The poverty-environment trap:

Climate change, natural resources, and population dynamics in Sub-Saharan Africa

PhD Defense — Edouard Pignède

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Introduction

Sub-Saharan Africa is at the heart of many challenges

- Facing higher climate change impacts, induced by GHG emissions for which they are not historically responsible (Bathiany et al., 2018; Ranasinghe et al., 2021)
- High demographic trend

  → 50% of the increase in the human population by 2050

- Rich in natural resources, whose demand is increasing
- High level of poverty, which makes it more vulnerable to shocks

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Research question

How do climate change and natural resource endowments affect economic development and population dynamics in Sub-Saharan Africa?

This dissertation

Contributions

- Improve the understanding of structural dynamics of the impacts of:
  - → climate change on inequalities, migration, and mortality
  - → mineral resources exploitation on urbanization
- At various temporal and spatial scales.

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Data & methods

- Use new high-coverage data
  - → Satellite imagery, remote sensing products, geological data
  - → Surveys such as census data from IPUMS, DHS, or LSMS-ISA
- Combination of ex-post impact evaluation and prospective modeling
  - → Empirical analysis of causal inference
  - → Quantitative spatial models (Redding and Rossi-Hansberg, 2017)

This dissertation

	Chapter 1	Chapter 2	Chapter 3	Chapter 4
Methodology				
Empirical analysis	×	×		×
Quant. spatial		×	×	
Main thematic				
Population dynamics	Inequality	Migration	Mortality	Urbanization
Environment	⟵	Climate change	⟶	Natural ressources
Geographic extent				
Country case study	×			
Continent wide		×	×	×

Who carries the burden of climate change?

Heterogeneous impact of drought in Sub-Saharan Africa.

Published in the *American Journal of Agricultural Economics*

Weather shocks and inequality

Context

- Droughts are the most important hazard impacting African continent (Trisos et al., 2022)
- Most vulnerable households, which have barriers to resources required for adaptation, may not be able to cope with droughts

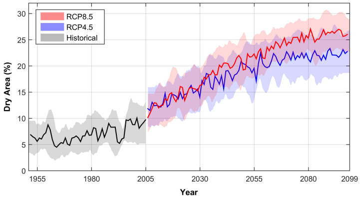

Figure: Climate change impact on drought occurence (Ahmadalipour et al., 2019)

Research gap

- Limited evidence on distributional impact of weather shocks (Hallegatte and Rozenberg, 2017)
- Measure the unconditional quantile treatment effect (Frölich and Melly, 2013)

Data & Method

Data

- Three waves of representative geo-referenced panel data from LSMS-ISA in Ethiopia and Malawi
- High-resolution Standardized Precipitation and Evaporation Index (SPEI)

Idenfication strategy

- Leverage the specific spatial and temporal patterns of drought in Ethiopia and Malawi
- Quantile treatment effect under the copula stability assumption (Callaway and Li, 2019)

Drought increases inequality

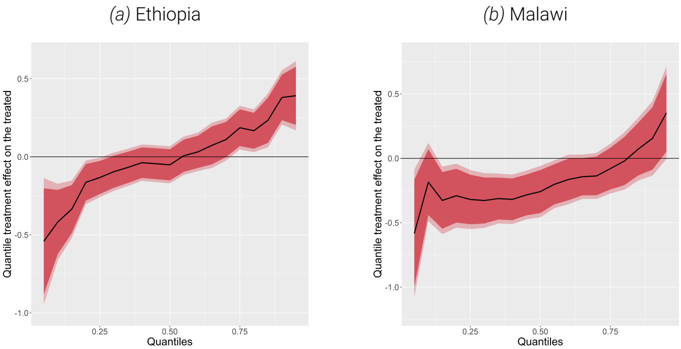

Figure: Quantile treatment effect on income per capita

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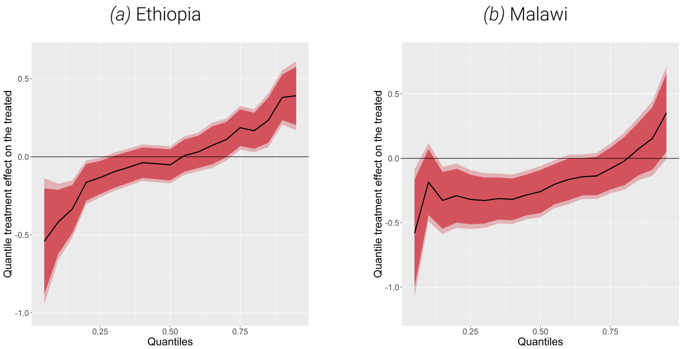

