

# Climate Change and Migration: the case of Africa

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# Motivation

- Implications of **climate change** ( $C\Delta$ ): at the center of the policy debate
- Drastic (potential) consequences for Sub-Saharan Africa (SSA):
  - High dependence on agriculture
  - Low usage of modern inputs
  - Rapid population growth

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  - High dependence on agriculture
  - Low usage of modern inputs
  - Rapid population growth
- **Great Climate Migration** (Lustgarten, 2020):
  - High vulnerability of SSA (in terms of migration responses to  $C\Delta$ )
  - Rigaud et al. (2018): intranational climate migration  $\sim$  millions by 2050

# Research Questions and Outline

1. How can  $C\Delta$  lead to migration flows in SSA (within/across countries)?
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This project: **Data + Model** = long-run GE effects of climate change

1. Climate change: agricultural productivity shock
  - FAO-GAEZ data: variation at **location-crop level**
2. Embed it in a multi-sector spatial GE model to quantify:
  - $\Delta$  migration by the end of the 21st century
  - Role of **migration and trade policies** on  $\Delta$  effects

# Main Results and Takeaways

## 1. Aggregate $C\Delta$ effects:

- Migration flows (22 million) and real GDP pc losses (-2%)
- Magnitude of results: determined by **spatial frictions**

## 2. Distributional effects:

- Heterogeneous migration responses across space [-280K, 270K]
- Country-level welfare effects: [-14%, 3%]
- Production adaptation across sectors + trade: mitigate  $C\Delta$  effects

## 3. SSA as the **European Union** ( $\downarrow$ trade and migration barriers):

- EU's **migration and trade policies**: aggregate vs. distributional trade-offs
- Main channel:  $C\Delta$ -induced **structural change**

1. Introduce CΔ migration into the **structural change/development** literature:
  - Climate shocks: **push-factors of migration** (past and future)  
(Henderson et al., 2017; Rigaud et al., 2018; Benveniste et al., 2020; Burzyński et al., 2022)
  - Mobility barriers: **obstacle for migration**, structural change, and development  
(Gollin et al., 2014; Bryan et al., 2014; Bustos et al., 2016; Lagakos et al., 2018; Bryan and Morten, 2019; Pellegrina and Sotelo, 2021; Imbert et al., 2022; Henderson and Turner, 2020)
2. Contribution to the **spatial climate change** literature:  
(Desmet et al., 2021; Balboni, 2021; Conte et al., 2024; Cruz and Rossi-Hansberg, 2024)
  - Crop-level CΔ (Costinot et al., 2016) and migration
  - CΔ, structural change (the “food problem”), and migration  
(Gollin et al., 2007; Nath, 2022; Conte et al., 2021; Cruz, 2024)
  - Carefully quantified **real-world policies** and their interaction with CΔ effects

# Road Map

## 1. Data:

- Main data sources
- Motivating evidence

## 2. Theory:

- Theoretical model
- Model quantification

## 3. Counterfactuals for Climate Migration:

- Main counterfactuals
- Policy experiment: SSA as the EU
- Additional experiments and robustness

## 4. Final remarks and further work



**Data**

## Spatial Data: $1^{\circ} \times 1^{\circ}$ grid cells ( $\sim 2000$ cells) [more](#)

### 1. GDP and Population:

- 2000: both values from (G-Econ, Nordhaus et al., 2006)
- 1975: population from (GHSP, Florczyk et al., 2019)
- 2080: population estimates (UN's Population Prospects, at the country level)

### 2. **Transportation network:** African extract from gROADS and transportation friction surface from Weiss et al. (2018)

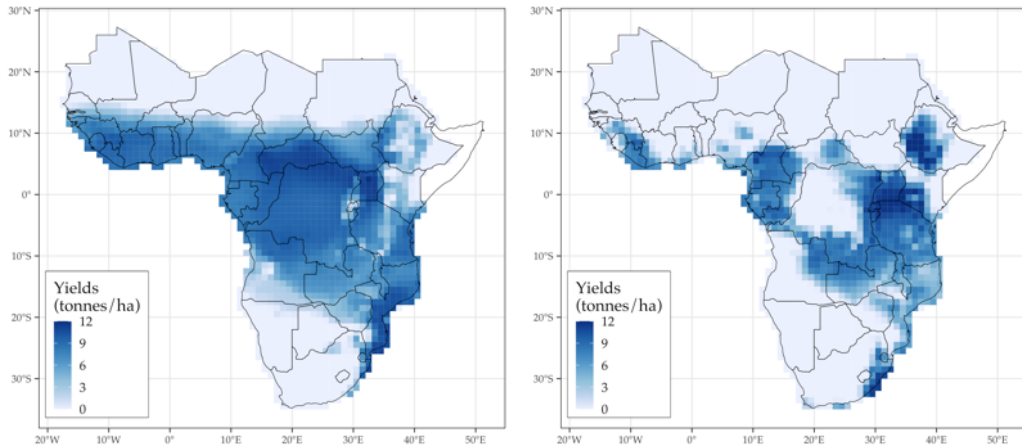
### 3. **Agriculture:** GAEZ agro-climatic potential yields (IIASA and FAO, 2012):

- Unit: tons/ha, subsistence (rainfed) technology
- Crops: cassava, maize, millet, rice, sorghum, wheat
- Time periods: 1975, 2000 and 2080 (**RCP 8.5**)

# CΔ and Agricultural Productivity

spatial-crop heter.

Figure 1: CΔ effects on potential yields of cassava for 2000 (left) and 2080 (right).



**Model**

# Model Outlook

- Static, multi-sector spatial GE model
- Ingredients from quantitative spatial economics (Allen and Arkolakis, 2014; Redding and Rossi-Hansberg, 2017):
  - Love for varieties (consumers) +
  - Trade frictions (production and trade) +
  - Congestion forces (location choice) =
  - Spatial allocation of economic activity
- Main outcomes: sectoral production in the most productive regions
- Sectoral specialization: disciplined by barriers to structural change (agricultural goods  $\equiv$  subsistence)

# Environment

- $N$  locations  $i, j \in S = \{1, \dots, N\} \in$  country  $c \in C$  countries,  $K - 1$  crops (agriculture),  $K \equiv$  non-agric. sector:
  - Sector-specific productivity  $A_i^k \in \mathcal{A} = \{A_1^1, \dots, A_N^K\}$  and land stock  $H_i \in \mathcal{H}$
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- Initial population  $\mathcal{L} = \{L_i^0\}_{i \in S}$ , inelastic supply labor and earn  $v_j$ :
  - Heterogeneous w.r.t. location choice  $\sim G(\theta, u_j(L_j/H_j)^{-\alpha})$
  - Migration barriers  $\bar{m}_{ij} = \text{dist}(i, j)^\phi \times m_{c(j)} \geq 1 \in \mathcal{M}$
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# Main Features

- **Technology:** Cobb-Douglas (labor + land) with Hicks-neutral  $b_i^k A_i^k \equiv \text{TFP}_i^k$   
( $A_i^k \equiv$  fundamental productivity,  $b_i^k \equiv$  efficiency shifter)
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- **Consumption choice:** Multi-level CES demand over location-sector varieties  $q_{ij}^k$  and CES aggregates  $C_j^k$ 
  - $\eta_k, \gamma_a, \sigma \equiv$  lower, middle, and upper level CES,  $\xi_k \equiv k$ 's trade elasticity
  - Bilateral expend. shares:  $\lambda_{ij}^k \propto (p_{ij}^k / P_j^k)^{-\xi_k} \equiv g(w, r, b^k, A^k, \mathcal{T}; \xi_k) \quad \forall i, j, k$

