Agriculture, Trade, Migration, and Climate Change

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Research Objective

- Evaluate the impact of climate change on agricultural production, incorporating three crucial aspects of market mechanisms;
  $\Rightarrow$ **farmers' crop choice, international trade, labor reallocation**
- Analyze the welfare implications of labor mobility for workers in agriculture when agricultural production is facing CC shocks.

Background and Motivation

- **CC productivity shock** is heterogeneous across **countries** and **crops**.
  - The figure below displays the potential yield changes by 2100 relative to 2020 for the highest revenue crops in each country/region under the RCP 8.5 scenario, according to the GAEZ project by the FAO.

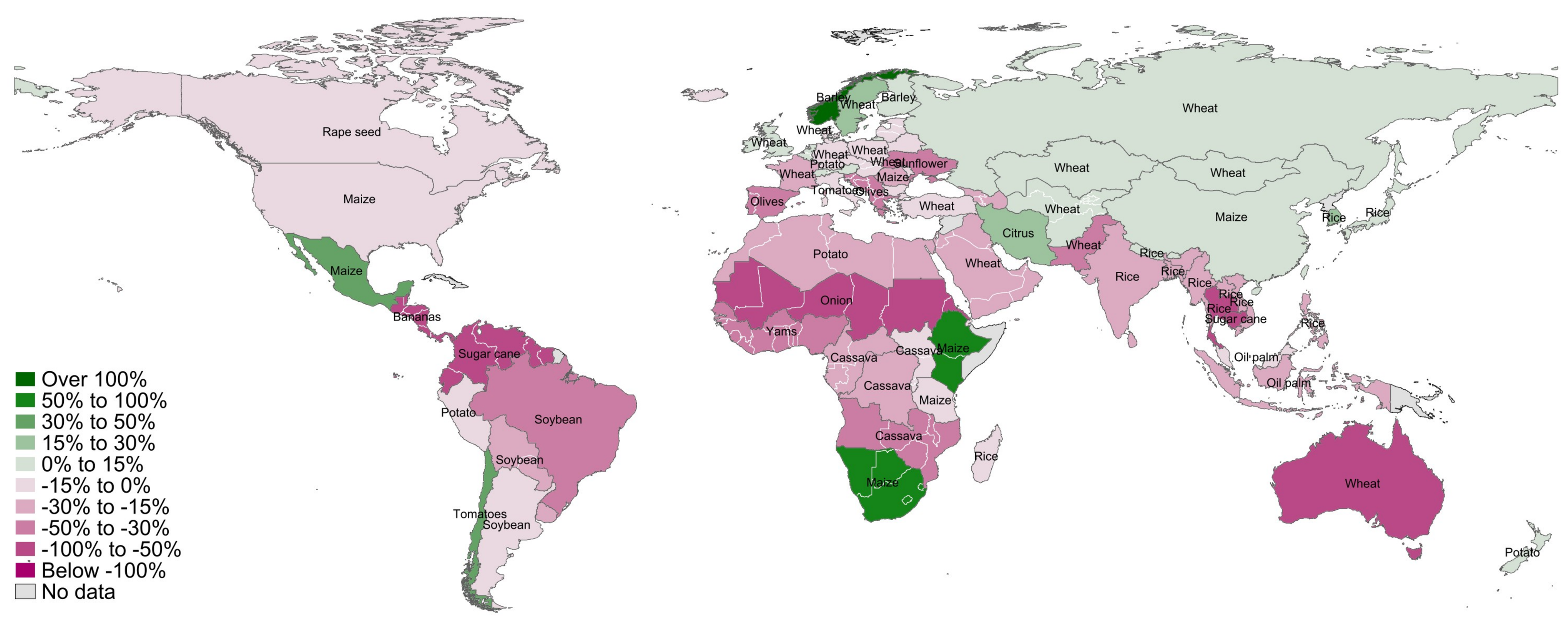

Figure 1. Potential Yield Changes under RCP 8.5 by 2100 (relative to 2020)

- CC shock affects the **potential multicropping capacity**.
  - Multicropping capacity varies by region, ranging from no cropping to triple cropping within a single year. The figure below displays the potential multicropping capacity changes by 2100 relative to 2020 under the RCP 8.5, according to the GAEZ project by the FAO.
  - CC shock can therefore affect the **effective size of harvest areas**.

