

Trade Risk and Food Security*

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ABSTRACT

We study the role of international trade risk for food security, the patterns of production and trade across sectors, and its implications for policy. We document that food import dependence across countries is associated with higher food insecurity, particularly in low income countries. We provide causal evidence on the role of trade risk for food security by exploiting the exogeneity of the Ukraine-Russia war as a major trade disruption limiting access to imports of critical food products. Using micro-level data from Ethiopia we empirically show that districts relatively more exposed to food imports from the conflict countries experienced a significant increase in food insecurity by consuming fewer varieties of foods. Motivated by this evidence, we develop a multi-country multi-sector model of trade and structural change with stochastic trade costs to study the impact and policy implications of trade risk. In the model, importers operate subject to limited liability and trade off the production cost advantage against the risk of higher trade costs when sourcing goods internationally. We find that trade risk can threaten food security, with substantial quantitative effects on trade flows and the sectoral composition of economic activity. We study the desirability of trade policy and production subsidies in partially mitigating exposure to trade risk and diversifying domestic economic activity.

JEL classification: E10, F10, F60, I30, O11, O41.

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

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1 Introduction

Global trade in agricultural goods is large. In 2016, the value of exports and imports accounted for 72 percent of world agricultural production. While international trade provides countries with the opportunity to specialize based on comparative advantage, increasing aggregate productivity and welfare, it can also expose countries to a range of risks. International trade can expose countries to unexpected shocks to trade costs, trade policy, geopolitical conditions, climate change, or production conditions in exporting countries, among others. Given the importance of agricultural trade in securing access to food for a vast number of importing countries, these risks may significantly threaten their food security, particularly among the more vulnerable ones. Thus, food security has become a major policy objective for national governments and international organizations, as set out in the United Nations' Sustainable Development Goals.

In this paper, we study the role of trade risk on food security, the patterns of production and international trade across sectors, and its implications for policy. In doing so, we make five key contributions. First, we use cross-country data to document salient features of the relation between food import dependence and food security, particularly for lower income countries. Second, we document the causal nature of this relation between trade dependence and food security by exploiting the exogeneity of the Ukraine-Russia war as a trade disruption shock that affected access to critical food products. Third, we develop a multi-country multi-sector model of trade and structural change with trade risk to study its impact and policy implications. Fourth, we estimate the model to match salient features of the data across countries that differ in agricultural comparative advantage and use it to study the impact of trade risk on production, trade, food security, and welfare. Fifth, we study the role for policy interventions to mitigate the economies' exposure to trade disruptions risk.

Our findings provide insights to better understand the role of risk on the sources and aggregate implications of international trade patterns. We find that trade risk can dramatically impact welfare, by threatening access to critical consumption goods like food. Moreover, we show that trade risk can significantly shape the cross-country patterns of production and trade, and therefore the sectoral composition of economic activity and aggregate productivity. Our findings point to the potential for policy interventions to mitigate the exposure to international trade risk. We find that trade policy and production subsidies can both be effective at partially mitigating the welfare costs of risk exposure, diversifying economic activity away from comparative advantage.

We begin by documenting salient features of the relation between international trade and food insecurity across countries. First, we document the importance of international trade in agricultural goods. We show there is substantial heterogeneity in the importance of international trade in securing access to food across countries. Second, we document the importance and growth of

international trade risk in recent years. Third, we show that food import dependence is associated with higher food insecurity and that, moreover, this relation is systematically accounted for by cross-country differences in the level of economic development. Fourth, we document that food price volatility is associated with food insecurity.

We complement these cross-country facts with causal micro-level evidence on the effect of trade disruptions on food security. We do so by exploiting the exogeneity of the Ukraine-Russia war as a major trade disruption that led to a sharp drop in the flow of key food items into African countries. Using micro-level data from Ethiopia we construct a district-level measure of import exposure to foods from the conflict countries, as a weighted average of the drop in imports of key food items and their import penetration into districts prior to the war. Using this measure we estimate the effect of the war shock on local food insecurity. We find that districts facing larger exposure to imports of wheat and sunflower oil from Ukraine and Russia, experienced a significant decline of food security relative to less exposed districts, consuming fewer varieties of foods.

We then develop a quantitative general equilibrium model to study the impact and policy implications of trade risk. The model embeds trade risk into a multi-sector model of trade and structural change, featuring risk averse, non-homothetic preferences with a low income elasticity for food. In our setup, there is a risk-return trade-off governing the international sourcing decisions of countries. We show that trade risk can induce countries to shift spending from risky imported varieties to safer domestic ones, despite the potential cost advantage of foreign producers. With a low income elasticity for food, this involves, other things equal, a shift of resources from other sectors towards domestic food production. Intuitively, this can be thought of as a form of self-insurance against food security risk from exposure to international trade. Nevertheless, this insurance can be costly from a macroeconomic perspective as the shift towards the less efficient domestic agricultural sector would lead to lower aggregate productivity.

In practice, however, importers may be willing to take on more trade risk than consumers within countries are willing to accept, due to market failures that drive a wedge between the producer and consumer evaluation of trade risk. We micro-found this wedge by modeling suppliers of goods as subject to limited liability when sourcing goods both domestically (risk-free) and internationally (under trade risk). This is consistent with evidence on the prevalence of limited liability firms engaged in international trade. As limited liability allows suppliers of goods to shut down in bad states of the world, it provides them with partial insurance against downside risk by limiting their losses in those states. In equilibrium, this leads them to over-expose themselves to trade risk by sourcing more international varieties.

In our model, we show analytically that risk per se alters the international sourcing decisions

of importers relative to an economy without risk. Importers equate the expected marginal return to ordering a unit of an imported variety to the expected cost of that variety, which consists of its (known) production cost in the foreign country and the associated risky trade cost. Importers weigh the value of alternative states of the world with the stochastic discount factor of its owners, domestic consumers. In the face of trade risk, importers order less from productive but risky foreign producers despite foreign comparative advantage. We show that limited liability can distort the pricing of trade risk, by driving a wedge between the expected marginal benefit and the marginal cost of a unit of imported variety. This induces importers to take on more trade risk, leading to a socially inefficient international sourcing of varieties.

We quantify the effect of trade risk on welfare, trade flows, structural change and aggregate productivity across countries that differ in their comparative advantage for producing agricultural goods. We first estimate the model without risk, including trade costs, to match salient features of the patterns of production and trade across countries, targeting the share of employment in agriculture by country, agricultural trade imbalances, and the extent of international trade openness. Our main quantitative experiment consists of introducing trade disruption risk, which we model as a low probability tail event that if realized would virtually bring international trade to a halt.

We find that trade risk has a substantial effect on welfare and trade-production patterns. In our baseline model with limited liability, trade risk reduces the extent of international trade and raises the share of employment in agriculture for food importers by 8 percentage points (from 20 to 28 percent) relative an open economy with certainty. Limited liability in fact tempers the effects of risk on trade, as without it the share of employment in agriculture would be an additional 8 percentage points higher and countries would trade less. Due to over-exposure to trade in our baseline model, there is excessive ex-post food price and food consumption variability. Intuitively, while the economy with risk but without limited liability also yields variability, this is tempered because countries partially self-insure by diversifying away from international trade. In our baseline model, trade risk also amplifies the variability of aggregate GDP. Without limited liability, GDP in the food importing country when high trade costs are realized is 62 percent of its respective value under low trade costs — vis-a-vis 42 percent in the baseline economy.

There are two frictions in the model that make the equilibrium inefficient, justifying policy-improving interventions. First, international financial markets are incomplete and as a result consumers across countries cannot insure each other against trade risk. Second, under limited liability, importers endogenously take on more risk than is optimal by importing more risky varieties, which in turn raises consumption volatility, and threatens food security. In addition, domestic policy-makers set policy to maximize domestic welfare, creating an incentive to manipulate the terms of

trade. We study optimal corrective domestic and border policies that could improve food security. Consistent with policies widely implemented across countries, we consider two types of policies: (i) subsidizing domestic production of agricultural goods; and (ii) protective import tariffs on food. In each case, we solve for optimal policies from the perspective of the economy without comparative advantage in food production. We quantify the welfare, sectoral, and productivity implications of the two policies.

We find that risk per se does not significantly affect optimal policy in an open economy. Intuitively, even though the economy is subject to risk, this is largely internalized and mitigated through the reliance on domestic production to self-insure against the trade cost risk. There is little left for a policymaker to do in this case. However, under limited liability, the economy is over-exposed to international trade risk, creating a strong role for policy to insure the economy by diversifying decisions away from comparative advantage. We find that the optimal subsidy to domestic agricultural producers is more than three times higher than in the open economy with risk alone, while the optimal tariff is more than twice as large. Both policies raise the domestic share of labor in agriculture in the country imposing the subsidy and limit international trade flows. As a result the policy to insulate domestic consumers against food security risk can alter the pattern of trade and sectoral production across countries.

Our paper contributes to a wide range of literature in international trade and macro-development. On the one hand, our paper contributes to a growing literature in international trade that studies the effect of risk on international trade patterns and aggregate outcomes. Our paper is most closely related to the work of [Burgess and Donaldson \(2012\)](#), [Caselli et al. \(2020\)](#), and [Allen and Atkin \(2022\)](#) who also introduce uncertainty in multi-sector models of trade with multiple locations.¹ We differ in that we study and quantify the role of trade risk per se. In our setup, global sourcing decisions are chosen before stochastic trade costs are realized, leading to a risk-return trade off for importers. Further, we emphasize food security risk for structural change in the context of a trade model featuring non-homothetic preferences, and we study the potential for policy interventions.

