Food Security Risk and Structural Transformation

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Introduction

- Economic development is accompanied by structural change and rural-urban migration
- Yet, in less developed countries this process has been slow
- ...despite the large gap in labor productivity and wages between agriculture and non-agriculture
- Why aren't more people moving out of agriculture and into cities in less developed countries?
- Literature has offered many useful insights on structural change
- This paper: food security risk hinders structural change

What We Do

- Build a quantitative framework
- Two key ingredients of the framework:
  - Non-homothetic preferences: close to subsistence $\rightarrow$ risk aversion $\uparrow$
  - Heterogeneity among households in risk exposure
    - agr price volatility: income risk to rural households Vs. expenditure risk to urban households
- Competitive equilibrium is not efficient: gains from trade/insurance between households
- Policy implications: agriculture subsidy or migration barriers can be welfare improving

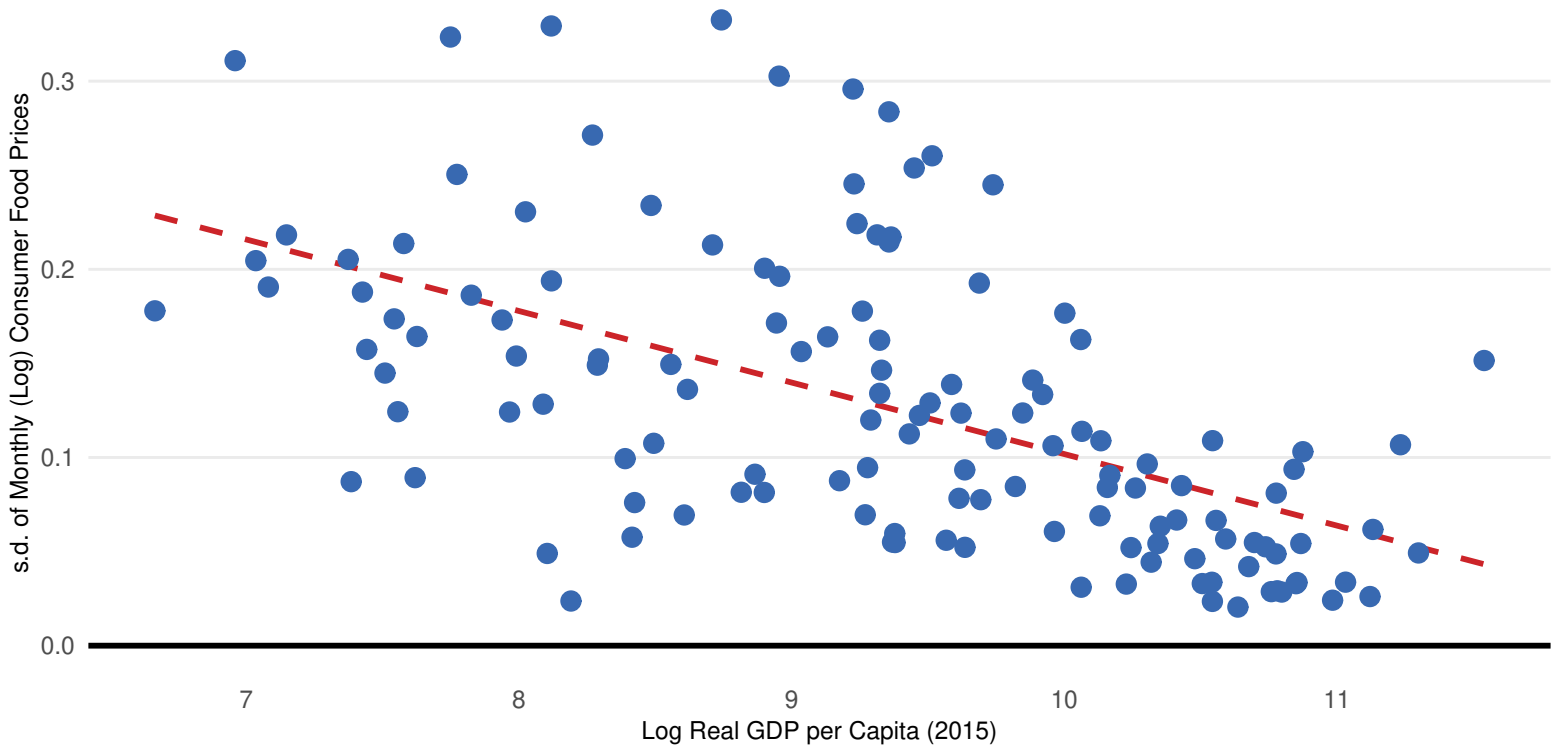
What We Find

- Calibrate our two-country model to a low-income country and ROW
- An insurance contract between rural and urban households
  - improves welfare by dampening agricultural consumption volatility
  - implies up to 6 p.p. higher agricultural employment share
  - lowers GDP and widens agricultural productivity gap, despite welfare gain
  - manifests itself as a barrier to agricultural good trade

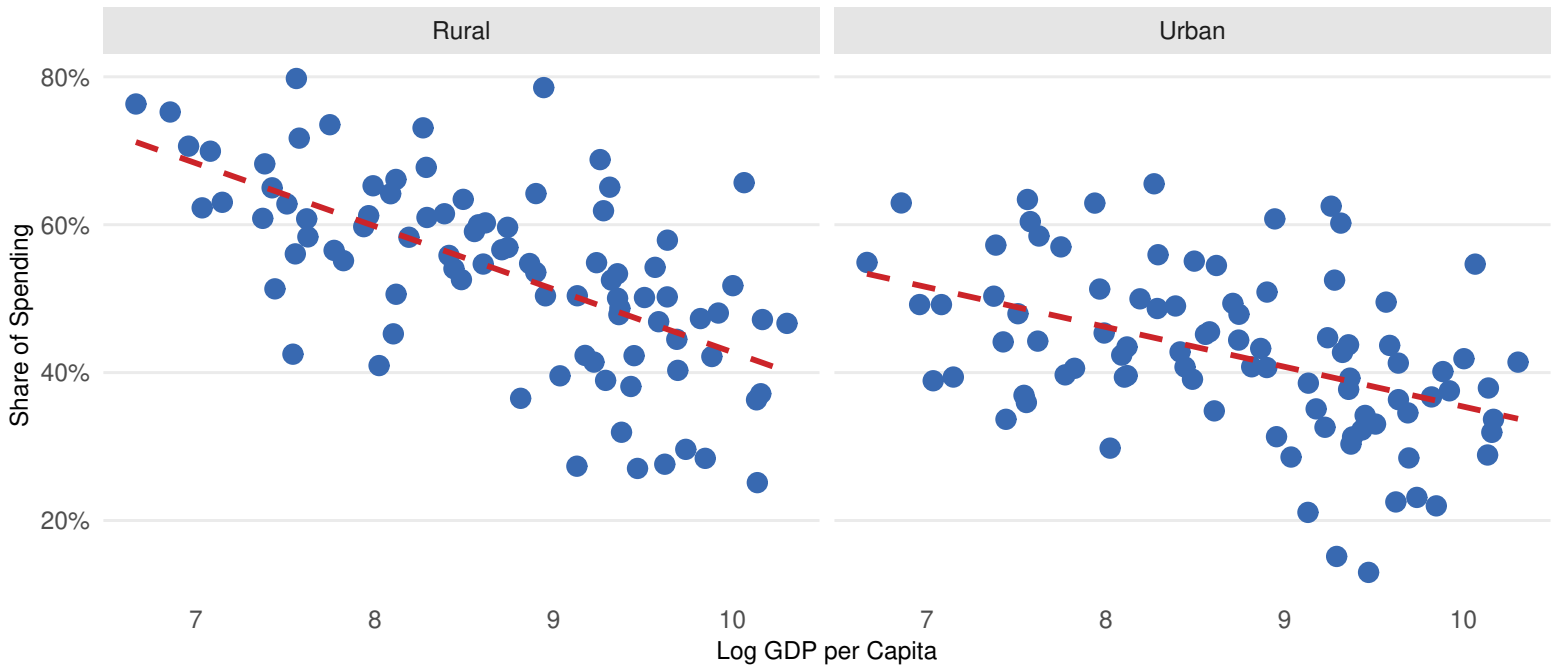
Literature

- Large literature on agricultural productivity and structural change
  - Gollin-Parente-Rogerson ’02, ’05, ’07, Restuccia-Yang-Zhu ’08, Adamopoulos-Restuccia ’14, Gollin-Lagakos-Waugh ’14
  - None of these studies focus on the uncertainty on food price volatility, with the exception of Adamopoulos-Leibovici ’24
- Internal migration and agricultural productivity gap
  - Ngai et al. ’17, Lagakos et al. ’20, Adamopoulos et al. ’24, Gai et al. ’24

