Climate Change, Comparative Advantages, and Structural Transformation in Agriculture

Job Market Paper

Sulpice Amonle

Department of Agri-Food Economics and Consumer Science
Université Laval

October 2026

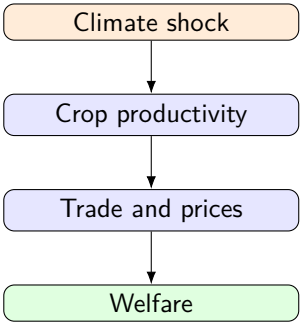
Table of contents

1. Introduction
2. Theoretical Framework
3. Data and descriptive facts
4. Empirical framework
5. Results and Discussion
6. Summary and concluding remarks

Introduction

Why should we care?

- We study why climate change makes households poorer and how climate-induced productivity losses affect welfare when food expenditure shares vary with income.
- Climate change is not only an average productivity shock. It reshapes **where crops can be produced efficiently**.
- In agriculture, this means changes in comparative advantage, food prices, trade flows, and household welfare.



Key concern

Poor countries spend a larger share of income on food, so the same food-price shock can generate much larger welfare losses.

Research question

How do climate shocks affect welfare when food demand is non-homothetic?

- How do climate shocks reshape agricultural comparative advantages?
- How do productivity shocks transmit through production, trade, prices, and consumption?
- How much do income effects amplify welfare losses?

Central mechanism

Climate shocks raise the relative price of food; because food expenditure shares are higher when income is lower, welfare losses are amplified in low-income countries.

Existing literature

- Ricardian trade and agriculture: Eaton & Kortum (2002); Costinot et al. (2016).
- Climate change and trade adaptation: Gouel & Laborde (2021); Nath (2025) .
- Structural change and non-homothetic demand: Comin et al. (2021).

This paper

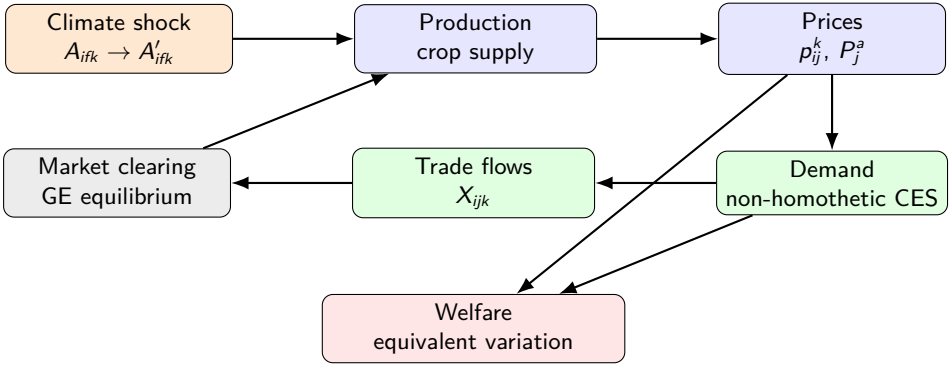
- Builds a multi-country Ricardian GE model with multiple crops.
- Embeds non-homothetic CES preferences.
- Measures welfare using money-metric utility and equivalent variation.
- Decomposes welfare losses into price and structural-change effects.

Contribution

The paper shows that ignoring income effects greatly understates the welfare cost of climate change.

Theoretical Framework

Model structure: GE channels



Channel

Productivity shocks affect prices; prices and income jointly determine food expenditure shares; expenditure shares affect welfare.

Theoretical Framework

Countries, goods, agents, and markets

- Countries: importing country j and exporting country i.
- Goods:
  - agricultural crops indexed by $k \in \{1, \ldots, K\}$,
  - outside good 0 representing manufacturing and services.
- Agents:
  - A representative consumer in each country.
  - competitive producers/farmers.
  - landowners allocating parcels across crops.
- Endowments: labor L_i and land N_i.
- Land is divided into fields f and parcels $\omega \in [0, 1]$.

Market structure

Perfect competition; iceberg trade costs; labor mobile within country and immobile across countries.