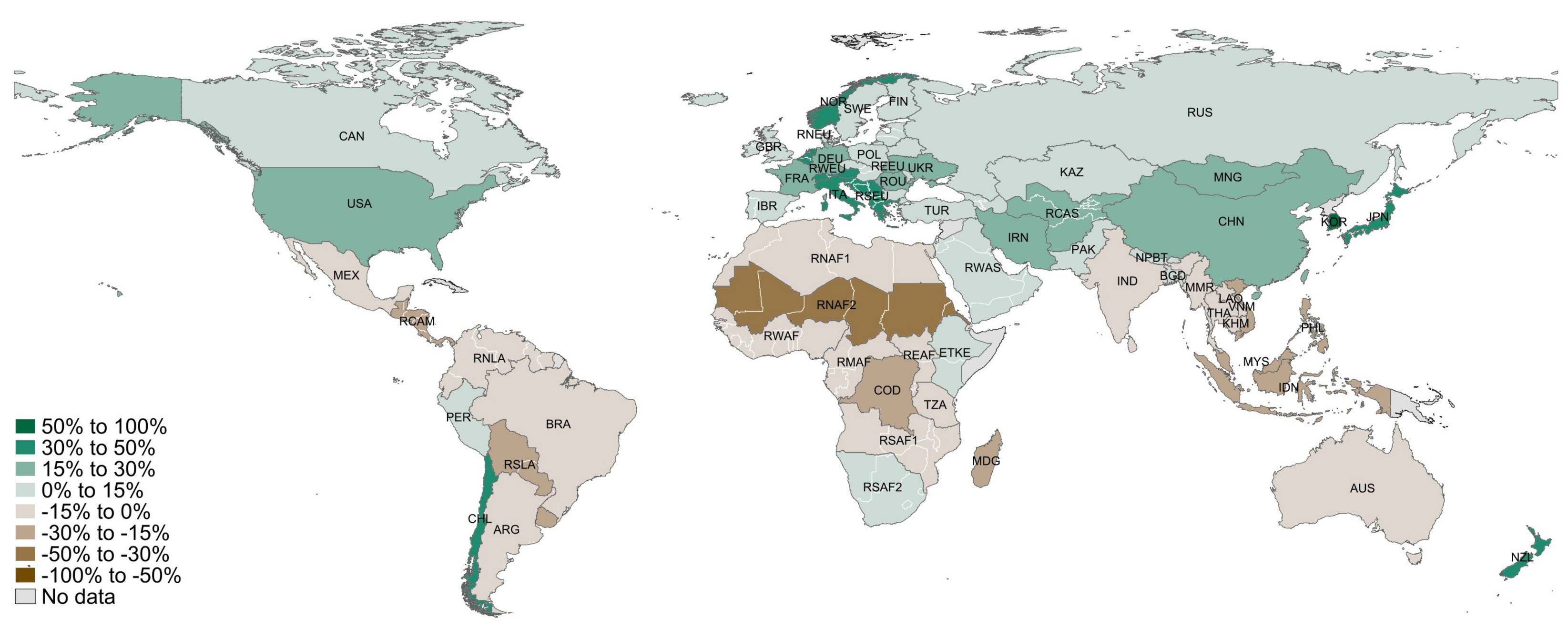

Figure 2. Potential Multicropping Changes under RCP 8.5 by 2100 (relative to 2020)

- **Labor mobility** and **dynamics** are crucial factors to consider.
  - The CC shock has the potential to reshape **cross-spatial and cross-sectoral labor reallocation**, particularly for developing economies, given the agricultural sector's substantial contribution to both GDP and employment.
  - Labor reallocation from agriculture to non-agriculture sector is closely relevant to **structural transformation** of the economy. The figure below displays the estimates of domestic net migration flows in 2015, with positive values indicating net flows from agriculture to non-agriculture, and negative values indicating the opposite.
  - **Population growth rates** for future projections differ by region. Recent projections suggest that the rapid population growth will persist mainly in developing economies, raising concerns about food security in those regions.

