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Trade Risk and Food Security*

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Abstract

International trade provides critical access to food, yet many food-importing countries protect agriculture even where productivity is low. We study how the risk of trade disruptions shapes food security, the global distribution of production, and optimal policy. We document that reliance on imported staples is linked to higher food insecurity, particularly in poorer countries. Exploiting the Ukraine–Russia war, we find that districts in Ethiopia more exposed to disrupted imports suffered sharper declines in food security. We develop a multi-sector model of trade with stochastic trade costs and non-homothetic preferences. Uncertainty over trade costs induces a risk–return trade-off in sourcing, leading importers to reallocate toward domestic production or more reliable partners. Quantitatively, food importers retreat most from trade, reallocate resources to agriculture, and face higher food insecurity. We analytically characterize and quantify optimal agricultural protection as insurance that fosters resilience to trade disruptions. Productivity growth can substitute for protection by reducing exposure to risk.

JEL classification: E10, F10, F60, I30, O11, 041.

Keywords: food security, trade, risk, structural change, productivity, trade policy.

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1 Introduction

Large differences in agricultural productivity across countries have made international trade a key channel for securing reliable access to food. For example, in Djibouti and Jordan 100 percent of their cereal consumption needs in 2018 were accounted for by imports of cereals.[1] International trade yields welfare gains by enabling specialization according to comparative advantage and by providing insurance against idiosyncratic production shocks. Yet, despite these potential gains, many food-importing countries systematically protect their domestic agricultural sectors even where productivity is low, pushing against specialization based on comparative advantage.

Exposure to the risk of trade disruptions can carry large welfare costs given that food is indispensable in consumption, making reliance on foreign suppliers inherently vulnerable and suggesting a motive for protection even with low agricultural productivity. Recent shipping disruptions and climate-related shocks, together with rising trade policy uncertainty and geopolitical tensions, have made these risks increasingly salient (Caldara and Iacoviello 2022; Caldara et al. 2020). Historically, famines and severe food crises often arose not from lack of domestic production but from disruptions to trade and distribution (Sen, 1981; Ó Gráda, 2007). Access risks may also be policy-driven, for example through export controls or trade restrictions that limit access to essential goods and operate like sharp increases in trade costs. Therefore, reliability can be just as important as cost, offering an economic rationale for why food security and agricultural protection are central policy priorities for national governments and international institutions (U.N. Sustainable Development Goals; Anderson et al. 2011).

In this paper, we study how exposure to trade risk affects food security and shapes governments' incentives to protect domestic agriculture. We show that even when international trade delivers efficiency gains, the possibility of rare but severe disruptions can fundamentally alter production and policy choices. We combine novel empirical evidence with a multi-country, multi-sector model in which stochastic trade costs, non-homothetic preferences, and ex-ante sourcing under uncertainty jointly determine food security, the global distribution of production, and optimal policy. Exposure to trade risk induces food-importing countries to reallocate resources toward domestic agriculture and adopt protective policies as insurance against food import disruptions, increasing resilience at the expense of foregone gains from specialization. Our analysis provides a novel rationale for the persistence of agricultural production and protection, even in low-productivity countries. We show that

[1] See FAOSTAT, Food Security Indicators, "Cereal Import Dependency Ratio," https://www.fao.org/faostat.

food insecurity arising from trade risk and the endogenous retreat from global markets leads to a re-evaluation of the traditional welfare gains from openness.

Our paper makes four key contributions. First, we assemble novel evidence on the frequency and magnitude of food trade disruptions and show that reliance on imported staples is systematically associated with higher food insecurity across countries, particularly in lower-income economies. We complement this with evidence from the 2022 Ukraine–Russia war, showing that Ethiopian districts more exposed to disrupted imports experienced larger declines in food security. Second, we develop and estimate a multi-country, multi-sector general equilibrium model in which importing firms choose suppliers before trade costs are realized and households have non-homothetic preferences over food, generating a precautionary motive to shift production toward domestic agriculture under trade risk. Third, we use the model to quantify the effects of rare trade disruptions on production, trade flows, and welfare, showing that countries with high food import dependence and high food expenditure shares experience sharp welfare losses in response to severe disruptions. Fourth, we use the model to characterize optimal policy both analytically and quantitatively, showing that trade risk generates a resilience motive for agricultural protection, providing an explanation of why net food importers tend to protect agriculture despite their comparative disadvantage. We also show that productivity enhancing reforms can substitute for protection by mitigating exposure to import disruptions.

This paper contributes to a growing literature that reexamines the gains from trade in the presence of risk. While canonical models emphasize gains from specialization and variety, we show that exposure to rare but severe disruptions can alter countries' production incentives and policy choices in fundamental ways. This mechanism offers a unified explanation for the persistence of agricultural production in low-productivity countries and the prevalence of agricultural protection among net importers. More broadly, the mechanism that we study applies to other essential goods such as energy, medical supplies, and critical inputs, whose global supply chains are vulnerable to disruption. The growing prevalence of export controls and sanctions illustrates how trade can be manipulated, creating sudden access risks akin to trade-cost shocks for importing economies. Our analysis, thus, informs current debates on trade resilience, strategic autonomy, and the limits of globalization.

We begin by documenting key empirical patterns on the relation between trade risk, food security, and policy. First, using historical data on food import volumes across countries from 1961 to 2023, we identify trade disruptions as large year-over-year declines in imports. Episodes involving drops of 20 percent or more are infrequent but recurring, occurring in about 10 percent of country-years. Second, using recent cross-country data, we show that greater reliance on cereal imports is associated with higher food insecurity, especially among poorer importers. Third, we provide micro-level evidence on the effect of trade disruptions for food security, exploiting the exogenous shock to Black Sea export capacity caused by the Ukraine–Russia war, which impeded access to critical food imports for Ethiopian consumers through port closures and maritime route blockages. Employing a shift-share approach, and utilizing geographic variation in import penetration prior to the war, we find that districts in Ethiopia more exposed to imports from the conflict countries experienced a significantly larger decline in food security. Fourth, using data on the nominal rate of assistance, we document that net food importers systematically protect domestic agriculture more than exporters, a pattern that pushes against the specialization implied by comparative advantage.

To interpret these patterns, we develop a multi-country multi-sector general equilibrium model of international trade risk and structural change, with uncertainty in trade costs and imperfect risk-sharing. The model allows us to study how the risk of trade disruptions affects food security, production and trade patterns, welfare, and optimal policy. A key conceptual novelty of the model lies in the interaction between trade risk and non-homothetic preferences. Importers choose suppliers before trade costs are realized, making sourcing decisions subject to uncertainty and giving rise to an ex-ante risk-return trade-off. We show analytically that trade risk generates a precautionary motive in sourcing: importers facing uncertainty about future trade costs weigh not only partners' cost advantages but also the risk premia associated with them. This risk–return trade-off leads them to substitute cheaper but riskier imports with domestic production (re-shoring) or with costlier but safer foreign suppliers (friend-shoring).

Our main quantitative experiment stress-tests the global economy under a tail-risk scenario capturing rare but severe food trade disruptions. We compare the equilibrium allocations in a risk-free world to those implied by our model when a low-probability, high-impact shock limits access to imported food in some states of the world. The disruption probability is set at 10 percent, consistent with the historical frequency of large import shortfalls and recent spikes in geopolitical and trade policy risk (Barro and Ursúa, 2012; Caldara et al., 2020; Caldara and Iacoviello, 2022). The experiment assesses how trade risk reshapes global production and trade patterns, food security, welfare, and optimal policy responses. To implement it, we calibrate a multi-country, multi-sector model spanning 70 countries and the rest of the world, with traded agriculture and manufacturing sectors and a non-traded services sector, using data from FAOSTAT, the OECD's TiVA database, and the World Bank's International Comparison Project.

We find large and systematic effects of trade risk on trade, production, food insecurity, and welfare. Trade risk leads all countries to reduce their participation in international trade, especially those initially most exposed. Countries retreat from trade as a self-insurance mechanism against the possibility of losing access to imported goods, particularly critical ones like food. Food importers shift their sourcing toward domestic agricultural production, in proportion to their initial agricultural trade deficits. On average, the share of labor in agriculture in food importing countries increases by 7.9 percent. The risk of losing access to food imports raises food insecurity, manifested in lower consumption and higher prices. As a result, trade risk lowers welfare by heightening food insecurity and reducing participation in international trade, thereby eroding the traditional gains from trade. These "risk costs" of globalization are particularly large for major food importers.

We next use our framework to study optimal tariffs and production subsidies, policy instruments governments often use to protect domestic agriculture. We begin by characterizing optimal tariffs under risk in a one-sector version of our model and comparing them to those in a world without risk. This allows us to analytically show that there are three motives for policymakers to impose tariffs under trade risk. The first is the traditional terms-of-trade motive: to exploit market power and improve national welfare, which is stronger when trade is risk-free and volumes are larger. The second is a resilience motive, as imports contribute relatively less to welfare in adverse states, inducing the planner to reallocate toward more reliable domestic production and import sources. The third arises from the state-contingent value of tariff revenue: tariff receipts are worth less in precisely the states where marginal utility is highest, which attenuates the incentive to raise tariffs under risk. These policy incentives arise from two key features of the environment: incomplete markets, which prevent agents from insuring consumption across states of the world, and terms-of-trade externalities, whereby individual importers do not internalize how their sourcing decisions affect world prices and aggregate exposure. As a result, private sourcing decisions do not fully reflect the value of reducing vulnerability to trade disruptions, leading the planner to set higher tariffs to strengthen resilience and welfare.

Next, we quantify how trade risk alters optimal tariffs and production subsidies in the full estimated model. Each country sets a uniform ad valorem import tariff and a production subsidy for domestic agriculture to maximize domestic welfare, accounting for how these instruments affect equilibrium sourcing and prices. Introducing trade risk raises both optimal tariffs and subsidies, but the effect is much stronger for food-importing countries. The optimal tariff for net importers increases by about 14 percentage points relative to the no-risk benchmark (from 14.4% to 28.3%), compared with a 6-point rise for net exporters. Similarly, optimal production subsidies rise by 4.2 points for importers and only 1.4 for exporters. Across countries, the increase in optimal protection is strongly negatively correlated with agricultural net exports: economies with larger agricultural trade deficits raise tariffs and subsidies more when risk is introduced. These results show that trade risk systematically strengthens the incentive for food-importing countries to adopt protective policies, mirroring the empirical patterns observed in the data.

While our multi-country model of trade risk and optimal policy analysis have broader relevance for understanding global trade under uncertainty, its sectoral dimension provides key insights into structural change and development. We illustrate the implications of our analysis for structural change in three steps. First, we show that with standard CES preferences (abstracting from non-homtheticities), the retreat from trade and the shift to domestic agricultural production are considerably attenuated for large food importers. This shows that non-homotheticities are important in mediating the effects of trade risk, particularly for countries that rely heavily on imports of agricultural goods. Second, we show that conditional on trade imbalances, risk disproportionately shifts resources towards domestic agricultural production in countries with high expenditure shares on food. The implication is that trade risk is a larger obstacle to trade and structural change for countries at earlier stages of their structural transformation process. This occurs because the utility cost of downside risk is greater for countries closer to subsistence, prompting stronger self-insurance retreat from trade. Third, we show that potential improvements in domestic agricultural productivity – often part of the development process but also achievable through targeted policy – can endogenously reduce exposure to trade risk and lessen the need for protective measures in lower-income importing countries.

Our paper contributes to a broad literature on international trade, uncertainty, and resilience. The long-run gains from trade through specialization, comparative advantage, and variety are well understood in models under certainty (Eaton and Kortum, 2002; Arkolakis et al., 2012). We show that accounting for the risk of trade disruptions can substantially reduce the benefits of globalization, especially for food-importing countries that depend on reliable access to essential goods. Our work complements the literature highlighting the role of trade in diversifying country-specific production risk (Cole and Obstfeld, 1991; Costinot et al., 2016; Fitzgerald, 2024) by focusing instead on *trade risk*—stochastic shocks to the trading technology itself. Related studies incorporate uncertainty into multi-sector or multi-location trade models (Burgess and Donaldson, 2012; Caselli et al., 2020; Allen and Atkin, 2022; Handley and Limão, 2017, 2022; Esposito, 2022; Gervais, 2018; Kramarz et al., 2020), and examine resilience through ex-ante investments in logistics and capacity (Kleinman et al., 2025). We differ in emphasizing *tail* trade risk, ex-ante sourcing under uncertainty, and the role of essential goods in shaping welfare and policy. Our analysis also connects to the literature on production networks and supply-chain resilience (Acemoglu et al., 2012; Carvalho et al., 2021; Elliott et al., 2022; Grossman et al., 2023), particularly Castro-Vincenzi et al. (2024), who study how firms diversify suppliers under climate risk. In contrast, we focus on global food trade, where aggregate disruptions—rather than local production shocks—propagate across countries, inducing precautionary reallocation toward safer partners and domestic agriculture, and motivating optimal protective policies.

Our work also relates to the literature on protectionist policy motives and the effects of trade disruptions. Several studies examine how governments respond to shocks through political or geopolitical channels: Hsiao et al. (2024) show that agricultural policies react to climate-induced production shocks through redistribution across interest groups, while Becko et al. (2025) highlight how geopolitical alignment considerations can raise optimal tariffs beyond traditional terms-of-trade motives. In contrast, we emphasize a non-political insurance rationale for agricultural protection: in our framework, trade cost shocks create an incentive for governments to insure domestic consumers against food import risk, making protection optimal even absent lobbying or strategic concerns. A related strand of work analyzes the economic consequences of trade disruptions themselves (Baqaee et al., 2022; Attinasi et al., 2023; Baqaee et al., 2023; Leibovici and Santacreu, 2023), focusing on ex-post responses to specific events such as the Ukraine–Russia war or U.S.–China decoupling. We instead study how the *ex-ante* risk of such disruptions shapes trade patterns and the design of optimal policies.

Our analysis also contributes to the macro-development literature on structural change—the shift from agriculture to manufacturing and services, a defining feature of the development process (Herrendorf et al., 2014). A long line of research has studied mechanisms driving this transformation, including non-homothetic preferences, changes in technology, and factor accumulation (Kongsamut et al., 2001; Ngai and Pissarides, 2007; Acemoglu and Guerrieri, 2008; Boppart, 2014; Comin et al., 2021). We adopt the preference structure of Comin et al. (2021) to capture income-driven structural change effects. A parallel literature explores how openness to trade shapes structural transformation in an open economy (Matsuyama, 1992; Tombe, 2015; Teignier, 2018; Lewis et al., 2022; Sposi et al., 2021; Gollin et al., 2025), but this work abstracts from risk. Chen et al. (2024) examine food security risk within countries and its implications for domestic insurance policies. In contrast, we focus on how *international* trade risk shapes food security, global production and trade patterns, and the rationale for protective agricultural policies.

Finally, our focus on food security also speaks directly to the literature on agriculture and macro-development. A large body of work studies why agricultural productivity is low in developing countries, and yet such a large share of the population is employed in agriculture — see, for instance, Restuccia et al. (2008), Caselli (2005), Lagakos and Waugh (2013), Adamopoulos and Restuccia (2014), Gollin et al. (2014), Brooks and Donovan (2020), Donovan (2021), Adamopoulos and Restuccia (2022), among others. We contribute to this literature by studying the role of international trade risk in shaping the sectoral allocation of labor and productivity within and across countries mediated by considerations about food security. While we emphasize the risk associated with losing access to essential imported goods in consumption, Brooks and Donovan (2025) study at the micro-level the risk of losing access to key inputs in agricultural production such as fertilizer.

The paper proceeds as follows. Section 2 presents aggregate stylized facts on food insecurity and micro-level evidence from Ethiopia during the Ukraine-Russia war. Section 3 develops our model of international trade risk and structural change. Section 4 presents the estimation of the model and Section 5 the main quantitative results. In Section 6 we analytically characterize and quantify optimal policy interventions. Section 7 discusses the development implications of our theory. Section 8 concludes.

2 Evidence on Trade Risk, Food Insecurity, and Policy

We begin by documenting salient features of the data linking food import dependence, food insecurity, and policy behavior across countries. Trade risk, understood as uncertainty about shocks that disrupt trade flows between countries, plays a central role in shaping these outcomes. Unlike country-specific production shocks such as droughts, which trade can help insure against, trade risk is inherently bilateral because a disruption at either end of the trade relationship can restrict access to essential goods. Because food is a basic consumption necessity, disruptions to international sourcing can have far-reaching implications for food security, welfare, and policy.

The analysis proceeds in four steps. First, we document the incidence of large food import disruptions and the heightened risks observed in recent years. Second, we show that reliance on food imports is systematically related to food insecurity across countries. Third, exploiting the exogeneity of the Ukraine–Russia war as a major food trade breakdown event, we study its causal effects on the food security of a developing country where food represents an important component of consumption. Fourth, we document that food-importing countries systematically protect domestic agriculture more than exporters, contrary to the pattern of specialization based on comparative advantage.