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- Richest households have a higher capacity to find alternative sources of income
- In Ethiopia, the richest households turn to the non-agricultural sector

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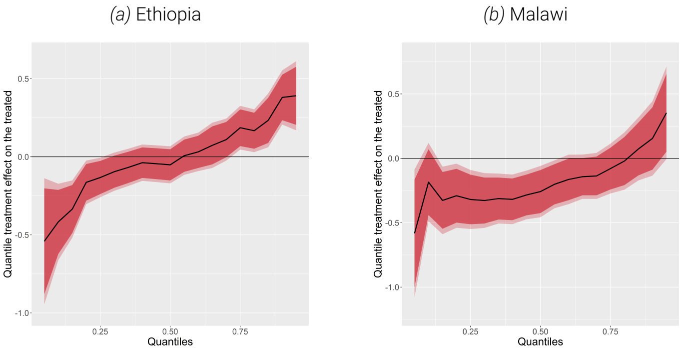


Figure: Quantile treatment effect on income per capita

- Richest households have a higher capacity to find alternative sources of income
- In Ethiopia, the richest households turn to the non-agricultural sector

→ Climate justice is a multilevel issue: within poor countries, climate change disproportionately burdens the poor

Climate immobility in sub-Saharan Africa

co-written with Julien Wolfersberger

Climate immobility

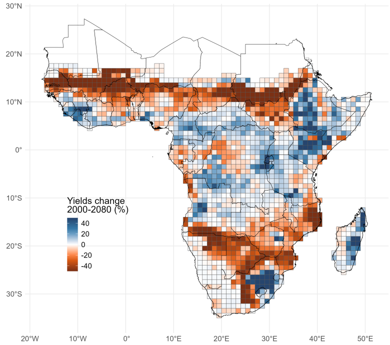


Figure: Spatial distribution of climate change impact on yields

Climate immobility

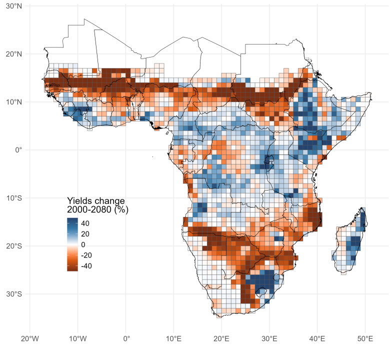
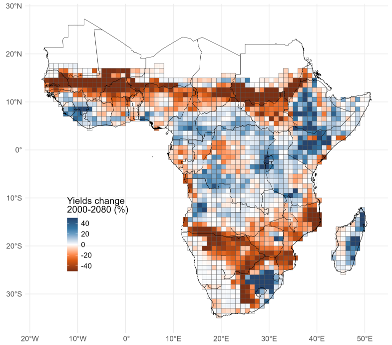


Figure: Spatial distribution of climate change impact on yields

Context

- Weather and climate have been recognized as important drivers of migration (Cattaneo et al., 2019; Defrance et al., 2022; Di Falco et al., 2024)
- As climate change impacts households' income, it may impose financial constraints blocking mobility, generating labor misallocations

Climate immobility



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Main contribution

- Focus on workers immobility

Method

Document motivating facts of immobility in 21 countries of SSA

- Look at heterogeneity in the migration induced by weather & climate shocks across individuals' income levels

Build a quantitative spatial model to measure the cost of immobility under future climate scenarios

- Consider channels of adaptation through migration, production and trade
- Take the model to rich census and satellite data
- Focus on spatial misallocation: workers unable to migrate due to (endogenous) resource constraints

Results

Motivating facts

- Droughts increase out-migration except for the poorest households
- Droughts ↓ distance of migration, except for the richest households
- Long-term changes in temperature ↓ out-migration for the poorest households

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Quantification results in 2080

- 31M trapped workers due to CC
- Substantial ↑ in the cost of CC, measured by welfare or GDP per capita
- Important spatial heterogeneity across districts and countries