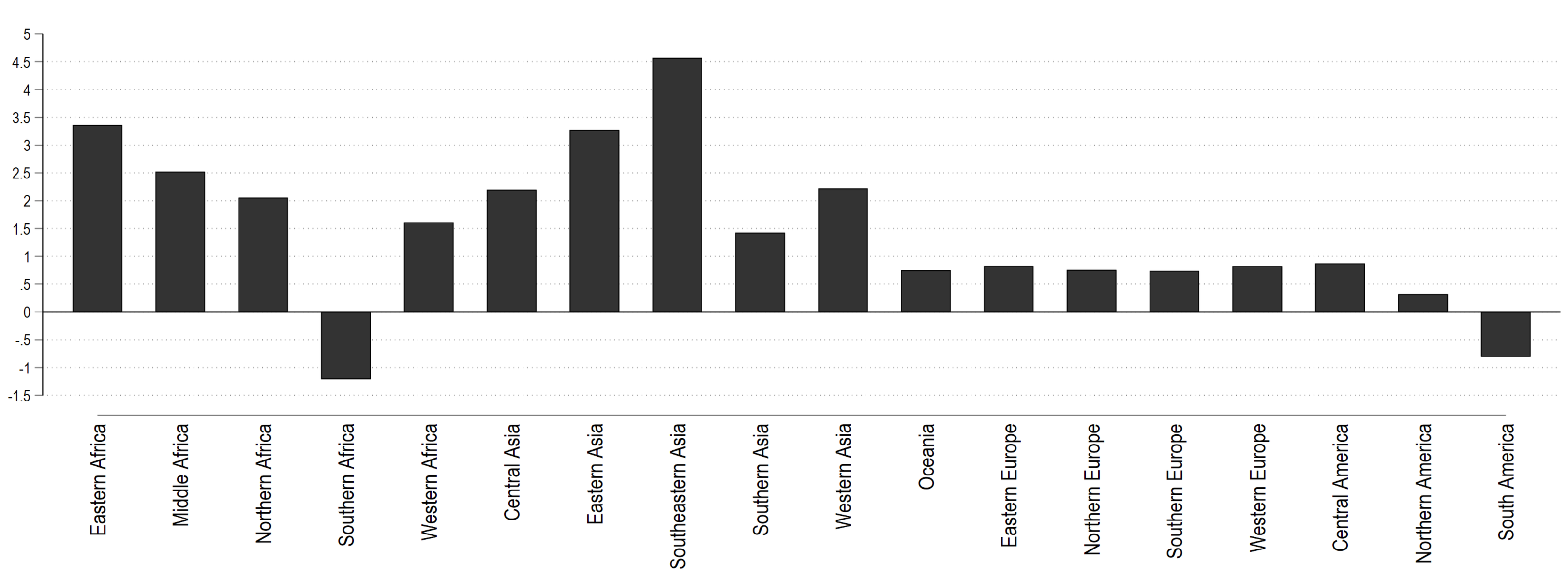

Figure 3. Migration Flow Estimates: Domestic Net Flows in 2015

Structural Model

- **Model Setup**
  - N countries, 2 sectors; Agriculture and Non-Agriculture.
  - All markets are perfectly competitive.
  - Wages for each labor market country-sector pair; w_t^{nA} and w_t^{nM}
- **Preference and Trade**
  - Aggregate consumption over agricultural and non-agricultural goods
  - CES aggregation over crop varieties and origins (Armington trade)
- **Household Mobility and Population Dynamics**
  - Dynamic discrete labor market choice of households (Caliendo et al., 2019)
  - Each period, households choose their labor market pair (country-sector)
  - Migration frictions and idiosyncratic shock $\epsilon_t^{mz} \sim$ iid Gumbel dist.
  - Destinations of *(higher lifetime utility / lower migration cost)*
    $\Longrightarrow$ higher migration share into that labor market
  - Exogenous population growth using Shared Socioeconomic Pathways (SSP2)
- **Agriculture Production**
  - Discrete crop choice of farmers (Eaton and Kortum, 2002; Sotelo, 2020).
  - Cobb-Douglas tech. with labor, land, and intermediate inputs.
  - Land productivity for each plot ω of country n: $A_t^{nj}(\omega) \sim$ iid Fréchet dist.
  - Crops of (*higher productivity / higher price / lower input factor cost*)
    $\Longrightarrow$ higher land share allocated for that crop
- **Non-Agriculture Production**
  - Cobb-Douglas tech. with labor and structure inputs
- **Market Clearing**
  - Market clearing is satisfied for goods and input factors.
  - Local governments owning land, intermediate inputs, and structural inputs redistribute rental revenues to households.
  - Household income in agriculture includes wages and per capita revenue from land and intermediate inputs.
  - Household income in non-agriculture includes wages and per capita revenue from structure input.