On the other hand, our paper contributes to a large literature in macro-development that studies structural change — that is, the shift from agriculture to manufacturing and services, a stylized feature of the process of development ([Herrendorf et al., 2014](#)). An important literature in growth and development studies mechanisms that could generate a structural transformation of the economy, e.g., [Kongsamut et al. \(2001\)](#), [Ngai and Pissarides \(2007\)](#), [Acemoglu and Guerrieri \(2008\)](#), [Boppart \(2014\)](#), [Comin et al. \(2021\)](#). We use the preference structure of [Comin et al. \(2021\)](#) to generate structural change income effects. There is also a large literature that examines

¹Our paper is also related to other studies of the role of risk in international trade, such as [Handley and Limão \(2022\)](#), [Esposito \(2022\)](#), [Gervais \(2018\)](#), and [Kramarz et al. \(2020\)](#), among others.

the interaction of international trade and structural change in an open economy, e.g., [Matsuyama \(1992\)](#), [Tombe \(2015\)](#), [Teignier \(2018\)](#), [Lewis et al. \(2022\)](#), [Sposi et al. \(2021\)](#). However, none of this work incorporates the role of risk. [Chen et al. \(2024\)](#) also study the role of food security risk for structural transformation, investigating the income-expenditure tension between rural and urban households and the role for domestic insurance policies. In contrast, our focus is on how trade risks affect food security, the pattern of production and trade, and the role for policy to mitigate these risks.

Our focus on food security speaks directly to the literature on agriculture and macro-development. There are several papers that study why agricultural productivity is low in developing countries, and yet such a large share of the population is employed in agriculture, among many others [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 \(2022\)](#). We contribute to this literature by studying the role of international trade risk in shaping the sectoral allocation of labor and productivity within countries and trade across countries.

Another strand of the literature related to our work has studied the effect and policy implications of trade disruptions. For instance, the work of [Baqae et al. \(2022\)](#), [Attinasi et al. \(2023\)](#), [Baqae et al. \(2023\)](#) have been recently investigating the effect of trade disruptions in various contexts such as the Ukraine war or U.S.-China decoupling. Similarly, [Leibovici and Santacreu \(2023\)](#) study the effects and policy implications of shortages of critical goods in an open economy. In contrast to our work, these studies examine the implications of trade disruptions ex-post, abstracting from the effect of risk.

The paper proceeds as follows. Section 2 presents aggregate stylized facts on food insecurity and micro-level causal evidence from Ethiopia during the Ukraine-Russia war. Section 3 develops our model of international trade risk and structural change. Section 4 presents the quantitative approach and results, while Section 5 conducts the policy analysis. We conclude in Section 6.

2 Evidence on International Trade and Food Insecurity

We first document a set of stylized facts on the relation between international trade and food insecurity across countries. We then provide causal evidence on this relation based on micro-level data. To do so, we exploit the exogeneity of a major trade disruption, the Ukraine-Russia war, on the food security of a developing country where food is an important component of consumption.

2.1 Stylized Facts

We document that agricultural trade across countries is sizable, exposing countries to potentially considerable trade risks associated with food price volatility and higher food insecurity.

Fact 1: International trade in agricultural goods is large. Agricultural goods are highly traded across the globe. In 2016, world trade, exports and imports, of agricultural goods accounted for 72 percent of the global production of agricultural goods. The extent to which countries are involved in international trade varies substantially, but it is not systematically correlated to the level of development.

Table 2 displays two measures of trade across deciles of the world distribution of income (first two columns) and the world distribution of each measure (last two columns). “Openness” is the ratio of the sum of exports and imports relative to production. “Imp. Dep.” is the import dependency ratio, measured as the difference between imports and exports relative to absorption (production plus imports less exports), multiplied by 100. Reported numbers are unweighted averages within each decile for the year 2016.

The first column indicates that the extent of trade is substantial across countries spanning all income levels. While the extent of openness in food trade exhibits heterogeneity across countries, it does not vary systematically with income. The second column also suggests that import dependency on agricultural goods varies across countries but not systematically with the level of development, except for the fact that the lowest income countries tend to be more net importers of agricultural goods relative to the highest income countries.

The third and fourth column indicate that both openness and import dependency vary dramatically across countries, when we do not condition on income. While all countries engage in trade, in the top end of the distribution this trade is over 19 times domestic production, while on the lower end only 0.14. According to the last column, import dependency also varies considerably across countries, with some being major net exporters and others major net importers. A comparison of the first two columns and the last two columns suggests that the variation in each trade measure across developed and developing countries is considerably more compressed compared to the variation across the world in each trade measure regardless of income.

Fact 2: There is considerable risk in international trade. Despite the extent of global food trade, engagement in trade is itself risky. There are many sources of trade risk, related to trade costs, trade policy, geopolitical conditions, climate change, and production risk in exporting countries. This risk manifests itself in international and domestic food price volatility.

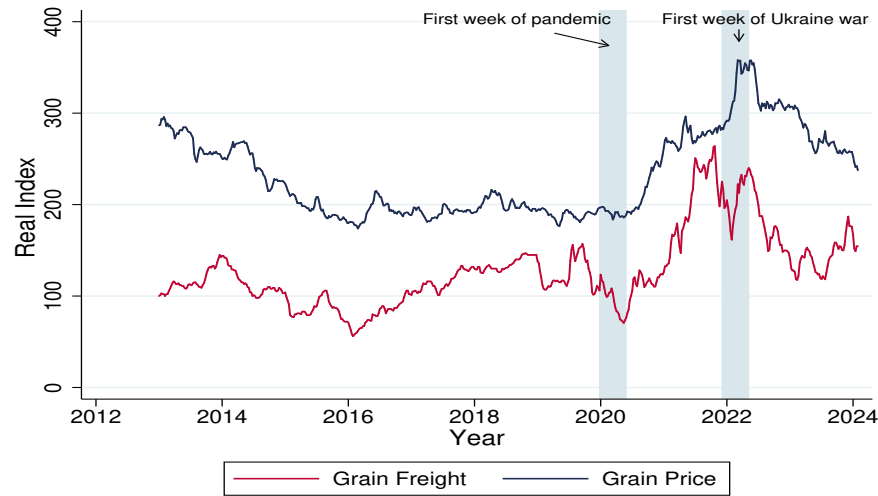
Table 2: Agricultural Trade Across Countries

Decile	GDP p.c. Decile		Measure Decile	
	Openness	Imp. Dep.	Openness	Imp. Dep.
1st	1.10	31.78	0.14	-130.27
2nd	0.32	8.86	0.31	-45.06
3rd	0.92	23.50	0.47	-8.10
4th	1.10	13.27	0.75	2.81
5th	0.81	0.78	0.93	5.91
6th	0.85	-15.37	1.18	16.78
7th	1.52	23.74	1.82	27.84
8th	1.74	6.67	2.45	40.26
9th	0.91	-14.33	3.71	59.22
10th	0.51	2.45	19.18	94.92
World	0.72	0.7	0.72	0.7

Notes: The first two columns display weighted averages when countries are ordered in deciles by real GDP per capita. The last two columns display weighted averages within deciles in the distribution of each measure. “Openness” is the sum of exports and imports over production within each decile. “Imp. Dep.” is the import dependency ratio, measured as the difference between imports and exports relative to absorption within each decile (multiplied by 100). Agricultural production and trade statistics are from FAOSTAT, while real GDP per capita is from the Penn World Table 10.01. All data are for 2016.

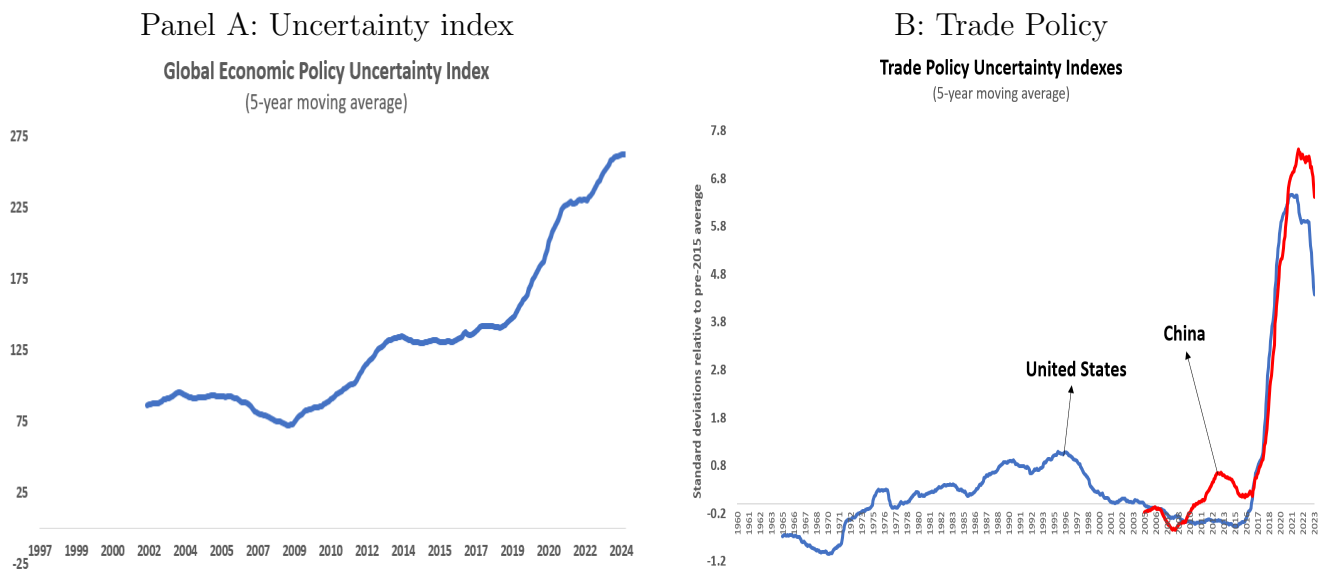
Figure 1 displays indices for exporting prices and freight rates for grains from all the major producing and exporting countries of the world to the main destination markets. Both indices are reported on a weekly basis, with data from the International Grains Council. The Grains and Oilseeds Freight Index summarizes cargo freight rates for grains from Argentina, Australia, Brazil, the Black Sea, Canada, Europe, and the United States to different countries across all continents. The Grains and Oilseeds Index summarizes exporting prices for wheat, maize, soyabeans, rice, barley from the main origin countries of the world to the different destinations. Both freight rates and exporting prices exhibit considerable volatility, with a standard deviation of the log of 0.30 for the freight index and 0.19 for the price index. The shaded bars in Figure 1 indicate the first week of the pandemic and the Ukraine-Russia war respectively, signifying spikes in both indices. The correlation of the logs of the freight and exporting price indices is 0.65.