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- **Non-/Agricultural expenditures:** shares  $\mu_j^k, k = a, K$ 
  - Non-homothetic upper-tier (Comin et al., 2021):

$$\mu_j^k = \Omega_k \times \underbrace{\left(P_j^k / P_j\right)^{1-\sigma}}_{\text{substitution effect}} \times \underbrace{\left(w_j / P_j\right)^{\varepsilon_k - (1-\sigma)}}_{\text{income effect}}$$

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- **Location choice:** destination  $j$  s.to an i.i.d. shock  $\varepsilon_j \sim G_j(z) = e^{-z^{-\theta} \times u_j(L_j/H_j)^{-\alpha}}$ 
  - $L_{ij} \equiv h(v/P, \mathcal{U}, \mathcal{M}, \theta, \alpha, \mathcal{L}) \quad \forall i, j$
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# **From Theory to Data: Calibration and Validation**



# From Theory to Data: Matching SSA in 2000

Parameters	Description	Source
<i>Panel A: Demand parameters</i>		
$\eta_k = 5.4$	Lower-tier CES ( $k \neq K$ , crops)	Costinot et al. (2016)
$\eta_K = 4$	Lower-tier CES (non-agriculture)	Desmet et al. (2018)
$\gamma_a = 2.5$	Mid-tier CES (across crops)	Sotelo (2020)
$\sigma = 0.26$	Upper-tier CES	Comin et al. (2021)
$\epsilon_a = 0.2$	Non-homothetic CES (agriculture)	Comin et al. (2021)
$\epsilon_K = 1$	Non-homothetic CES (non-agriculture)	Comin et al. (2021)
<i>Panel B: Supply parameters</i>		
$\tilde{\zeta}_k = 5.66$	Sectoral trade elasticity ( $k \neq K$ , crops)	Pellegrina (2022)
$\tilde{\zeta}_K = 6.63$	Sectoral trade elasticity (non-agriculture)	Pellegrina (2022)
$\alpha^k = 0.39$	Crop labor share ( $k \neq K$ )	Fajgelbaum and Redding (2022)
$\alpha^K = 0.58$	Non-agricultural labor share	Fajgelbaum and Redding (2022)
<i>Panel C: Location choice parameters</i>		
$\theta = 3.65$ (0.15)	Migration elasticity	Gravity estimation
$\beta = 0.32$	Congestion to population density	Desmet et al. (2018)

	Subset	Description	Data source / Moment matched
$\mathcal{L}$	–	SSA's initial population	Population data in 2000 and 1990
	$\{b_i^k, \Omega_k\}_{i,k}$	Production and consumption shifters	Spatial-sectoral output/expenditures
$\mathcal{H}$	–	Land endowments	Grid cell land areas
$\mathcal{A}$	$\{A_i^k\}_{i \in S, k \neq K}$	Agricultural productivities	FAO-GAEZ data <a href="#">go</a>
	$\{A_i^K\}_{i \in S}$	Non-agricultural productivities	Spatial distribution of GDP
$\mathcal{U}$	–	Amenities	Spatial distribution of population
$\mathcal{T}$	$\text{dist}(i,j)$	Bilateral travel distances	Transportation data
	$\delta = 0.22(0.06)$	Distance elasticity of $\tau$	Spatial dispersion of prices <a href="#">go</a>
	$\{t_c\}_c$	Country-level tariffs	H6-level tariff data <a href="#">go</a>
	$\tau^F = 4.15(1.45)$	Border effect (e.g., NTB)	Aggregate bilateral trade flows
$\mathcal{M}$	$\text{dist}(i,j)$	Bilateral travel distances	Transportation data
	$\phi = 0.45(0.02)$	Distance elasticity of $m_{ij}$	Internal migr. flows (from census) <a href="#">go</a>
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results: trade network

gravity estimation

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# **Climate Change and Migration: Counterfactuals and Policy Experiments**

# Main Counterfactual

- Solve for 2080's equilibrium with  $\mathcal{G}(S)$  but using:
  - $\mathcal{L}$  for 2080 +
    1.  $\{A_i^k\}_{k \neq K}$  with  $C\Delta$  -
    2.  $\{A_i^k\}_{k \neq K}$  (no  $C\Delta$ )



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    1.  $\{A_i^k\}_{k \neq K}$  with  $C\Delta$  -
    2.  $\{A_i^k\}_{k \neq K}$  (no  $C\Delta$ )
- **Results:**  $C\Delta$  migration ( $\sim 22$  million), welfare losses (real GDP pc  $\downarrow 1.7\%$ ), non-agricultural employment ( $\downarrow 0.82\%$ ) [CΔ migration](#) [empl. results](#) [welfare results](#)

	Aggregate	Location Level			Country Level			
		Bottom decile	Median	Top decile	Angola	Senegal	Nigeria	Tanzania
$\Delta$ Population (K)	22,315.27	-108.05	-0.63	94.59	-1,686.26	-347.16	133.24	2,760.20
$\Delta$ Non-agric.	-0.82	-10.89	-1.40	16.16	4.92	2.78	-0.31	-2.53
$\Delta$ Real GDP pc	-1.76	-22.86	-3.76	4.56	-16.60	-32.81	-1.11	2.50

# Policy Experiment: SSA as frictionless as the European Union

## A. Trade, Migration, and Sectoral Specialization: mitigating role

- Trade: attenuates "the food problem" (Gollin et al., 2007; Nath, 2022)
- Trade and migration: substitutes as adaptation (Conte et al., 2021)
- Migration: key adaptation (Cruz and Rossi-Hansberg, 2024)

## B. Policy Experiment: SSA as the European Union (trade/migration policies)

	Baseline	SSA as frictionless as the EU		
		Migration Policy	Trade Policy	Both
$\Delta$ Pop. (M)	22.32	34	9.18	20.46
$\Delta$ Non-agric. (%)	-0.82	-0.54	-0.84	-0.76
$\Delta$ GDP pc (%)	-1.76	-1.01	-1.31	-1.41
[bottom, top]	[-14.62; 3.27]	[-11.32; 4.69]	[-6.32; 3.69]	[-5.64; 3.35]

EU vs SSA spatial frictions

Alternative welfare measures

Level CA effects

Policy 2: road corridors in SSA

# Additional Experiments, Extensions, and Robustness Checks

1. Less crop switching: larger welfare losses
2. Homothetic preferences: major welfare gains
  - Economy substitutes out agricultural consumption for non-agriculture
3. Tariff revenues: slightly larger welfare losses
  - Distortive effect of tariff redistribution (to less productive regions)
4. Endogenous fertility: reduces population growth in damaged locations
  - Less climate migration
5. ~~Rest of the World: larger migration flows and welfare losses~~
6. Productivity growth: attenuates welfare losses; ambiguous migration effects
7. Alternative climate damages: (amenities, non-agric.) mildly magnifies effects
8.  $\Delta$  assumptions: weaker effects with RCP 4.5 (less severe)

# **Final Remarks**

# Final Remarks

- Study and quantify **climate migration in SSA** by combining:
  - Rich **spatial data** for SSA
  - Tractable, transparent **spatial GE** model
- **Main results:**  $C\Delta$  effects on migration, welfare, and structural change
  - Sector adaptation and trade: key adaptation mechanisms
  - **Trade and migration policies:** powerful mitigation tools (EU as benchmark)

**Thank you!**

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# References I

- Abel, Guy J and Joel E Cohen**, “Bilateral international migration flow estimates for 200 countries,” *Scientific data*, 2019, 6 (1), 1–13.
- Allen, Treb and Costas Arkolakis**, “Trade and the Topography of the Spatial Economy,” *The Quarterly Journal of Economics*, 2014, 129 (3), 1085–1140.
- Asturias, Jose, Manuel García-Santana, and Roberto Ramos**, “Competition and the welfare gains from transportation infrastructure: Evidence from the Golden Quadrilateral of India,” *Journal of the European Economic Association*, 2019, 17 (6), 1881–1940.
- Atkin, David and Dave Donaldson**, “Who’s getting globalized? The size and implications of intra-national trade costs,” Technical Report, National Bureau of Economic Research 2015.
- , **Arnaud Costinot, and Masao Fukui**, “Globalization and the Ladder of Development: Pushed to the Top or Held at the Bottom?,” Technical Report, National Bureau of Economic Research 2021.
- Baez, Javier, German Caruso, Valerie Mueller, and Chiyu Niu**, “Heat Exposure and Youth Migration in Central America and the Caribbean,” *American Economic Review*, 2017, 107 (5), 446–50.
- Balboni, Clare Alexandra**, “In Harm’s Way? Infrastructure Investments and the Persistence of Coastal Cities,” 2021.