Demand side

- Non-homothetic CES preferences.
- Food expenditure shares vary with income.
- Representative household faces budget constraint.
- Agricultural goods are CES aggregates of crops and origins.

Supply side

- Outside good: constant returns to scale in labor.
- Crop production uses land and labor in fixed proportions.
- Parcel productivity follows a Frechet distribution.
- Crop choice maximizes the value of marginal product of land.

Why these assumptions matter

They keep the model tractable while allowing climate shocks to affect comparative advantage, trade flows, prices, and welfare.

Stage 1: The representative household allocates expenditure between agriculture and the outside good:

$$\sum_{b\in\{0,a\}} (\beta_b)^{1/\alpha} \left(\frac{C_j}{L_j}\right)^{\varepsilon_b(1-\alpha)/\alpha} \left(\frac{C_j^b}{L_j}\right)^{(\alpha-1)/\alpha} = 1.$$

- $b \in \{0, a\}$: outside good and agricultural aggregate.
- β_b: preference weight.
- α: elasticity of substitution between broad goods.
- ε_b: income elasticity parameter.

Engel channel

$$s_j^a = \beta_a \left(\frac{P_j^a}{P_j}\right)^{1-\alpha} \left(\frac{C_j}{L_j}\right)^{(1-\alpha)(\varepsilon_a-1)}.$$

When $\varepsilon_a < 1$, poorer countries allocate a larger share of expenditure to food.

Stage 2: crop aggregator

$$C_j^a = \left[\sum_k (\beta_{jk})^{1/\kappa} (C_{jk})^{(\kappa-1)/\kappa} \right]^{\kappa/(\kappa-1)}.$$

Stage 3: varieties by exporter

$$C_{jk} = \left[\sum_i (\beta_{ijk})^{1/\sigma} (C_{ijk})^{(\sigma-1)/\sigma} \right]^{\sigma/(\sigma-1)}.$$

- C_{ijk}: consumption in country j of crop k from exporter i.
- κ: elasticity of substitution across crops.
- σ: elasticity of substitution across origins within a crop.

Demand for imported varieties

Demand depends on prices, crop substitution, origin substitution, and income per capita.

Crop production on parcel ω uses land productivity and labor requirements:

$$q_{ifk}(\omega) = \min\left\{A_{ifk}(\omega), \frac{L_{ifk}(\omega)}{\nu_{if}(\omega)}\right\}.$$

- $A_{ifk}(\omega)$: yield/productivity of parcel ω in field f.
- $\nu_{if}(\omega)$: labor requirement per unit of output.
- Production is Leontief: land productivity and labor are complements.

Crop choice

Land is allocated to the crop with the highest value of marginal product:

$$\pi_{ifk} = \Pr\left(p_{ik}A_{ifk}(\omega) > p_{i\ell}A_{if\ell}(\omega),\ \forall \ell \neq k\right).$$

Under the Frechet distribution, crop supply is:

$$q_{ik} = \sum_f s_{if} A_{ifk} \left[\frac{(p_{ik} A_{ifk})^\theta}{(\gamma_i)^\theta + \sum_k (p_{ik} A_{ifk})^\theta} \right]^{(\theta-1)/\theta}.$$

- $A_{0,i} = w_i$; s_{if}: field area; $\gamma_i = A_{0,i} \nu_{0,i}$: Labor costs;
- A_{ifk}: average productivity of crop k in field f.
- θ: dispersion of productivity across parcels.
- Smaller θ means larger productivity dispersion and stronger comparative advantage.

Climate shock

Climate change is modeled as a productivity shock: $A_{ifk} \to A'_{ifk}$.

Iceberg trade costs imply:

$$p_{ij}^k = \tau_{ij}^k p_i^k, \qquad \tau_{ij}^k \geq 1.$$

The value of exports of crop k from i to j is:

$$X_{ijk} = p_{ij}^k C_{ijk}.$$

Trade channel

Countries import from origins with lower delivered prices. Climate change changes delivered prices by changing productivity and domestic producer prices.

- Trade costs include geography, bilateral frictions, and tariffs.
- Trade can mitigate climate losses by reallocating food supply toward less affected origins.