Figure 1: 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.

Figure 2: Trade Policy Uncertainty



Notes: Author calculations.

In addition to trade disruption risk leading to shipping and export price volatility, another important source of international risk is policy uncertainty. Panel A of Figure 2 plots the global economic policy uncertainty index from Davis (2016) over time. As is readily observed, there has been a substantial increase in policy uncertainty over the last 15 years. Panel B of this figure plots a trade policy uncertainty index for the United States and China from Davis et al. (2019) and Caldara et al. (2020), respectively. Both of these indexes indicate a sharp increase over the last decade.

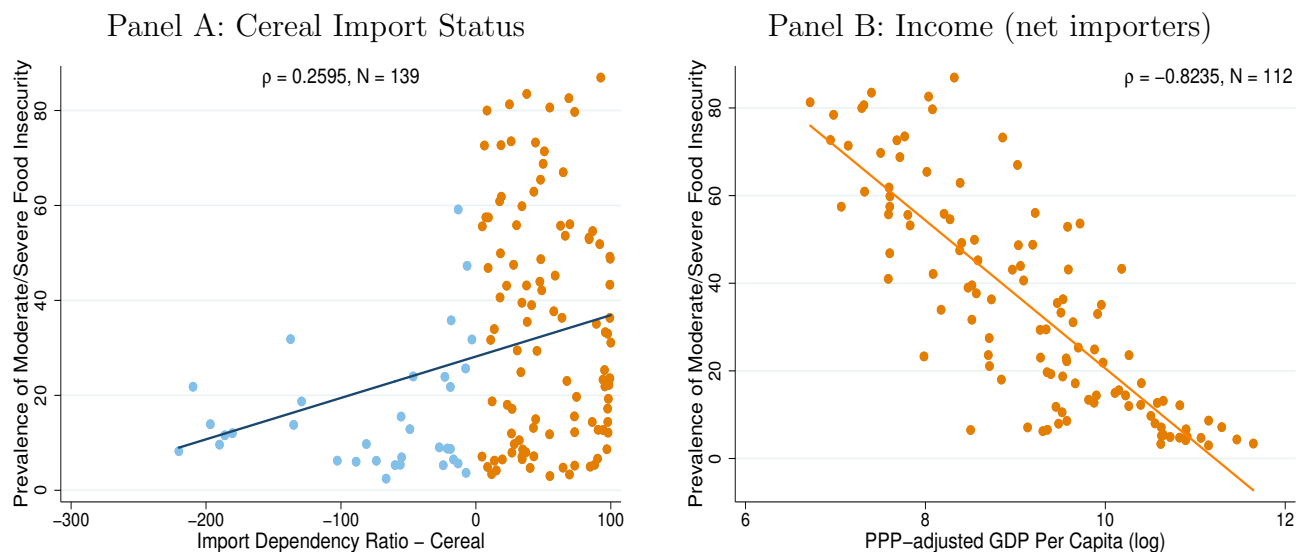
Fact 3: Importing is associated with higher food insecurity. The Food and Agricultural Organization (FAO) explicitly measures food insecurity across countries using answers to survey questionnaires within countries where respondents are asked about themselves or their families, regarding their experiences and challenges in accessing food.² Based on their answers, each respondent is assigned a probability of being beyond a threshold of severity, which is then used to estimate the prevalence of food insecurity in the population, using thresholds based off a common global reference scale. As a measure of food insecurity we use the prevalence of moderate to severe food insecurity in the population (percent) for each country from FAOSTAT. This measure captures perceived food insecurity by consumers and does not rely on the use of a particular set of prices.

In Panel A of Figure 3 we plot the prevalence of food insecurity against the import dependency ratio for cereals (common staple foods). Positive values for the import dependency ratio represent net importers of cereals, while negative values represent net exporters. In Panel A the net importers are the orange points, while the net exporters the light blue points. We find that the group of net exporters faces on average lower food insecurity than the group of net importers. The average prevalence of moderate to severe food insecurity is 16.1 percent for net exporters but more than double, at 34.6 percent for net importers. This mean disparity however confounds considerable dispersion within the group of net importers. As Panel B indicates the variation within the group of net importers is systematically negatively correlated with the level of development, whereby lower income countries face higher insecurity than higher income countries.

Fact 4: Food price volatility is associated with food insecurity. Global food crises are not uncommon events and result in high food price volatility. Figure 4 shows that over the last twenty years there have been three major crises, which resulted in international real food prices rising over two-year periods by around 25 percent during 2009-2011 and around 40 percent during 2006-2008

²The questions are asked as part of the Food Insecurity Experience Scale (FIES) survey module in more general surveys. The yes/no questions are ordered to cover the full range of food insecurity from least to most severe: worried about not having enough food; unable to eat healthy and nutritious food; ate only a few kinds of foods; had to skip a meal; ate less than should; ran out of food; were hungry but did not eat; went without eating for a whole day.

Figure 3: Food Insecurity Across Countries



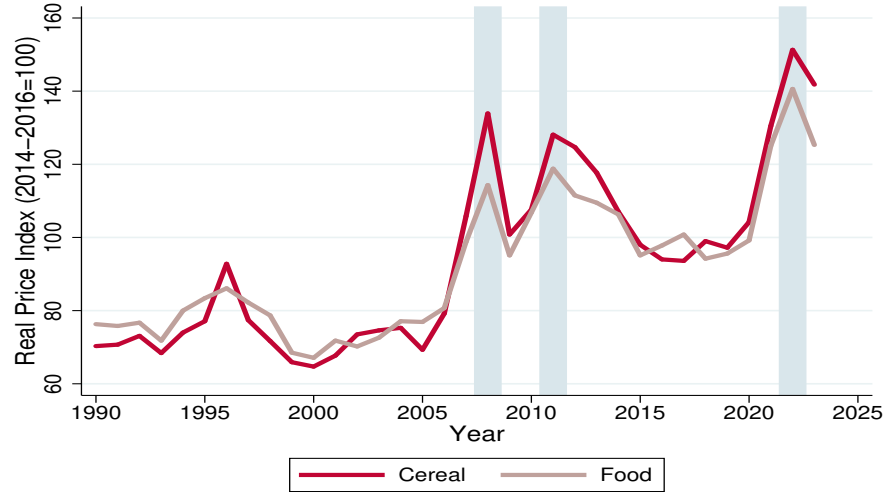
Notes: Each point in the scatter plots represents a country. The y-axis measures the prevalence of moderate to severe food insecurity in the population. The x-axis measures the import dependency ratio for cereals (Panel A) and log - real GDP per capita (Panel B).

and 2020-2022.

Domestic consumer food prices also exhibit volatility but the extent varies across countries. Further, food price volatility is correlated with food insecurity across countries. In Figure 6 we plot monthly food price volatility within countries against the prevalence of moderate to severe food insecurity. The correlation between food price volatility and food insecurity is 0.52.

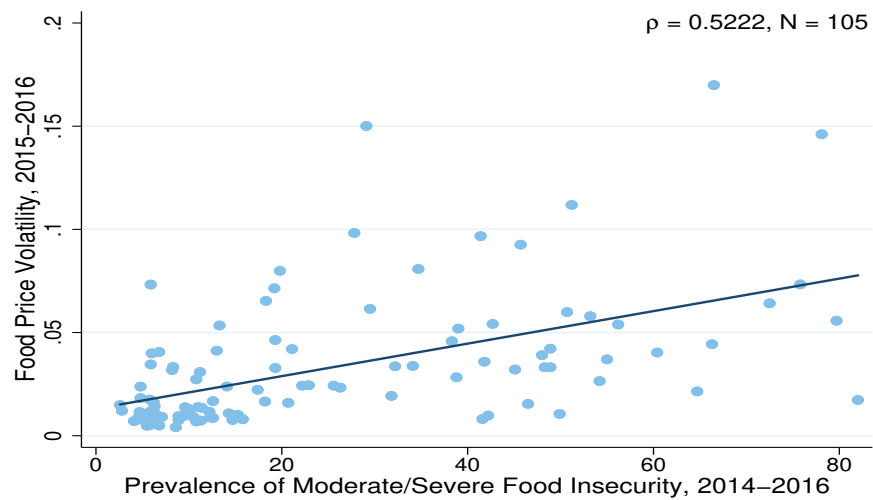
Fact 5: Limited liability across countries, sectors, and trade. Next, we investigate the prevalence of firms subject to limited liability across countries. Previous studies show that limited liability can significantly affect firms' response to risk. We examine the prevalence of limited liability across countries using data from the World Bank Enterprise Survey. We identify firms listed either as “publicly listed” companies or “private held, limited liability” companies as being subject to limited liability — we classify all other firms as not subject to limited liability. We focus on firms in the food manufacturing sectors that are engaged in international trade via exports. Data limitations prevent us from more directly examining the form of incorporation of the broader set of firms engaged in the production, importing, and distribution of food. The first column of Table 3 reports the share of exporting firms in the food manufacturing sector that are subject to limited liability — we report these shares by the level of economic development of the

Figure 5: Food Prices and Food Crises



Notes: Annual real food price indices, 2014-2016 = 100. FAO.