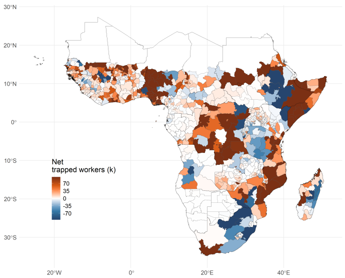

Figure: Spatial distribution of trapped workers

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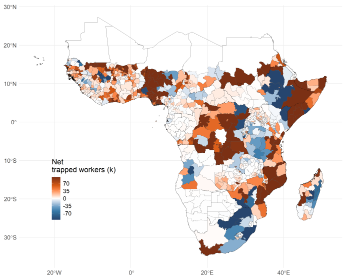

Figure: Spatial distribution of trapped workers

→ Provide some evidence on how decrease in migration costs could mitigate trapped workers

Climate change, adaptation, and mortality

Climate mortality

Context

- Climate change has a strong impact on mortality
  - → From 1991 to 2018, climate change accounted for 2 deaths for 100,000 individuals by year (Vicedo-Cabrera et al., 2021)
  - → By the end of the century, high temperatures could provoke 73 deaths for 100,000 individuals by year (Carleton et al., 2022)

	Number of deaths				
Region	Undernutrition	Vector-borne disease	Diarrhoeal Disease	Heat	Total
SSA	61,890	22,725	23,865	10,081	118,561
World	84,697	32,977	32,955	94,621	245,250

Table: Additional deaths attributable to climate change in 2050 according to WHO

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Research gap

- Projections of climate-induced mortality missed major mechanisms
  - → General equilibrium effects
  - → Adaptation to health-related impacts of climate change
- Method to quantify the impact of selected policies in reducing the mortality burden of climate change

The Model

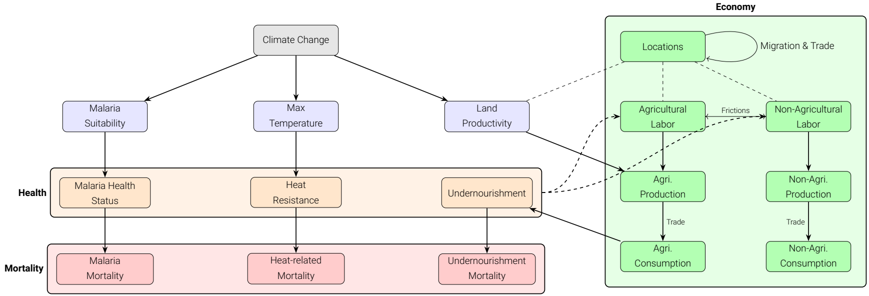

Figure: Schematic representation of the model

Results

- Climate change is a major driver of mortality
  - → By 2050, climate-induced mortality reaches almost 40 individuals per 100,000 in SSA
  - → Main drivers are undernutrition and malaria prevalence.
- Policies targeting specific mortality channels are effective but can have:
  - → Side-effects on other mortality channels
  - → Generational trade-offs
  - → Distributional impacts

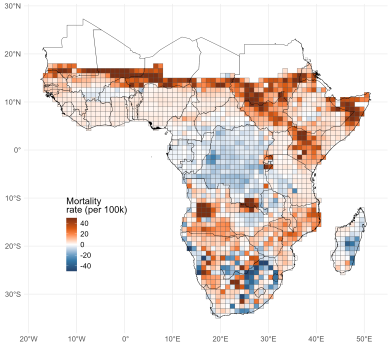

Figure: Spatial distribution of climate change-induced mortality

Golden Towns

Artisanal mining and urbanization in Africa

co-written with Victoire Girard

Artisanal mining and urbanization

Context

- The African continent is urbanizing at high speed: from 15% in 1960 to 50% in 2020.
- Artisanal and small-scale mining (ASM) is a high-scale, labor-intensive activity, whose location depends on mine deposits
- 60 million people depend on ASM in sub-Saharan Africa — 63% of them involved with gold extraction (Hruschka, 2022)

Research gap

- Lack of reliable statistics on ASM
- Tracking long-term urbanization is challenging in low-income countries

⇒ Limited evidence on how ASM impacts development and population dynamics

Data & Method

Urbanization

- Levy satellite-based data on human settlements to measure urbanization
- Build a panel of cities spanning 1975 to 2020

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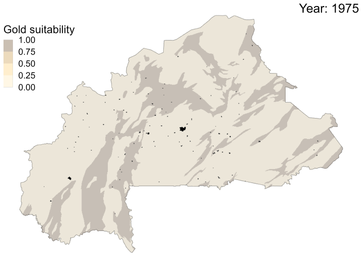