2.1 Food Trade Risks

We begin by documenting the frequency and magnitude of food trade disruptions across countries and place them in the context of rising geopolitical and trade policy risks in recent years.

Food trade disruptions. To identify episodes of food trade disruptions, we use annual data from the Food and Agricultural Organization (FAO) on the volume of food imports by country from 1961 to 2023, covering all countries with available data.[2] We define a food trade disruption as a year-over-year decline in food imports exceeding a threshold $X\%$. The main analysis uses a threshold of 20 percent, which captures infrequent but substantial import downturns.[3] Following the macroeconomics rare-disasters literature (e.g., Barro and Ursúa, 2012), we compute the probability of a food trade disruption as the share of disruption events relative to all country–year observations.

With a 20 percent threshold, we identify 1,051 trade disruptions in the data, corresponding to an estimated annual probability of 9.5 percent (1,051/11,034). The average decline in import volumes during these episodes is 34 percent. Figure 1 presents the distribution of disruption sizes across all countries and years. Although infrequent, food trade disruptions are recurrent features of global food trade. The results are robust to alternative thresholds for defining disruption events.

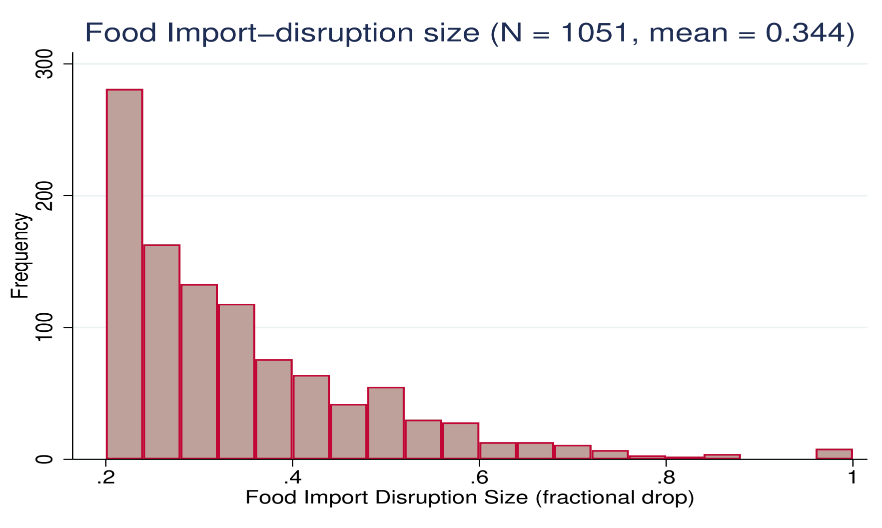
While some import declines could reflect demand contractions, several factors suggest they primarily capture trade disruptions. The 20 percent threshold isolates sharp and infrequent breaks rather than cyclical fluctuations that would typically arise from domestic demand changes. Many of these episodes coincide with observable external shocks such as conflicts, export bans, or transport bottlenecks, and our goal is to characterize the frequency of such large import shortfalls rather than identify each causal event.

Heightened recent risks. In recent years, geopolitical risks and trade policy uncertainty are on the rise, with direct implications for food trade. We consider the global geopolitical risk index (GPR) from Caldara and Iacoviello (2022), and the trade policy uncertainty index

[2]The data are from the "Trade Indices" of the FAOSTAT database, series *Import Quantity Index (2014–2016=100)*, which includes all crops and livestock products. Downloaded from https://www.fao.org/faostat/en/#data/TI, May 23, 2025.

[3]This threshold follows the rare–disasters literature, which classifies extreme events using large declines in macro aggregates (e.g., $\geq 10\%$ drops in consumption or GDP; Barro and Ursúa, 2012). The choice aims to exclude routine business–cycle variation while capturing severe disruptions. Using 15 and 25 percent cutoffs yields disruption frequencies of 12.7 and 6.8 percent, respectively.

Figure 1: Histogram of Trade Disruptions



Notes: Food import disruption frequencies by size. Data on volume of imports for crops and livestock products from FAOSTAT, all countries, 1961-2023. A food import disruption is measured as a proportionate decline in the food import quantity index of 20% or more.

(TPU) from Caldara et al. (2020).[4] Both the indices are textual analysis based-metrics of the frequency of occurrences of geopolitical tensions and trade policy instability from newspaper articles in major newspapers. In Figure 2 we plot the monthly GPR in Panel A and TPU in Panel B, for the last 20 years. As can be seen the geopolitical risk index spikes at the onset of the Ukraine-Russia war due to the hightened geopolitical volatility of the period since 2022. The trade policy uncertainty index initially spikes in the second half of the 2010s during the US-China trade tensions, followed by a sharp spike since the end of 2024 associated with the US trade policy re-alignment.

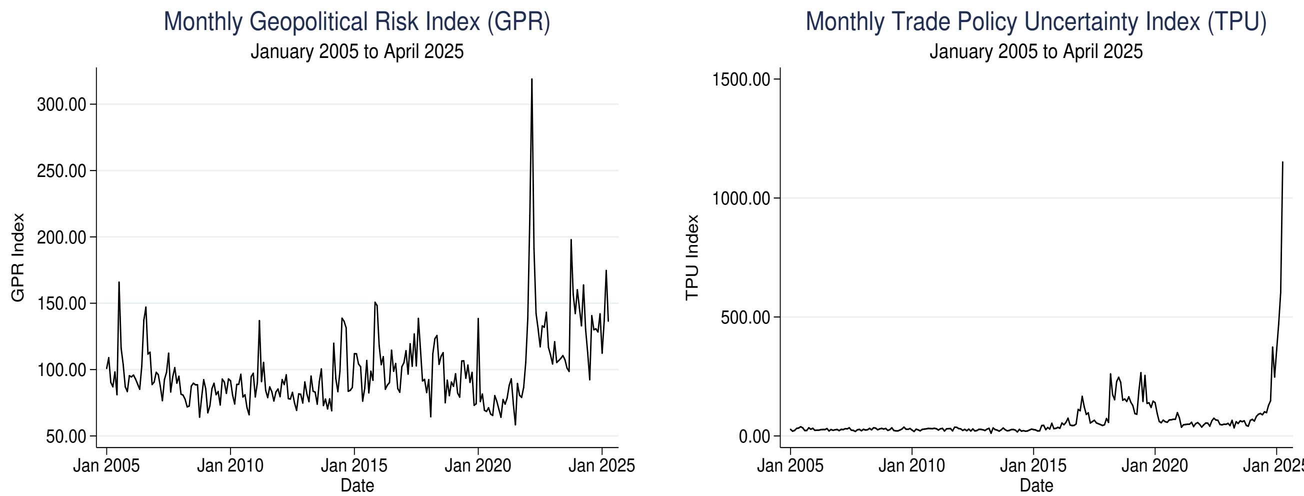
2.2 Food Insecurity and Trade Across Countries

The evidence above shows the prevalence of large food trade disruptions, raising the question of whether reliance on imported food is associated with greater vulnerability of food security. To examine this relationship, we use cross-country data from the Food and Agricultural Organization (FAO). The FAO constructs comparable measures of perceived food insecurity across countries based on survey responses about households' experiences and difficulties in accessing food. We use the prevalence of moderate to severe food insecurity in the population

[4]The GPR index is available at https://www.matteoiacoviello.com/gpr.htm and the TPU index at https://www.matteoiacoviello.com/tpu.htm. Both downloaded May 22, 2025.

Figure 2: Risk Indices

A: Geopolitical Risk B: Trade Policy Uncertainty



Notes: Monthly GPR and TPU indices, January 2005-April 2025.

(percent) reported by FAOSTAT, which does not rely on the use of a particular set of prices.

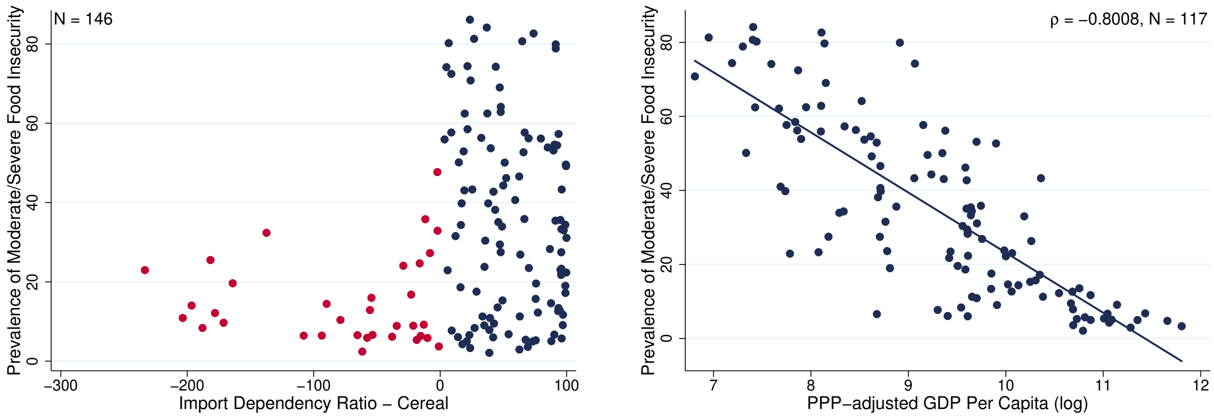
Panel A of Figure 3 plots the prevalence of moderate to severe food insecurity against the import dependency ratio for cereals, defined as net imports (imports minus exports) relative to domestic absorption. Positive values correspond to net importers (shown in blue) and negative values to net exporters (shown in red). Many countries rely heavily on cereal imports to meet domestic demand, in some cases by as much as 100 percent. On average, the prevalence of moderate to severe food insecurity is more than twice as high among net importers as among net exporters (35.3 versus 14.9 percent). This mean difference, however, masks considerable dispersion within the group of net importers. While exporters tend to cluster around the low mean, some importing countries experience very high rates of food insecurity while others report little to none. As Panel B of Figure 3 shows, the variation within importers is systematically negatively correlated with income: lower-income importing countries tend to have higher food insecurity than higher-income ones.[5]

The relations that we document are robust to alternative measures of food insecurity. In Appendix A we consider two additional FAOSTAT indicators: the prevalence of undernourishment in the population and the relative volatility of consumer food prices to general prices.

[5]Data on the prevalence of moderate to severe food insecurity, the cereal import dependency ratio, and real GDP per capita in PPP-adjusted international dollars for all countries and years are obtained from FAOSTAT, "Food Security and Nutrition/Suite of Food Security Indicators," https://www.fao.org/faostat. Downloaded December 7, 2024. Figures are based on averages of these variables over 2014–2022.

Figure 3: Food Insecurity Across Countries

Panel A: Cereal Import Status　　　Panel B: Income (net importers)



Notes: Each point in the scatter plots represents a country. The y-axis measures the prevalence of moderate to severe food insecurity in the population. The x-axis measures the import dependency ratio for cereals (Panel A) and log - real GDP per capita (Panel B).

Both measures yield patterns similar to those for the experiential indicator above—food insecurity is on average higher and more dispersed among cereal importers than among exporters. These associations remain economically and statistically significant even after controlling for differences in real GDP per capita across countries.

2.3 Micro-Evidence from the Ukraine-Russia War

While the cross-country patterns above reveal a strong association between food insecurity and reliance on food imports, they do not identify a causal effect of trade disruptions. To assess whether actual trade shocks affect food security at the micro level, we exploit the exogeneity of the Ukraine–Russia war as a major food trade disruption. The conflict disrupted exports from two of the world's largest suppliers of cereals and vegetable oils, on which many African countries, especially in Eastern Africa, depend heavily for basic consumption needs. In particular, Black Sea port closures and maritime route blockages sharply limited access to Ukrainian and Russian grain, creating a sudden shock to import availability.

We focus on Ethiopia, a large Eastern African economy that relies substantially on imports of wheat and sunflower oil from Ukraine and Russia. Our identification strategy uses variation across districts in pre-war exposure to these imports. Districts that consumed a larger share of these goods prior to the war were more exposed to the subsequent disruption.

Comparing changes in food insecurity across districts with different degrees of pre-war import dependence allows us to isolate the impact of the trade shock on household food security.

We use microdata for Ethiopia from the World Bank's *High Frequency Phone Survey (HFPS) 2020–2023*, a nationally representative, longitudinal survey that tracks households' socio-economic conditions through repeated phone interviews. The survey includes detailed questions on food security, such as whether households "ate only a few kinds of foods" or "ate less than they thought they should." We focus on these two measures as complementary indicators of food insecurity. The HFPS is part of the Living Standards Measurement Study – Integrated Surveys on Agriculture (LSMS-ISA) program, which allows us to link it to the earlier 2018–2019 in-person LSMS survey for Ethiopia. From this baseline survey we obtain detailed information on household food consumption, production, and market participation, which we use to construct pre-war measures of import exposure. We restrict the analysis to a balanced panel of households observed in both 2020 and 2023.

To quantify the causal impact of the Ukraine–Russia war on food insecurity, we use a shift-share approach, and estimate the following district-level specification:

$$\Delta\text{Food Insecurity}_{it} = \beta \sum_{c} \text{Import Exposure}_{ci0} \cdot \text{Trade Shock Size}_{ct} + u_{it},$$

where i indexes districts, c crops, and 0 denotes the pre-war period. The dependent variable is the change in the share of households reporting food insecurity between 2020 and 2023. The specification compares districts with different degrees of pre-war exposure to Ukrainian and Russian food imports, absorbing any time-invariant district characteristics through first differencing.

The size of the trade shock for each crop c is measured by the absolute decline in per capita imports from Ukraine and Russia relative to pre-war per capita consumption in each district, $\text{Trade Shock Size}_{cit} = \Delta IMP^{UR}_{ct}/C_{ci0}$. District-level pre-war import exposure combines the expenditure share of each crop in total food consumption with the share accessed through markets rather than home production, $\text{Import Exposure}_{ci0} = \text{Food Consumption Share}_{ci0} \times (1 - \text{Own Production Share}_{ci0})$. These exposure measures are constructed using median household values within each district based on the 2018–2019 LSMS survey. We focus on two major imported goods, wheat and sunflower oil, which together account for a large share of Ethiopian imports from Ukraine and Russia.

Table 1 reports the estimated effects of the Ukraine–Russia war on district-level food insecurity, with standard errors clustered at the district level. Households in districts more exposed to the drop in imports from the conflict countries experienced a significant increase

Table 1: Estimated Effects of Ukraine-Russia War on Food Security

	Dependent Variable (change in share):	
	(1)	(2)
	Fewer Kinds of Foods	Ate Less Food
War Import Disruption	-0.124***	-0.054
	(-3.28)	(-1.20)
Observations	298	298
$F - stat$	10.78	1.44
R^2	0.03	0.02

Note: Each column shows the estimate from an OLS regression of the exposure to the import disruption shock from the Ukraine-Russian war on the change in the share of households that are food insecure at the district-level. The measure of food insecurity in column (1) is whether households "ate fewer kinds of foods" and in column (2) whether they "ate less than they should." The sample is a balanced panel of districts. t-statistics in parentheses, *** represents significance at the 1% ($p < 0.01$) level.

in food insecurity, primarily through reduced dietary variety. Column (1), which examines the share of households reporting that they "ate only a few kinds of foods," shows a negative and statistically significant coefficient at the 1 percent level, indicating that larger import disruptions are associated with higher food insecurity. A one-standard-deviation increase in the war-induced shock corresponds to a 0.16-standard-deviation increase in the share of food-insecure households. Column (2), which measures households reporting that they "ate less than they thought they should," also yields a negative coefficient, though the estimate is not statistically significant.

Taken together, the results suggest that more exposed districts faced a deterioration in diet quality, even if total food consumption was not significantly reduced. This pattern is consistent with households in more affected areas adjusting along the composition rather than the quantity margin, substituting away from imported staples toward less diverse or locally available foods. The evidence highlights that even in the absence of outright shortages, trade disruptions can compromise food security through reductions in dietary variety and quality, illustrating the vulnerability that arises from dependence on imported food.

Table 2: Nominal Rate of Assistance, 2000-2011

	All countries	GDP per capita $< \$5,000$	GDP per capita $\$5,000 - \$15,000$	GDP per capita $> \$15,000$
Net importer	44.52%	32.16%	43.47%	54.12%
Net exporter	4.14%	-1.96%	9.43%	11.81%

Note: Data from World Bank.

2.4 Protective Policies

The evidence above shows that reliance on food imports exposes countries to trade shocks that can compromise food security. We next examine how governments respond to this vulnerability through protective agricultural policies. In practice, such protection often takes the form of production subsidies to farmers or tariffs on imported agricultural goods. Indeed, tariffs on agricultural products are typically higher than those in other industries (Huang et al., 2018).