## References II

- Benveniste, Hélène, Michael Oppenheimer, and Marc Fleurbaey**, “Effect of border policy on exposure and vulnerability to climate change,” *Proceedings of the National Academy of Sciences*, 2020, 117 (43), 26692–26702.
- Borchert, Ingo, Mario Larch, Serge Shikher, and Yoto V Yotov**, “The international trade and production database for estimation (ITPD-E),” *International Economics*, 2021, 166, 140–166.
- Bryan, Gharad and Melanie Morten**, “The aggregate productivity effects of internal migration: Evidence from Indonesia,” *Journal of Political Economy*, 2019, 127 (5), 2229–2268.
- , **Shyamal Chowdhury, and Ahmed Mushfiq Mobarak**, “Underinvestment in a profitable technology: The case of seasonal migration in Bangladesh,” *Econometrica*, 2014, 82 (5), 1671–1748.
- Burzyński, Michał, Christoph Deuster, Frédéric Docquier, and Jaime De Melo**, “Climate Change, Inequality, and Human Migration,” *Journal of the European Economic Association*, 2022, 20 (3), 1145–1197.
- Bustos, Paula, Bruno Caprettini, and Jacopo Ponticelli**, “Agricultural productivity and structural transformation: Evidence from Brazil,” *American Economic Review*, 2016, 106 (6), 1320–65.
- Cai, Ruohong, Shuaizhang Feng, Michael Oppenheimer, and Mariola Pytlikova**, “Climate variability and international migration: The importance of the agricultural linkage,” *Journal of Environmental Economics and Management*, 2016, 79, 135–151.



## References III

- Caliendo, Lorenzo, Luca David Opromolla, Fernando Parro, and Alessandro Sforza**, “Goods and factor market integration: a quantitative assessment of the EU enlargement,” *Journal of Political Economy*, 2021, 129 (12), 3491–3545.
- Comin, Diego, Danial Lashkari, and Martí Mestieri**, “Structural change with long-run income and price effects,” *Econometrica*, 2021, 89 (1), 311–374.
- Conte, Bruno, Klaus Desmet, and Esteban Rossi-Hansberg**, “On the Geographic Implications of Carbon Taxes,” 2024.
- , — , **Dávid Krisztián Nagy, and Esteban Rossi-Hansberg**, “Local sectoral specialization in a warming world,” *Journal of Economic Geography*, 2021, 21 (4), 493–530.
- Costinot, Arnaud, Dave Donaldson, and Cory Smith**, “Evolving comparative advantage and the impact of climate change in agricultural markets: Evidence from 1.7 million fields around the world,” *Journal of Political Economy*, 2016, 124 (1), 205–248.
- Cruz, José-Luis**, “Global warming and labor market reallocation,” *Available at SSRN 4946752*, 2024.
- and **Esteban Rossi-Hansberg**, “The economic geography of global warming,” *Review of Economic Studies*, 2024, 91 (2), 899–939.
- Desmet, Klaus and Esteban Rossi-Hansberg**, “Spatial Development,” *The American Economic Review*, 2014, 104, 1211–1243.

## References IV

- , **Dávid Krisztián Nagy**, and **Esteban Rossi-Hansberg**, “The geography of development,” *Journal of Political Economy*, 2018, 126 (3), 903–983.
- , **Robert E. Kopp**, **Scott A. Kulp**, **Dávid Krisztián Nagy**, **Michael Oppenheimer**, **Esteban Rossi-Hansberg**, and **Benjamin H. Strauss**, “Evaluating the Economic Cost of Coastal Flooding,” *American Economic Journal: Macroeconomics*, April 2021, 13 (2), 444–86.
- Donaldson, Dave**, “Railroads of the Raj: Estimating the impact of transportation infrastructure,” *American Economic Review*, 2018, 108 (4-5), 899–934.
- and **Richard Hornbeck**, “Railroads and American economic growth: A “market access” approach,” *The Quarterly Journal of Economics*, 2016, 131 (2), 799–858.
- Ducruet, César**, **Réka Juhász**, **Dávid Krisztián Nagy**, and **Claudia Steinwender**, “All aboard: The effects of port development,” Technical Report, National Bureau of Economic Research 2020.
- Eckert, Fabian** and **Michael Peters**, “Spatial structural change,” *Unpublished Manuscript*, 2018.
- Fajgelbaum, Pablo** and **Stephen J Redding**, “Trade, Structural Transformation, and Development: Evidence from Argentina 1869–1914,” *Journal of Political Economy*, 2022, 130 (5), 1249–1318.
- Fan, Tianyu**, **Michael Peters**, and **Fabrizio Zilibotti**, “Service-led or service-biased growth? Equilibrium development accounting across Indian Districts,” Technical Report, National Bureau of Economic Research 2021.

## References V

- Florczyk, AJ, C Corbane, D Ehrlich, S Freire, T Kemper, L Maffneni, M Melchiorri, M Pesaresi, P Politis, M Schiavina et al.,** “GHSL Data Package 2019,” *Luxembourg. EUR*, 2019, 29788.
- Gollin, Douglas, David Lagakos, and Michael E Waugh,** “The agricultural productivity gap,” *The Quarterly Journal of Economics*, 2014, 129 (2), 939–993.
- , **Stephen L Parente, and Richard Rogerson,** “The food problem and the evolution of international income levels,” *Journal of Monetary Economics*, 2007, 54 (4), 1230–1255.
- Gröger, André and Yanos Zylberberg,** “Internal labor migration as a shock coping strategy: Evidence from a typhoon,” *American Economic Journal: Applied Economics*, 2016, 8 (2), 123–53.
- Henderson, J Vernon, Adam Storeygard, and Uwe Deichmann,** “Has climate change driven urbanization in Africa?,” *Journal of development economics*, 2017, 124, 60–82.
- **and Matthew A Turner,** “Urbanization in the developing world: too early or too slow?,” *Journal of Economic Perspectives*, 2020, 34 (3), 150–173.
- IIASA and FAO,** “Global Agro-Ecological Zones (GAEZ v3. 0),” 2012.
- Imbert, Clement, Marlon Seror, Yifan Zhang, and Yanos Zylberberg,** “Migrants and firms: Evidence from china,” *American Economic Review*, 2022, 112 (6), 1885–1914.

## References VI

- Lagakos, David, Ahmed Mushfiq Mobarak, and Michael E Waugh**, "The welfare effects of encouraging rural-urban migration," Technical Report, National Bureau of Economic Research 2018.
- Lustgarten, Abrahm**, "The Great Climate Migration Has Begun," *The New York Times*, Jun 2020.
- Morten, Melanie and Jaqueline Oliveira**, "The Effects of Roads on Trade and Migration: Evidence from a Planned Capital City," *American Economic Journal: Applied Economics*, 2024. Forthcoming.
- Nagy, Dávid Krisztián**, "Hinterlands, City Formation and Growth: Evidence from the U.S. Westward Expansion," *The Review of Economic Studies*, 01 2023, p. rdad008.
- Nath, Ishan B**, "The Food Problem and the Aggregate Productivity Consequences of Climate Change," Technical Report 2022.
- Nordhaus, William, Qazi Azam, David Corderi, Kyle Hood, Nadejda Makarova Victor, Mukhtar Mohammed, Alexandra Miltner, and Jyldyz Weiss**, "The G-Econ database on gridded output: methods and data," *Yale University, New Haven*, 2006, 6.
- Pellegrina, Heitor S**, "Trade, productivity, and the spatial organization of agriculture: Evidence from Brazil," *Journal of Development Economics*, 2022, p. 102816.
- **and Sebastian Sotelo**, "Migration, Specialization, and Trade: Evidence from Brazil's March to the West," Technical Report, National Bureau of Economic Research 2021.