Solving the Equilibrium

- **Temporary Equilibrium (TE)**
  - Given labor allocation path, TE solves (1) household, (2) farmer, (3) firm, (4) market clearing conditions of static problem for each time t
- **Sequential Equilibrium (SE)**
  - Given an initial allocation of labor, SE solves household dynamic migration problem, where TE is satisfied for each time t
- **Dynamic Hat Algebra**
  - Solving system of nonlinear equations in *time ratios*, i.e., $\dot{y}_{t+1} \equiv (y_{t+1}/y_t)$
  - The transition path toward SE can be solved without requiring the level of large set of fundamental variables (land productivity, migration cost, trade cost)

Data and Quantification

- **Global Agro-Ecological Zones (GAEZ)** ver. 4 database
  - Agro-climatic potential yield ($\mathcal{A}_t^{nj}$): Provide upper limit of agronomically feasible production based on potential precipitation, temperature, soil condition, etc.
  - Potential Number of Multi-Cropping Practices (N_t^n): Based on agro-climatic inputs, such as the length of growing seasons, lands are classified into nine zones ranging from zero to triple (rice) cropping.
- **Matching Model with GAEZ Data**
  - Time changes in land productivity ($\dot{A}_{t+1}^{nj}$) can be captured by changes in agro-climatic potential yield ($\dot{\mathcal{A}}_{t+1}^{nj}$), circumventing the need to estimate the level of land productivity itself.
  - Time changes in the effective size of harvest area ($\dot{H}_{t+1}^n$) can be captured by changes in multicropping capacity ($\dot{N}_{t+1}^n$)
- **Migration Flow Estimates**
  - The transition path toward SE using dynamic hat algebra is conditional on the initial migration flows ($\mu_{-1}^{ns,mz}$).
  - I construct a matrix of cross-country and cross-sector bilateral migration by expanding cross-country migration flow estimates by Abel and Cohen (2019).
  - The migration flow estimates are constructed to match with the observed sectoral employment changes from 2010 to 2015 with 5-year step size.

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Key Results

- **Baseline Simulation**
  - Climate Change RCP 8.5 and population growth SSP2 scenario.
  - Labor mobility with migration elasticity $\nu = 4$.
  - The model is quantified for 60 regions, covering 145 countries worldwide, and for 12 major crops: rice, maize, wheat, potato and sweat potato, sugarcane, soybean, tomatoes, citrus, oil palm, cassava, tea, bananas.
  - The initial year is 2020, and the model is quantified with 5-year step sizes.

- **Structural Transformation in the Labor Market**
  - Smooth transition of labor from agriculture to non-agriculture sector.
  - Two exceptions; Southern Africa and South America.