To document patterns of agricultural protection across importing and exporting countries, we use cross-country and product-level data on the nominal rate of assistance compiled by (Anderson et al., 2011) for the World Bank. The nominal rate of assistance is defined as the difference between the domestic farm-gate price and the world price of an agricultural good, divided by the world price. Any policy that drives a wedge between these two prices—excluding transport and distribution costs—enters this measure, capturing distortions from (i) domestic subsidies and (ii) border measures. A positive rate implies a subsidy, while a negative rate implies a tax. The dataset reports this measure by country and agricultural product over several years.

Table 2 reports average nominal rates of assistance across countries and products over 2000–2011 by product-level import status and country-level income group. Net importers protect agriculture substantially more than net exporters across all income levels. On average, the nominal rate of assistance for importers is around 45 percent, compared with about 4 percent for exporters. The pattern holds within each income bracket: low-income importers provide positive assistance to farmers, while low-income exporters often tax agriculture. This systematic difference highlights a robust empirical regularity: countries that depend more on imported food tend to protect their domestic agricultural sectors more than countries that are net exporters, a pattern that runs counter to predictions from comparative advantage.

Motivated by the cross-country and micro-level evidence on the vulnerability associated with food imports, we next ask a broader question: how does the risk of trade shocks affect ex-ante patterns of sectoral production and trade across countries? To answer this question, in the next section we develop a structural model to study the aggregate implications of trade risk. Through the lens of our model, we also show that trade risk can rationalize why food importing countries may choose ex-ante to protect domestic agriculture to achieve food security.

3 A Model of Trade Risk and Structural Change

We develop a multi-country, multi-sector model of international trade with structural change, where suppliers of goods make sourcing decisions subject to risk. The global economy consists of N countries, indexed by $n \in \{1, ..., N\}$, with J sectors in each country, indexed by $j \in \{1, ..., J\}$. Each sector in each country produces a domestic sectoral variety that is sold both domestically and internationally. In addition, each sector in each country produces a sectoral good for domestic consumption. This good is an aggregate of the domestic variety and sector-specific varieties from all other countries. Critically, the international sourcing of varieties is subject to trade risk. Sectoral goods are then aggregated into a final good that is consumed by households. Final goods are produced using a non-homothetic technology, leading to a systematic relation between the composition of consumption baskets and the level of economic development. Thus, each country is populated by the following agents: a producer of a domestic sectoral variety in each sector, a producer of sectoral goods in each sector, a producer of final goods, and a representative household.

3.1 Risk and timing

We begin by describing the source of risk and the timing of decisions in our model, and then proceed to describe each of the agents in the following subsections.

Trade risk As in standard models of international trade, international purchases are subject to trade costs that we model as bilateral sector-specific iceberg trade costs. These trade costs affect the sourcing decisions of producers of sectoral goods. But in contrast to standard models of international trade, international sourcing in our model is subject to trade risk. We model trade risk as connectivity shocks between countries, represented as stochastic bilateral iceberg trade costs. Unlike productivity or preference shocks, these shocks capture the possibility that established trade routes are suddenly disrupted—for example by geopolitical tensions, policy shifts, or shipping interruptions—making access to foreign suppliers uncertain.

Let S denote the set of possible states of the world, and let $s \in S$ denote an individual state of the world. Moreover, let $\pi(s)$ denote the probability that state $s \in S$ is realized. If state s is realized, importing one unit of sectoral variety j from country n into country i requires purchasing $\tau^j_{in}(s) \geq 1$ units. Let $\mathcal{T}(s) = \left\{\tau^j_{in}(s)\right\}^{j \in J}_{i \in N, n \in N}$ be the array of all bilateral trade costs and sectors in state s.

In our framework, trade shocks are left unrestricted and can take a variety of forms. Bilateral shocks may capture disruptions that sever or impair trade links between particular country pairs. Sector-specific shocks may capture disruptions that affect trade in a given good across all countries, such as a global shortage of a staple. More broadly, trade shocks may reflect regional or systemic events that simultaneously affect groups of countries or sectors. By allowing the bilateral, sectoral, and higher-order components of $\tau^j_{in}(s)$ to vary across states of the world, the model can capture a broad range of disruptions relevant for food security and trade risk.

Timing We study a static one-period model, where the period consists of two sub-periods: Before and after the trade cost shock is realized. We now describe the timing of events, and in the following subsections describe each stage in detail.

Before the shock is realized, the following take place simultaneously. (a) The producers of the domestic sectoral varieties hire labor, produce varieties, and sell them to producers of sectoral goods. Profits (losses) are transferred to (paid by) the household. (b) The producers of the sectoral goods order sectoral varieties domestically and internationally subject to risk. (c) Households supply labor to producers of domestic sectoral varieties, earn labor income, earn profits from producers of sectoral varieties. (d) The market for labor clears, with the supply of labor from households equal to demand for labor by producers of domestic sectoral varieties, pinning down the equilibrium wage in each country. (e) The market for domestic sectoral varieties clears, with the supply of domestic sectoral varieties equal to demand for them by producers of sectoral goods across all countries, pinning down the equilibrium price of varieties in each sector and country.

After the shock is realized, the following take place simultaneously. (a) The producers of sectoral goods produce sectoral goods given trade cost realizations and sell them to producers of final goods. Profits (losses) are transferred to (paid by) the household. (b) The producers of final goods produce final goods by purchasing sectoral goods. Profits (losses) are transferred to (paid by) the household. (c) Households earn profits from all domestic producers of sectoral and final goods, and use total earnings to purchase final goods to be used for consumption. (d) The market for sectoral goods clears, with the supply of sectoral goods equal to demand for sectoral goods by producers of final goods, pinning down the equilibrium price of sectoral goods. (e) The market for final goods clears, with the supply of final goods equal to the demand for final goods by households, pinning down the equilibrium price of final goods.

3.2 Producers of domestic sectoral varieties

Producers of domestic sectoral varieties in sector j of country i are endowed with a technology for producing differentiated country-specific varieties in sector j. The technology is constant returns to scale and uses only labor as an input,

$$y_i^j = z_i^j \ell_i^j,$$

where y_i^j is the total amount of the domestic sectoral variety that country i produces in sector j to be sold to all countries (including domestically), ℓ_i^j denotes the labor used to produce this variety, and z_i^j is a sector-specific productivity level in country i.

Producers of domestic sectoral varieties are representative within each sector and country. Thus, they choose labor to maximize profits subject to the production technology, taking the price and wages as given. All these choices and their respective payoffs take place prior to the realization of the shocks. Their problem is given by:

$$\max_{\ell_i^j} \pi_i^j = p_i^j y_i^j - w_i \ell_i^j \quad \text{subject to} \quad y_i^j = z_i^j \ell_i^j.$$

3.3 Producers of sectoral goods

In each country i, a sectoral good j is produced by a representative sectoral good producer using an Armington aggregator across country-specific sectoral varieties. The production technology features constant elasticity of substitution (CES) and is given by:

$$Y_i^j(s) = \left[\sum_{n=1}^{N} \left[q_{in}^j(s) \right]^{\frac{\eta_j - 1}{\eta_j}} \right]^{\frac{\eta_j}{\eta_j - 1}}$$

where $q_{in}^j(s)$ is the quantity of the sectoral variety from sector j produced in country n consumed in i when state of the world $s \in S$ is realized. The elasticity of substitution across varieties from different countries within a sector is $\eta_j > 0$.

For quantity $q^j_{in}(s)$ of variety n in sector j to arrive and be consumed in country i in state of the world $s \in S$, the country of origin n has to produce and ship the following amount:

$$\widetilde{y}^j_{in} = q^j_{in}(s)\tau^j_{in}(s),$$

since iceberg costs imply that $\tau^j_{in}(s)-1$ per unit melt in transit. Therefore, sectoral producers in country i have to place a *deterministic* order of $\widetilde{y}^j_{in}$ units prior to the realization of the shock to receive a *stochastic* quantity $q^j_{in}(s)$ that depends upon the realization of the state of the world.

The sectoral good producer in sector j and country i chooses how much to order of each variety, taking into account that the quantities delivered depend on the trade cost shock. As a result, they order varieties under trade cost risk by solving the following problem:

$$\max_{\{\widetilde{y}^j_{in}\}^N_{n=1}} \mathbb{E}\left\{u'\left[c_i(s)\right]\left[\Pi^j_i(s) = P^j_i(s)Y^j_i(s) - \sum_{n=1}^{N} p^j_n \widetilde{y}^j_{in}\right]\right\}$$

subject to

$$Y^j_i(s) = \left[\sum_{n=1}^{N}\left[\frac{\widetilde{y}^j_{in}}{\tau^j_{in}(s)}\right]^{\frac{\eta_j-1}{\eta_j}}\right]^{\frac{\eta_j}{\eta_j-1}},$$

where $P^j_i(s)$ is the sectoral price of good j in country i, and $u'\left[c_i(s)\right]$ weighs payoffs across states of the world according to the marginal utility of the owner of the firm, that is, the domestic representative household.

3.4 Producers of final goods

Within each country is a final good producer that aggregates sectoral goods and sells them as a final good to consumers. The production technology is defined implicitly by a non-homothetic CES function, as in Comin et al. (2021),

$$\sum_{j=1}^{J} b^j_i \left[\frac{Q^j_i}{Y_i^{\epsilon_j}}\right]^{\frac{\sigma-1}{\sigma}} = 1$$

where Y_i is the final good in country i, and Q^j_i is the amount of sectoral good j consumed in country i. b^j_i is a sectoral parameter that weights the contribution of sectoral good j to the final good in country i. The non-homotheticity parameter for sectoral good j, ϵ_j, controls the relative income elasticities of demand across goods. If $\epsilon_j = 1\ \forall j$, then the technology is a standard CES technology with unit income elasticities of demand across all sectors.

The problem of final good producers is then given by:

$$\max_{Y_i(s),\left\{Q_i^j(s)\right\}_{j=1}^J} \Pi_i(s) = P_i(s)Y_i(s) - \sum_{j=1}^J P_i^j(s)Q_i^j(s)$$

subject to

$$\sum_{j=1}^J b_i^j \left[\frac{Q_i^j(s)}{Y_i^{\epsilon_j}(s)}\right]^{\frac{\sigma-1}{\sigma}} = 1.$$

Note that, given that all decisions and payoffs of the final good producers take place after the shocks are realized, its choices are not subject to risk. Yet, they do depend on the realized state of the world.

3.5 Households

In each country i there is a representative household that has monotonic preferences over consumption of the final good. We let preferences be sensitive to risk, so we model them as being of the constant relative risk aversion (CRRA) class, given by,

$$u\left(c_i\right) = \frac{C_i^{1-\gamma}}{1-\gamma}$$

where C_i denotes per capita consumption, and $\gamma > 0$ denotes the household's degree of relative risk aversion.

Households are endowed with L_i units of labor, which we also interpret as the total population of country i. The representative household in each country owns all firms, and as a result is entitled to their profits.

The representative household's budget constraint in country i in state of the world s is:

$$P_i(s)C_i(s) = w_i L_i + \Pi_i(s) + \sum_{j=1}^J \Pi_i^j(s) + \sum_{j=1}^J \pi_i^j$$

where the left-hand side denotes expenditures on final goods. The right-hand side consists of total labor income, which is independent of the state of the world given it is accrued prior to the realization of the shock, plus the total profits transferred from all firms.

3.6 Equilibrium

A competitive equilibrium in the world economy consists of prices and allocations such that the following conditions hold in each country i: (a) given prices and wages, households choose consumption optimally; (b) given prices, producers of domestic varieties choose inputs and production optimally; (c) given prices, producers of sectoral goods choose inputs and production optimally; (d) given prices, producers of final goods choose inputs and production optimally; (e) the market for labor clears prior to the shock, $L_i = \sum_{j=1}^{J} \ell_i^j$; (f) the market for domestic sectoral varieties clears prior to the shock, $y_i^j = \sum_{n=1}^{N} \widetilde{y}_{ni}^j$; (g) the market for sectoral goods clears after the shock, $Q_i^j(s) = Y_i^j(s) \ \ \forall s$; (h) the market for final goods clears after the shock, $C_i(s) = Y_i(s) \ \ \forall s$.

3.7 How risk affects international sourcing decisions

We now characterize how trade risk affects import decisions in our model. We focus here on the sourcing problem of sectoral good producers and derive the optimality conditions that determine their demand for domestic and foreign varieties. This allows us to isolate how uncertainty in trade costs modifies the standard logic of comparative advantage. While the emphasis here is on the mechanism at the level of the importing firm, our quantitative analysis accounts for all the general equilibrium feedbacks that risk induces.

Sourcing without risk. If trade costs are deterministic, the import share of variety n relative to the domestic variety in sector j of country i is:

$$\frac{\widetilde{y}_{in}^j}{\widetilde{y}_{ii}^j} = \left(\frac{p_n^j}{p_i^j} \cdot \frac{\phi_{ii}^j}{\phi_{in}^j} \right)^{-\eta_j},$$

where

$$\phi_{in}^j(s) := P_i^j(s) \cdot \left[Y_i^j(s) \right]^{1/\eta_j} \cdot \left[\tau_{in}^j(s) \right]^{(1-\eta_j)/\eta_j}$$

denotes the effective demand for imports from country n. In this benchmark, sourcing depends solely on relative prices, which reflect productivity differences across producers, and on effective demand, which captures barriers to trade and demand conditions in the importing country, with the elasticity of substitution η_j governing the strength of reallocation across suppliers. Firms therefore allocate demand to the lowest-cost sources, and the resulting pattern of trade based on comparative advantage, as in standard models of international trade.

Sourcing with risk. With stochastic trade costs, the first-order condition for sourcing variety n in sector j of country i can be written as:

$$\left(\tilde{y}^j_{in}\right)^{-1/\eta_j}\ \mathbb{E}\left[u'(C_i(s))\,\phi^j_{in}(s)\right] = p^j_n\,\mathbb{E}[u'(C_i(s))],$$

where $\phi^j_{in}(s)$ is the effective demand term defined above. Dividing through by expectations and rearranging yields:

$$\left(\tilde{y}^j_{in}\right)^{-1/\eta_j}\ \mathbb{E}[\phi^j_{in}(s)]\,\mathbb{E}\left[\frac{u'(C_i(s))}{\mathbb{E}[u'(C_i)]}\cdot\frac{\phi^j_{in}(s)}{\mathbb{E}[\phi^j_{in}(s)]}\right] = p^j_n.$$

The last expectation can be decomposed into one plus a covariance term:

$$\mu^j_{in} := \operatorname{cov}\left(\frac{u'(C_i(s))}{\mathbb{E}[u'(C_i)]},\ \frac{\phi^j_{in}(s)}{\mathbb{E}[\phi^j_{in}(s)]}\right).$$

Thus, the relative import share of variety n compared to the domestic variety becomes:

$$\frac{\tilde{y}^j_{in}}{\tilde{y}^j_{ii}} = \left(\frac{p^j_i}{p^j_n}\cdot\frac{\mathbb{E}[\phi^j_{in}(s)]}{\mathbb{E}[\phi^j_{ii}(s)]}\cdot\frac{1+\mu^j_{in}}{1+\mu^j_{ii}}\right)^{\eta_j}.$$

The risk premium μ^j_{in} captures whether imports arrive in high- or low-marginal-utility states. If imports tend to arrive in good times, then $\mu^j_{in} < 0$, which raises the effective cost of sourcing from n and lowers its import share. In this way, trade risk shifts sourcing away from the pattern implied by comparative advantage. These re-allocations operate along two margins. First, firms may substitute away from foreign varieties toward domestic ones, even if the latter are less productive, capturing the idea of "reshoring" as a form of self-insurance. Second, firms may substitute toward more expensive but less risky partners, capturing the idea of "friend-shoring."

Beyond these direct effects on sourcing, additional forces arise once general equilibrium interactions are taken into account. Because households cannot fully insure consumption across states of the world, private attempts by firms to self-insure through reshoring or friend-shoring are not neutral: shifts in sourcing patterns affect equilibrium prices, which in turn feed back into the effective riskiness of different suppliers. These price adjustments can partially undo firms' precautionary motives, leaving countries overexposed to risky trade partners. We return to these issues in Section 6, where we analyze the general equilibrium implications of trade risk and the role of policy in addressing the resulting wedge between private and social incentives.

4 Estimation

We now bring the model to the data. Our goal is to estimate the key structural parameters that allow the model to replicate observed sectoral patterns of production and trade across countries. To do so, we estimate the model without risk, ensuring that it matches observed bilateral trade flows, sectoral expenditure patterns, and relative prices. This estimated version of the model serves as the empirical benchmark against which we later introduce trade risk and quantify its implications for production, trade, and welfare in Section 5.

We use harmonized cross-country data for the year 2018 drawn from multiple sources. Bilateral trade flows by sector across all country pairs are taken from the OECD's Trade in Value Added (TiVA) database. Data from the Food and Agricultural Organization of the United Nations (FAOSTAT) provide product-level imports, exports, and production, which we use to construct agricultural trade imbalances. Sectoral expenditure patterns and prices by country are obtained from the World Bank's International Comparison Program, while additional aggregates such as population counts are taken from the World Bank's World Development Indicators.