## References VII

- Redding, Stephen J and Esteban Rossi-Hansberg**, “Quantitative spatial economics,” *Annual Review of Economics*, 2017, 9, 21–58.
- Rigaud, KK, B Jones, J Bergmann, V Clement, K Ober, J Schewe, S Adamo, B McCusker, S Heuser, and A Midgley**, “Groundswell: Preparing for Internal Climate Migration (Washington, DC: World Bank),” 2018.
- Sotelo, Sebastian**, “Domestic trade frictions and agriculture,” *Journal of Political Economy*, 2020, 128 (7), 2690–2738.
- Takeda, Kohei**, “The Geography of Structural Transformation: Effects on Inequality and Mobility,” 2022.
- Weiss, D, A Nelson, HS Gibson, W Temperley, S Peedell, A Lieber, M Hancher, E Poyart, S Belchior, N Fullman et al.**, “A global map of travel time to cities to assess inequalities in accessibility in 2015,” *Nature*, 2018, 553 (7688), 333.



# Appendix

## Contribution to the Literature: Details [back](#)

- [Weather shocks and migration](#): empirical literature (Baez et al., 2017; Cai et al., 2016; Gröger and Zylberberg, 2016; Henderson et al., 2017)
- [Spatial structural change](#) (Desmet and Rossi-Hansberg, 2014; Eckert and Peters, 2018; Fan et al., 2021; Fajgelbaum and Redding, 2022; Takeda, 2022)
- [Migration \(barriers\) and development](#) (Bryan and Morten, 2019; Caliendo et al., 2021; Morten and Oliveira, 2024; Lagakos et al., 2018)
- [Market integration and development](#) (Asturias et al., 2019; Donaldson, 2018; Nagy, 2023; Ducruet et al., 2020; Sotelo, 2020; Atkin and Donaldson, 2015; Donaldson and Hornbeck, 2016; Atkin et al., 2021)

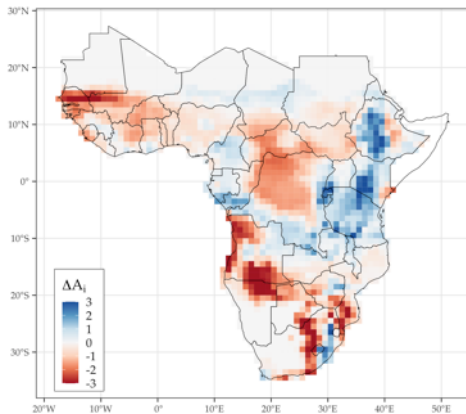


## Additional Data Sources [back](#)

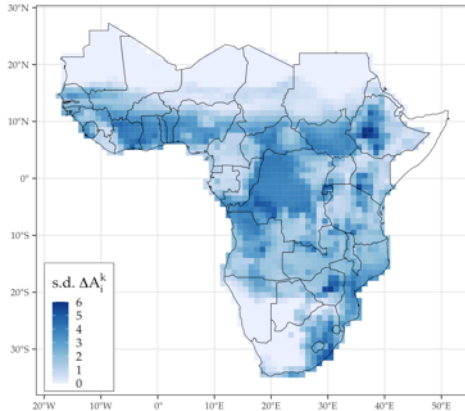
- **Sectoral production data** (2000 circa):
  - Crop-cell-level production (tons, FAO-GAEZ)
  - Crop-country-level production (US\$, FAOSTAT)
  - Country-level sectoral VA (WBDI)
- **Trade data:** country-pair-sector trade flows (1990-2005) from the International Trade and Production Database (ITPD-E, Borchert et al., 2021)
- **Migration data:** country-pair flows (1990-2005, from Abel and Cohen, 2019)

# Heterogeneous Effects of $C\Delta$ [back](#)

A: Change in average suitability to agriculture (ton/ha)

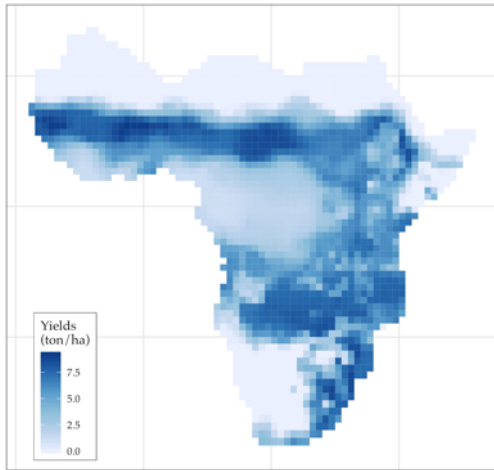


B: Standard deviation of changes in crop suitabilities at the location level

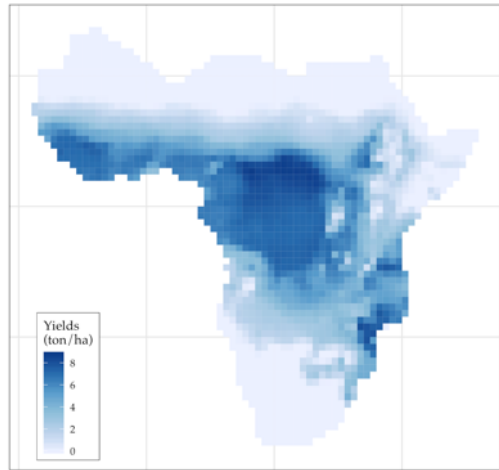


# Drawing $\{A_i^k\}$ from FAO-GAEZ [back](#)

A: Sorghum potential yields (2000)

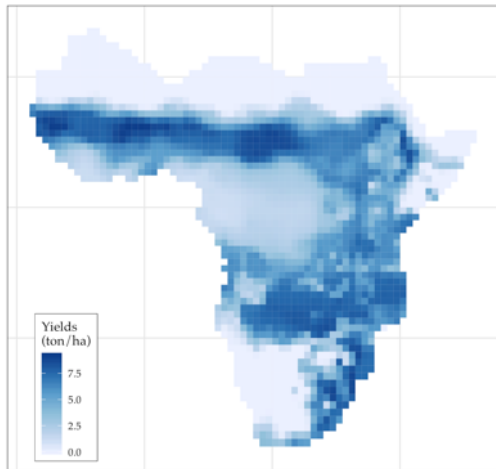


B: Rice potential yields (2000)