Figure: Urbanization in Burkina Faso

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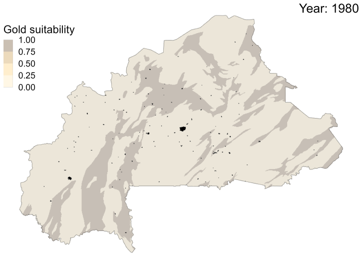

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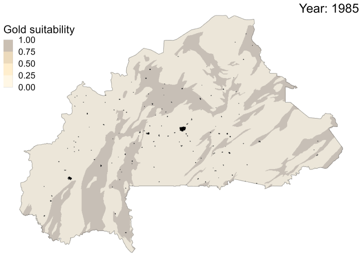

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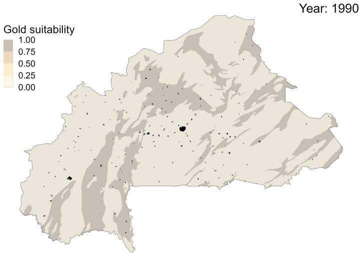

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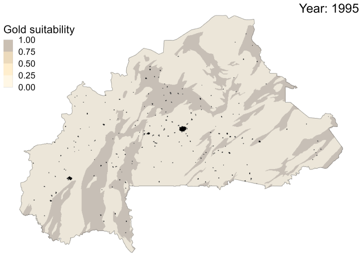

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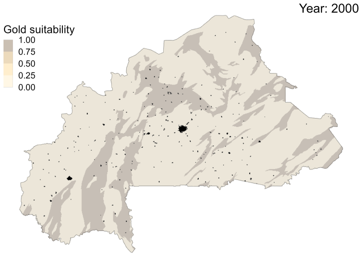

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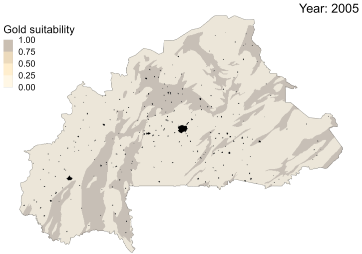

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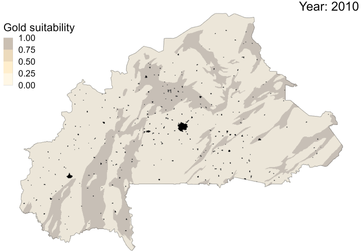

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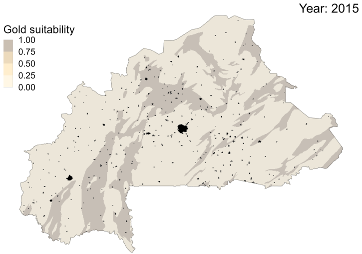

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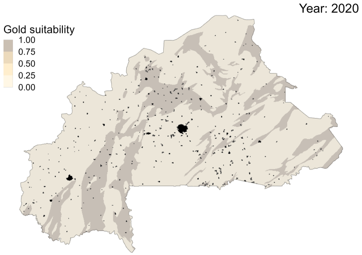

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Artisanal mining

- We exploit exogenous variations in the value of potential local ASgM activities.
- Spatial exposure: gold mining requires a gold suitable geology (Girard et al., 2022)
- Time exposure: Variations in the world price of gold dictate how much miners earn — and artisanal miners are price takers (Alvarez et al., 2016; Sanchez de la Sierra, 2020)

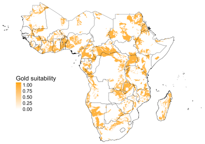

Figure: Gold suitability

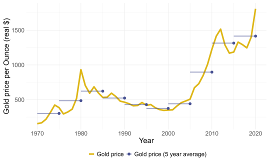

Figure: World price of gold

Artisanal mining

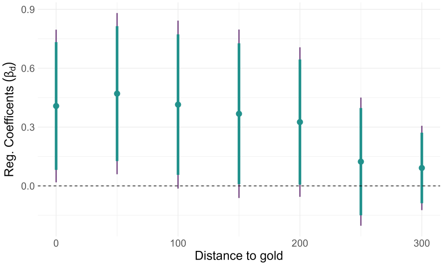

Figure: Artisanal mining and urbanization

- Artisanal mining drives urbanization.