Based on these data, our quantitative implementation covers three broad sectors in each country: agriculture ($j = a$), manufacturing ($j = m$), and services ($j = s$). We estimate the global equilibrium of the model for 71 countries, including a rest-of-the-world aggregate, restricting attention to all countries with available data and a population of at least one million.

Our estimation strategy proceeds in two steps. We begin by fixing a set of parameters to values commonly used in the literature, which we refer to as pre-determined parameters. These govern key elasticities of substitution, non-homotheticities, and risk preferences, and allow our quantitative implementation to be consistent with prior empirical evidence. We then estimate the remaining parameters, including sectoral productivities, bilateral trade costs, preference weights, and population sizes, so that the model without risk exactly reproduces a set of observed trade and expenditure patterns in the data.

Pre-determined parameters We set a number of the parameters to values used in previous studies. The set of pre-determined parameter values we choose along with their description are provided in Table 3. The elasticity of substitution across varieties within sectors η_j is set to 6 for both agriculture and manufacturing. Broda and Weinstein (2006) estimate an average elasticity across industries at the 3-digit level ranging from 4 (1990-2001) to 7 (1972-1988). Their reported average numbers are higher at the 5-digit level and for com-

Table 3: Pre-determined Parameters

Parameter	Value	Description
γ	2	Risk aversion
$\{\eta_j\}_{j\in\{a,m\}}$	6	Elasticity within sectors (substitutes)
σ	0.50	Elasticity across sectors (complements)
ε_m	1.00	Mfct. Non-homotheticity
ε_a	0.10	Agr. Non-homotheticity

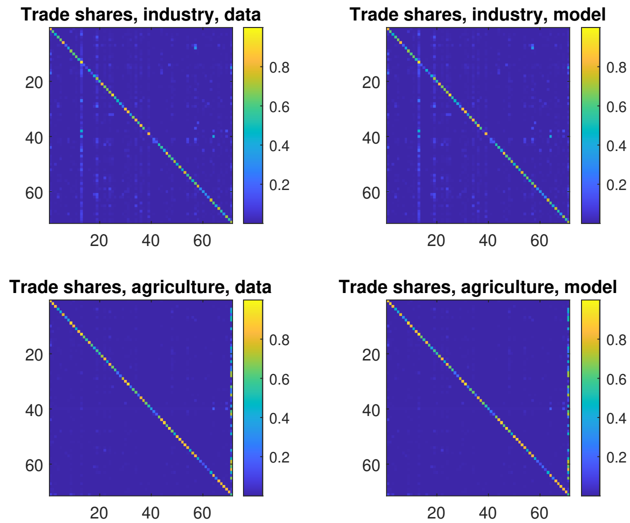
modities. Simonovska and Waugh (2014) find trade elasticities at the macro level around 4. Another key elasticity in our model is the elasticity of substitution across broad sectors σ. The empirical literature provides a wide range of estimates. Duarte and Restuccia (2010) report a value of 0.4 between manufacturing and services, while Sposi et al. (2022) find a lower estimate of 0.23 across agriculture, manufacturing, and services in final consumption. Estimates in Comin et al. (2021) fall between 0.31 using CEX data with fixed effects and 0.50 across countries with fixed effects. At the higher end, Herrendorf et al. (2013) obtain values around 0.85–0.89. In light of this evidence, we choose $\sigma = 0.50$, which lies in the middle of the reported range and implies that sectors are complements. We normalize the non-homotheticity parameter in manufacturing to 1, and choose the one in agriculture $\varepsilon_a = 0.10$, which implies that food is a necessity good. This choice is consistent with the estimates of Comin et al. (2021) across countries. Finally, we set the coefficient of relative risk aversion in the household's utility function to 2, consistent with values commonly used in the macroeconomics literature.

Multi-country estimation Given the predetermined parameters described above, the model parameters that remain to be estimated for each country are: (i) sectoral productivities z_i^j; (ii) bilateral sector-specific trade costs τ_{in}^j; (iii) sectoral good preference parameters by country b_i^j; (iv) population size by country L_i. We measure L_i directly using population data. We then estimate the remaining parameters jointly to match each country's bilateral trade flows across sectors (including domestic purchases), sectoral expenditure shares, and sectoral relative prices.

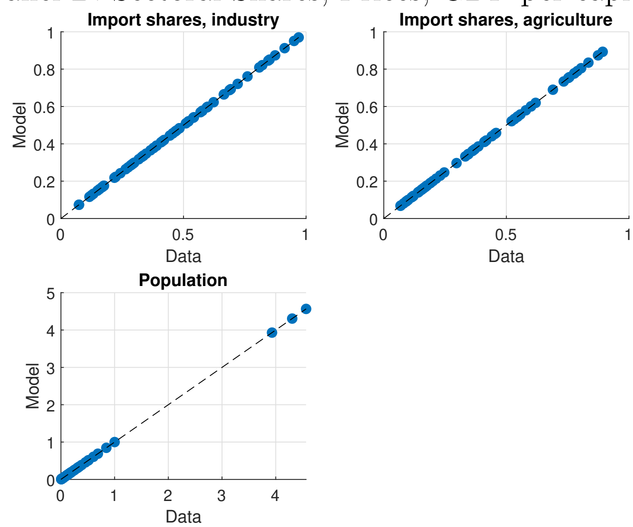
We implement this estimation approach by deriving a system of analytical expressions in the economy without risk that map estimable parameters to data targets, and we use this system to back out the parameters of the model. By construction, the estimated parameters imply the model with no risk matches all target moments exactly. Moreover, the estimated model also aligns well with non-targeted moments, such as cross-country sectoral production

Figure 4: Target Moments: Model vs. Data

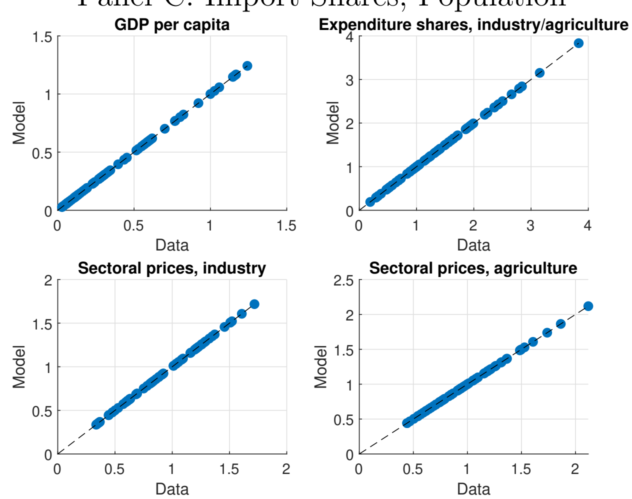
Panel A: Bilateral Trade Shares



Panel B: Sectoral Shares, Prices, GDP per capita



Panel C: Import Shares, Population



Notes: Comparing targeted moments from model without risk to the data.

patterns and aggregate GDP per capita.

We now illustrate how the parameters can be backed out by feeding data into analytical expressions implied by the no-risk equilibrium. Let θ_{in}^j denote the share of country i's absorption of sector j sourced from n (so $\sum_n \theta_{in}^j = 1$), and let θ_{ii}^j be the domestic sourcing share. First, relative productivities follow from relative sectoral prices and domestic sourcing shares:

$$\frac{z_i^k}{z_i^j} = \frac{P_i^j}{P_i^k} \frac{\left(\theta_{ii}^j\right)^{\frac{1}{1-\eta_j}}}{\left(\theta_{ii}^k\right)^{\frac{1}{1-\eta_k}}}.$$

Second, bilateral trade costs are backed out from bilateral-to-domestic import share ratios and relative unit costs:

$$\frac{\theta_{in}^j}{\theta_{ii}^j} = \left(\frac{(w_n/z_n^j)\,\tau_{in}^j}{(w_i/z_i^j)}\right)^{1-\eta_j}.$$

Finally, preference weights are identified from relative sectoral expenditure shares and relative prices under the non-homothetic CES aggregator:

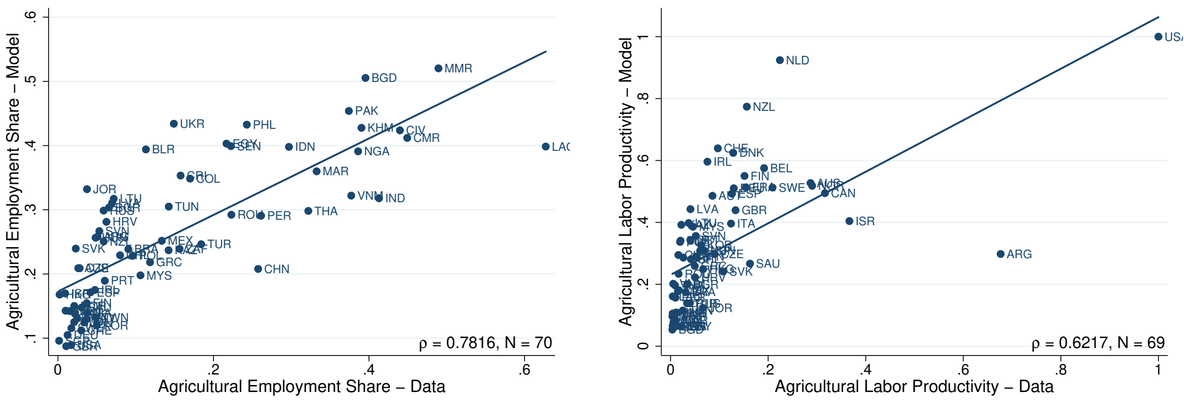
$$\left(\frac{e_i^j}{e_i^k}\right)^{1/\sigma} \frac{P_i^j}{P_i^k} = \frac{b_i^j}{b_i^k} \left[\frac{w_i}{P_i} \sum_{r=1}^{J} \varepsilon_r e_i^r\right]^{\frac{(1-\sigma)}{\sigma}(\varepsilon_j - \varepsilon_k)}.$$

Here e_i^j denotes the expenditure share on sector j in country i, and the income term is an endogenous object of the model jointly determined with prices and shares, not taken from external GDP per capita data.

One issue we need to confront for implementing our estimation approach is that trade is balanced at the country level in our model, whereas this is not the case in the data. To execute our estimation approach and to ensure that the estimated parameters reproduce the target moments exactly, we rebalance the trade flow data to ensure trade is balanced in the aggregate. We do so while ensuring that agricultural sectoral imbalances are preserved.

Our estimation approach exactly matches the targeted data: Panels A–C of Figure 4 plot the equilibrium moments implied by the model against those targeted in the data. The estimation procedure also aligns well with moments not directly targeted. Figure 5 shows that the estimated model reproduces the share of employment in agriculture (Panel A) and agricultural labor productivity (Panel B), both taken from the World Development Indicators, with productivity measured as value added per worker. Agricultural productivity in both the data and the model is reported relative to the United States.

Figure 5: Non-Target Moments: Model vs. Data



A: Agric. Employment Share

B: Agric. Labor Productivity

Notes: The data values for "Agric. Employment Share" and "Agric. Labor Productivity" are taken directly from the World Development Indicators, with the latter measured as agricultural value added per worker. The model values are the ones implied by the trade equilibrium of the estimated model. Agricultural labor productivity in both model and data are relative to the US.

5 Quantitative Results

We use the estimated model to quantitatively assess the effects of trade risk on trade flows, sectoral production, food insecurity, and welfare across countries. In our main experiment, we model trade risk as a low-probability, high-impact disruption in which countries revert to autarky. We interpret the differences between the benchmark open-economy outcomes and those under risk as a measure of countries' exposure and vulnerability to trade disruptions. This exercise can be viewed as a stress test of current patterns of sectoral production and trade under tail risk.[6]

5.1 Main Experiment

We introduce trade risk into our baseline estimated model and solve for the new competitive equilibrium. We then compare this equilibrium with risk to the benchmark outcomes under a riskless open economy. Specifically, we consider two possible states of the world: with probability π, the global agricultural trade remains open and bilateral sector-specific trade costs equal their estimated values; with probability $1 - \pi$, countries revert to autarky in

[6] In Appendix C we report a complementary exercise that quantifies the effects of observed volatility in real shipping freight rates, which directly map into the stochastic trade costs in our model and capture one type of cyclical trade risk.

agriculture, i.e., $\tau_{ij}^a \to \infty$ for all i, j.

We estimate the trade disruption probability in international food trade, $(1 - \pi)$, by drawing on the historical incidence of import disruptions and the recent spikes in geopolitical risk and trade policy uncertainty indices, documented in Section 2.1 above.[7] We first estimate the effect of geopolitical risk and trade policy uncertainty on the probability of import disruptions in food trade over the entire period 1985-2023. We then combine the estimated conditional probabilities with the increase of geopolitical risk and trade policy uncertainty indices since 2022, to calculate the predicted chance of a food trade disruption, over a period of elevated risks. The details of our estimation are in Appendix B. The predicted probability of a trade disruption from the jointly estimated model is 10.5 percent. Based on this, along with the historical incidence of import disruptions of 9.5 percent documented in Section 2.1, we anchor the probability of trade breakdown in our main experiment at 10 percent ($\pi = 0.90$). We view this calibration as an intentionally extreme experiment that provides a stark benchmark for assessing global vulnerability to severe trade disruptions.

We begin by reporting average effects by food import status—on trade flows, sectoral production, food security, and welfare. We then explore cross-country heterogeneity in these effects, leveraging differences in trade patterns, sectoral productivities, GDP per capita, population size, and sectoral expenditure shares. In particular, we examine how the impact of tail risk varies with the magnitude of countries' agricultural trade imbalances.

5.2 Average effects of trade risk

Table 4 reports the average effects of tail trade risk by food import status in the riskless open benchmark economy ("No Risk"), distinguishing between net food importers and net food exporters. The first and third columns show the average levels of key outcomes in the benchmark economy for each group, while the second and fourth columns show average changes induced by the introduction of risk. All statistics are weighted averages across countries within each group, using weights based on the relative magnitude of each country's agricultural trade imbalance.

The changes in the aggregate import share in response to trade risk, for both importers and exporters, indicate that risk discourages international trade. This withdrawal from trade acts as a form of self-insurance: countries, driven by a precautionary motive, internalize trade risk by reducing trade in order to mitigate the potential costs of entering a bad state of the

[7] This hybrid approach blends the macroeconomics rare-disasters literature (e.g., Barro and Ursúa, 2012) with the more recent geopolitical risk and trade policy uncertainty indices literatures (Caldara and Iacoviello, 2022; Caldara et al., 2020).

Table 4: Average Effects of Trade Risk

	Food Importers		**Food Exporters**	
	No Risk	**Risk**	**No Risk**	**Risk**
Aggregate Import Share (%)	34.7	-9.2	32.6	-1.9
Agricultural Labor share (%)	21.1	+6.6	29.8	-0.6
Food Insecurity (ratio)				
Food Consumption (open/closed)	–	1.77	–	1.18
Rel. Food Price (closed/open)	–	5.83	–	1.52
Welfare costs of risk (%)	–	-8.9	–	-1.0

Note: Average effects from tail trade risk, for food importers (first two columns) and food exporters (next two columns). "No Risk" refers to the levels in the estimated benchmark open economy without risk. "Risk" refers to the change relative to the no risk economy, except for the food insecurity values which are ratios. Levels and changes are weighted averages within import status groups, where the weights are the relative magnitude of the countries' agricultural trade imbalances.

world.

This has important implications for the sectoral composition of the economy. In particular, trade risk raises domestic agricultural production for net importers of agricultural goods, with the share of labor in agriculture increasing by 6.6 percentage points on average. Because these countries have relatively low productivity in agriculture, this expansion is costly: they are forced to reallocate resources into a sector where they are least efficient, precisely the reason they were relying on imports to begin with. Conversely, trade risk reduces agricultural production among net exporters, who no longer need to produce as much for export—resulting in a decline of 0.6 percentage points on average.

We report the effect of trade risk on two metrics of food insecurity: the dispersion of food consumption and the dispersion in the relative price of food. We define consumption dispersion as the ratio of consumption levels in the "good" state—where the economy remains open—to the "bad" state—where the economy reverts to autarky and goods fail to arrive. Price dispersion is defined analogously, as the ratio of relative food prices between the bad and good states. Table 4 shows that trade risk increases both types of dispersion by lowering consumption and raising prices in the bad state. Intuitively, border closures are costly because the expected goods do not arrive. As a result, trade risk directly undermines food security, particularly for net importers of food.

We measure the welfare costs of trade risk as the compensating equivalent change in consumption that would make households in the open, riskless economy as well off as those in the economy with risk. Specifically, we ask: by how much would consumption in the open economy without risk need to adjust for utility to match that in the economy with risk? The last row of Table 4 shows that trade risk leads to substantial welfare losses, which are much larger on average for net food importers. These losses stem from two channels: first, greater food insecurity, which directly lowers utility; and second, weaker gains from trade, as countries scale back international exchange. Net importers are hit especially hard, since their relatively low agricultural productivity makes them more dependent on foreign food, leaving them more exposed when trade becomes risky.