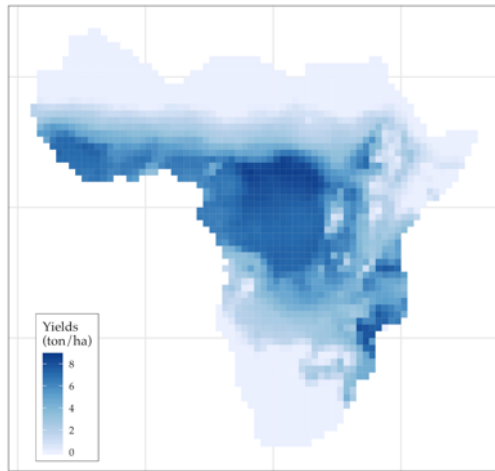


# Drawing tariffs $\{t_c\}$ from the data [back](#)

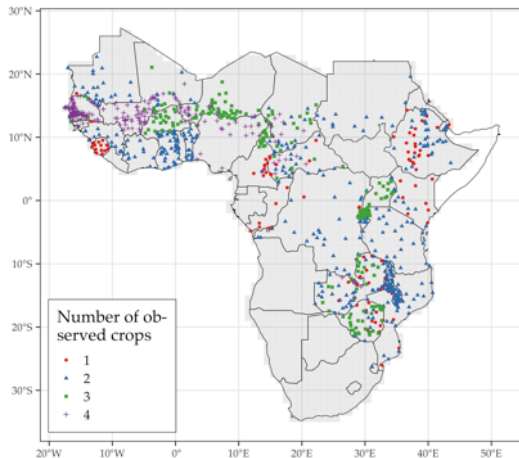
A: Raw bilateral tariffs data



B: Aggregated (importer  $c$  level)



## Newly Collected Price Data [back](#)



Crop price data from WFP-VAM project (FAO):

- ~ 40 countries and 900 markets (coordinates)
- 4 crops: maize, millet, sorghum, rice
- Covers 2000–2018

No origin-destination structure: [use price dispersion](#) to pin down  $\delta$

# Quantification Results: Outer Loops

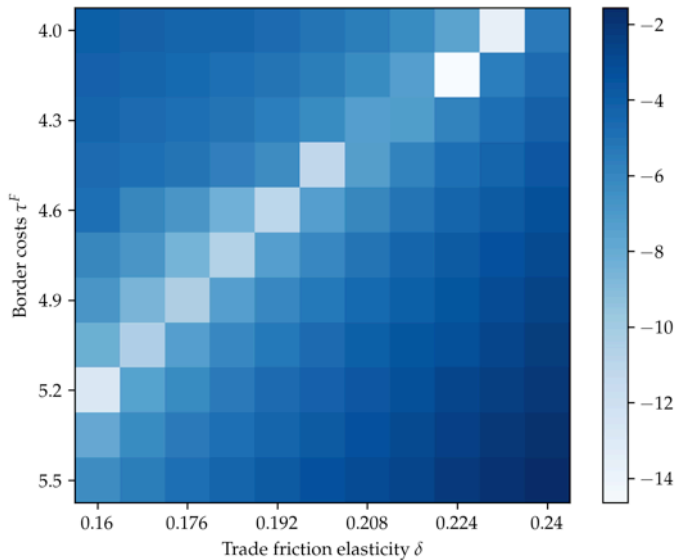
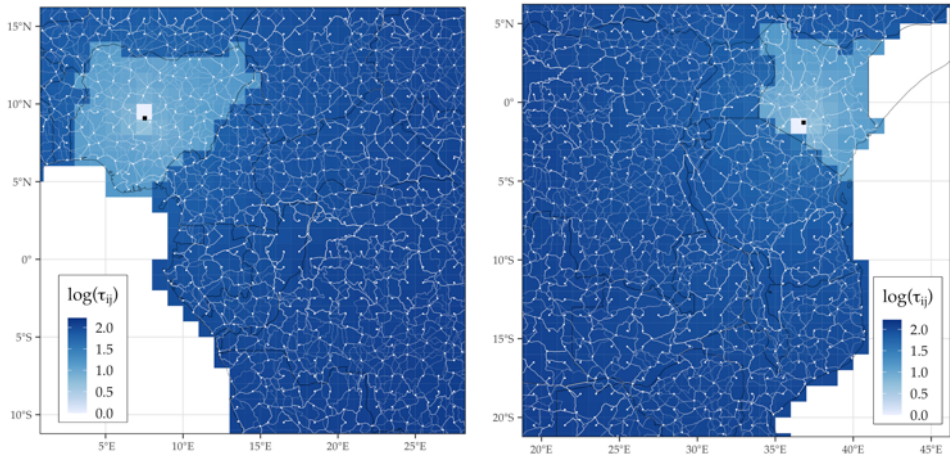
[back](#)

Figure 2: Quantified trade network for two subsamples of SSA. [back](#)



# Gravity Estimation for Migration Elasticity [back](#)

Bilateral migration flows between  $i$  and  $j$ :

$$L_{ij} = \frac{(v_j/P_j)^\theta \bar{m}_{ij}^{-\theta} u_j (L_j/H_j)^{-\beta}}{\sum_{s \in S} (v_s/P_s)^\theta \bar{m}_{is}^{-\theta} u_s (L_s/H_s)^{-\beta}} \times L_i^0, \text{ where} \quad (1)$$

$$\bar{m}_{ij} = \text{distance}(i, j)^\phi \times m_{c(j)}. \quad (2)$$

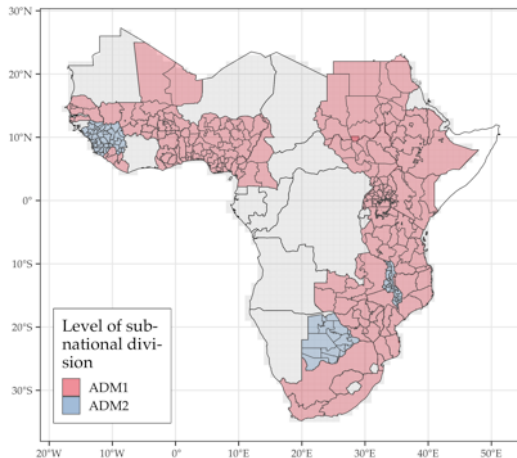
Set  $m_{c(j)} = 1$  (migration within countries), take logs:

$$\log(L_{ij}) = -\nu \log(\text{distance}(i, j)) + a_j + b_i + \varepsilon_{ij}, \quad (3)$$

where  $\nu \equiv \phi\theta$ . Estimate Equation (3) with internal migration (and distances) data.



# Newly Collected Migration Data [back](#)

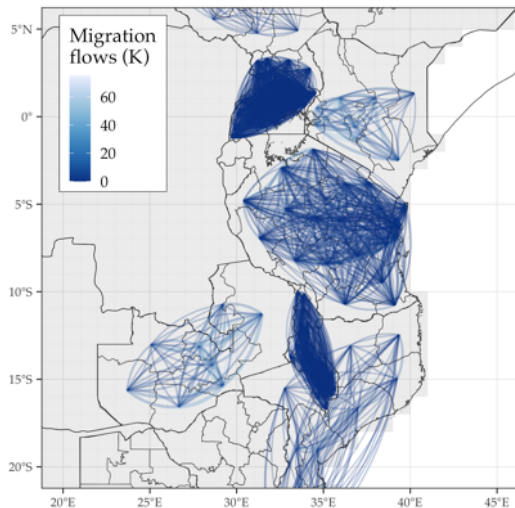


Internal migration data from IPUMS (census):

- ~ 24 countries, 40 years
- Individual-level data (~ 17 mi obs.)
- Aggregated at admin  $\times$  admin level

Identification: **total internal migration** to pin down  $\theta$

# Newly Collected Migration Data [back](#)



Internal migration data from IPUMS (census):

- ~ 24 countries, 40 years
- Individual-level data (~ 17 mi obs.)
- Aggregated at admin  $\times$  admin level

Identification: **total internal migration** to pin down  $\theta$

Table 1: Estimates of gravity equation of within country migration [back](#)