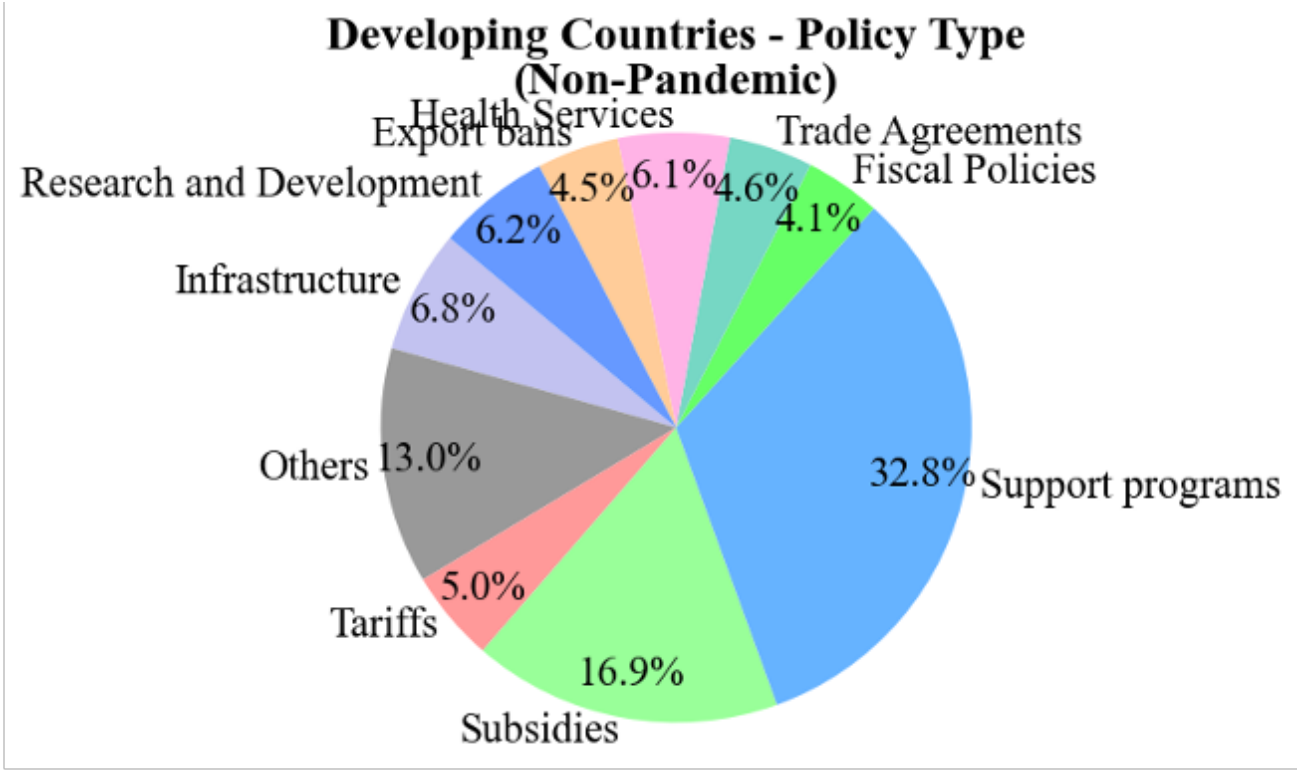
Fact 1: Poor countries have higher volatility in food prices than other goods



Fact 2: Poor countries have higher expenditure share on food



Fact 3: Food security policies focus on subsidies



Data: FAO FAPDA Policy Database

A Model of Food Security Risk and Labor Allocation

- Open-economy structural change model (Sposi et al. or Caselli et al.)
- Two-country $i \in \{1, 2\}$, two sectors $k \in \{a, n\}$
- Rural household members make sectoral choices (Roy model)
- Urban households members only work in non-agriculture
- Both agr and non-agr goods tradable