Figure 6: Food Price Volatility and Food Security



Note: Food price volatility is the standard deviation in the logarithm of monthly domestic food prices within each country over 2015-2016. Food insecurity is a three-year average over 2014-2016. Source: FAOSTAT.

Table 3: Limited liability across countries, sectors, and trade

GDP per capita	Food mfct. exporters	All	Food mfct.	Exporters
< \$5,000	40.7%	25.5%	23.7%	42.8%
\$5,000 – \$15,000	50.7%	26.5%	27.4%	33.5%
> \$15,000	62.6%	37.7%	47.4%	50.5%

country in which they operate.

We observe that a sizable share of food manufacturers that export are subject to limited liability. While this share is larger across firms in richer countries, the shares are sizable at all stages of economic development. For instance, 40.7% of food manufacturing exporters in poor countries (GDP per capita below \$5,000 at constant 2017 U.S. Dollars) are subject to limited liability, increasing up to 62.6% in richer countries (GDP per capita higher than \$15,000 at constant 2017 U.S. Dollars).

As the second to fourth columns show, a critical firm characteristic associated with being subject to limited liability is their participation in international trade. Exporters are systematically more likely than their non-exporter counterparts to operate subject to limited liability. In contrast, firms in food manufacturing do not differ systematically from firms in other sectors in their likelihood to be set up as limited liability corporations.

These findings show that operating subject to limited liability is widespread regardless of the level of economic development. To the extent that suppliers of food are likely to operate in such an environment, their sourcing decisions may over-expose them to international trade risk. We investigate the potential of these effects in the following sections.

2.2 Causal Evidence from the Ukraine War

We complement the stylized facts relating international trade and food security with micro-level causal evidence on the effect of trade shocks. We consider the effect of a major trade disruption shock, the Ukraine-Russian war, on food security across districts in Ethiopia that differ with respect to their import market exposure to the shock.

Empirical approach We use a first-differencing approach and estimate the following specification

$$\Delta \text{Food Insecurity}_{it} = \beta \sum_c \text{Import Exposure}_{ci0} \cdot \text{Trade Shock Size}_{cit} + u_{it}$$

where c is a crop index, i the district index, and 0 refers to the period prior to the shock. Our district-level measure of food insecurity is the share of district households that report being insecure about access to food.

Our measure of the size of the trade shock for crop c in district i is the absolute change in quantity of per capita imports of that crop from Ukraine and the Russian Federation normalized by the level of per capita consumption of that crop in district i prior to the trade shock,

$$\text{Trade Shock Size}_{cit} = \frac{\Delta IMP_{ct}^{UR}}{C_{ci0}}.$$

Our measure of district-level import exposure to the trade shock for each crop, is the product of the share of crop c in the total food expenditures of district i , and the consumption share not satisfied by own production, before the war,

$$\text{Import Exposure}_{ci0} = \text{Food Consumption Share}_{ci0} \times [1 - \text{Own Production Share}_{ci0}].$$

Our measure of exposure is meant to capture the variation of penetration of crop imports into the food baskets of households across districts. The first term captures how important the crop is in the food basket of households, while the second term the dependence on outside sources for the consumption of that crop.

To the extent that there are time invariant differences across districts, the first differencing absorbs these district fixed effects.

Data We use micro data for Ethiopia from the World Bank’s *High Frequency Phone Survey 2020-2023*, conducted through rotating interviews over the period 2020-2023. These are national longitudinal high-frequency surveys where households are interviewed on a variety of socio-economic conditions including food security, in different waves of the surveys. The high frequency phone surveys are implemented through the Living Standards Measurement Study - Integrated Survey on Agriculture (LSMS-ISA) program, and as a result the two surveys can be connected at the household-level. We leverage detailed consumption and production data from the 2018-2019 in-person LSMS survey for Ethiopia, to estimate initial measures of exposure, prior to the pandemic and the war.

We construct the district-level measure of import exposure to the war shock for two major imported agricultural goods into Ethiopia from Ukraine and Russia, wheat and sunflower oil. The size of the shock for each crop into each district is the change in the real quantity of imports per capita from the conflict countries relative to the per capita level of consumption of each crop in each

Table 5: 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	-0.109*** (-3.03)	-0.045 (-1.08)
Observations	298	298
$F - stat$	9.17	1.16
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 are in the parentheses, *** represents significance at the 1% ($p < 0.01$) level.

district, based on the 2018-2019 LSMS survey prior to the war. The import exposure weight prior to the war, for each crop in each district, is constructed as the product of median household share of that crop in total food consumption and the median household share of consumption not satisfied by own production. Both of these shares are constructed from the 2018-2019 LSMS in-person survey.

We use two measures of food insecurity from the food insecurity suite of the questionnaires in the high frequency phone interviews from 2020 and 2023. The first measure is about the variety of foods consumed and is the answer to a question of whether the household “ate only few kinds of foods.” The second measure is about the total amount of food eaten and is the answer to the question of whether the household “ate less than thought they should.” We use a balanced panel of households between the two dates of the surveys to construct for each district the share of households that answer “yes” to each of the above questions.

Results We use the first differencing regression approach that relies on relative exposure to estimate the causal effect of the war across districts. Standard errors are clustered at the district-level. The results for each of our two food insecurity measures are shown in Table 5.

We find that households in districts facing larger exposure to the drop in imports from the conflict countries experience a significant increase in food insecurity, relative to households in districts less exposed, that takes the form of having to reallocate consumption towards fewer varieties. Column (1), on the kinds of foods eaten, shows that the war shock coefficient is negative (import drop increases food insecurity) and statistically significant at the 1 percent level. The share of food insecure households associated with a one-standard-deviation change in the war-induced shock decreases by -0.15 standard deviations. Column (2), on the amount of food eaten is also negative but the effect is not statistically significant. These results together suggest that while households in districts more exposed on average did not go hungry, they did have to switch to less variety in their diet.

These findings provide evidence in support of a causal relation between international trade risk and food security. In the next sections we investigate the aggregate implications of this relation and the potential for policy interventions to mitigate these effects.

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 and limited liability. The global economy consists of N countries, indexed by $n \in \{1, \dots, N\}$, with J sectors in each country, indexed by $j \in \{1, \dots, J\}$. 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 that is consumed domestically by aggregating the domestic sectoral variety with sector-specific varieties from every other country. 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 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 that manifest in bilateral iceberg trade costs being stochastic.

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. Given the only fundamentals subject to risk in our model are trade costs, we have that states of the world index trade costs: If state s is realized, importing one unit of sectoral variety j from country n into country i requires purchasing $\tau_{in}^j(s) \geq 1$ units. Let $\mathcal{T}(s) = \{\tau_{in}^j(s)\}_{i \in N, n \in N}^{j \in J}$ be the array of all bilateral trade costs and sectors in state s .

To reduce the dimensionality of this object, note that the trade shocks can be further decomposed into a bilateral component and a sector-specific component:

$$\tau_{in}^j(s) = \bar{\tau}_{in}(s) \bar{\tau}^j(s).$$

Thus, if trade relations between countries i and n collapse, this can be captured by $\bar{\tau}_{in}(s) \rightarrow \infty$. If, on the other hand, trade in sector j collapses globally this can be captured by $\bar{\tau}^j(s) \rightarrow \infty$.

Timing While we study a static one-period model, 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 in detail.

The following take place simultaneously before the shock is realized:

- **Producers of domestic sectoral varieties:** Hire labor, produce varieties, and sell them to producers of sectoral goods. Profits (losses) are transferred to (paid by) the household.
- **Producers of sectoral goods:** Purchase sectoral varieties domestically and internationally subject to risk.
- **Households:** Supply labor to producers of domestic sectoral varieties, earn labor income.
- **Market for labor clears:** Supply of labor from households equals demand for labor by producers of domestic sectoral varieties, pinning down the equilibrium wage in each country.
- **Market for domestic sectoral varieties clears:** Supply of domestic sectoral varieties equals demand for them by producers of sectoral goods across all countries, pinning down the

equilibrium price of varieties in each sector and country.

The following take place simultaneously after the shock is realized:

- **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.
- **Producers of final goods:** Produce final goods by purchasing sectoral goods. Profits (losses) are transferred to (paid by) the household.
- **Households:** Earn profits from all domestic producers, use total earnings to purchase final goods to be used for consumption.
- **Market for sectoral goods clears:** Supply of sectoral goods equals demand for sectoral goods by producers of final goods, pinning down the equilibrium price of sectoral goods.
- **Market for final goods clears:** Supply of final goods equals 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 only uses 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 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:

$$\max_{\ell_i^j} \pi_i^j = p_i^j y_i^j - w_i \ell_i^j$$

subject to

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

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:

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

where $q_{in}^j(s)$ is the quantity of the sectoral variety from sector j produced in country n consumed in i when shocks $s \in S$ are realized. ω_{in}^j is a preference shifter that weighs country i 's purchases of sectoral varieties in sector j across the alternative sources — we have that $\sum_{n=1}^N \omega_{in}^j = 1$. The elasticity of substitution across varieties from different countries within a sector is $\eta_j > 0$. With $\eta_j > 1$, varieties from different countries are more substitutable than under Cobb-Douglas.