5.3 Cross-country effects of trade risk

After examining the average effects of trade risk by agricultural import status, we next report the changes in trade patterns, production, food security, and welfare for all countries. The country-level results reflect the rich heterogeneity in sectoral productivities and expenditures, trade patterns, income, and population across the 71 countries in our dataset. Given the role of agricultural trade imbalances in our framework, we report the results for the key variables of interest against each country's agricultural net exports to output ratio as observed in the data and reproduced in the model without risk, using a series of scatter plots. This allows us to discern cross-country patterns in how the effects of trade risk vary with the extent of trade exposure.

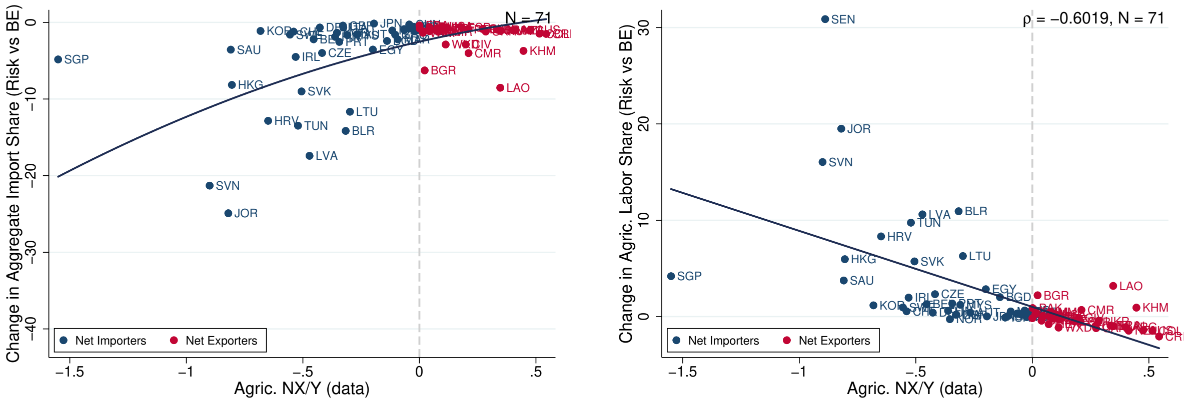
Aggregate Import Share Panel A of Figure 6 plots the country-by-country change in the aggregate import share between the equilibrium with risk and the riskless open benchmark economy, against each country's agricultural net exports–to–output share in the data.[8] The figure compares how import shares respond to the introduction of trade risk. In all cases, countries reduce their overall trade relative to the riskless economy. Importantly, the largest reductions occur among countries that were most actively engaged in trade—especially the largest net importers of food—yielding an inverted U-shaped relationship between trade exposure and the impact of risk. We interpret the magnitude of these reductions as a measure of countries' vulnerability to trade risk, with highly exposed importers facing the greatest adjustment.

Agricultural Employment Share Panel B of Figure 6 shows the country-by-country change in the equilibrium share of employment in agriculture between the economy with risk and the riskless economy. With trade risk, all countries that are net importers in the baseline

[8] By construction, the estimated model without risk reproduces each country's agricultural net exports–to–output ratio observed in the data.

Figure 6: Imports and Sectoral Composition

A. Change in Aggregate Imports B. Change in Agricultural Employment

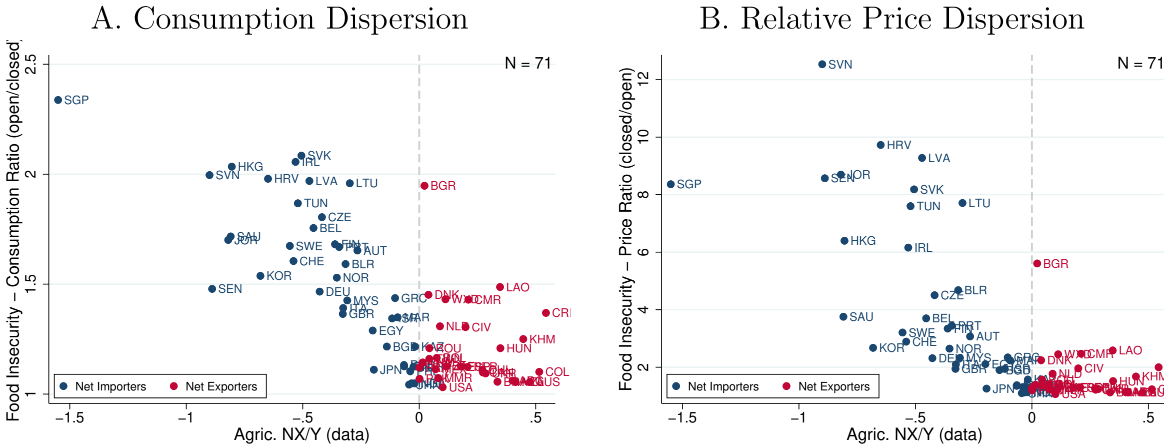


Notes: "Change in Aggregate Import Share (Risk vs BE)" and "Change in Agric. Labor Share (Risk vs BE)" refer to the country-by-country difference between the equilibrium in the economy with risk and that of the riskless open benchmark economy, for the import share and the agricultural employment share respectively. "Agric. NX/Y (data)" is the agricultural net exports to output ratio in the data (benchmark economy).

economy increase their agricultural employment share, while net exporters tend to reduce it. This reallocation reflects a precautionary response: countries that rely heavily on food imports shift labor toward domestic production to insure against the risk of losing access to foreign supply. Conversely, net exporters no longer face the same demand from abroad and scale back agricultural activity. Moreover, these changes are systematically related to the size of agricultural trade imbalances: the countries that experience the largest increases in agricultural employment are those with the largest net import positions, highlighting the importance of the misalignment between the domestic expenditure share and the domestic output share in agriculture.

Food Insecurity We examine two metrics of food insecurity generated by the model. The first is a measure of consumption dispersion, defined as the ratio of consumption when international trade remains open to consumption when trade collapses and countries revert to autarky. The second is a measure of price dispersion, defined as the ratio of the relative price of agricultural goods under autarky to that under openness. Figure 7 plots these two measures—consumption dispersion in Panel A and price dispersion in Panel B—against each country's agricultural trade imbalance. Introducing trade risk worsens food security outcomes under both metrics for all countries. However, both the average level of food insecurity and its within-group dispersion are higher among net importers than among net exporters. This reflects the fact that when risk materializes, importers lose access to foreign

Figure 7: Food Insecurity



Notes: "Consumption Ratio (open/closed)" refers to the ratio of consumption if the good (open economy) state occurs relative to if the bad state (autarky) occurs. "Price Ratio (closed/open)" refers to the ratio of the relative price of agricultural goods in the bad relative to the good state. "Agric. NX/Y (data)" is the agricultural net exports to output ratio in the data (benchmark economy).

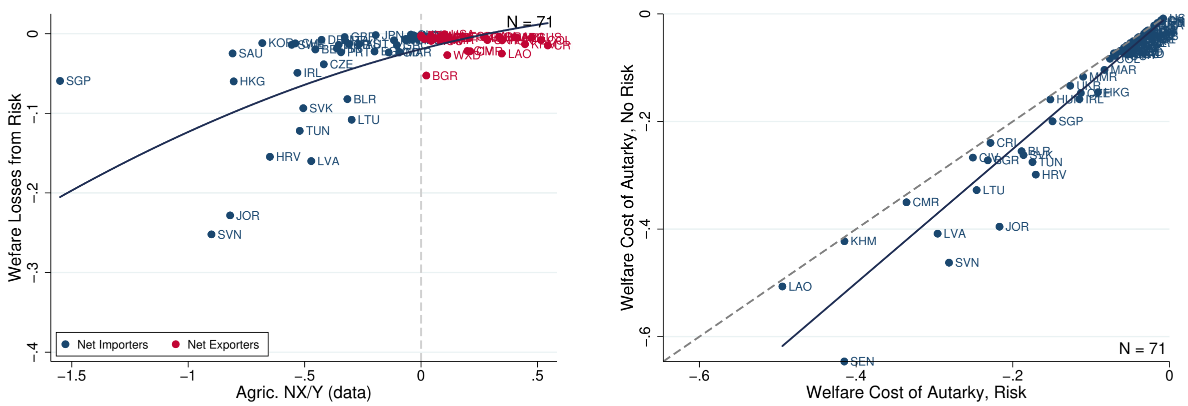
food supply and must rely on insufficient domestic production, resulting in sharp declines in consumption and spikes in food prices. We note that the higher level and dispersion of food insecurity for importers our model produces in the face of trade risk are qualitatively consistent with the evidence in Figure 3 we documented in Section 2.2.

Welfare Losses from Risk We measure each country's welfare loss from trade risk as the compensating equivalent change in utility between the equilibrium of the riskless open economy and that of the economy with risk. Panel A of Figure 8 plots these country-level welfare losses against agricultural trade imbalances. Risk leads to welfare losses for all countries relative to the riskless open economy, with the sharpest losses occurring in countries with the largest food imports. These losses vary with both the extent of food insecurity introduced by risk and the scale of the reduction in international trade. The withdrawal from trade, in turn, implies forfeiting the gains from openness captured by the model—comparative advantage, specialization, and access to a broader range of imported goods.

Risk and the Welfare Gains from Trade We next examine how trade risk affects the welfare gains from international trade. We measure these as the compensating equivalent change in consumption that would make a household in a given country indifferent between the economy with trade risk and one with permanent autarky. That is, we ask how much

Figure 8: Welfare

A. Welfare Losses B. Welfare Gains From Trade



Notes: "Welfare Losses from Risk" refers to the compensating equivalent change in utility between the economy with risk and the riskless open benchmark economy. "Agric. NX/Y (data)" is the agricultural net exports to output ratio in the data (economy without risk). "Welfare Cost of Autarky, No Risk" and "Welfare Cost of Autarky, Risk" refer to the country-by-country welfare losses from moving from on open economy to autarky under no risk and under risk respectively.

consumption a country would be willing to sacrifice to avoid transitioning to a world in which trade is fully and permanently shut down. This welfare cost of autarky captures the potential gains from trade. We then compare these gains in the economy with trade risk to those in the riskless economy. It is important to distinguish this measure from the welfare cost of risk discussed earlier: while both are expressed in consumption-equivalent terms, the former reflects the value of access to trade, whereas the latter captures the cost of uncertainty about that access.

In Panel B of Figure 8 we plot the cross-country welfare losses from moving to autarky in the riskless benchmark economy (vertical axis) against the losses from moving to autarky in the economy with risk (horizontal axis). We add a solid best-fit line and a dashed 45-degree line. If the welfare gains from openness were the same with and without risk, then all countries would lie on the 45-degree line. However, as is clear from the figure, all countries fall below the 45-degree line, implying that the welfare gains from openness are smaller under risk for all countries.

There are two reasons why the welfare gains from trade are lower under risk. First, even if countries do not adjust how much they trade, their expected welfare gains decline due to the possibility of losing access to imported goods—an especially costly outcome for essential sectors. Second, in the presence of risk, countries internalize this possibility and reduce their trade engagement as a form of self-insurance. As a result, both the direct cost of uncertainty and the endogenously reduced trade flows lower the measured gains from openness. These risk-related frictions may discourage countries from fully integrating into global markets.

While all countries gain less from trade under risk, the size of this reduction is not the same for everyone. The countries that lose the most gains are those that cut back trade the most when risk is introduced, no matter whether they are importers or exporters. As shown by comparing Panel B of Figure 8 with Panel A of Figure 6, these countries are also the ones that stood to benefit the most from trade in a world without risk.

6 Optimal Policies

The analysis so far shows how private agents respond to trade risk: importers internalize the possibility of disrupted food supplies by sourcing less from abroad and producing more domestically. Yet, governments in food-importing countries reinforce this retreat from trade through tariffs on food and subsidies to domestic farmers, as documented in Section 2.4. To what extent are such protective policies optimal in our model? If private agents already internalize trade risk, to what extent is there a misalignment between private and public evaluations of risk that creates additional motives for governments to intervene?

To address these questions, we proceed in two steps. First, we study a one-sector version of our model and analytically characterize optimal tariffs under risk, contrasting them with the policies governments would choose in a riskless economy. Second, using the full estimated model, we quantify optimal tariffs and subsidies for each country.

6.1 Optimal Policy Problem

We now turn to the normative question of how a country exposed to trade–cost risk should set policy to maximize domestic welfare. In our model, trade risk affects both the level and variability of consumption across states, creating scope for policy to influence outcomes through its impact on ex ante sourcing decisions and the resulting allocation of resources across states of the world.

We focus on the unilateral problem of a domestic policymaker who can set a uniform ad valorem import tariff on agricultural goods, or alternatively, a production subsidy for domestic agriculture. The policymaker takes the behavior of the rest of the world as given and chooses policy to maximize domestic welfare, subject to the decentralized equilibrium conditions of the economy. In doing so, the policymaker internalizes how the chosen instrument affects equilibrium sourcing and production decisions before trade-cost shocks are realized, and thus the resulting allocation of consumption and prices across states of the world.

Formally, the policymaker in country i chooses a vector of policy instruments Ω_i—such as import tariffs or production subsidies—to maximize expected domestic welfare,

$$\max_{\Omega_i} \mathbb{E}_s\left[\frac{c_i(s;\Omega_i)^{1-\gamma}}{1-\gamma}\right],$$

subject to the competitive equilibrium conditions described in Section 3, which determine the state–contingent allocations $\{c_i(s;\Omega_i)\}$ as functions of policy Ω_i. The policymaker internalizes how these equilibrium responses affect both the level and the variability of consumption across states when choosing the policy that maximizes expected welfare.

The objective places greater weight on states where marginal utility is high, reflecting the policymaker's concern with both the level and the stability of consumption across states of the world. By influencing sourcing and production decisions ex ante, policy instruments shape this trade–off between average consumption and its variability. In what follows, we first characterize the optimal policy analytically in a simplified version of the model and then quantify its magnitude in the full estimated multi–country framework.

6.2 Analytical Characterization of Optimal Tariff

We begin by characterizing the unilateral optimal policy analytically in a one-sector version of our model that only abstracts from the multi–sector layer and the associated non–homothetic preferences of the full model. All other features remain as in the baseline framework: CES aggregation of domestic and imported varieties, iceberg trade costs are stochastic, sourcing decisions are made before the realization of shocks. We also focus here exclusively on uniform ad valorem import tariffs, with tariff revenues rebated lump-sum to the representative household. This allows us to provide a sharp characterization of the forces shaping policy incentives. In the next subsection we numerically solve for both tariffs and production subsidies in the full model.

We highlight the key optimality conditions here. Let M_i denote total imports of country i. The planner's first–order condition for the optimal tariff t is

$$\mathbb{E}_s\left[\frac{u'(C_i(s))}{\mathbb{E}_s[u'(C_i(s))]}\left(\frac{dY_i(s)}{dt} - \frac{1}{P_i(s)}\frac{dM_i}{dt}\right)\right] = 0,$$

where $Y_i(s)$ denotes state–contingent output and $P_i(s)$ the final–good price. The planner chooses t taking as given the global equilibrium allocation and recognizing how the tariff influences import expenditures, tariff revenue, and domestic welfare across all realizations of trade–cost shocks.

Using the equilibrium sourcing conditions of final–good producers and the induced response of import prices to the tariff, the effects of t on aggregate output and total imports can be expressed as

$$\frac{dY_i(s)}{dt} = -\,\eta\,\frac{1}{P(s)}\,M_i \sum_{n\neq i} \alpha_{in}\,\frac{\varphi_{in}(s)/\mathbb{E}_s[\varphi_{in}(s)]}{1+\mu_{in}}\,\big(1-\widehat{\vartheta}_{in}\big),$$

$$\frac{dM_i}{dt} = \frac{M_i}{1+t}\left[(\eta-1)\sum_{n\neq i} \alpha_{in}\,\widehat{\vartheta}_{in} - \eta\right],$$

where $\eta > 1$ is the elasticity of substitution across varieties, $\alpha_{in} \equiv \frac{p_n \tilde{y}_{in}}{M_i}$ is the ex–ante import share from source n, and $\widehat{\vartheta}_{in} \equiv \frac{p_n \tilde{y}_{in}}{\sum_m p_m \tilde{y}_{mn}}$ is country i's risk-adjusted share of global expenditure on variety n. These objects are determined by ex–ante sourcing decisions that already incorporate the effects of trade–cost risk through the covariance term μ_{in}.

