Martin and Minot (2022) estimate using the logarithms of prices, their estimates of β_1 can be directly interpreted as elasticities.

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

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

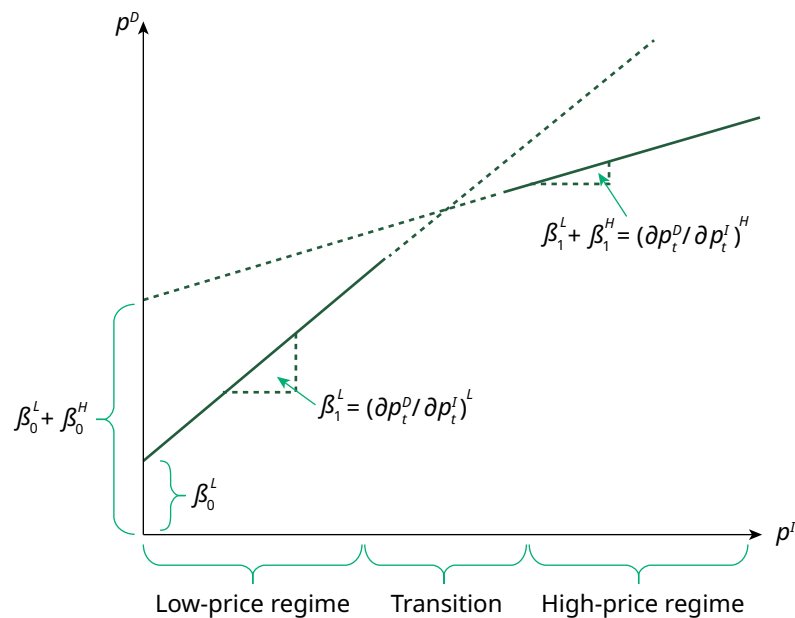
In equation (10), the function $g(\cdot)$ ranges from 0 for low values of p_t^I to 1 for high values. When $g(\cdot) = 0$, the long-term relationship between p_t^I and p_t^D is $p_t^D = \beta_0^L - \beta_1^L p_t^I$, which we refer to as the low-price regime. When $g(\cdot) = 1$, the long-term relationship 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 in equation (11) 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 $\gamma \rightarrow \infty$ 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.

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.

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 $\beta_1^L = \left(\partial p_t^D / \partial p_t^I \right)^L$ 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 Insulation



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:

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

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:

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

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,²³ 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.

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

²³ For small values of the tariff, $\tau = \ln(1 + t^*)$ is approximately equal to t^* .

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:

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

where α is a discount factor ($0 < \alpha \leq 1$); the quadratic function $(p_t^d - p_{t-1}^d)^2$ represents the costs of changing domestic prices and $a(p_t^d - p_t^*)^2$ 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,²⁴ aligns with the behavior of most of the world price series under study. This results in a simple, parsimonious ECM.

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

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.

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

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:

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

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

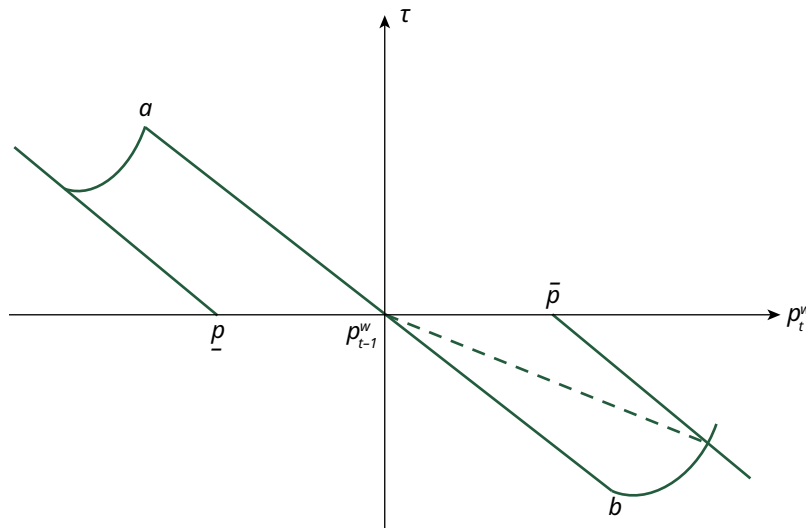


Figure A5.1, drawing on Figure 4 of Freund and Özden (2008) and Figure 3 of Giordani et al. (2016), is useful in identifying at least two ways in which a finding that $\delta < 1$ might be consistent with behavioral theory while avoiding potentially dire implications for market stability. In this figure, 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 $\bar{p}$, then the compensating reduction in protection associated with a world price increase does not begin until the world price reaches $\bar{p}$. 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.