For quantity $q_{in}^j(s)$ 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:

$$\tilde{y}_{in}^j = q_{in}^j(s) \tau_{in}^j(s),$$

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

3.3.1 Problem without limited liability

To sharpen the exposition, we first present the problem of sectoral producers without limited liability, and we then extend it to feature limited liability.

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:

$$\begin{aligned} & \max_{\{\tilde{y}_{in}^j\}_{n=1}^N} \mathbb{E} \left\{ u' [c_i(s)] \left[\Pi_i^j(s) = P_i^j(s) Y_i^j(s) - \sum_{n=1}^N p_n^j \tilde{y}_{in}^j \right] \right\} \\ & \text{subject to} \\ & Y_i^j(s) = \left[\sum_{n=1}^N \omega_{in}^j \left[\frac{\tilde{y}_{in}^j}{\tau_{in}^j(s)} \right]^{\frac{\eta_j-1}{\eta_j}} \right]^{\frac{\eta_j}{\eta_j-1}}, \end{aligned}$$

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

3.3.2 Problem with limited liability

Motivated by the pervasiveness of limited liability across firms engaged in international trade, as documented in the previous section, we extend the model such that international and domestic sourcing decisions are made under limited liability.

Given the timing of decisions and risk realizations, producers of sectoral goods may make losses in certain states of the world. Under limited liability, we assume that the payoffs of sectoral good producers are bounded below by κ : Losses or profits cannot be below this value. Thus, the realized profits of the sectoral good producer in state of the world s are given by:

$$\max \left\{ \Pi_i^j(s) = P_i^j(s) Y_i^j(s) - \sum_{n=1}^N p_n^j \tilde{y}_{in}^j, \kappa \right\}.$$

This setup nests the case of no limited liability with $\kappa = -\infty$ as well as our benchmark case with $\kappa = 0$. Limited liability effectively insulates importers against high trade cost contingencies.

To make the problem quantitatively tractable, we model payoffs probabilistically following [Train \(2009\)](#). In particular, we assume that realized profits and the lower bound for payoffs κ are subject to idiosyncratic Extreme Value Type I (Gumbel) shocks ε_Π and ε_κ , respectively, with parameter ϕ . These shocks are independent and identically distributed between them and across underlying infinitesimal sectoral producers.

The sectoral producer's problem under trade risk and limited liability is then given by:

$$\begin{aligned} & \max_{\{\tilde{y}_{in}^j\}_{n=1}^N} \mathbb{E} \left[u' [C_i(s)] \max \left\{ \Pi_i^j(s) = P_i^j(s) Y_i^j(s) - \sum_{n=1}^N p_n^j \tilde{y}_{in}^j + \varepsilon_{\Pi}, \kappa + \varepsilon_{\kappa} \right\} \right] \\ & \text{subject to} \\ & Y_i^j(s) = \left[\sum_{n=1}^N \omega_{in}^j \left[\frac{\tilde{y}_{in}^j}{\tau_{in}^j(s)} \right]^{\frac{\eta_j-1}{\eta_j}} \right]^{\frac{\eta_j}{\eta_j-1}}. \end{aligned}$$

3.4 Producers of final goods

Within each country there 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. \(2021\)](#),

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

where Y_i is the final good in country i , and Q_i^j is the amount of sectoral good j consumed in country i . b_i^j 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:

$$\begin{aligned} & \max_{Y_i(s), \{Q_i^j(s)\}_{j=1}^J} \Pi_i(s) = P_i(s) Y_i(s) - \sum_{j=1}^J P_i^j(s) Q_i^j(s) \\ & \text{subject to} \\ & \sum_{j=1}^J b_i^j \left[\frac{Q_i^j(s)}{Y_i^{\epsilon_j}(s)} \right]^{\frac{\sigma-1}{\sigma}} = 1. \end{aligned}$$

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:

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

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. In turn, the firms operating under uncertainty weigh outcomes across states of the world according to the household's preferences.

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

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

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 its 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 :

- Given prices and wages, households choose consumption optimally
- Given prices, producers of domestic varieties choose inputs and production optimally
- Given prices, producers of sectoral goods choose inputs and production optimally
- Given prices, producers of final goods choose inputs and production optimally
- Market for labor clears prior to the shock: $L_i = \sum_{j=1}^J \ell_i^j$

- Market for domestic sectoral varieties clears prior to the shock: $y_i^j = \sum_{n=1}^N \tilde{y}_{ni}^j$
- Market for sectoral goods clears after the shock: $Q_i^j(s) = Y_i^j(s) \quad \forall s$
- Market for final goods clears after the shock: $C_i(s) = Y_i(s) \quad \forall s$

Throughout, we let wages in the first country to be the numeraire.

3.7 How risk affects international sourcing decisions

We now proceed to describe how risk affects international sourcing decisions. We first examine the model without limited liability, and then we contrast it with the optimal choices under limited liability.

Without limited liability The solution of this problem in country i is encoded by a set of first-order conditions with respect to variety n in sector j :

$$\omega_{in}^j (\tilde{y}_{in}^j)^{-\frac{1}{\eta_j}} \mathbb{E} \left\{ u'(C_i) P_i^j (Y_i^j)^{\frac{1}{\eta_j}} (\tau_{in}^j)^{\frac{1-\eta_j}{\eta_j}} \right\} = p_n^j \mathbb{E}[u'(C_i)].$$

Note that we omit the dependence of the variables on the realization of state of the world s whenever variables are within the expectations operator.

We denote the variety-specific trade cost term, weighted by the sectoral revenue term by:

$$\varphi_{in}^j \equiv P_i^j (Y_i^j)^{\frac{1}{\eta_j}} (\tau_{in}^j)^{\frac{1-\eta_j}{\eta_j}}.$$

Then, the first-order conditions can be re-written as:

$$\omega_{in}^j (\tilde{y}_{in}^j)^{-\frac{1}{\eta_j}} \mathbb{E} \{ u'(C_i) \varphi_{in}^j \} = p_n^j \mathbb{E}[u'(C_i)]$$

or, equivalently, as:

$$\omega_{in}^j (\tilde{y}_{in}^j)^{-\frac{1}{\eta_j}} \mathbb{E} (\varphi_{in}^j) \mathbb{E} \left\{ \frac{u'(C_i)}{\mathbb{E}[u'(C_i)]} \frac{\varphi_{in}^j}{\mathbb{E}(\varphi_{in}^j)} \right\} = p_n^j. \quad (1)$$

Then, the definition of the covariance operator implies we can rewrite the expression as:

$$\mathbb{E} \left\{ \frac{u'(C_i)}{\mathbb{E}[u'(C_i)]} \frac{\varphi_{in}^j}{\mathbb{E}(\varphi_{in}^j)} \right\} = \mathbb{E} \left\{ \frac{u'(C_i)}{\mathbb{E}[u'(C_i)]} \right\} \mathbb{E} \left\{ \frac{\varphi_{in}^j}{\mathbb{E}(\varphi_{in}^j)} \right\} + \mathbb{C} \left\{ \frac{u'(C_i)}{\mathbb{E}[u'(C_i)]}, \frac{\varphi_{in}^j}{\mathbb{E}(\varphi_{in}^j)} \right\}$$

$$= 1 + \mathbb{C} \left\{ \frac{u'(C_i)}{\mathbb{E}[u'(C_i)]}, \frac{\varphi_{in}^j}{\mathbb{E}(\varphi_{in}^j)} \right\} \equiv 1 + \mu_{in}^j$$

where \mathbb{C} denotes the covariance operator, and μ_{in}^j is the covariance of the household's marginal utility with the weighted bilateral sector-specific trade cost term, which can be interpreted as the risk premium. If μ_{in}^j is positive and high then this implies that the trade costs are low when the marginal utility of consumption is high, implying that the variety from country n is less risky. Then we can re-write the first-order conditions of the sectoral good producer as:

$$\omega_{in}^j (\tilde{y}_{in}^j)^{-\frac{1}{\eta_j}} \mathbb{E}(\varphi_{in}^j) (1 + \mu_{in}^j) = p_n^j$$

This implies that the relative demand for orders in country i and sector j , for the varieties of countries k and n is given by,

$$\frac{\tilde{y}_{ik}^j}{\tilde{y}_{in}^j} = \left(\frac{\omega_{ik}^j \frac{p_k^j}{\mathbb{E}(\varphi_{ik}^j)(1+\mu_{ik}^j)}}{\omega_{in}^j \frac{p_n^j}{\mathbb{E}(\varphi_{in}^j)(1+\mu_{in}^j)}} \right)^{-\eta_j}$$

This implies that country i in sector j will order relatively more from the country that it prefers its good (higher ω_{ik}^j), has a lower cost of production (lower p_n^j), a lower expected weighted trade cost (higher $\mathbb{E}[\varphi_{in}^j]$), and is less risky (higher μ_{in}^j). The last of these is what is specific to the choice under trade risk, not present in standard analyses of import choices.