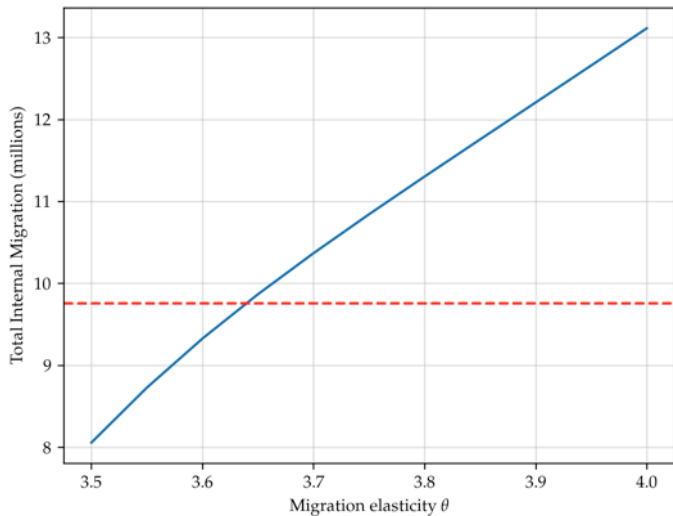
	$\log(L_{ij})$			
	(1)	(2)	(3)	(4)
	OLS	IV	OLS	IV
log(distance)	-1.576*** (0.1222)	-1.593*** (0.1192)	-1.606*** (0.1226)	-1.630*** (0.1179)
Origin $i$ FE	Yes	Yes	Yes	Yes
Destination $j$ FE	Yes	Yes	Yes	Yes
Controls	No	No	Yes	Yes
Observations	4,913	4,913	4,913	4,913
R <sup>2</sup>	0.86747	0.86745	0.86787	0.86784

**Notes:** Standard errors clustered at country-level. \*\*\*: 0.01, \*\*: 0.05, \*: 0.1.

**Separate identification:**  $\hat{v} \equiv \theta\phi = 1.63 \rightarrow$  with a guess for  $\theta$ , retrieve  $\phi = \hat{v}/\theta$ .

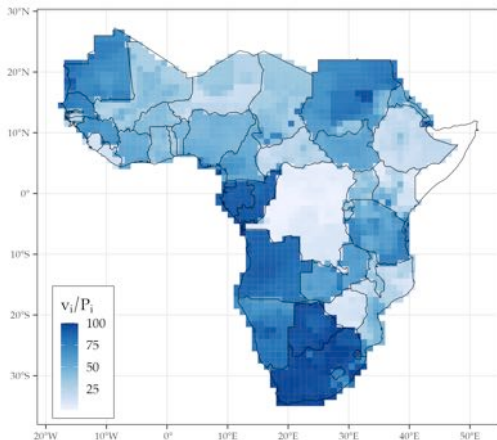
## Quantification Results: Outer Loops [back](#)

Figure 3: Results of the outer loops that solve for  $\theta$

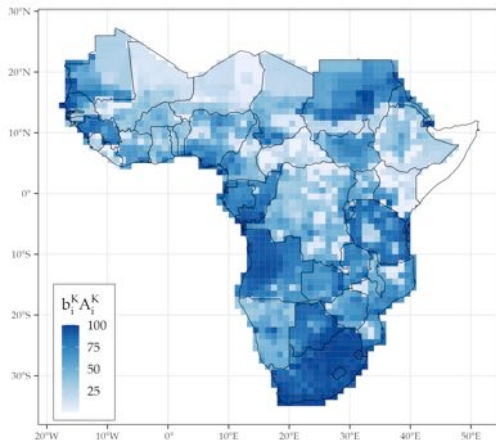


# Quantification Results [back](#)

A: Observed real wages in 2000



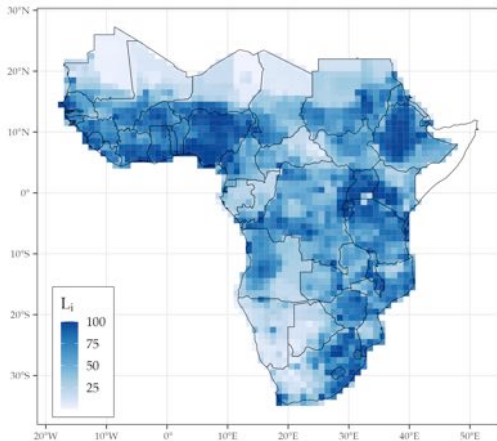
B: Quantified non-agric. productivities



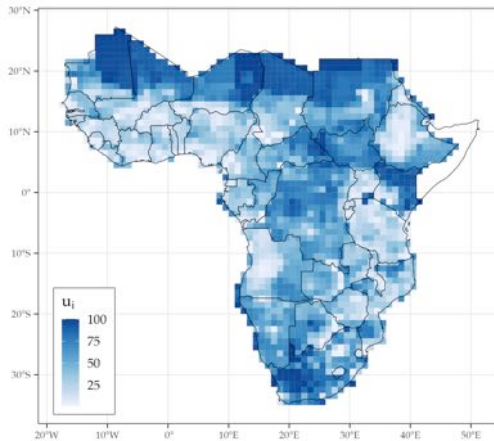
**Notes:** All results are shown in percentiles, where 1 (100) stands for the bottom (top) percentile of each sample. A and B document, respectively, the spatial distribution of the real wages in 2000 and the product of the quantified non-agricultural productivities productivity shifter of the non-agricultural sector.

# Quantification Results [back](#)

A: Observed population in 2000



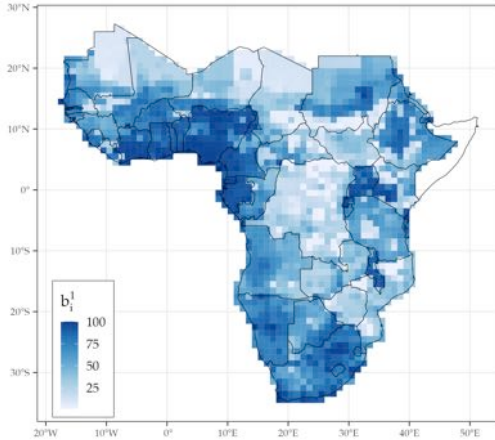
B: Quantified amenities



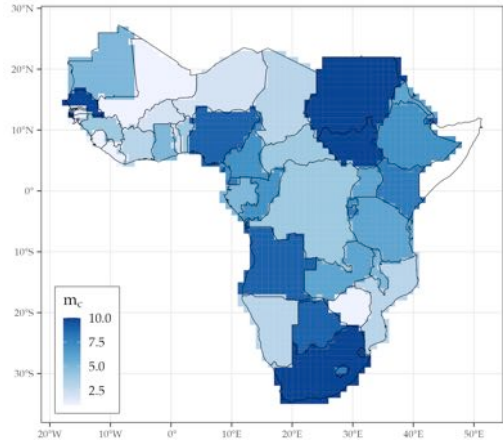
**Notes:** All results are shown in deciles, where 1 (100) stands for the bottom (top) decile of each sample. A and B document, respectively, the spatial distribution of observed population in 2000 and the quantified amenities .

# Quantification Results [back](#)

A: Quantified shifters (cassava)



B: Quantified migration barriers



**Notes:** All results are shown in deciles, where 1 (100) stands for the bottom (top) decile of each sample. A and B document, respectively, the spatial distribution of the quantified cassava shifters and country migration barriers (the latter in deciles).