Artisanal mining

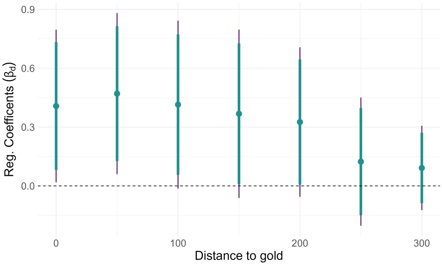

Figure: Artisanal mining and urbanization

- Artisanal mining drives urbanization.
- But this urbanization is concentrated in poorer cities, with lower living standards.
- ASgM exposed cities are more remote, with poor infrastructure and fewer industries.

→ New dimension of resource curse: urbanization with low living standards

Conclusion

Conclusion

Main takeaways

- Climate justice
  - → Most vulnerable people cannot adapt to climate change
  - → They bear the cost in terms of high-inequality, poverty, and mortality
  - → Risk of exacerbation of inequality with climate change

→ Climate-induced poverty trap: Vital need to fight poverty and climate change now, to avoid long-term impact for the most vulnerable population

- Resource curse
  - → ASM leads to a bad-quality urbanization in SSA

→ Without investment in new infrastructures, cities may not be successful and sustainable

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Appendix

Chapter 1

- Drought occurence
- QTT Consumption
- QTT Asset
- Paralel trends
- Copula stability
- Share of consumption in income

Chapter 2

- IPUMS countries
- Migration response
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- Malaria suitability
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Drought occurrence

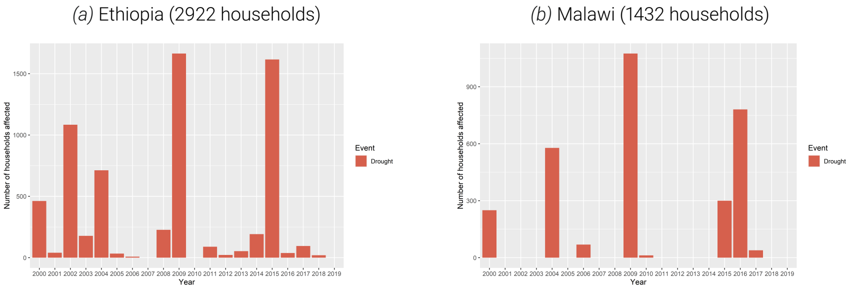


Figure: Number of households affected by drought over time in Ethiopia and Malawi

- One major drought affecting a large proportion of the population occurred just before the last year of the survey
- No major drought occurred between the first wave of the survey to the last wave of the survey

QTT on Consumption per capita

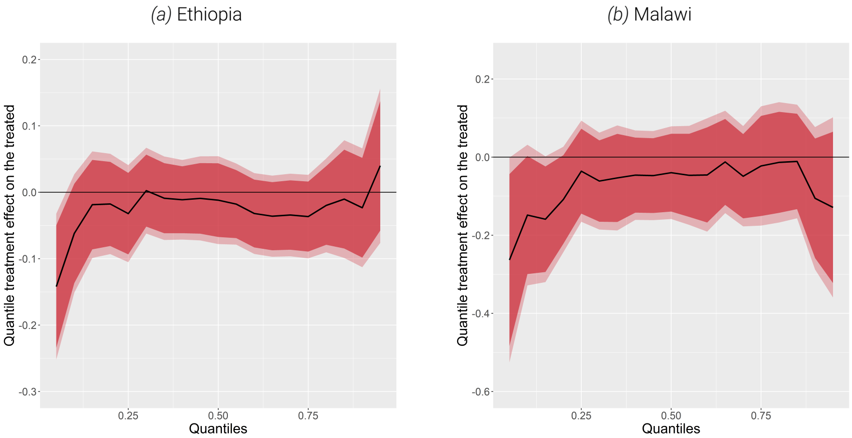


Figure: Quantile treatment effect of consumption per capita

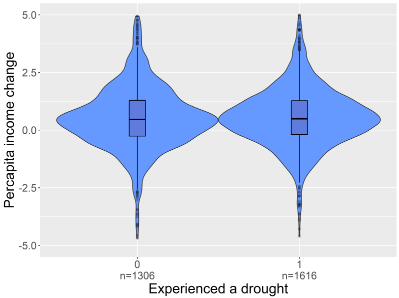
- Share of consumption in income

QTT on Asset

Figure: Quantile treatment effect of asset

Distributional difference-in-differences assumption — Income per capita

(a) Ethiopia



(b) Malawi

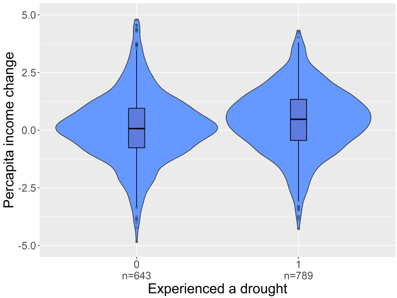


Figure: Distribution of change in the log of per-capita income for the treated and the control group between t−1 and t−2