With limited liability When producers of sectoral goods operate subject to limited liability, their problem is solved in two steps. First, we follow [Train \(2009\)](#) in integrating the discrete choice implicit in the firm's payoff due to limited liability. Following the derivations therein, we have that the probabilities that realized profits are non-negative and negative, respectively, are given by:

$$\Pr [\Pi_i^j(s) \geq 0] = \frac{\exp [\Pi_i^j(s)/\phi]}{\exp[\kappa/\phi] + \exp [\Pi_i^j(s)/\phi]}$$

$$\Pr [\Pi_i^j(s) < 0] = \frac{\exp[\kappa/\phi]}{\exp[\kappa/\phi] + \exp [\Pi_i^j(s)/\phi]}$$

Given these probabilities, the sectoral producer's problem can be rewritten as:

$$\begin{aligned}
& \max_{\{\tilde{y}_{in}^j\}_{n=1}^N} \mathbb{E} \left\{ u'(C_i(s)) \ln [\exp(\Pi_i^j(s)/\phi) + \exp(\kappa/\phi)] \right\} \\
& \text{subject to} \\
& \Pi_i^j(s) = P_i^j(s) Y_i^j(s) - \sum_{n=1}^N p_n^j \tilde{y}_{in}^j \quad \forall s \\
& Y_i^j(s) = \left[\sum_{n=1}^N \omega_{in}^j \left[\frac{\tilde{y}_{in}^j}{\tau_{in}^j(s)} \right]^{\frac{\eta_j-1}{\eta_j}} \right]^{\frac{\eta_j}{\eta_j-1}} \quad \forall s
\end{aligned}$$

The first order conditions with respect to y_{in}^j are given by:

$$\omega_{in}^j (\tilde{y}_{in}^j)^{-\frac{1}{\eta_j}} \mathbb{E} \left\{ u'(C_i) \frac{\exp[\Pi_i^j(s)/\phi]}{\exp[\kappa/\phi] + \exp[\Pi_i^j(s)/\phi]} P_i^j (Y_i^j)^{\frac{1}{\eta_j}} (\tau_{in}^j)^{\frac{1-\eta_j}{\eta_j}} \right\} = p_n^j \mathbb{E} \left[u'(C_i) \frac{\exp[\Pi_i^j(s)/\phi]}{\exp[\kappa/\phi] + \exp[\Pi_i^j(s)/\phi]} \right]$$

This can be re-written as:

$$\omega_{in}^j (\tilde{y}_{in}^j)^{-\frac{1}{\eta_j}} \mathbb{E} (\varphi_{in}^j) \mathbb{E} \left\{ \frac{u'(C_i)}{\mathbb{E}[u'(C_i)]} \frac{\mathbb{E}[u'(C_i)] \frac{\exp[\Pi_i^j(s)/\phi]}{\exp[\kappa/\phi] + \exp[\Pi_i^j(s)/\phi]}}{\mathbb{E} \left[u'(C_i) \frac{\exp[\Pi_i^j(s)/\phi]}{\exp[\kappa/\phi] + \exp[\Pi_i^j(s)/\phi]} \right]} \frac{\varphi_{in}^j}{\mathbb{E}(\varphi_{in}^j)} \right\} = p_n^j \quad (2)$$

As can be seen by comparing equations (1) and (2), limited liability drives a wedge between the expected value marginal product and the marginal cost of ordering an extra unit of variety n , indicated in blue in equation (2). This wedge distorts the pricing of risk from the point of view of the sectoral producer, inducing over-exposure to risk relative to the model without limited liability.

4 Quantitative analysis

In this section, we use the model to study the extent to which international trade risk affects the patterns of production and trade across countries that differ in their comparative advantage for producing agricultural goods. To do so, we begin by estimating the model without risk to match salient features of the patterns of production and trade across such countries. We then use the estimated model to study the impact of international trade risk. First, we investigate how aggregate and sectoral patterns of production and international trade are affected when decisions are made subject to risky trade. Second, we investigate the implications of our findings for food

security. Third, we investigate the welfare costs of international trade risk. We conclude this section by examining the role of various channels featured by our model in accounting for our findings.

To quantify the role of risk on the pattern of production and trade, we consider a world economy populated by two countries ($N = 2$) and two sectors ($J = 2$). We let one sector ($j = m$) consist of manufactures, while the other sector ($j = a$) is given by agriculture. Then, we let one country ($n = m$) have comparative advantage in manufactures, and the other country ($n = a$) have comparative advantage in agriculture. In Section 4.1, we describe how we map these sectors and countries with their empirical counterparts.

4.1 Parameterization

To parametrize the model, we partition the parameter space into two sets of parameters: predetermined parameters, and parameters estimated to match salient features of the patterns of production and trade observed in the data.

Predetermined parameters Predetermined parameters are set to standard values from the literature, and consist of the risk aversion parameter γ , the elasticity of substitution within sectors between domestic and imported varieties $\{\eta_j\}_{j \in \{a, m\}}$, the elasticity of substitution across sectors σ , and the sector-specific non-homotheticity parameters ε_j . We abstract from cross-country differences in population, so we normalize the labor endowments in each country to unity.³

Table 6 reports the values of the predetermined parameters that we use throughout. We begin by setting γ to 2 as standard in macro models with risk. We set the elasticity of substitution within sectors between domestic and imported varieties to be relatively high, such that it is relatively easy to substitute imports with domestic alternatives. We make this choice in an attempt to approximate an economy with perfect substitution across alternative sources, as in Eaton and Kortum (2002), while retaining the computational tractability of avoiding corner solutions implied by a finite elasticity of substitution. On the other hand, we assume sectoral goods are complementary to each other. In particular, we set σ to 0.50, a value that implies stronger complementarities than typically assumed in models with Cobb-Douglas aggregation (e.g., Caliendo and Parro 2015) yet weaker complementarities than estimated by Stockman and Tesar (1995) between tradables and non-tradables. Finally, we set the non-homotheticity parameters for agriculture and manufactures to 0.05 and 1, respectively, as parametrized by Comin et al. (2021).

³Additionally, we set the dispersion of Gumbel shocks to the payoffs of sectoral producers such that they do not affect aggregate outcomes.

Table 6: Predetermined parameters

Parameter	Value	Description
γ	2	Risk aversion
$\{\eta_j\}_{j \in \{a,m\}}$	8	Elasticity within sectors: Domestic vs. imports
σ	0.50	Elasticity across sectors
ε_m	1.00	Non-homotheticity: Manufactures
ε_a	0.05	Non-homotheticity: Agriculture
L	1.00	Population: Country m
L^*	1.00	Population: Country a

Estimated parameters The set of parameters estimated to match moments of the data consists of the sectoral productivities z in each country and sector, the sectoral absorption weights b in each country and sector, and the iceberg trade cost τ across each source-destination country pair in each sector. We estimate these parameters in a version of the model without risk — we investigate the impact of introducing risk in the next section.

To simplify the analysis, we normalize to unity the productivity of country a in sector a and the productivity of country m in sector m — that is, productivity is set to unity in each country in their sector of comparative advantage. Moreover, we set the sectoral weight on manufactures to unity in both countries, and estimate the sectoral weight on agriculture in each country to match salient features of the data. Finally, we assume domestic trade is frictionless (i.e., $\tau_{ii}^j = 1 \forall i, j$) and that international trade in all countries and sectors is subject to a common iceberg trade cost τ (i.e., $\tau_{in}^j = \tau \forall i \neq n, \forall j$). Thus, we estimate two productivity parameters, two sectoral absorption weights, and one trade cost parameter.

We estimate these parameters to match salient features of the data on the pattern of production and international trade across countries. For each country, we target the share of the labor force that works in agriculture as well as the sectoral trade imbalance in agriculture relative to output of agricultural goods. In addition, we target the world-level degree of international trade openness as captured by the ratio of imports to GDP.

To compute empirical counterparts to these moments, we use data from the World Bank’s World Development Indicators to partition countries into two groups based on their revealed comparative advantage in agriculture. For each country, we compute the share of the country’s exports accounted by agriculture relative to the share of global exports accounted by agriculture — we refer to this

Table 7: Estimated parameters

Parameter	Value	Description	
(z_m, z_a)	(1.00, 0.38)	Productivity: Country m	
(z_m^*, z_a^*)	(2.21, 1.00)	Productivity: Country a	
(b^m, b^a)	(1.00, 0.08)	Sectoral weights: Country m	
(b^{m*}, b^{a*})	(1.00, 0.05)	Sectoral weights: Country a	
τ	1.15	Iceberg trade cost	
Moment		Target value	Model
World: Imports/GDP		0.284	0.284
Country m : Labor share in agriculture		0.196	0.196
Country m : Agr. NX / Agr. Output		-1.160	-1.160
Country a : Labor share in agriculture		0.322	0.322
Country a : Agr. NX / Agr. Output		0.328	0.328

ratio of shares as the country's revealed comparative advantage (RCA) in agriculture. For each country, we compute the average value of this ratio over the period 2010 and 2019, and then partition countries into two groups: (i) countries whose average RCA in agriculture is higher than the median are classified as country a , while (ii) countries whose average RCA in agriculture is lower than the median are classified as country m . Throughout, we restrict attention to countries with a population of at least a million people.

These two groups of countries are our empirical counterparts to the countries in the model. Then, we use data from the World Bank's World Development Indicators to compute the average share of the labor force in agriculture across each of these two groups countries. Similarly, we compute the net exports to output ratio in agriculture for each of these two groups of countries. Finally, we use data on global trade and output to compute the world-level imports-to-GDP ratio.

Table 7 reports the estimated parameters along with the targeted moments and their model counterparts. We observe the target moments can be matched exactly. In particular, the estimated parameters imply country a , with comparative advantage in agriculture, has 32.2% of its labor force in agriculture and is a net exporter of agricultural goods. In contrast, country m only has 19.6% of its labor in agriculture and runs a significant deficit in agricultural trade: imports of these goods exceed exports by more than twice the amount of output of these goods that is produced

Table 8: Aggregate outcomes

		No risk	Baseline	No limited liability
<i>1. Ex-ante outcomes: Level</i>				
Imports / Absorption	Country m	0.45	0.38	0.18
	Country a	0.21	0.18	0.09
<i>2. Ex-post outcomes: Closed/Open ratio</i>				
Aggregate GDP	Country m	0.85	0.38	0.66
	Country a	0.96	0.79	0.89

domestically. Finally, as in the data, the model implies a world-level imports-to-GDP ratio of 28.4%.