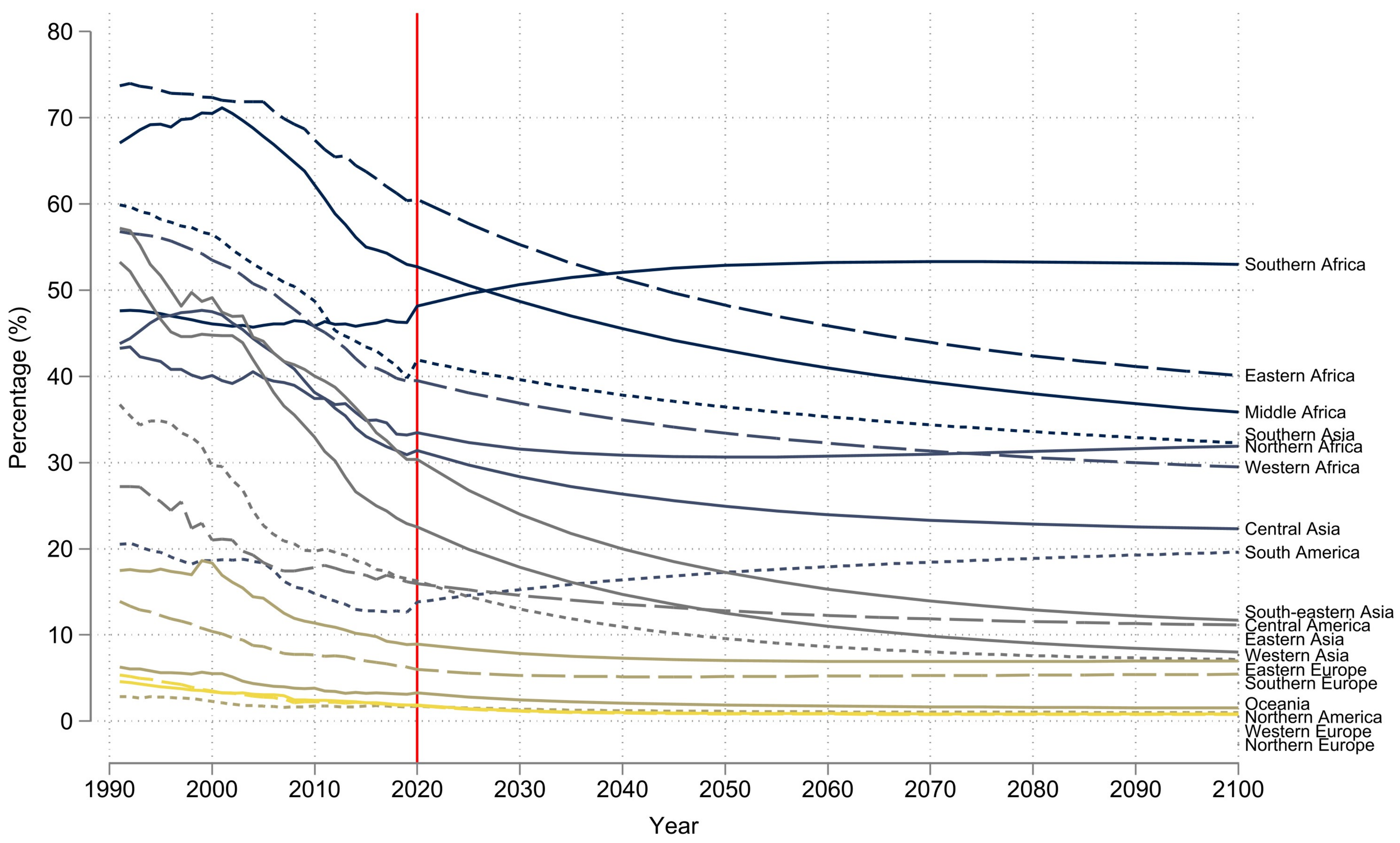

Figure 1. Simulation Result: Path of Employment Share in Agriculture

- **Welfare Impact of RCP8.5** under **Labor Mobility**
  - The figure below displays below displays the consumption equivalent variation under RCP 8.5 scenario relative to the no climate shock scenario for workers in agriculture when labor mobility is considered in the model.
  - [**RCP8.5**/SSP2/Mobility] compared to [**NoCC**/SSP2/Mobility]
  - Aggregate global welfare impact of workers in agriculture is 0.04%.