Copula stability assumption — Income per capita

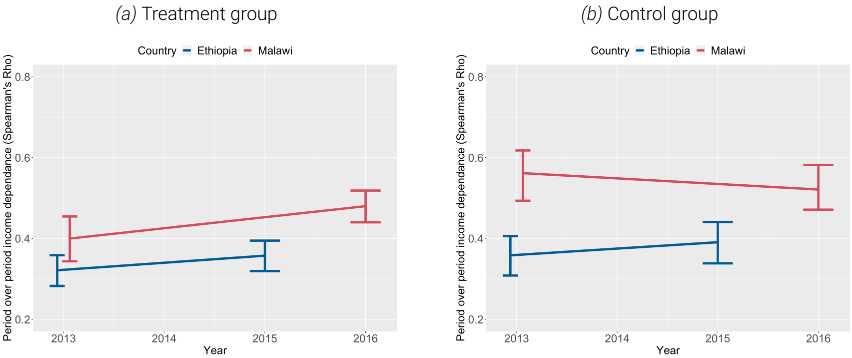


Figure: Evolution of the year-over-year income dependence (Spearman's rho) in Ethiopia and Malawi for the control and treatment group in all panel waves

Share of consumption in income

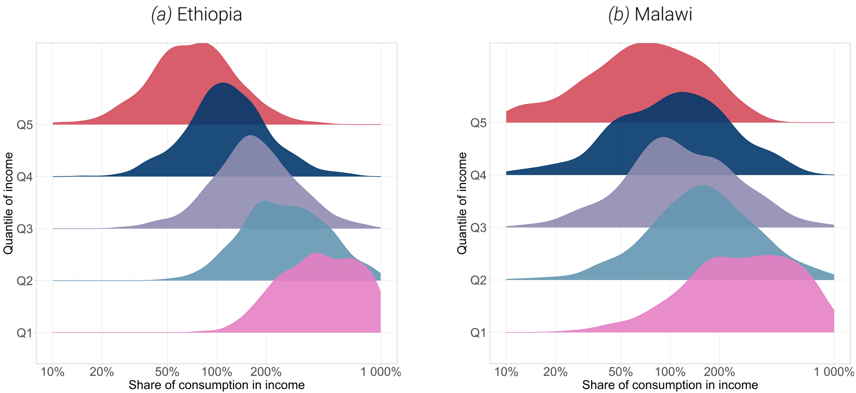
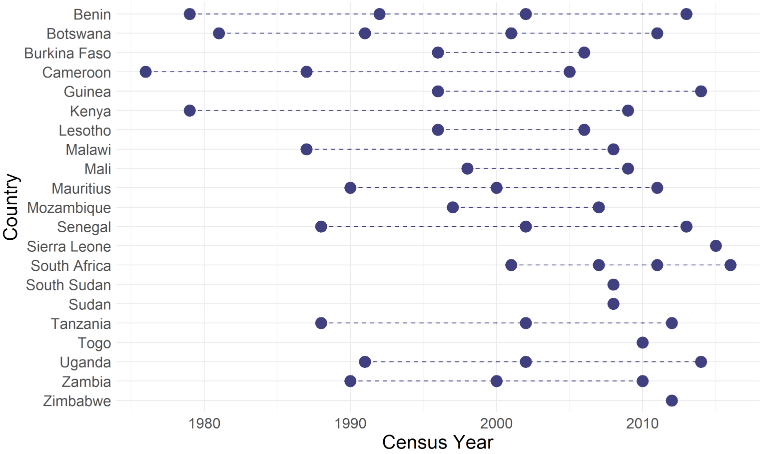