Substituting $\frac{dY_i(s)}{dt}$ and $\frac{dM_i}{dt}$ into the planner's first–order condition yields the following expression for the optimal tariff under trade risk:

$$1+t^{\text{risk}} = \frac{\left[(\eta-1)\sum_{n\neq i}\alpha_{in}\widehat{\vartheta}_{in} - \eta\right]\cdot \mathbb{E}_s\left[\frac{u'(C_i(s))}{\mathbb{E}_s[u'(C_i(s))]}\frac{1}{P_i(s)}\right]}{\eta\cdot\sum_{n\neq i}\mathbb{E}_s\Bigg[\underbrace{\frac{u'(C_i(s))}{\mathbb{E}_s[u'(C_i(s))]}\frac{1}{1+\mu_{in}}}_{\text{risk-adjusted weight}}\cdot\underbrace{\frac{\varphi_{in}(s)/\mathbb{E}_s[\varphi_{in}(s)]}{P_i(s)}}_{\text{state-contingent payoff}}\Bigg]\,\alpha_{in}(\widehat{\vartheta}_{in}-1)}. \tag{1}$$

This expression reveals three distinct motives for tariffs under trade risk. First, a *terms of trade motive*: by restricting imports, the domestic policymaker can influence the relative price of its imports in world markets. This channel operates through the interaction between import shares α_{in} and the country's market power $\widehat{\vartheta}_{in}$, and it remains present and in fact stronger in the absence of risk, when trade volumes are larger.

The second motive reflects a desire for *resilience*. This channel is captured by the denominator in equation (1), which summarizes the risk-adjusted value of imports across states of the world. Two components drive this term. First, the planner places greater weight on adverse states when marginal utility is high, as reflected in $\frac{u'(C_i(s))}{\mathbb{E}[u'(C_i(s))]}\frac{1}{1+\mu_{in}}$. This increases the importance of outcomes where trade disruptions are most costly. Second, the state-contingent payoff from imports, given by $\frac{\varphi_{in}(s)/\mathbb{E}[\varphi_{in}(s)]}{P_i(s)}$, is lower in those same states because trade costs rise and less imports arrive to destination. As a result, imports contribute relatively less to welfare precisely when they are most needed, making it desirable for the planner to tilt sourcing toward more reliable domestic production. The desire for resilience thus raises the optimal tariff under trade risk, as the planner gives greater weight to securing reliable domestic supply in adverse states.

The third motive reflects the role of *tariff revenue*. In the presence of uncertainty, tariff revenue can, in principle, provide consumption insurance, since revenue collected ex ante delivers resources in states where marginal utility is high. This mechanism is captured by the term $\mathbb{E}_s\left[\frac{u'(C_i(s))}{\mathbb{E}_s[u'(C_i(s))]}\frac{1}{P_i(s)}\right]$, which measures the real value of tariff revenue in different states of the world. In our environment, adverse states are characterized by low consumption (and thus high $u'(C_i(s))$) and high domestic prices, so that $\frac{1}{P_i(s)}$ is low precisely when $u'(C_i(s))$ is high. The resulting negative covariance between marginal utility and the real value of tariff revenue implies that tariff receipts pay out little when they are most valuable. Consequently, tariff revenue is a poor hedge against trade disruptions, and this channel *reduces* the optimal tariff relative to an environment without risk.

In the absence of trade risk, both the final–good price $P_i(s)$ and the marginal utility of consumption $u'(C_i(s))$ are constant across states, and $\widehat{\vartheta}_{in}$ collapses to ϑ_{in}. The optimal tariff then simplifies to

$$1 + t^{\text{no risk}} = \frac{(\eta - 1)\sum_{n\neq i}\alpha_{in}\vartheta_{in} - \eta}{\eta\sum_{n\neq i}\alpha_{in}\vartheta_{in} - \eta} \;=\; 1 + \frac{1}{\varepsilon}, \quad \text{where} \quad \varepsilon \equiv \eta\,\frac{1 - \sum_{n\neq i}\alpha_{in}\vartheta_{in}}{\sum_{n\neq i}\alpha_{in}\vartheta_{in}}.$$

Here, η denotes the elasticity of substitution across import sources, α_{in} the share of imports from country n in total absorption, and ϑ_{in} the share of global expenditure on variety n that comes from country i—that is, country i's market share in the world demand for good n. Together, these parameters determine ε, the elasticity of foreign export supply faced by country i, which governs the extent of its market power in world markets and therefore the potential gains from improving its terms of trade through tariffs. This is the standard expression for the optimal tariff in an Armington setting with market power: by restricting import demand, the country can improve the relative price of its imports abroad.

Two useful special cases help illustrate the determinants of the optimal tariff. Under perfect substitution across import sources ($\eta \to \infty$), country i behaves as a price taker in world markets, implying $\varepsilon \to \infty$ and hence $t^{\text{no risk}} \to 0$. Similarly, in the small open economy limit ($\vartheta_{in} \to 0$ for all $n \neq i$), the country's market share in global demand vanishes, eliminating its ability to influence international prices. In both cases, the terms-of-trade motive disappears and the optimal tariff without risk is zero.

In sum, the channels described in this section show that trade risk introduces a resilience motive that raises optimal tariffs, while the state-contingent value of tariff revenue attenuates

Table 5: Optimal import tariffs and production subsidies by agricultural net export status

Panel A: Import tariffs (%)				
Country	Autarky	No risk	Risk	Δ (risk–no risk)
Net importer	0.00	14.4	28.3	13.9
Net exporter	0.00	13.7	19.7	6.0
Panel B: Production subsidies (%)				
Country	Autarky	No risk	Risk	Δ (risk–no risk)
Net importer	0.00	3.0	7.2	4.2
Net exporter	0.00	−1.8	−0.4	1.4

this incentive. In the next section, we evaluate their quantitative significance and the extent to which it depends on countries' pattern of comparative advantage.

6.3 Quantifying Optimal Policies

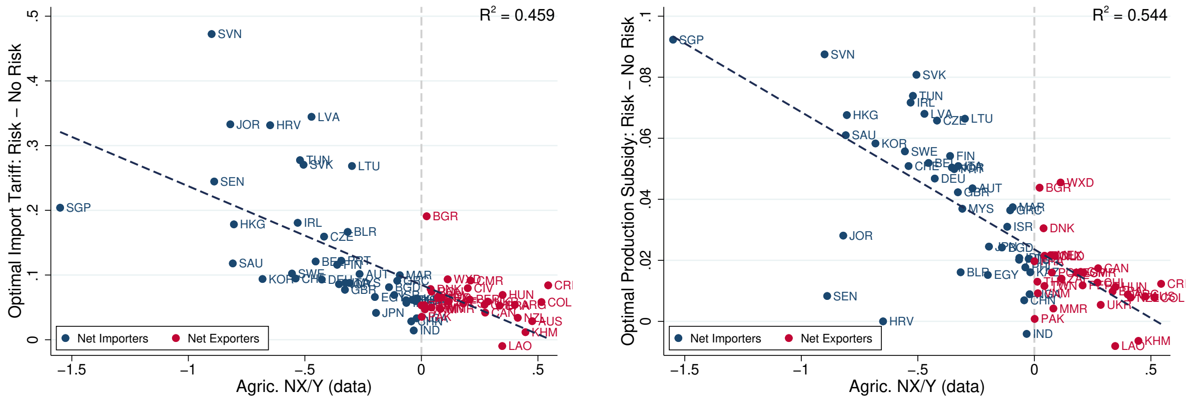
We now quantify the optimal trade and industrial policies. To do so, we solve for the unilateral optimal policy of each country in the full multi–country, multi–sector model with the trade–risk process characterized in Section 5. We consider two instruments separately: a uniform ad-valorem import tariff on agricultural goods and a uniform production subsidy to domestic agriculture. In each case, tariff revenues or subsidy costs are rebated to the representative household in lump sum, with all other countries' allocations determined endogenously in the global competitive equilibrium.

Panel A of Table 5 reports optimal import tariffs for net food importers and exporters across three environments: autarky without risk, open economy without risk, and open economy with risk. Under autarky, optimal tariffs are zero since there is no trade to tax. Once countries open to trade, optimal tariffs become positive in both groups, reflecting the standard terms–of–trade motive. Introducing trade risk further raises the optimal tariff in both cases, but the increase is substantially larger for net food importers (13.9 percentage points) than for net exporters (6.0 percentage points). This finding indicates that trade risk amplifies optimal tariffs more strongly in countries that are more dependent on agricultural imports.

The Panel A of Figure 9 plots the change in the optimal import tariff between the risk and no–risk cases against the ratio of agricultural net exports to output. Countries with

Figure 9: Optimal Policies Under Risk vs. Without Risk

A. Import Tariffs B. Production Subsidies



Notes: Each vertical axis represents the difference between the respective optimal policy under risk and that under no risk. "Agric. NX/Y (data)" is the agricultural net exports to output ratio in the data (benchmark economy).

larger agricultural trade deficits raise tariffs more when trade risk is introduced, generating a clear negative relationship with an R^2 of 0.46. This pattern confirms the importance of the previous finding that exposure to trade disruptions amplifies optimal protection: economies that rely more heavily on imported food use tariffs more aggressively to insure against adverse shocks.

We next turn to production subsidies to domestic agriculture. Panel B of Table 5 reports optimal production subsidies in the same three environments. In the no–risk benchmark, net food importers have positive optimal subsidies, while net exporters have negative ones (production taxes). This pattern reflects standard terms–of–trade considerations: for importers, supporting domestic production reduces reliance on costly imports, while for exporters, expanding supply depresses export prices and is welfare-reducing. Introducing trade risk raises the optimal subsidy for net importers by 4.2 percentage points and brings it closer to zero for net exporters. For importers, expanding domestic production provides insurance against potential import shortfalls. For exporters, the insurance value of additional output is smaller since their exposure to import disruptions is limited, leading to a more muted adjustment.

The Panel B of Figure 9 plots the change in optimal production subsidies between the risk and no–risk cases against the ratio of agricultural net exports to output. As with tariffs, countries with larger agricultural trade deficits raise subsidies more when trade risk is introduced, generating a strong negative relationship with an R^2 of 0.54. This pattern points to a stronger incentive for countries that rely heavily on food imports to expand domestic production as protection against trade disruptions. The slope is slightly steeper than for tariffs, suggesting that production policy adjustments respond even more sharply to import dependence.

Taken together, these results show that trade risk systematically raises the incentive for food–importing countries to adopt protective policies. Both optimal tariffs and production subsidies increase with exposure to import disruptions, and the magnitudes are sizable for countries with large agricultural trade deficits. The quantitative results mirror the mechanisms highlighted earlier, showing that risk raises the welfare value of insulating domestic food supply from external shocks.

Comparison to observed protective polices To assess how the model's predictions relate to real-world policies, we compare our results to observed measures of agricultural protection across countries. In Section 2.4, we documented that the Nominal Rate of Assistance (NRA)—a summary measure of agricultural protection—is systematically higher in net food–importing countries than in net exporters. The NRA encompasses both the border and industrial policies analyzed here, as well as other interventions such as price supports, quotas, and input subsidies. Our qualitative results on optimal tariffs and production subsidies are consistent with these observed patterns: countries that rely more on food imports exhibit stronger protective policies. While the NRA and our policy instruments capture related mechanisms, they differ in scope and definition, so we are restricted to compare them qualitatively. The alignment between observed and model-implied patterns is consistent with trade risk being a driver of agricultural protection in food-importing countries.

7 Implications for Structural Change and Development

So far, we have examined how trade risk shapes trade flows, sectoral production, and policy responses across countries. These countries, however, differ markedly in the role that agriculture plays in their economies—both in terms of consumption, as captured by the expenditure share on food, and in terms of production, as captured by agriculture's share of value added and employment. A well-established feature of economic development is the process of structural transformation, whereby early-stage economies devote a high share of resources to food consumption and agricultural production, while more advanced economies shift toward manufacturing and services (e.g., Herrendorf et al., 2014). Our framework highlights that trade risk can alter this process: by pushing production and expenditure away from comparative advantage, it can slow down structural transformation and, in turn, economic development.

In this section, we examine the implications of trade risk for structural change along three dimensions. First, we study the role of non-homothetic preferences—the key mechanism driving structural transformation—in shaping the aggregate effects of trade risk. Second, we analyze how the impact of trade risk varies across countries depending on their agricultural expenditure shares. Third, we study how gains in agricultural productivity interact with trade risk, influencing both the pace of structural transformation and countries' ability to ensure food security.

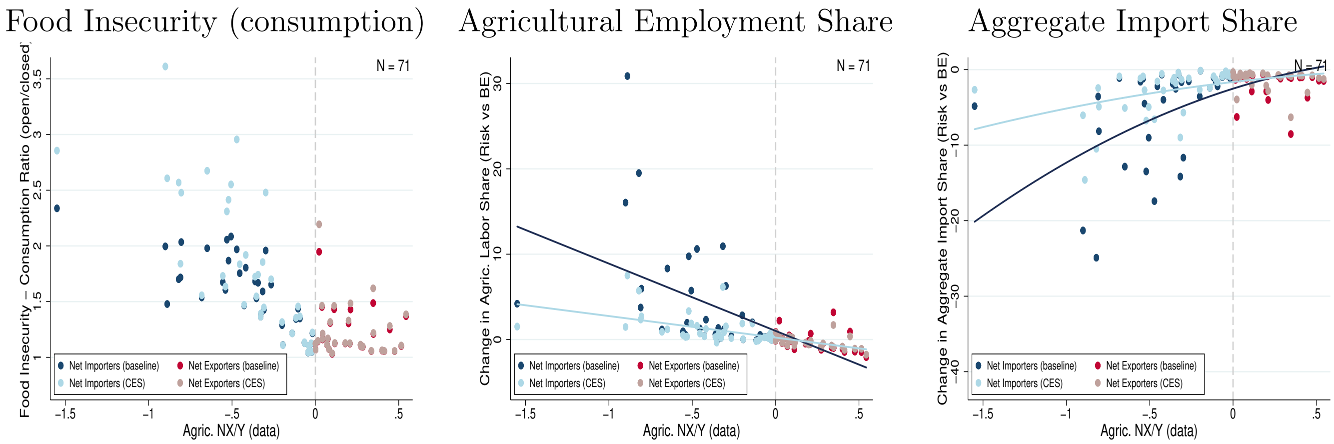
7.1 Non-Homothetic Preferences

We begin by examining the role of non-homothetic preferences in shaping the effects of trade risk. In our multi-sector model, these preferences shift expenditure and production patterns across sectors as income changes, and thus play a key role in generating structural transformation. To assess their importance, we re-estimate the model under homothetic CES preferences—setting $\epsilon_j = 1$ for all j—while matching the same data targets as in the baseline estimation. We then introduce the same tail trade risk process as in the main experiment of Section 5.1 and compare the resulting equilibrium outcomes under CES preferences with those obtained in the baseline economy featuring non-homothetic preferences.

Figure 10 plots the change in food security (Panel A), the agricultural employment share (Panel B), and the aggregate import share (Panel C) resulting from the introduction of trade risk, comparing the outcomes under CES (homothetic) and baseline (non-homothetic) preferences. Each variable is plotted against countries' agricultural trade imbalances in the data. Two main observations emerge. First, the *direction* of the effects of trade risk across net food importers and exporters does not depend on non-homothetic preferences. All countries reduce their participation in trade, food insecurity rises for all but especially for importers, and net food importers (exporters) increase (decrease) their agricultural production. From a macroeconomic perspective, these patterns underscore that trade risk affects all highly traded goods, not only food.

The second observation is that under CES preferences the effects on the sectoral labor allocation and aggregate imports are quantitatively more muted, especially for food importers (compare dark and light blue points in Panels B and C). Non-homothetic preferences, which make food a necessity good, amplify the response of agricultural production and trade to the introduction of risk in countries that rely heavily on food imports. As Panel A shows, however, food insecurity is higher under CES preferences for large food importers. Intuitively, with non-homothetic preferences, these countries retreat more from trade and expand domestic agriculture, making them less vulnerable to disruptions. Under CES pref-

Figure 10: Comparison of Non-homothetic Preferences to CES



Notes: Each figure compares the difference between the equilibrium metric in the economy with risk and that of the riskless open benchmark economy, for the baseline model with non-homothetic preferences against the counterparts with CES preferences. "Agric. NX/Y (data)" is the agricultural net exports to output ratio in the data.

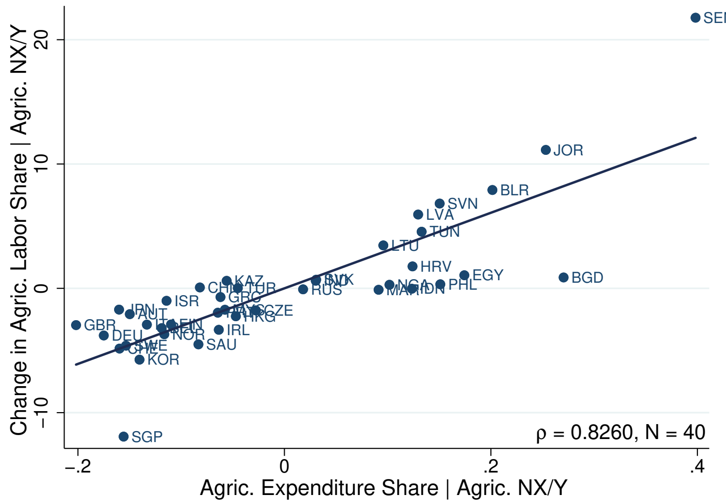
erences, where this adjustment is weaker, large importers remain more exposed. Overall, we find that non-homotheticities play a central role in mediating the effects of trade risk, particularly for essential consumption goods.