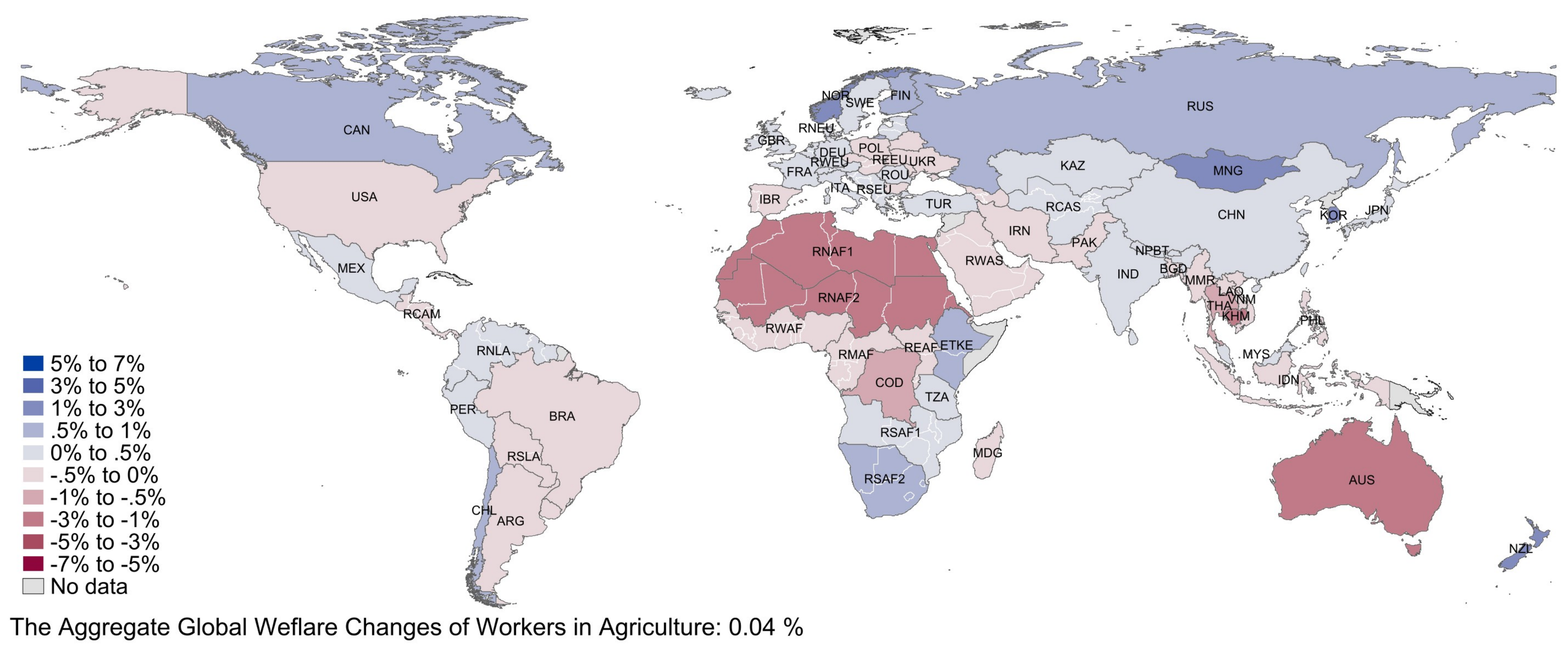

Figure 2. Welfare Impact of Climate Change RCP 8.5 (under Labor Mobility)

- **Welfare Impact of RCP8.5** under **No Labor Mobility**
  - The figure below displays the consumption equivalent variation under RCP 8.5 scenario relative to the no climate shock scenario for workers in agriculture, assuming labor is immobile.
  - [**RCP8.5**/SSP2/No mobility] compared to [**NoCC**/SSP2/No mobility]
  - Aggregate global welfare impact of workers in agriculture is 0.05%.
  - The impact of climate shocks is relatively stronger, both positively and negatively, when labor is immobile, suggesting that **labor mobility plays a mitigating role** in adjusting to climate shocks.

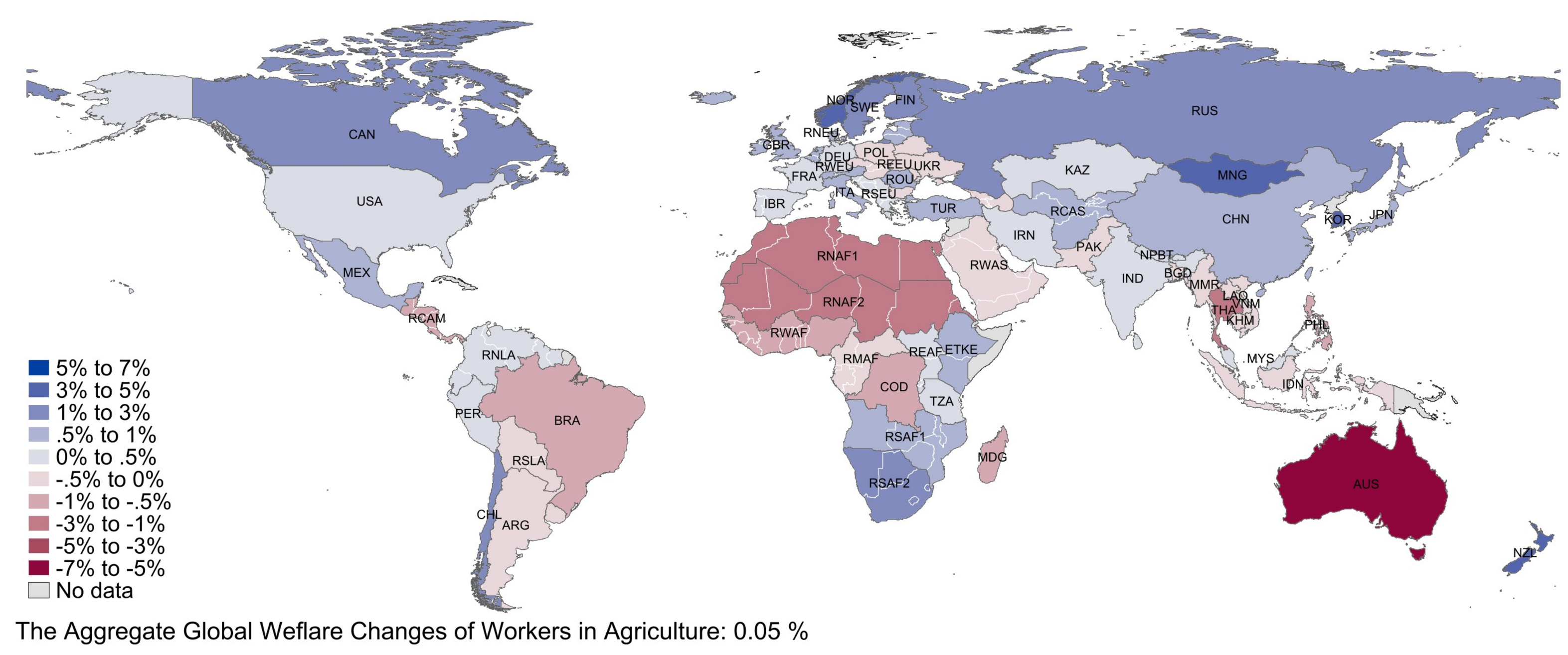

Figure 3. Welfare Impact of Climate Change RCP 8.5 (under No Labor Mobility)

- **Path of Crop Prices**
  - The figure below displays the price path for major crops among the top five producers of each crop under the baseline scenario [RCP8.5/SSP2/Mobility].