Validating the model: backcasting exercise using  $\mathcal{L}$  and  $\{A_i^k\}_{k \neq K}$  for 1975; check:

- model-implied population differences between 2000 and 1975
- extra: model-implied agricultural employment in 2000

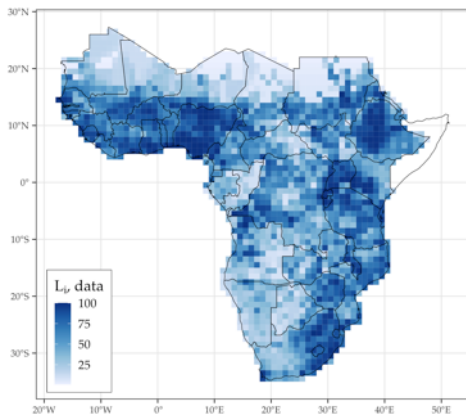


Validating the model: **backcasting exercise** using  $\mathcal{L}$  and  $\{A_i^k\}_{k \neq K}$  **for 1975**; check:

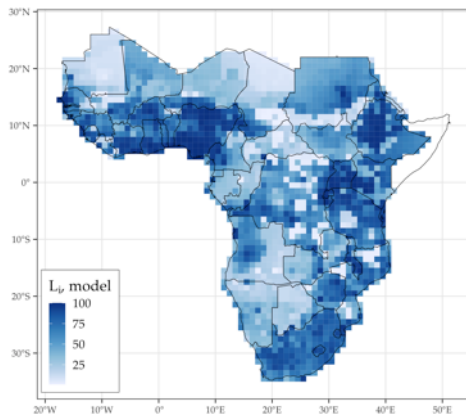
- model-implied **population differences** between 2000 and 1975
- extra: model-implied **agricultural employment** in 2000

Figure 4: Backcasting exercise: population distribution in 1975. [back](#)

A: Observed population in 1975



B: Estimated population in 1975



Validating the model: **backcasting exercise** using  $\mathcal{L}$  and  $\{A_i^k\}_{k \neq K}$  for 1975; check:

- model-implied **population differences** between 2000 and 1975
- extra: model-implied **agricultural employment** in 2000.

Figure 5: Model goodness of fit: backcasting results for differences in population and labor shares in agriculture for 2000. [back](#)

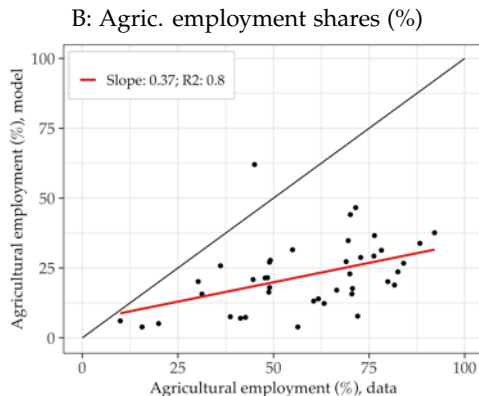
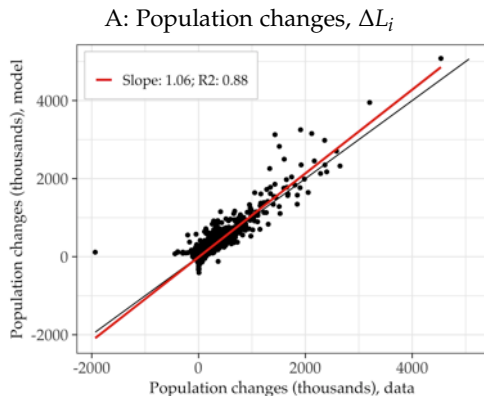
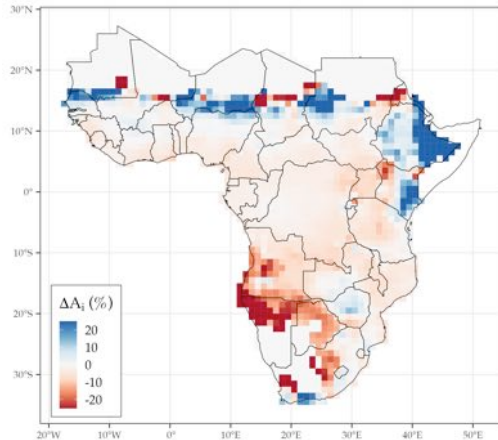


Figure 6: Change in agricultural suitabilities in SSA. [back](#)

A: Change in average suitability to agriculture (1975–2000).



B: Change in average suitability to agriculture (2000–2080).

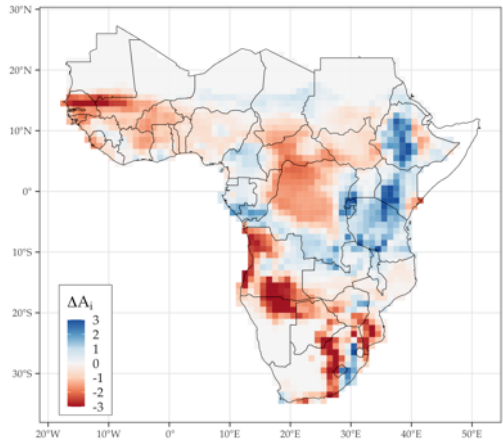
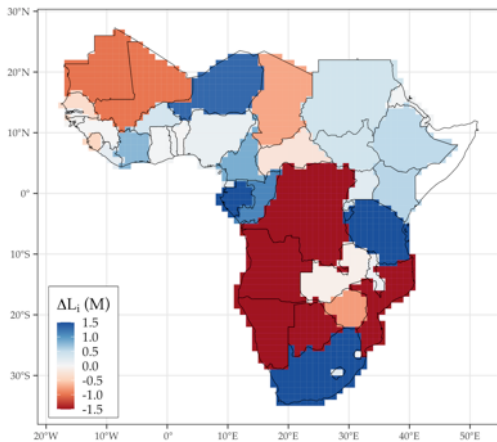


Figure 7: [Climate migration](#) in SSA – baseline results for 2080. [back](#)

A: Country level



B: Gridcell level

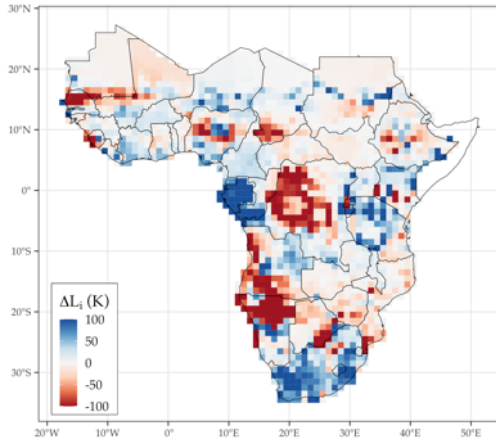
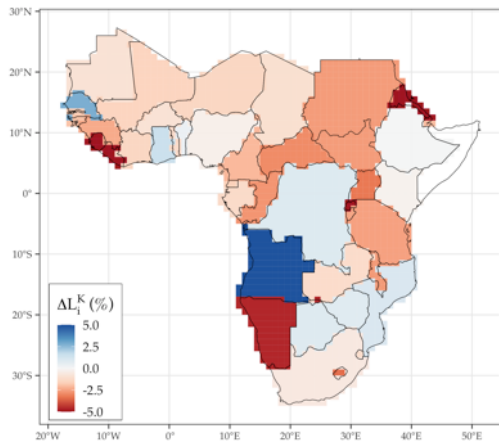


Figure 8: Climate change impact on [non-agricultural employment](#). [back](#)

A: Country level



B: Gridcell level

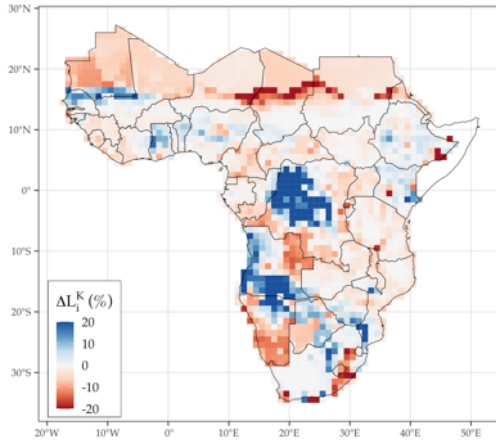
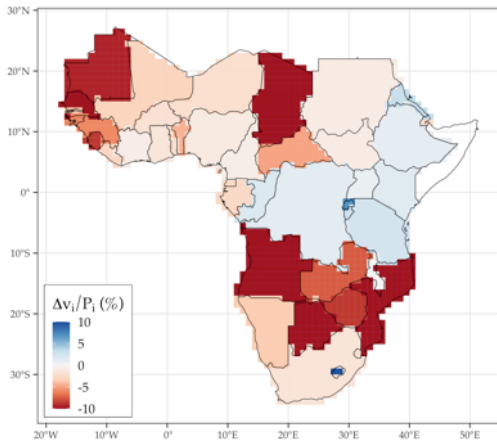