The Rural Household's Problem

- Non-homothetic CES utility (Comin et al.):

$$u(C) = \frac{C^{1-\sigma} - 1}{1-\sigma},$$

$$\phi^{\frac{1}{\varepsilon}} C^{\frac{(1-\varepsilon)\mu_a}{\varepsilon}} C_a^{\frac{\varepsilon-1}{\varepsilon}} + (1-\phi)^{\frac{1}{\varepsilon}} C^{\frac{(1-\varepsilon)\mu_n}{\varepsilon}} C_n^{\frac{\varepsilon-1}{\varepsilon}} = 1$$

subject to budget constraint

$$P_a C_a + P_n C_n = e$$

- Rural household chooses consumption after prices are realized

The Rural Household's Problem

- Solution:

$$\frac{C_a}{C_n} = \frac{\phi}{1-\phi}\left(\frac{P_a}{P_n}\right)^{-\varepsilon} C^{(1-\varepsilon)(\mu_a-\mu_n)}$$

  - features both income effect and price effect ($\mu_a < \mu_n$, $\varepsilon > 0$)
  - relative risk aversion $\in [1-(1-\sigma)/\mu_n, 1-(1-\sigma)/\mu_a]$, decreases in C

- Denote the indirect utility as $V(e, P_a, P_n)$

The Rural Household's Problem

- Household members are heterogeneous in abilities (z_a, z_n)
  - Drawn from a Frechet distribution with dispersion parameter κ
  - Wage income associated with agr (nonagr): $w_a z_a$ $(w_n z_n)$
- Allocate members into sectors by comparative advantage before prices/wages are realized
  - Choose agricultural employment share to maximize expected utility
- Without uncertainty: a member chooses agriculture if $z_a/z_n > w_n/w_a$
- With uncertainty: the cut-off may be higher or lower than w_n/w_a

Urban Household's Problem

- No access to agricultural production
- Members are homogeneous in ability with income $w_n \bar{z}$
- Utility function is identical to that of the rural household

Production and Trade

- A continuum of goods in agriculture (a) and non-agriculture (n)
- Good $z \in [0,1]$ in sector $k \in \{a, n\}$ of country i is produced by

$$Y_{ik}(z) = A_{ik}(z) L_{ik}(z)^{\beta_k} \left[M_{ika}^{\gamma_{ka}}(z) M_{ikn}^{\gamma_{kn}}(z) \right]^{1-\beta_k},$$

- The mean of the distribution of $A_{ik}(z)$ is volatile
- Both goods tradable but subject to iceberg trade costs $\tau_{ijk} \geqslant 1$
- The composite good in each sector k is an aggregator of varieties:

$$Q_{ik} = \int_0^1 \left(q_{ik}(z)^{\frac{\eta-1}{\eta}} dz \right)^{\frac{\eta}{\eta-1}}$$

- Trade balance: $P_{ia} Q_{ia} \pi_{ija} + P_{in} Q_{in} \pi_{ijn} = \pi_{jia} P_{ja} Q_{ja} + \pi_{jin} P_{jn} Q_{jn}$

Risk Associated with Agricultural Price Volatility

- Rural and urban households have different risk exposures
- Consider a simple example:
  - $P_a \propto w_a$, volatility σ_a
  - $P_n \propto w_n$, constant
- Urban households face expenditure risk arising from P_a
  - $\sigma_a \uparrow \Rightarrow$ hopes the rural households to supply more labor to agriculture to dampen the volatility
- Rural households face income risk arising from w_a
  - $\sigma_a \uparrow \Rightarrow$ chooses a smaller agricultural employment share

On the Efficiency

- Social welfare function:

$$(1-\lambda)N\mathbb{E}[U(C)] + \lambda N^{\text{urban}}\mathbb{E}[U(C^{\text{urban}})]$$

- Efficiency requires equating the marginal utility of consumption between households
- Structural change models with rural and urban households are generally not efficient for two reasons
  - income levels differ between rural and urban HH (common in literature)
  - different risks (novel in this paper)
- Potential social surplus from policies

Calibration

- We calibrate no-insurance economy to data moments in 2018
- Country i as "average" low-income and country j as ROW
- For simplicity, assume all uncertainty arises from T_{ia}, the location parameter of the Frechet distribution of $A_{ia}(z)$, perfectly correlated between two countries