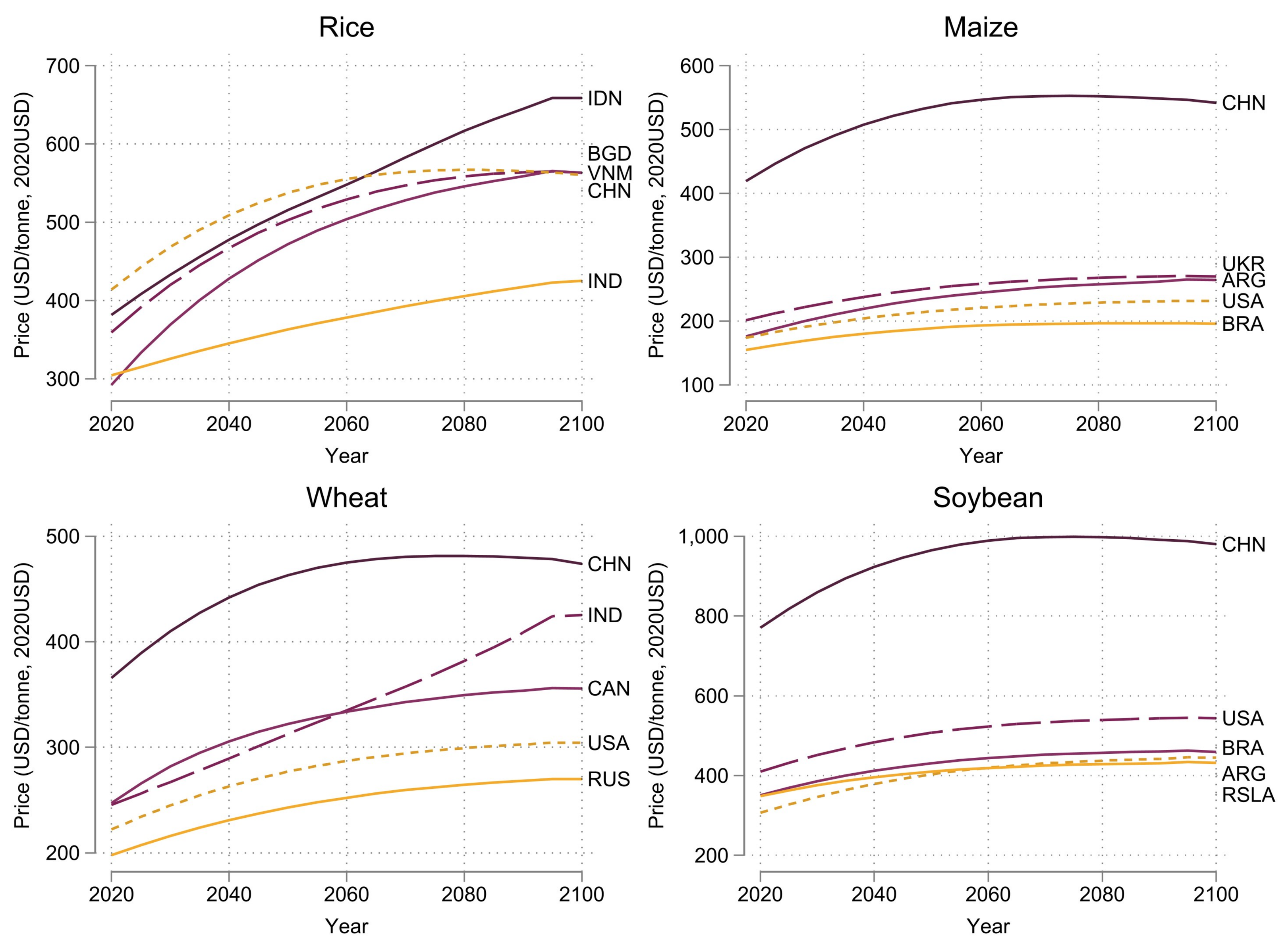

Figure 4. Welfare Impact of Climate Change RCP 8.5 (under No Labor Mobility)

Policy Analysis: Migration Cost

- **Welfare Impact of Labor Mobility**
  - The figure below displays the consumption equivalent variation under the current level of migration frictions relative to the infinite migration frictions (no labor mobility).
  - [RCP8.5/SSP2/current $\zeta^{ns,mz}$] compared to [RCP8.5/SSP2/$\zeta^{ns,mz} \to \infty$]
  - Aggregate global welfare impact of workers in agriculture is 17.31%.