4.2 Experiment

We now use the estimated model to investigate the effect of risk on the pattern of production and trade, food security, and welfare. The key experiment consists of introducing trade risk to the open economy model without risk estimated in the previous section.

To simplify the analysis, we consider a version of our model with two possible states of the world ($S = 2$): open and closed. With probability π , the world economy is open to international trade as captured by the estimated trade costs τ . With probability $1 - \pi$, the world economy is approximately closed to international trade, with trade costs $\tau \rightarrow \infty$. Throughout the rest of the paper, we set $\pi = 0.90$ to examine the outcomes implied by an economy subject to a small yet non-trivial risk of operating under international trade autarky.

We interpret differences between the model with risk and the riskless model as informative about the effects of risk. In addition, we often also report outcomes for an economy with risk but without limited liability ($\kappa = \infty$) and for an economy in autarky without risk. We use these additional outcomes to learn about the extent of over-exposure to risk as well as to benchmark our findings relative to the effects of trade openness relative to autarky in economies without risk.

4.3 Results

We now examine the effects of risk on the patterns of production and trade, and their implications for food security. We report aggregate outcomes in Table 8, and sectoral outcomes in Table 9.

Aggregate outcomes We begin by examining the aggregate implications of risk for the patterns of production and international trade across countries. The top panel of Table 8 reports the imports-to-absorption ratio for each country, which is determined prior to the resolution of uncertainty. Comparing the first and second columns of the table, we find that trade risk reduces the extent to which countries trade internationally: In country m , the imports-to-absorption ratio decreases from 45% to 38%, while this ratio declines from 21% to 18% in country a .

The bottom panel of the table compares aggregate GDP in the economy with risk across the two alternative states of the world relative to its riskless counterpart. In particular, the first column reports the aggregate GDP in the riskless closed economy relative to aggregate GDP in the riskless open economy. The second column reports aggregate GDP in the economy with risk when high trade costs are realized relative to aggregate GDP in this economy when low trade costs are realized. We find that trade risk amplifies the GDP differences across these two alternative states of the world. In the economy with risk, when high trade costs are realized, GDP in country m is only 38% of its respective value under low trade costs. In contrast, GDP in country m in autarky without risk is 85% of its value under trade openness without risk. We observe analogous yet more muted findings for country a .

The third column of the table reports the respective outcomes in an economy with risk but without limited liability. We find that, when producers of sectoral goods do not make purchases subject to limited liability, their sourcing decisions are adjusted even more relative to the economy without risk. For instance, the imports-to-absorption ratio is significantly lower in this economy than either in the economy without risk or in our baseline with risk where firms are subject to limited liability. These risk-mitigation actions, thus, reduce the differences in ex-post outcomes across shocks. For instance, without limited liability, aggregate GDP in country m when high trade costs are realized is 66% of its respective value under low trade costs — vis-a-vis 38% in the economy with limited liability. We observe analogous effects, yet more muted, for country a . These findings show that limited liability significantly amplifies economies' exposure to risk.

Agricultural outcomes We next turn our attention to the sectoral implications, focusing specifically on the agricultural sector. Table 9 presents the findings. The top panel examines ex-ante outcomes, such as the labor and import shares, as well as the sectoral net exports to output ratio. As above, we report outcomes for the estimated model without risk, the baseline with risk, and the economy with risk but without limited liability. In addition, we report outcomes for the riskless economy without trade.

In country m , with comparative advantage in manufacturing, we observe a progressive increase

Table 9: Agricultural outcomes

<i>1. Ex-ante outcomes: Level</i>					
		No risk, open	Baseline	No limited liability	No risk, autarky
Labor share	Country <i>m</i>	0.20	0.28	0.36	0.45
	Country <i>a</i>	0.32	0.28	0.26	0.22
Import share	Country <i>m</i>	0.63	0.41	0.23	0.00
	Country <i>a</i>	0.08	0.07	0.03	0.00
NX/Output	Country <i>m</i>	3.08	1.36	0.64	0.00
	Country <i>a</i>	-0.71	-0.50	-0.33	0.00
<i>2. Ex-post outcomes</i>					
		No risk	Baseline	No limited liability	
Food price variability (closed/open ratio)	Country <i>m</i>	1.09	3.24	1.87	
	Country <i>a</i>	0.97	0.92	0.91	
Food cons. variability (closed/open ratio)	Country <i>m</i>	0.93	0.60	0.75	
	Country <i>a</i>	0.99	0.94	0.97	
Food consumption (closed, risk/no risk ratio)	Country <i>m</i>	-	0.64	0.81	
	Country <i>a</i>	-	0.94	0.97	

in the labor share in agriculture as we move from the riskless open economy (20%) to autarky (45%). Underlying this pattern is a significant shift of labor towards agriculture as we move from a riskless to an environment with risk, and further to autarky. Country *a* features an analogous reallocation of labor from agriculture toward manufacturing as the world economy moves from a riskless world with trade toward a world with trade risk and further to autarky.

These changes in the pattern of production across sectors are accompanied by substantial changes in the pattern of trade. In country *m*, the import share in agriculture declines significantly from 63% in the riskless open economy to 41% in the baseline with risk — and further to 23% in the economy with risk but without limited liability. Similar patterns, yet more muted, are also observed in country *a*. The net exports to output ratio in agriculture follows a similar pattern, with sectoral imbalances substantially reduced as we move from the riskless open economy to the environments with risky trade.

Food security Given the significant impact of risk on the patterns of production and trade of agriculture, we now investigate the impacts on food security. To do so, we focus on three dimensions that capture significant aspects of food security: the variability of food prices, the variability of food consumption, and the level of food consumption in the worst case scenario. The bottom panel of Table 9 presents the findings.

As we move from the riskless economy with trade to our baseline with risky trade, we observe that the variability of food prices and food consumption in country m increase substantially. For instance, the ratio between the relative price of food in the closed economy and the relative price of food in the open economy increases from 1.09 to 3.24. In tandem, we observe that food consumption in the closed economy relative to the open economy declines from 0.93 without risk to 0.60 in our baseline with risk — that is, food consumption if high trade costs realize is 60% of its counterpart if low trade costs are realized. Thus, trade risk leads to a substantial increase of food insecurity in country m . Notice that, while these effects are partially mitigated without limited liability, they remain substantially higher in both environments with trade risk.

Interestingly, food security is barely affected in country a . Given this country has comparative advantage in producing agricultural goods, its trade dependence on these goods is much lower than country m . Thus, international trade shocks have a much smaller impact on food security in this economy.

Beyond variability, another important dimension of food insecurity is the level of food consumption in the worst case scenario. In our analysis, the worst case scenario is given by the world economy under international trade autarky. Thus, we compare the level of food consumption under autarky in the economy with risk relative to its counterpart in the economy without risk. We observe that food consumption in country m under trade autarky is much lower in the economy with risk — 64% of the level of food consumption of the economy under trade autarky but without risk. Consistent with our previous findings, food security in country a is also modestly affected along this dimension.

4.4 Welfare costs relative to riskless open economy

We now turn to an analysis of the welfare costs of trade risk. These welfare costs provide a critical summary statistic for understanding the broader economic impact of trade risks. We compute the welfare costs of risk as the compensating equivalent (CE) gains or losses relative to the open economy with riskless trade. That is, we compute the share of aggregate consumption that households would be willing to give up in the open economy with riskless trade to achieve the level of utility they would obtain in each of the alternative environments. Table 10 presents our findings. In addition to the economies with risky trade (second and third columns), we also report the welfare cost of riskless autarky (fourth column) to benchmark our findings.

In country m , which specializes in producing non-agricultural goods, trade risk has a significant negative impact on welfare. Compared to a riskless open economy, welfare in country m is 13.48%

Table 10: Welfare costs relative to riskless open economy

		No risk, open	Baseline	No limited liability	No risk, autarky
Consumption equiv.	Country m	0.00%	-13.48%	-8.43%	-14.56%
gains / losses	Country a	0.00%	-3.15%	-2.25%	-4.16%

lower. This is a significant welfare loss, close to the welfare cost of riskless autarky (14.56%), despite the low probability (10%) of being subject to high trade costs. This welfare cost is partially mitigated to 8.43% in the economy without limited liability.

Conversely, country a , with comparative advantage in agriculture, faces lower welfare costs due to trade risk. In our baseline model, the welfare cost of risk is 3.15% relative to the riskless open economy benchmark — the loss is even lower without limited liability. These findings point to the greater resilience of this economy to trade risk, particularly given its lower dependence on trade and agricultural imports.

4.5 Key channels

To deepen our understanding of the mechanisms underlying our main findings, we explore several alternative versions of our baseline model. This analysis helps isolate the impact of various features of the model on the implied economic outcomes. Table 11 presents the results, comparing the baseline model with three alternative environments: a model with higher risk aversion ($\gamma = 4$), a model without sectoral imbalances (i.e., we re-estimate to match counter-factually balanced sectoral trade), and a model with homothetic production technology (constant elasticity of substitution, CES). Note we compute the results for each of these versions using parameters estimated based on their respective riskless open economy versions.

Risk aversion We begin by investigating the role of risk aversion on our findings. We find that the economy with higher risk aversion ($\gamma = 4$) implies aggregate and agricultural outcomes that are relatively similar to those of our baseline. However, the welfare cost of risk increases significantly for country m : from 13.48% in the baseline to 23.88% under higher risk aversion.

No sectoral trade imbalances Given our various discussions on the role of comparative advantage and specialization of production, we now investigate how sectoral trade imbalances affect our findings. We observe that the economy without sectoral trade imbalances features a similar amount of trade as the baseline, while exhibiting significantly lower vulnerability to trade shocks.