7.2 Trade Risk Across Food-Expenditure Shares

We now examine the extent to which the effects of trade risk vary across the development spectrum. In our framework, differences in development are captured by countries' food expenditure shares, which decline as income rises. This exercise allows us to assess whether countries at earlier stages of development, where food accounts for a larger share of spending, respond differently to trade risk than richer economies. When food takes up a large portion of consumption, households are closer to subsistence and therefore face a higher welfare cost from adverse shocks. This property emerges from the interaction between constant relative risk aversion and non-homothetic preferences, which together imply stronger effective risk aversion at lower income levels. As a result, our framework offers a rationale for why lower-income countries tend to insulate themselves more from international trade by engaging less in it, despite their low productivity in agriculture.

To examine this relationship, we focus on net importers of agricultural goods, all of which increase their share of domestic food production in response to trade risk. Figure 11 plots the change in the agricultural employment share between the equilibria with and without

Figure 11: Agricultural expenditure share and the shift to domestic production

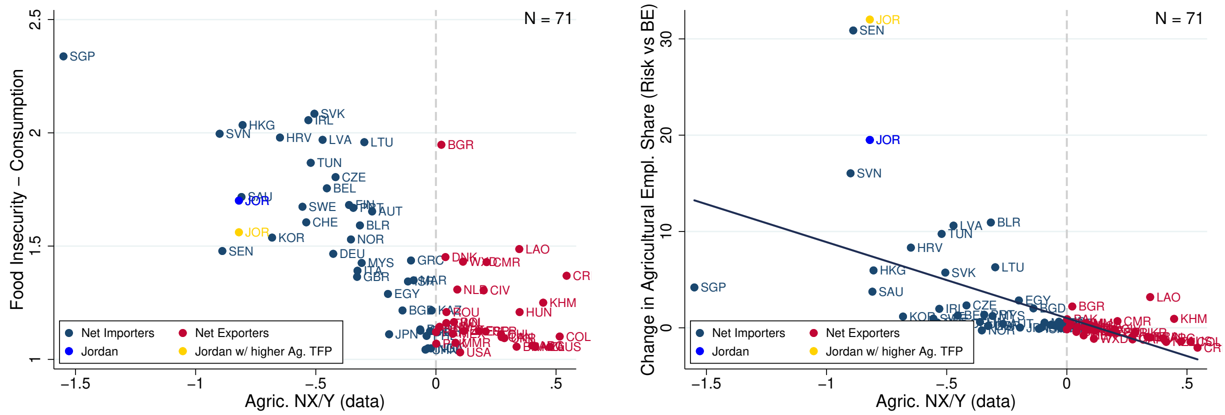


Notes: "Change in Agric. Labor Share (Risk vs BE)" refers to the country-by-country difference between the equilibrium agricultural employment share in the economy with risk and that of the riskless open benchmark economy. "Agriculture: Expenditure Share" is the agricultural expenditure share in the riskless economy.

risk for all net importers, against their food expenditure shares, controlling for agricultural trade imbalances.[9] The figure shows that food importers at earlier stages of structural transformation—those with higher food expenditure shares—shift more strongly toward domestic agricultural production in response to trade risk.

To illustrate, take for example Jordan and Hong Kong—both net importers of agricultural goods with similar agricultural net import–to–output ratios of around 80 percent. However, Jordan's expenditure share on food is twice that of Hong Kong. While both countries shift toward domestic production following the introduction of trade risk, the shift is much more pronounced for Jordan: the share of employment in agriculture rises by 19.4 percentage points in Jordan, compared to 6.6 percentage points in Hong Kong. In other words, conditional on agricultural trade imbalances, countries with higher food expenditure shares respond more strongly to trade risk because they stand to lose more from a trade disruption—particularly when the affected good is a necessity like food.

Figure 12: Agricultural Productivity Improvement: Jordan



A: Food Insecurity (consumption)

B: Agric. Employment Share

Notes: "Change in Agric. Labor Share (Risk vs BE)" refers to the country-by-country difference between the equilibrium agricultural employment share in the economy with risk and that of the riskless open benchmark economy. "Food Insecurity (consumption)" refers to the ratio of consumption if the good (open economy) state occurs relative to if the bad state (autarky) occurs. "Agric. NX/Y (data)" is the agricultural net exports to output ratio in the data (benchmark economy).

7.3 Agricultural Productivity Improvements

We next examine whether improvements in agricultural productivity can mitigate the adverse effects of trade risk on food security. Using our model, we evaluate whether such productivity gains could serve as a market-based alternative to protective policies, allowing countries to achieve greater food security without relying on trade barriers or subsidies. We do so by comparing baseline outcomes to a counterfactual in which agricultural productivity is raised to estimates of its potential level, holding other factors constant.

To quantify the scope for agricultural productivity improvements, we draw on modeled estimates of potential yields from the Global Agro-Ecological Zones (GAEZ) project of the Food and Agriculture Organization, as analyzed in Adamopoulos and Restuccia (2022). These estimates measure the maximum attainable output per unit of land based on geographic characteristics—such as soil, climate, and topography—the biological requirements of each crop, and assumptions about water access and input use. They are constructed using agronomic simulation models that assess how effectively land could be utilized under improved agricultural practices. We use these potential yields to calibrate counterfactual

[9] Specifically, we remove the effect of agricultural imbalances by plotting the residualized values of both the change in agricultural employment and the food expenditure share, based on partial regressions of each variable on agricultural imbalances (the Frisch–Lovell–Waugh approach).

Table 6: Average Effects of Trade Risk with Agricultural Productivity Improvements

	Food Importers		**Food Exporters**	
	GAEZ	**Baseline**	**GAEZ**	**Baseline**
Aggregate Import Share (%)	-7.2	-9.2	+0.2	-1.9
Agricultural Labor share (%)	+8.6	+6.6	+4.4	-0.6
Food Insecurity (ratio)				
Food Consumption (open/closed)	1.69	1.77	1.18	1.18
Rel. Food Price (closed/open)	4.52	5.83	1.50	1.52
Welfare costs of risk (%)	+16.7	-8.9	+11.6	-1.0

Note: Average effects from tail trade risk, for food importers (first two columns) and food exporters (next two columns). "Baseline" refers to the changes in the baseline economy from the introduction of risk. "GAEZ" refers to the effects from the introduction of risk when agricultural productivities in all countries increase to their GAEZ potential levels. Changes are weighted averages within import status groups, where the weights are the relative magnitude of the countries' agricultural trade imbalances.

experiments in which agricultural total factor productivity (TFP) is raised to its estimated potential level, while holding all other model parameters constant.

To illustrate the implications of agricultural productivity improvements, we conduct a counterfactual experiment for Jordan, a food importer that faces substantial exposure to trade risk. In this experiment, we increase agricultural total factor productivity (TFP) by 100%—consistent with the estimated gap between actual and potential yields from GAEZ—while holding all other model parameters fixed. Figure 12 reports the resulting changes in food insecurity (Panel A) and the agricultural employment share (Panel B). The yellow "JOR" marker denotes the new equilibrium under higher productivity. The results show that such a productivity improvement substantially reduces food insecurity, as measured by consumption dispersion, from 1.64 to 1.49, and expands domestic food production, with agricultural employment rising by 10 percentage points (from 20 to 30 percent).

We also solve for optimal tariff and subsidy policies under trade risk for Jordan, with its GAEZ implied higher agricultural productivity, and compare them to the corresponding optimal policies with Jordan's observed actual productivity. We find that the optimal tariff falls from 51 percent under Jordan's actual agricultural productivity to 34 percent under its GAEZ productivity. The corresponding drop in the optimal subsidy is from 6.4 percent to -3.2 percent (tax). In other words, agricultural productivity improvements reduce the optimal policies. Taken together, these findings indicate that agricultural productivity growth–through improved technologies, allocations, reforms– can partly offset exposure to trade risk and lower the need for protective policies such as tariffs or subsidies.

To more systematically examine the effects of agricultural productivity improvements, we run a counterfactual where we introduce trade risk in a world where agricultural productivity in every country increases to its potential level from GAEZ (relative to the United States). The average results of this experiment are reported in Table 6, column one for importers of food, and column three for exporters. Columns two and four repeat the effects of trade risk without agricultural productivity improvements. Improving agricultural productivity for all countries results in an improvement in food security and welfare for all countries, but especially current food importers. While risk still induces importing countries to retreat from trade this is smaller than without the productivity improvements. Current net importers of food engage more in domestic agricultural production than at current agricultural productivity levels.

8 Concluding remarks

We show that the risk of losing access to global markets can fundamentally reshape trade, production, and policy. Using new cross-country evidence and micro data from Ethiopia during the Ukraine–Russia war, we document that dependence on imported staples heightens food insecurity, particularly in poorer economies. Motivated by these facts, we develop a multi-country, multi-sector model in which stochastic trade costs, non-homothetic preferences, and ex-ante sourcing under uncertainty jointly determine food security, structural transformation, and optimal policy.

Trade risk induces food importing countries to retreat from openness and reallocate resources toward domestic agriculture as a pre-caution against abrupt supply disruptions. Quantitatively, rare disruptions cause large welfare losses and significant shifts in employment toward low-productivity agriculture. We show that trade risk rationalizes protective agricultural policies as insurance against unreliable imports, a distinct motive from the political economy or market power forces the literature has considered. However, productivity growth in agriculture can substitute for protection by lowering exposure to risky imports and improving welfare directly.

Conceptually, our paper unifies insights from trade under uncertainty, structural change, and optimal policy. By modeling risk on the trading technology itself and embedding non-homothetic demand, we provide a novel rationale for why countries maintain domestic production of essential goods even when it defies comparative advantage under certainty. Our results highlight that trade risk fundamentally alters the gains from openness and the motives for optimal policy protection.

While our analysis has focused on food security, we note that trade risk can play an important role in understanding the international sourcing of other critical final goods in consumption (e.g, water, electricity, vaccines) or intermediate goods in production (e.g., fertilizers, semi-conductors). Our framework can be used to think about both the positive and normative aspects of these issues, and extend to the formation of resilient trade networks, interactions between trade and financial insurance markets, or the complementarity of insurance and political economy policy motives.

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Online Appendix

A Cross-Country Evidence on Food Security and Trade

In Section 2 we showed the relationship between the Food and Agricultural Organization's (FAO) experiential measure of food security and import dependence on cereals. Here we examine two alternative measures of food insecurity. The first is the prevalence of undernourishment in the population, which is a measure of calorie consumption relative to a threshold needed for survival. While the experiential measure is available for all countries, the undernourishment measure is available from the FAO only for lower income countries. The second measure is food price volatility relative to general price volatility, which can be computed from FAO data for a wide range of countries.[10]

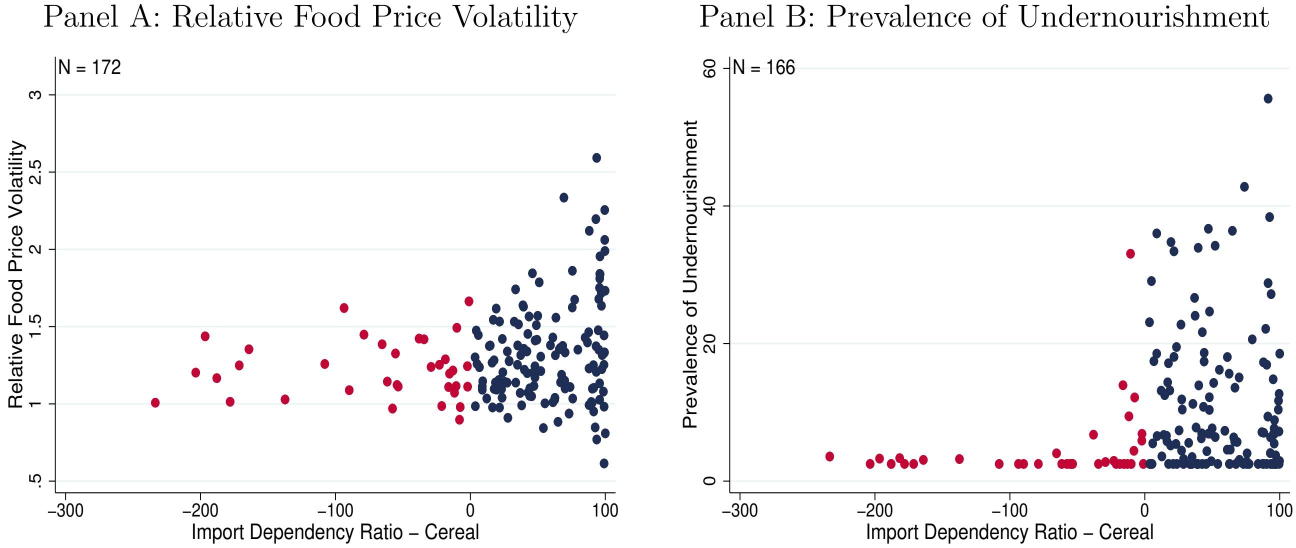
Figure 13 plots the undernourishment measure and the relative food price volatility measure for all countries against the import dependency ration in cereals. Panel A plots relative food price volatility for each country as the ratio of standard deviation in the logarithm of monthly domestic food prices within each country over 2014-2023, relative to the standard deviation of monthly logarithm of the CPI in each country over the same period. Panel B plots the prevalence of undernourishment in the population, where we have replaced all countries with an undernourishment rate of under 2.5, to exactly 2.5 for the purposes of illustration. Both measures are plot against the cereal import dependency ratio as in Figure 3, Panel A.

The message conveyed is similar to that with the experiential measure of food insecurity. On average, net importers face higher food insecurity than exporters. The relative consumer food price volatility is 1.39 for importers, whereas only 1.22 for exporters. The prevalence of undernourishment jumps from 4.69 for exporters to 11.31 for importers. In addition, the higher dispersion in either metric of food insecurity is higher for importers than exporters, just as in Figure in Figure 3, Panel A.

Next we ask whether the patterns of food insecurity with respect to import dependency are driven by income differences across countries. In Table 7 we regress each measure of food insecurity against the import dependency ratio alone (first column under each measure), as well as controlling for the logarithm of real GDP per capita (second column for each measure). In each case we find that the measure of food insecurity is significantly associated with importing cereals, and remains highly statistically significant even after controlling for real GDP per capita. In other words, the effect of import exposure on food insecurity is not driven by income variation.

[10] All the data are from the FAO database, FAOSTAT. Data on the prevalence of undernourishment are obtained from FAOSTAT suite, "Food Security and Nutrition/Suite of Food Security Indicators," (downloaded December 7, 2024). The monthly data "Food Indices (2015=100)" and "Consumer Prices, General Indices" are obtained from the "Consumer Price Indices" suite of the FAO (downloaded April 21, 2025). Figures are based on averages of these variables over 2014-2023. All data are available from https://www.fao.org/faostat.

Figure 13: Metrics of Food Insecurity and Import Dependency



Notes: Each point in the scatter plots represents a country. The y-axis in Panel A measures relative food price volatility, as the ratio of the standard deviation in the logarithm of monthly domestic food prices within each country over 2014-2023, relative to the same moment for the general CPI. The y-axis in Panel B measures prevalence of undernourishment in the population. The x-axis measures the import dependency ratio for cereals in both panels. Source: FAOSTAT.

B Estimation of Probability of Trade Disruption

As described in Section 2.1, to identify food trade disruptions empirically, we use annual data from FAOSTAT on the volume of food imports by country over 1961-2023 for the entire world. A food trade disruption is defined as an annual drop in food imports of 20% or more. Using all country-year observations we find the annual trade disruption probability is 9.53%.

Here, we estimate the effect of geopolitical risk and trade policy uncertainty on the probability of import disruptions in food trade. This approach is analogous to that in Caldara and Iacoviello (2022) who estimate the effect of geopolitical risk on the probability of an economic disaster.