Market clearing and equilibrium

Factor market clearing

$$\sum_{f,k} L_{ifk}(\omega) = L_i, \qquad \sum_{f,k} N_{ifk}(\omega) = N_i.$$

Goods market clearing

$$q_i^k = \sum_j \tau_{ij}^k C_{ijk}, \qquad \forall i, k.$$

Equilibrium object

An equilibrium is a set of prices, production, consumption, and trade flows such that:

- consumers maximize utility,
- producers maximize profits,
- all goods and factor markets clear,
- trade flows are consistent with delivered prices and trade costs.

Baseline welfare change is measured using equivalent variation:

$$\Delta W = \frac{e(P,u) - e(P',u)}{e(P,u)}.$$

- $e(\cdot)$: expenditure function.
- P and P': pre- and post-climate-change price systems.
- u: reference utility level.
- P^h: hypothetical post-shock price index that keeps expenditure shares fixed; it separates the pure price effect from the effect of changing consumption shares.

Decomposition

$$\Delta W = 1 - \underbrace{\frac{e(P'(s',.),u)}{e(P^h,u)}}_{\text{structural-change effect}} \times \underbrace{\frac{e(P^h,u)}{e(P(s,.),u)}}_{\text{price effect}}.$$

Data and descriptive facts

Data

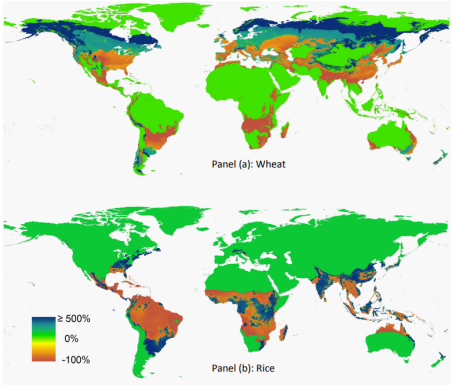
- **Sample:** 50 economies and 10 major crops.
- **Crops:** banana, soybean, cotton, sugarcane, maize, tomato, oil palm, wheat, rice, white potato.
- **Productivity:** GAEZ 2010 crop yields, under current and future climate.
- **Trade and production:** GTAP v11, 2011.
- **Tariffs:** GTAP protection data; TRAINS/WITS when needed.
- **Trade costs:** CEPII gravity variables.
- **Income and GDP:** World Bank WDI.
- **Input-output structure:** GTAP v11, complemented by WIOD.

Main limitation

Sample coverage is not exhaustive: included countries represent 89.7% of world crop output value, while selected crops account for 71.1%.

Key takeaways from facts to the model:

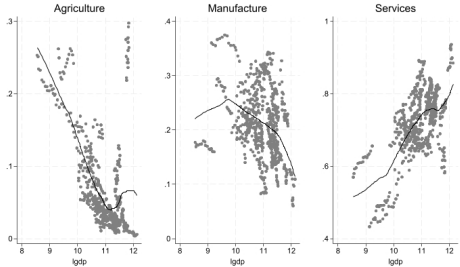
- Crop productivity varies substantially across space.
- This heterogeneity is the source of Ricardian comparative advantage.
- Climate change shifts these productivity patterns and therefore trade incentives.



Notes: Figure shows data from Costinot et al. (2016). Percent changes in yield due to climate change in GAEZ model for wheat and rice. Large green areas are those for which yields are zero both before and after climate change.

Key takeaways from facts to the model

- Agriculture's value-added share falls with income.
- Services become more important as countries develop.
- Low-income countries remain more exposed to agricultural productivity and food-price shocks.



Notes: Each sub-figure displays the share of each sector in aggregate value added versus GDP per capita in 43 countries from 2000 to 2014 using World Input-Output Database.

Preference parameters are estimated by matching model-implied and observed expenditure ratios:

$$\min_{\alpha,\beta_0,\beta_a,\varepsilon_0,\varepsilon_a} \sum_i \sum_{b\in\{0,a\}} \left[\left(\frac{\beta_a}{\beta_0}\right)^{\alpha} \left(\frac{P_i^a}{P_i^0}\right)^{1-\alpha} \left(\frac{C_i}{L_i}\right)^{\varepsilon_a - 1} - \left(\frac{E_i^a}{E_i^0}\right) \right]^2 .$$

- E_i^a/E_i^0: observed expenditure ratio between agriculture and outside good.
- P_i^a/P_i^0: relative price index.
- C_i/L_i: real consumption per worker.
- Estimator: nonlinear least squares / minimum distance.