Table 11: Key channels

	Baseline	Higher risk aversion	No sectoral imbalances	Homothetic technology
<i>1. Aggregate outcomes</i>				
Imports / Absorption				
Country m	0.38	0.36	0.35	0.44
Country a	0.18	0.17	0.21	0.21
GDP (closed/open ratio)				
Country m	0.38	0.41	0.60	0.57
Country a	0.79	0.80	0.72	0.81
<i>2. Agricultural outcomes</i>				
Labor share				
Country m	0.28	0.30	0.22	0.20
Country a	0.28	0.27	0.30	0.32
Import share				
Country m	0.41	0.36	0.28	0.62
Country a	0.07	0.07	0.16	0.08
Food cons. variability (closed/open ratio)				
Country m	0.60	0.64	0.72	0.45
Country a	0.94	0.94	0.85	0.93
<i>3. Welfare (CE gains/losses vs. riskless open economy)</i>				
Country m	-13.48%	-23.88%	-5.98%	-6.99%
Country a	-3.15%	-3.73%	-4.03%	-2.38%

Note: All results based on the baseline model with trade risk and limited liability.

For instance, the imports-to-absorption ratio in country e is 0.35 without sectoral trade imbalances vs. 0.38 in the baseline. Yet, despite this similarity in trade openness, the GDP ratio between high vs. low trade costs is significantly higher than in the baseline (0.60 vs. 0.38), implying trade risk is less disruptive in the absence of sectoral trade imbalances. This lower vulnerability to trade risk in country e leads to much lower welfare costs of risk relative to the riskless open economy, from -13.48% in the baseline to -5.98% in the absence of sectoral trade imbalances. The effects are similar yet much more muted for country a , given its lower trade dependence and comparative advantage in agriculture.

Homothetic technology Finally, we investigate the role of non-homotheticities in accounting for our findings. Overall, we observe the economy with homothetic technology features higher trade integration while being more resilient to trade risk. For instance, country m sees an increase in the

imports-to-absorption ratio from 0.38 to 0.44, and an improvement of the GDP closed-to-open ratio from 0.38 to 0.57. As a result, we find the welfare cost of risk declines from -13.48% to -6.99% in this country. For country a , the effects are less pronounced but qualitatively identical. Our findings point to the importance of non-homotheticities in accounting for our findings.

5 Optimal trade policy and production subsidies

In this section, we study the role for policy interventions to mitigate the exposure to international trade risk. We focus on policies introduced by the government in the country that has a comparative disadvantage in agriculture (country m) given its relatively higher vulnerability to trade risk. We consider the potential desirability of two policies that are often implemented across countries: (i) a subsidy to domestic agricultural producers; and (ii) a tariff on imports of agricultural goods. Optimal policies are chosen to maximize welfare of the representative agent of country m prior to the shock. Thus, our focus is on ex-ante optimal policies. We consider each policy in turn.

To implement these policies, we extend the model such that the country implementing the policies is populated by a government. The government finances production subsidies via lump-sum taxes levied on households of the respective country. Similarly, revenues from import tariffs are rebated back to households through lump-sum transfers. Thus, the government's budget constraint is balanced in all states of the world.

5.1 Optimal policies and welfare

We begin by examining the optimal policies and their associated welfare implications. Table 12 presents our findings under the alternative policies and economic environments.

Production subsidies represent a key policy tool that could help countries mitigate the risks associated with international trade. As expected, we find that the optimal subsidy is zero in a closed economy without risk. In contrast, in a riskless open economy, the optimal subsidy rate is 6.97%, as country m finds it optimal to manipulate terms of trade by reducing the relative supply of the good with comparative advantage. The optimal subsidy rate almost triples to 17.02% in our baseline model, as the economy's over-exposure to international trade leads policymakers to mitigate trade risk. Interestingly, this difference in the optimal subsidy rate is primarily accounted by the interaction between limited liability and risk. In the absence of limited liability, risk per se does not significantly change the optimal subsidy rate. This is due to the internalization of risk via increased reliance on domestic production, leaving little room for government intervention.

Table 12: Optimal policy and welfare

		Production subsidy	Welfare gains (vs. no policy)	Import tariffs	Welfare gains (vs. no policy)
No risk, autarky	Country m	0.00%	0.00%	0.00%	0.00%
	Country a	—	0.00%	—	0.00%
No risk, open	Country m	6.97%	0.40%	11.74%	0.78%
	Country a	—	-0.26%	—	-0.53%
Baseline	Country m	17.02%	1.70%	20.96%	4.62%
	Country a	—	-0.05%	—	-0.15%
No limited liability	Country m	4.39%	0.07%	9.91%	-0.14%
	Country a	—	-0.05%	—	-6.21%

The welfare gains from these subsidies are significant. In the baseline with trade risk, optimal production subsidies in country m lead to welfare gains of 1.70% relative to the equilibrium without the optimal policy. These effects underscore the subsidy’s role in stabilizing the domestic agricultural sector and enhancing overall economic welfare. In contrast, the welfare gains are significantly lower in the absence of either risk or limited liability.

In contrast to production subsidies, import tariffs can directly regulate the inflow of agricultural goods, thereby controlling the degree of exposure to international markets. In the open economy without risk, country m finds it optimal to impose an import tariff of 11.74% on agricultural goods, yielding a welfare gain of 0.78% — these are accounted by the standard channels examined in the literature. The optimal policy intervention almost doubles in our baseline, with an optimal tariff of 20.96% leading to a substantial welfare gain of 4.62%. These findings indicate that tariffs serve as a critical lever to safeguard against external shocks, particularly in countries with a comparative disadvantage in agriculture.

5.2 Aggregate outcomes under the optimal policies

We now examine key aggregate outcomes under the optimal policies. We focus on their implications for international trade openness, as captured by the imports-to-absorption ratio, and aggregate GDP. We report our findings in Table 13.

We find that the production subsidy in country m does not alter the imports-to-absorption ratio. This suggests that while the subsidy aims to bolster domestic agricultural production, it does not

Table 13: Optimal policy, aggregate outcomes

	Country	No policies	Production subsidy	Import tariff
<i>1. Ex-ante outcomes: Level</i>				
Imports / Absorption	Country m	0.38	0.38	0.31
	Country a	0.18	0.18	0.15
<i>2. Ex-post outcomes: Closed/Open</i>				
Aggregate GDP	Country m	0.38	0.44	0.50
	Country a	0.79	0.80	0.83

reduce the reliance on imports. In contrast, the introduction of an import tariff leads to a noticeable decrease of this ratio to 0.31, indicating a substantial shift towards domestic consumption. We find analogous effects for country a in response to the policies implemented by country m .

We find that the policies reduce the variability of aggregate GDP across states of the world. In particular, the ratio of aggregate GDP under high vs. low trade cost realizations increases from 0.38 in the absence of policies to 0.44 and 0.50 under the optimal production subsidies and import tariffs, respectively.

5.3 Agricultural outcomes under the optimal policies

We now examine key agricultural outcomes under the optimal policies. We report our findings in Table 13. We find that both policies lead to a significant increase of the share of labor in agriculture, from 0.28 in the absence of policy interventions, to 0.37 under either policy. Consistent with our findings above, they differ on their impact on international trade flows. While both reduce the import share and sectoral imbalance in agricultural trade, the impact is significantly larger under the optimal import tariff.

Both policies also have a significant impact on food security. On the one hand, both reduce the variability of food consumption across states of the world. In particular, they increase the ratio of food consumption between the high and low trade cost realizations from 0.60 to 0.66 and 0.79 under the production subsidies and import tariffs, respectively. On the other hand, both policies significantly increase the amount of food consumption in the worst case scenario, under the high trade cost realization relative to its counterpart without risk.

Table 14: Optimal policy, agricultural outcomes

	Country	No policies	Production subsidy	Import tariff
<i>1. Ex-ante outcomes: Level</i>				
Labor share	Country m	0.28	0.37	0.37
	Country a	0.28	0.25	0.24
Import share	Country m	0.41	0.36	0.18
	Country a	0.07	0.15	0.06
NX/Output	Country m	1.36	0.54	0.36
	Country a	-0.50	-0.30	-0.21
<i>2. Ex-post outcomes</i>				
Food cons. variability (closed/open)	Country m	0.60	0.66	0.79
	Country a	0.94	0.86	0.95
Food consumption (closed, relative to no risk)	Country m	0.64	0.73	0.82
	Country a	0.94	0.87	0.95

6 Concluding remarks

Food security has become a key policy objective for governments and international organizations. While the importance of food security for welfare is ubiquitous, the implications for international trade flows, sectoral production patterns, and potential policy responses are less understood. Our starting point is the observation that trade in agricultural goods is large, and many countries rely on food imports to meet domestic demand. While trade can have a significant impact on welfare and productivity in the long-run, trade disruption risks may significantly limit these gains.

We study the role of trade risk for food security, sectoral patterns of production and trade, as well the potential for policy interventions to mitigate these risks. We document cross-country stylized facts and provide micro-level causal evidence on the impact of international trade on food security. We develop a general equilibrium model of international trade risk and structural change, to interpret this evidence and to examine the aggregate implications of trade risk. In our model, importing decisions are subject to trade cost risk, leading to a tradeoff between international purchases that can be cheaper but risky vs. domestic purchases that are more expensive but safer. We find that trade risk has a substantial quantitative impact on welfare, trade, and production patterns across countries. The potential policy responses to secure a stable food supply for the domestic population include subsidies to domestic farmers and protective tariffs on food imports.

Such policies are widespread across the world. We show that they can have substantial effects on diversifying sectoral economic activity.

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 goods in consumption or production. Our framework can be used to think about both the positive and normative aspects of these issues.

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