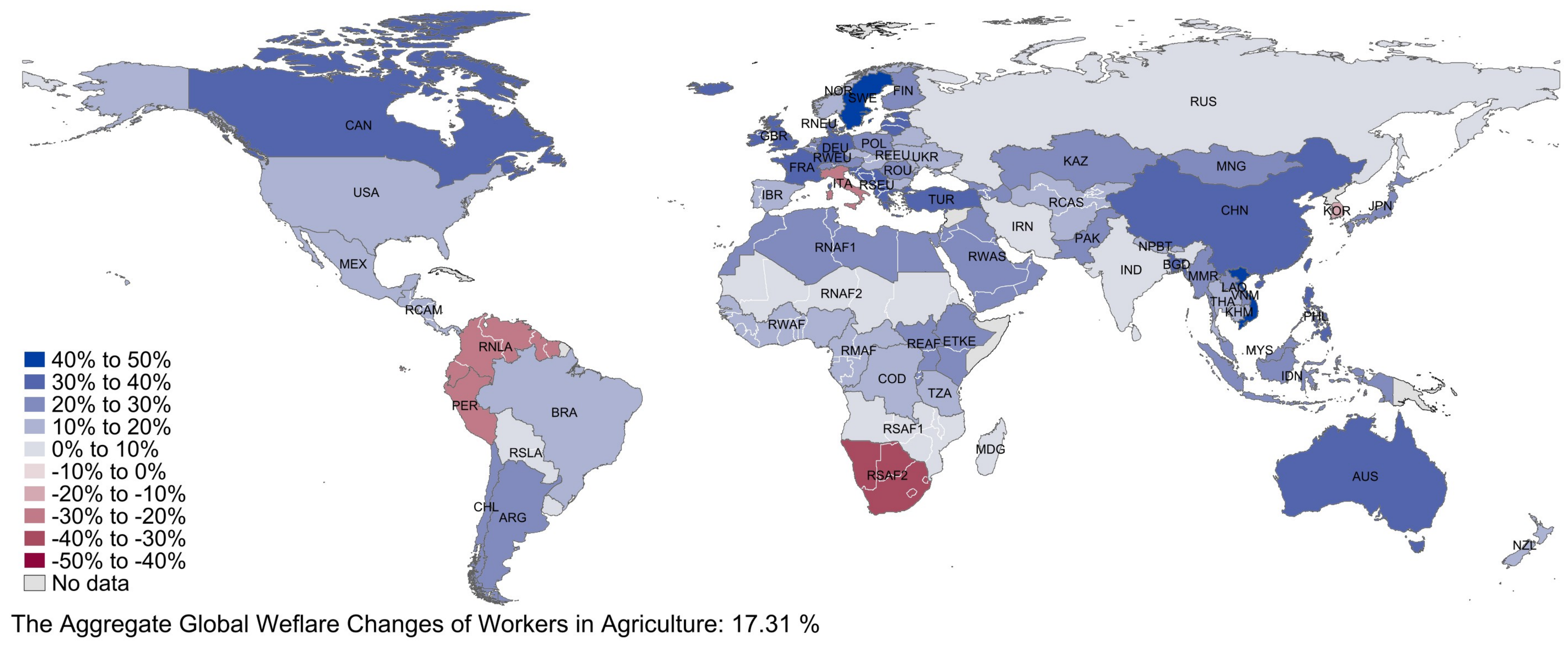

Figure 5. Welfare Impact of Labor Mobility under Climate Change

Key Takeaways

- **Large Heterogeneity across Regions and Crops**
  - Northern Africa, Brazil, and Australia are more negatively affected
  - Certain crops, e.g., rice, wheat, and bananas, are expected to see stronger price increases among major producers.

- **Welfare Implications**
  - Labor mobility and population growth have a greater welfare impact than the climate change shock itself.
  - **Malthusian Trap?** Don't be too pessimistic just yet; The current model assumes that technology remains fixed at its current level.

- **Role of Labor Mobility**
  - Labor mobility plays a nontrivial role in mitigating the adverse effects of climate change on agriculture.

Reference

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