We create a dummy variable D_{it} for country i and year t that takes the value of 1 if there is a trade disruption, i.e., a year-to-year decline in the import quantity index of 20% or more as defined above. Then we estimate linear probability models of the following form,

$$D_{it} = \beta_{GPR} GPR_t + \beta_{TPU} TPU_t + \delta \Delta IM_{it-1} + \epsilon_{it}$$

where GPR is the annualized average global geopolitical risk index from Caldara and Iacoviello (2022), and TPU is the annualized average trade policy uncertainty index from Caldara et al. (2020), as described in Section 2.1. Variable ΔIM_{it-1} is the one-period lagged

Table 7: Food Insecurity and Import Dependency, Controlling for Income

	Experiential Measure		Food Price Volatility		Undernourishment Measure	
IDR	0.079***	0.031**	0.001***	0.001***	0.033***	0.016**
	(0.003)	(0.047)	(0.008)	(0.002)	(0.004)	(0.05)
constant	28.47***	183.7***	1.28***	0.68***	8.86***	69.49***
	(0.000)	(0.000)	(0.000)	(0.001)	(0.000)	(0.000)
log GDP per capita		−16.25***		0.062***		−6.35***
		(0.000)		(0.002)		(0.000)
Obs.	146	144	172	168	166	159
R^2	0.058	0.685	0.041	0.095	0.049	0.554

Note: All columns contain estimates from OLS regressions of measures of food security (experiential measure, food price volatility, and undernourishment) on the import dependency ratio (first column for each measure) as well as log-real GDP per capita (second column for each measure). p-values are in the parentheses, ***, **, and * represent significance at the 1% ($p < 0.01$), 5% ($p < 0.05$), and 10% ($p < 0.10$) level respectively.

import growth for country i, which controls for food trade vulnerability, since a previous year drop in food imports may signal trade distress or supply chain fragility.

Both the GPR and TPU indices are textual analysis based-metrics of the frequency of occurrences of geopolitical tensions (GPR) and trade policy and uncertainty (TPU) from newspaper articles in major newspapers. Both indices are reported on a monthly basis and cover a long periods of time. In Section 2.1 we show the evolution of geopolitical risk and trade policy uncertainty indices over recent years.

Table 8 displays the effect of geopolitical risk and trade policy uncertainty on the probability of a food import disruption. The estimates of the linear probability model are reported in three columns. The first and second columns, in turn, show the effect of the GPR and TPU alone, while the third column shows the effect when both indices are included. Lagged import growth is controlled for in all estimations. The data availability and year coverage of the different variables dictate the period, provided in the last row, over which we estimate the trade disruption probabilities.

From columns one and two, both coefficients β_{GPR} and β_{GPR} are positive and individually statistically significant at the 1% level, suggesting that elevated geopolitical risk and hightened trade policy uncertainty separately predict food trade disruptions. A one-unit increase in the global GPR index raises the probability of a trade disruption by 0.07 percentage points. The effect of trade policy uncertainty is higher, with a one-point increase in the TPU index raising the probability of a trade disruption by 0.14 percentage points. When both TPU and GPR are included in the regression (third column), GPR remains highly

Table 8: Probability of Food Trade Disruption

	(1) Geopolitical Risk	(2) Trade Policy Uncertainty	(3) Both
GPR Index	0.00073***		0.00071***
	(23.36)		(13.90)
TPU Index		0.0014***	0.000056
		(23.59)	(0.58)
Import Growth Lag	0.0762***	0.1044***	0.0762***
	(11.87)	(17.73)	(11.87)
Observations	7,251	10,839	7,251
R^2	0.098	0.085	0.098
$F - statistic$	393.59	502.88	262.48
Estimation Period	1985–2023	1963–2023	1985–2023

Notes: Linear probability model estimates. Dependent variable is dummy D_{it}, that takes the value of 1 if drop in imports is 20% or more. Standard errors in parentheses. $^{*}p < 0.10$, $^{**}p < 0.05$, $^{***}p < 0.01$.

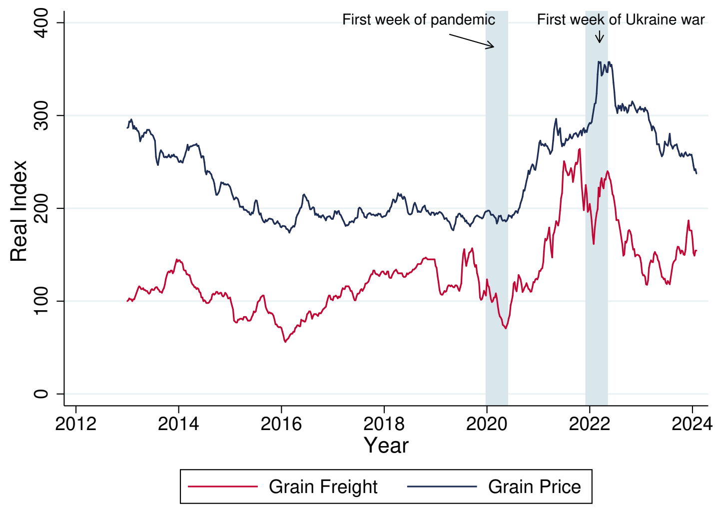
significant, while TPU becomes statistically insignificant. This suggests that, while GPR and TPU individually have strong predictive power, GPR has stronger explanatory power for trade disruptions when controlling for both geopolitical and trade policy uncertainty. We note however, that the sample period for TPU alone is much longer, starting in the early 1960s.

We next use these estimates to calculate the predicted chance of a food trade disruption since 2022. Using the estimated coefficient $\beta_{GPR} = 0.0007$ from the linear probability model and the average GPR of 138.06 since January 2022, the predicted probability of a trade disruption is $0.00073 \times 138.06 = 10.06\%$. When we use the estimated coefficient from the individual TPU regression and the average TPU since January 2022, the predicted probability of a trade disruption is $0.0014 \times 136.90 = 19.15\%$. The predicted probability of a trade disruption from the jointly estimated linear probability model is $.0007067 \times 138.06 + .0000566 \times 136.90 = 10.53\%$. These estimates reflect the elevated geopolitical, and especially trade policy risk since 2022. Reconciling the historical frequency of trade disruptions of 9.5% calculated above with the regression-based conditional probabilities given recent elevated geopolitical and trade policy risk levels, we follow a conservative approach and set the probability of a trade disruption in our main experiment to 10%.

C Impact of Cyclical Trade Risk

Throughout the paper we focus on tail trade risk—low-probability, high-impact events that can lead to abrupt trade disruptions. However, trade is also exposed to more frequent, moderate fluctuations that can significantly affect food access. These recurrent disruptions—driven

Figure 14: Grain Shipping Costs and Exporting Prices Volatility



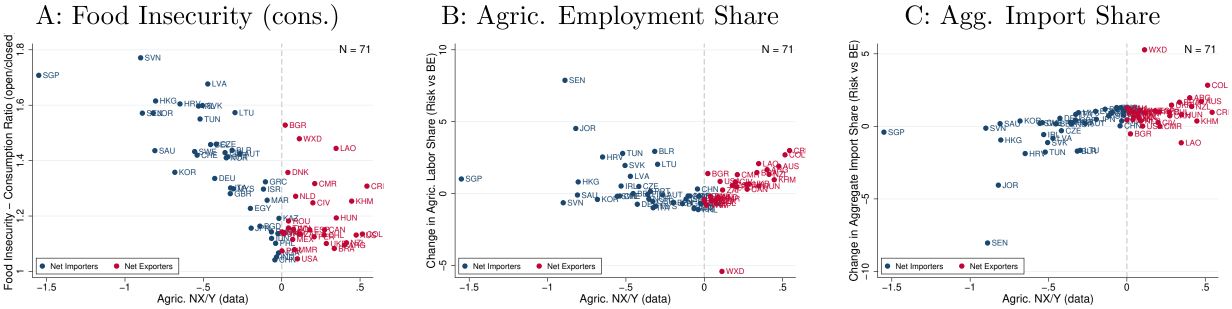
Notes: "Grain Freight" is the Grains and Oilseeds Freight Index, weekly data (1 January 2013 = 100). "Grain Price" is the Grains and Oilseeds Price Index, daily data (January 2000 = 100), in weekly frequency. Source: International Grains Council.

by various sources such as price volatility in global agricultural markets, supply chain bottlenecks, and fluctuations in transportation costs—can be thought of as cyclical or regular trade risk. Food crises and price spikes are not uncommon, with three major episodes in the past two decades. For example, the 2007–08 crisis triggered widespread food riots in many countries.

Cyclical trade risk manifests in both international and domestic food price volatility. One key contributor to these fluctuations is maritime shipping costs, which influence the delivered price of imported goods. Figure 14 displays indices for exporting prices and freight rates for grains from all major producing and exporting countries to primary destination markets. The Grains and Oilseeds Freight Index covers shipments from regions such as Argentina, Australia, Brazil, the Black Sea, Canada, Europe, and the United States. The Grains and Oilseeds Price Index reports export prices for key staple crops including wheat, maize, soybeans, rice, and barley. Both series—reported at weekly frequency—exhibit substantial volatility: the standard deviation of the log of the freight index is 0.30, and that of the price index is 0.19. The shaded bars in Figure 14 indicate the periods surrounding the onset of the COVID-19 pandemic and the Ukraine–Russia war, both of which coincided with sharp spikes in freight rates and export prices. The correlation between the logs of the two indices is 0.65.

To quantify the effects of cyclical trade risk, we use the observed volatility in real freight rates from Figure 14 to calibrate symmetric fluctuations in trade costs. We consider an environment with two equally likely states of the world: one in which bilateral trade costs are lower than the baseline estimates, and another in which they are higher. The 50 percent probability is consistent with the empirical observation that freight rates were above trend in

Figure 15: Impact of Regular Risk



Notes: "Change in Agric. Labor Share (Risk vs BE)" refers to the country-by-country difference between the equilibrium agricultural employment share in the economy with risk and that of the riskless open benchmark economy. "Food Insecurity (consumption)" refers to the ratio of consumption if the good (open economy) state occurs relative to if the bad state (autarky) occurs. "Change in Aggregate Import Share (Risk vs BE)" refers to the country-by-country difference between the equilibrium import share in the economy with risk and that of the riskless open benchmark economy. "Agric. NX/Y (data)" is the agricultural net exports to output ratio in the data (benchmark economy).

7 out of the 15 years in our sample. The dispersion in trade costs across states is calibrated so that the standard deviation matches the observed volatility in freight rates, which has a log standard deviation of 0.30. This setup captures the magnitude of cyclical fluctuations in trade costs implied by historical variation in shipping conditions.

The results of the cyclical trade risk experiment are presented in Figure 15. Panels A, B, and C plot, respectively, food insecurity under the consumption metric, the change in the agricultural employment share, and the change in the aggregate import share—each against countries' agricultural trade imbalances. The effects of cyclical risk move in the same direction as those of tail risk, but are less pronounced. In equilibrium, cyclical risk also leads to higher levels and greater dispersion of food insecurity among net importers relative to exporters. Countries most exposed to trade respond more strongly by reducing their participation in international trade, and among net food importers, the shift toward domestic agricultural production is most pronounced in more vulnerable economies. These patterns resemble the tail risk results because, while the trade cost shocks under cyclical risk are less severe, the probability of experiencing elevated trade costs is higher.

D Optimal Tariff Characterization

We consider a one-sector version of the full model developed in Section 3. The final good producer in the single sector continues to bundle domestic and imported varieties using a CES aggregator, trade costs are stochastic, and variety sourcing decisions are made prior to the realization of uncertainty. Except for the multi-sector layer and the non-homothetic structure over sectors, the one-sector version is identical to the full model. Households consume the single aggregate good comprising the different varieties and market clear as in the full model.

We focus on tariffs as a policy instrument in the analytical characterization. Specifically, the government imposes unilaterally a single ad valorem tariff t on all imported varieties, and rebates the tax revenue lump-sum to the domestic representative household. We first describe the components of the one-sector model that are affected by the tariff and derive the corresponding equilibrium conditions. We then solve the optimal policy problem.

D.1 Equilibrium with tariffs

Imports are subject to tariffs: for $n \neq i$, the final good producer must pay a price of $(1+t)p_n$ per unit of $\widetilde{y}_{in}$. No tariff applies to the domestic variety ($n = i$). The total revenue, rebated to consumers, is,

$$R_i = t \cdot \sum_{n \neq i} p_n \widetilde{y}_{in},$$

which is fixed ex-post since $\widetilde{y}_{in}$ is chosen ex-ante and independent of the realization of s.

Final Good Producer The final good producer (importer) in country i chooses input quantities $\{\widetilde{y}_{in}\}_{n=1}^{N}$ ex-ante to maximize the expected discounted value of profits, where discounting reflects the marginal utility of income of the domestic household:

$$\max_{\{\widetilde{y}_{in}\}_{n=1}^{N}} \Pi_i = \mathbb{E}_s \left[u'\left(C_i(s)\right) \left(P_i(s) Y_i(s) - E_i\right)\right]$$

$$\text{s.t.} \quad Y_i(s) = \left[\sum_{n=1}^{N} \left(\frac{\widetilde{y}_{in}}{\tau_{in}(s)} \right)^{\frac{\eta-1}{\eta}} \right]^{\frac{\eta}{\eta-1}}$$

$$\text{s.t.} \quad E_i \equiv \sum_{n=1}^{N} (1 + t \cdot \mathbf{1}_{n \neq i}) p_n \widetilde{y}_{in}$$

where E_i is total expenditure on domestic and foreign varieties, and $\mathbf{1}_{n \neq i}$ is an indicator variable that takes the value of 1 for any imported variety and 0 for the domestic variety.

The final good producer's first order condition with respect to variety n is,

$$\tilde{y}_{in}^{-1/\eta} \mathbb{E}_s[\varphi_{in}(s)] \cdot (1 + \mu_{in}) = (1 + t \cdot \mathbf{1}_{n \neq i}) p_n \rightarrow \tilde{y}_{in} = \left(\frac{\mathbb{E}_s[\varphi_{in}(s)] \cdot (1 + \mu_{in})}{(1 + t \cdot \mathbf{1}_{n \neq i}) p_n} \right)^{\eta}. \tag{2}$$

which is identical to xx in the full model, except for the tariff.

We define spending on domestic varieties as $D_i = p_i \cdot \widetilde{y}_{in}$, and imports (pre-tariff spending on foreign varieties) as,

$$M_i = \sum_{n \neq i} p_n \widetilde{y}_{in}$$

Then total expenditure can be re-written as $E_i = D_i + (1+t) \cdot M_i$. We also define the import share of country n in total imports of country i as,

$$\alpha_{in} \equiv \frac{p_n \tilde{y}_{in}}{M_i}.$$

Households In country i the representative household has CRRA preferences over state-contingent consumption:

$$u(C_i(s)) = \frac{C_i(s)^{1-\gamma}}{1-\gamma},$$

where $C_i(s)$ is per capita consumption in state s and $\gamma > 0$ is the coefficient of relative risk aversion.

Households are endowed with L_i units of labor (also the population), own all domestic firms, and receive profits and tariff revenue. Their state-contingent budget constraint is:

$$P_i(s)C_i(s) = w_i L_i + \pi_i + \Pi_i(s) + R_i,$$

where π_i and $\Pi_i(s)$ are the profits from domestic variety and final good producers, and R_i is tariff revenue as defined above.

Equilibrium Given that households consume only the single aggregate good produced the market clearing condition is,

$$Y_i(s) = C_i(s), \quad \forall s.$$

Without loss of generality, we normalize the wage in country i to serve as the numeraire, i.e., $w_i = 1$.

D.2 Optimal policy problem

The planner in country i imposes a tariff t on all imported varieties ($n \neq i$), taking as given the structure of the world economy and the equilibrium responses of prices and quantities. The planner internalizes how the tariff affects import expenditures, tariff revenues, the domestic price index, and thus household welfare, across all possible realizations of trade cost shocks.

The objective of the planner is to choose a tariff t to maximize consumer welfare,

$$\max_t \mathbb{E}_s \left[u \left(C_i(s) \right) \right]$$

subject to consumption in each state s is given by the household's budget constraint:

$$C_i(s) = \frac{L_i + R_i + \Pi_i(s)}{P_i(s)},$$

Note that sourcing quantities $\{\tilde{y}_{in}\}$ and unit prices of varieties p_n are determined ex-ante (before the realization of s), as are total expenditures E_i, tariff revenues R_i, and imports M_i

that depend on them. In contrast, $P_i(s), Y_i(s)$ and $\Pi_i(s)$ depend on the realized trade cost shocks $\tau_{in}(s)$. Total labor L_i is fixed.

The first order condition of the planner's problem with respect to the tariff is,

$$\mathbb{E}_s \left[u'(C_i(s)) \cdot \frac{dC_i(s)}{dt} \right] = 0. \tag{3}$$

Using the household budget constraint, the market clearing condition for goods, and the definition of profits we can re-write the planner's first order condition as,

$$\mathbb{E}_s \left[\frac{u'(C_i(s))}{\mathbb{E}_s[u'(C_i(s))]} \cdot \frac{dY_i(s)}{dt} \right] = \mathbb{E}_s \left[\frac{u'(C_i(s))}{\mathbb{E}_s[u'(C_i(s))]} \cdot \frac{1}{P_i(s)} \right] \cdot \frac{dM_i}{dt}. \tag{4}$$

To derive the analytical expression for the optimal tariff that we show in the text, we solve for $\frac{dY_i(s)}{dt}$ and $\frac{dM_i}{dt}$, taking into account the effect of the tariff on world variety prices p_n and the sourcing decisions of final good producers $\widetilde{y}_{in}$.