Figure 9: Climate change impact on [real GDP per capita](#). [back](#)

A: Country level (%)



B: Gridcell level (%)

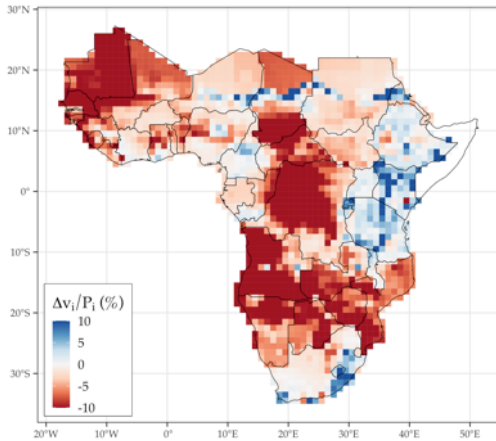
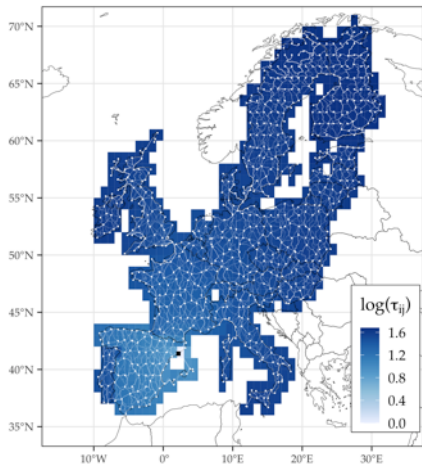
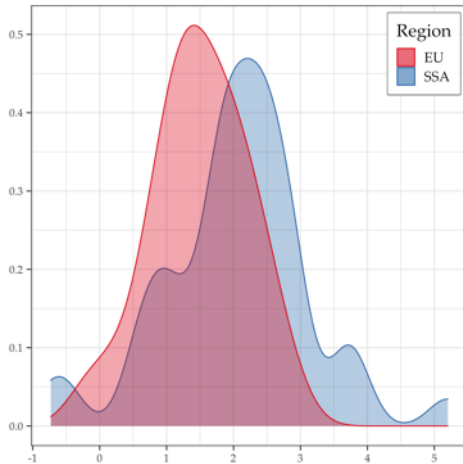


Figure 10: Estimated trade and migration frictions in the European Union [back](#)

A: Country border effects  $\tau^F$  in the European Union



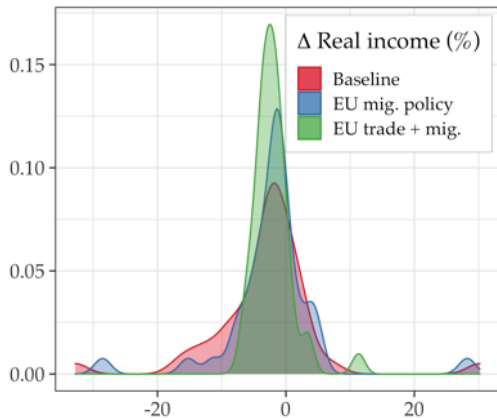
B: Country migration barriers  $\{m_c\}_c$  in the European Union and SSA, in logs



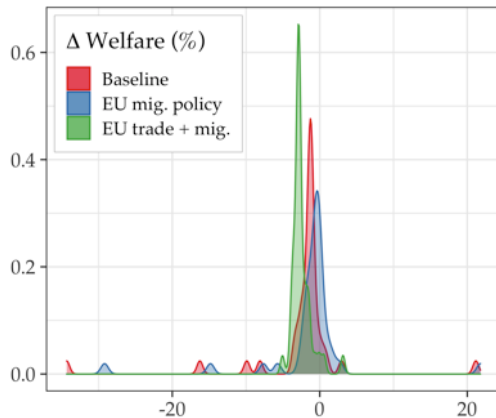
**Notes:** Panel A presents trade frictions in the EU as done for SSA in Figure 2 (in this context, trade frictions are relative to Barcelona (Spain), represented by the black dot). Panel B plots the distribution of country migration barriers  $\{m_c\}_c$  in SSA and the EU.

Figure 11: Welfare effects of climate change for the baseline and different EU policies [back](#)

Panel A: Real income per capita



Panel B: Welfare (amenities, mig. barriers, etc.)



**Notes:** Panel A and B plot the country-level distributions of welfare in three different policy scenarios for SSA: baseline, EU migration policy, and EU trade and migration policy. Panel A refers to the baseline welfare measure (real income per capita). Panel B refers to an alternative welfare measure that also account for mobility barriers and congestion.

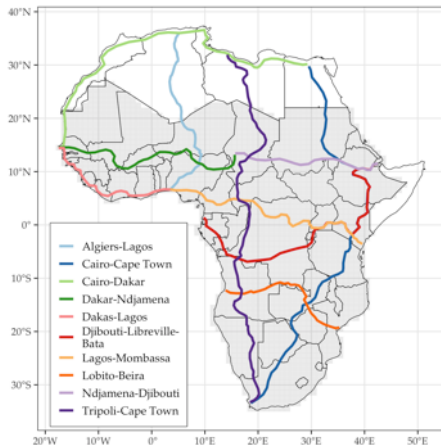


	(1) With climate change	(2) No climate change	(3) Climate change effect (%)
<i>Panel A - Welfare <math>W_R</math>:</i>			
Baseline	1.01	1.00	1.16
EU mig. policy	0.88	0.87	1.18
EU trade policy	1.65	1.69	-2.12
Both policies	1.84	1.90	-3.32
No mig. barriers ( $\bar{m}_{ij} = 1$ )	5.34	5.39	-0.89
<i>Panel B - Real income per capita <math>v_j/P_j</math>:</i>			
Baseline	0.98	1.00	-1.76
EU mig. policy	1.18	1.19	-1.01
EU trade policy	1.35	1.36	-1.31
Both policies	1.63	1.65	-1.41
No mig. barriers ( $\bar{m}_{ij} = 1$ )	1.32	1.32	-0.66

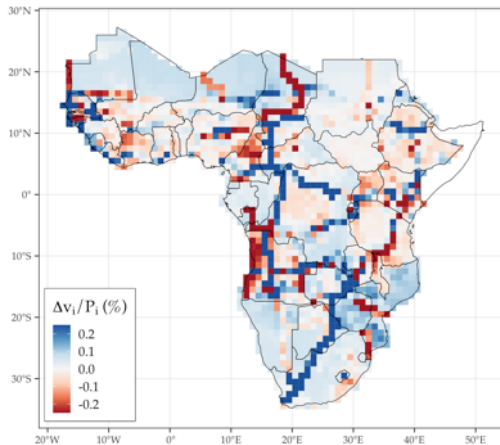
**Notes:** Columns 1 and 2 document the aggregate welfare and real income in levels normalized to the baseline, no climate change scenario. Column 3 refers to their percentage difference. [back](#)

Figure 12: The Trans-African Highway (TAH) project and its welfare effects [back](#)

Panel A: The proposed TAH project



Panel B: Economic effects (real GDP pc, DiD)



**Notes:** Panel A illustrates the highways designed for the TAH project. Panel B documents the (difference-in-differences) climate change effects (in real GDP per capita) of the TAH project.