Empirical framework

Calibrated parameters

Parameter	Value	Interpretation
β_0	0.51	Weight on outside good
β_a	0.49	Weight on agriculture
ε_0	1.00	Income elasticity, outside good
ε_a	0.79	Income elasticity, agriculture
α	0.50	Broad-good substitution
κ	2.82	Elasticity of substitution between crops
σ	5.40	Elasticity of substitution between varieties
θ	2.46	Productivity dispersion

Interpretation

$\varepsilon_a < 1$ is consistent with Engel's law: as real income increases, the share of expenditure spent on food declines. κ, σ, and θ are taken from Costinot et al. (2016).

Why the counterfactual is informative?

- Climate shocks are introduced as productivity shocks: $A_{ifk} \rightarrow A'_{ifk}$.
- We compare competitive equilibrium before and after the climate-induced productivity shock.
- Source of variation:
  - Spatial variation in potential crop yields across fields and countries.
  - Cross-country variation in income, prices, and expenditure shares.

Results and Discussion

Income effects matter

Specification	Global welfare change	Interpretation
Homothetic preferences	-0.26%	income effects ignored
Non-homothetic preferences	-4.6%	Food shares respond to income

Main result

Ignoring non-homothetic demand substantially understates the welfare cost of climate change.

Results and Discussion

Welfare losses by income group

Income group	$\varepsilon_a = 0.79$	0.83	0.86	0.91	0.95
Low income	-15.2%	-16.3%	-18.1%	-21.1%	-25.3%
Lower-middle	-7.4%	-8.1%	-9.2%	-11.1%	-13.8%
Upper-middle	-3.1%	-3.3%	-3.6%	-4.1%	-4.9%
High income	-0.3%	-0.3%	-0.3%	-0.4%	-0.4%
World	-4.6%	-5.2%	-6.4%	-8.4%	-11.5%

Takeaway

- Losses are largest in low-income countries and increase when food demand becomes more income-sensitive.
- **Robust pattern:** across specifications, welfare losses remain larger for poorer countries and the price channel remains central.

Results and Discussion

Mechanism: price effect versus structural-change effect

Component	$\varepsilon_a = 0.79$	0.83	0.86	0.91	0.95
Price effect	-2.2%	-3.3%	-5.2%	-8.2%	-11.0%
Structural-change effect	-2.4%	-1.8%	-1.2%	-0.2%	-0.4%

- Welfare losses are mainly driven by the cost-of-living effect of higher relative food prices.
- Structural change matters, but the price channel becomes dominant as food demand becomes more income-sensitive.
- The policy implication is direct: stabilizing access to affordable food is central for welfare.

Results and Discussion

Trade counterfactual: tariff removal

Income group	Baseline loss	Loss with tariff removal
Low income	-15.2%	-14.8%
Lower-middle income	-7.4%	-6.9%
Upper-middle income	-3.1%	-3.6%
High income	-0.3%	-0.2%
World	-4.6%	-2.8%

Interpretation

- Effects are heterogeneous across groups because trade liberalization changes both import prices and the pattern of specialization.
- Trade liberalization partially offsets welfare losses by improving access to food and reallocating production toward less affected origins.

Summary and concluding remarks

1. Climate change reshapes agricultural comparative advantage through productivity shocks.
2. Non-homothetic preferences are quantitatively important.
3. Global welfare losses rise from about 0.26% to 4.6% when income effects are included.
4. Losses are highly unequal across income groups.
5. The main welfare channel is the price effect, not only structural reallocation.
6. Trade liberalization can mitigate losses, but it does not fully offset them.

Policy message

Climate adaptation policies should combine agricultural resilience, trade openness, and social protection targeted toward food-price vulnerability.

Q&A

Thank you!

Questions and Comments?