Calibration: Parameters Common Across Countries

- 9 parameters governing production and trade
  - Trade elasticities $\theta_a = \theta_n = 4$
  - EOS across varieties within each industry $\eta = 4$
  - Labor shares: $\beta_a = \beta_n = 0.33$
  - Intermediate shares

$$\begin{bmatrix} \gamma_{aa} & \gamma_{an} \\ \gamma_{na} & \gamma_{nn} \end{bmatrix} = \begin{bmatrix} 0.6 & 0.4 \\ 0 & 0 \end{bmatrix}$$

- 5 parameters on preferences
  - $\phi = 0.350$, $\mu_a = 1$, $\mu_n = 3.678$, and $\varepsilon = 0.197$ from Yao-Zhu '21
  - We set $\sigma = 4$
    - implied relative risk aversion ranging from 1.8 to 4
  - We set $\kappa = 3$
    - implied migration elasticity around 1.6 (risk consideration lowers the elasticity)

Calibration: Country-Specific Parameters

- $\{N_1, N_1^u, N_2, N_2^u\} = \{0.673, 0.327, 3.797, 7.296\}$ to match population shares
- $T_{1a} = T_{1n} = -2.845$ to match home agr. emp. share
- $\{T_{2a}, T_{2n}\} = \{0.558, -0.312\}$ to match foreign agr. emp. share and the ratio of GDP per capita
- $\sigma_{1a} = \sigma_{2a} = 0.930$ to match the price volatility of agr good
- Trade costs chosen to match trade shares

$$\begin{bmatrix} \tau_{11a} & \tau_{12a} \\ \tau_{21a} & \tau_{22a} \end{bmatrix} = \begin{bmatrix} 1 & 0.161 \\ 0.630 & 1 \end{bmatrix}, \quad \begin{bmatrix} \tau_{11n} & \tau_{12n} \\ \tau_{21n} & \tau_{22n} \end{bmatrix} = \begin{bmatrix} 1 & 0.311 \\ 0.311 & 1 \end{bmatrix}$$

Quantitative Analysis: Food Security Policy

- Allowing for Arrow-Debreu securities to be traded among households
  - addresses the inefficiency from risk perfectly
  - does not address the inefficiency from level differences (no net transfer)
  - A-D economy can be the first best (with $\lambda = 0.94$ requiring no net transfer)
- Real-world policies subsidizing agricultural employment to improve food security may also be welfare-improving
  - The urban household pays τ_1 (flat) per unit of agricultural labor to the rural household
  - The rural household is subject to an income tax of rate τ_2, tax revenue rebated to the urban household
    - τ_2 does not directly affect sectoral choice, but reallocates surplus
  - A stand-in government chooses τ_1 and τ_2 to maximize social welfare

The Impact of the Insurance

	No risk	Baseline	With insurance			
			A-D	Urban bias $\lambda = 1$, IR	Rural bias $\lambda = 0$, IR	Utilitarian $\lambda = 0.5$
Subsidy rate (τ_1 / w_a, %)		–				
Agr. emp. share (%)		46.3				
Real GDP (Δ, %)		–				
Real agr. productivity (Δ, %)		–				
Nominal APG		2.40				
Agr. import (% total import)		12.8				

The Impact of the Insurance

	No risk	Baseline	With insurance			
			A-D	Urban bias $\lambda = 1$, IR	Rural bias $\lambda = 0$, IR	Utilitarian $\lambda = 0.5$
Subsidy rate (τ_1 / w_a, %)		–				
Agr. emp. share (%)	44.4	46.3				
Real GDP (Δ, %)		–				
Real agr. productivity (Δ, %)		–				
Nominal APG		2.40				
Agr. import (% total import)		12.8				

The Impact of the Insurance

	No risk	Baseline	With insurance			
			A-D	Urban bias $\lambda = 1$, IR	Rural bias $\lambda = 0$, IR	Utilitarian $\lambda = 0.5$
Subsidy rate (τ_1 / w_a, %)		–	0			
Agr. emp. share (%)		46.3	48.9			
Real GDP (Δ, %)		–				
Real agr. productivity (Δ, %)		–				
Nominal APG		2.40				
Agr. import (% total import)		12.8				

The Impact of the Insurance

	No risk	Baseline	With insurance			
			A-D	Urban bias $\lambda = 1$, IR	Rural bias $\lambda = 0$, IR	Utilitarian $\lambda = 0.5$
Subsidy rate (τ_1 / w_a, %)		–	0			
Agr. emp. share (%)		46.3	48.9			
Real GDP (Δ, %)		–	-0.6			
Real agr. productivity (Δ, %)		–	-4.2			
Nominal APG		2.40	2.66			
Agr. import (% total import)		12.8				

The Impact of the Insurance

	No risk	Baseline	With insurance			
			A-D	Urban bias $\lambda = 1$, IR	Rural bias $\lambda = 0$, IR	Utilitarian $\lambda = 0.5$
Subsidy rate (τ_1 / w_a, %)		–	0			
Agr. emp. share (%)		46.3	48.9			
Real GDP (Δ, %)		–				
Real agr. productivity (Δ, %)		–				
Nominal APG		2.40				
Agr. import (% total import)		12.8	11.6			

The Impact of the Insurance

	No risk	Baseline	With insurance			
			A-D	Urban bias $\lambda = 1$, IR	Rural bias $\lambda = 0$, IR	Utilitarian $\lambda = 0.5$
Subsidy rate (τ_1 / w_a, %)		–	0	33.2		
Agr. emp. share (%)		46.3	48.9	52.8		
Real GDP (Δ, %)		–	-0.6	-1.5		
Real agr. productivity (Δ, %)		–	-4.2	-9.6		
Nominal APG		2.40	2.66	3.10		
Agr. import (% total import)		12.8	11.6	10.3		

The Impact of the Insurance

	No risk	Baseline	With insurance			
			A-D	Urban bias $\lambda = 1$, IR	Rural bias $\lambda = 0$, IR	Utilitarian $\lambda = 0.5$
Subsidy rate (τ_1 / w_a, %)		–	0	33.2	25.6	
Agr. emp. share (%)		46.3	48.9	52.8	53.0	
Real GDP (Δ, %)		–	-0.6	-1.5	-1.5	
Real agr. productivity (Δ, %)		–	-4.2	-9.6	-9.7	
Nominal APG		2.40	2.66	3.10	3.11	
Agr. import (% total import)		12.8	11.6	10.3	10.3	

The Impact of the Insurance

	No risk	Baseline	With insurance			
			A-D	Urban bias $\lambda = 1$, IR	Rural bias $\lambda = 0$, IR	Utilitarian $\lambda = 0.5$
Subsidy rate (τ_1 / w_a, %)		–	0	33.2	25.6	108.7
Agr. emp. share (%)		46.3	48.9	52.8	53.0	62.3
Real GDP (Δ, %)		–	-0.6	-1.5	-1.5	-4.1
Real agr. productivity (Δ, %)		–	-4.2	-9.6	-9.7	-18.2
Nominal APG		2.40	2.66	3.10	3.11	4.20
Agr. import (% total import)		12.8	11.6	10.3	10.3	9.2

The Impact of the Insurance

	No risk	Baseline	With insurance			
			A-D	Urban bias $\lambda = 1$, IR	Rural bias $\lambda = 0$, IR	Utilitarian $\lambda = 0.5$
Subsidy rate (τ_1 / w_a, %)	–	–	0	33.2	25.6	108.7
Agr. emp. share (%)		46.3	48.9	52.8	53.0	62.3
Real GDP (Δ, %)	-1.8	–	-0.6	-1.5	-1.5	-4.1
Real agr. productivity (Δ, %)	-5.0	–	-4.2	-9.6	-9.7	-18.2
Nominal APG	2.34	2.40	2.66	3.10	3.11	4.20
Agr. import (% total import)	13.6	12.8	11.6	10.3	10.3	9.2

Conclusion

- Larger food price volatility in poor countries
  - Another source of barrier to rural-urban migration
- We provide a framework to examine the role of food security, where the competitive equilibrium is not efficient due to different risk exposures between rural and urban households
- An insurance contract between rural and urban households mitigates the risk and improves welfare, but...
  - reduces GDP and enlarges the agricultural productivity gap
  - manifests itself as an implicit barrier to agricultural good trade