Figure: Share of consumption in income by quantile of income

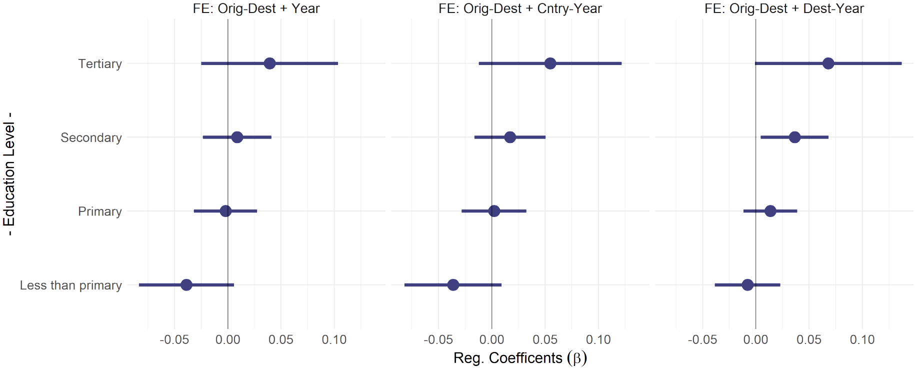
Empirical model — IPUMS data

Figure: Countries and census years considered from IPUMS



Empirical motivations

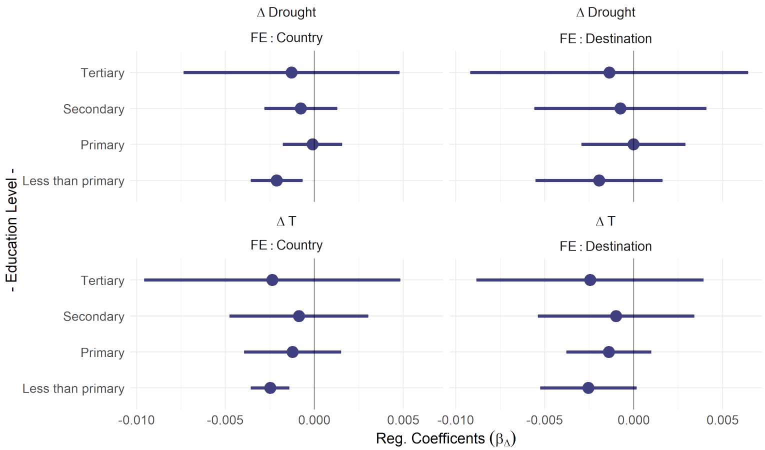
Figure: Elasticity of migration in response to drought events



Empirical motivations

Results — Long difference

Figure: Elasticity of migration in response to drought events



Empirical motivations

Results — Distance of migration

Dependent Variable:	Migration rate (log)							
Education	Less than primary		Primary		Secondary		Tertiary	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Variables								
Droughts	-0.008	0.004	0.014	0.020	0.036**	0.042**	0.068*	0.066*
	(0.016)	(0.017)	(0.013)	(0.013)	(0.016)	(0.017)	(0.035)	(0.036)
Droughts × Distance > 300 km		-0.223***		-0.144**		-0.173**		0.051
		(0.072)		(0.066)		(0.086)		(0.169)
Observations	11,630	11,630	11,253	11,253	9,773	9,773	6,617	6,617
Mean dep. var.	0.004	0.004	0.006	0.006	0.010	0.010	0.015	0.015
Mean mig. dist.	204.0	204.0	225.1	225.1	258.5	258.5	279.6	279.6

Table: Drough-induced migration by distance of migration

Calibration parameters

Parameter	Description	Source
$\alpha_A = 0.6$	Crop land share in production	Fajgelbaum and Redding (2022)
$\theta = 1.1$	Dispersion of within-admin land productivity distribution	Gouel and Laborde (2021)
$\nu = 3$	Dispertion of workers distribution preferences for locations	Morten and Oliveira (2024)
$\eta_k = 5.4$	Elasticity of substitution between varieties (agriculture)	Costinot et al. (2016)
$\eta_M = 4$	Elasticity of substitution between varieties (manufacturing)	Desmet et al. (2018)
$\sigma = 0.26$	Elasticity of substitution between goods for final demand	Conte (2023)
$\delta = 0.16$	Distance elasticity of trade costs	Conte (2023)
$\tau = 7.8$	Cross country trade tariffs	Conte (2023)
$\gamma = 2.5$	Elasticity of substitution between agricultural goods	Conte (2023)
$\epsilon_A = 0.2$	Non-homotetic parameter for agricultural goods	Conte (2023)
$\epsilon_M = 1$	Non-homotetic parameter for non-agricultural goods	Conte (2023)

Table: Calibrated migration costs validation

◂ Back

Model fit

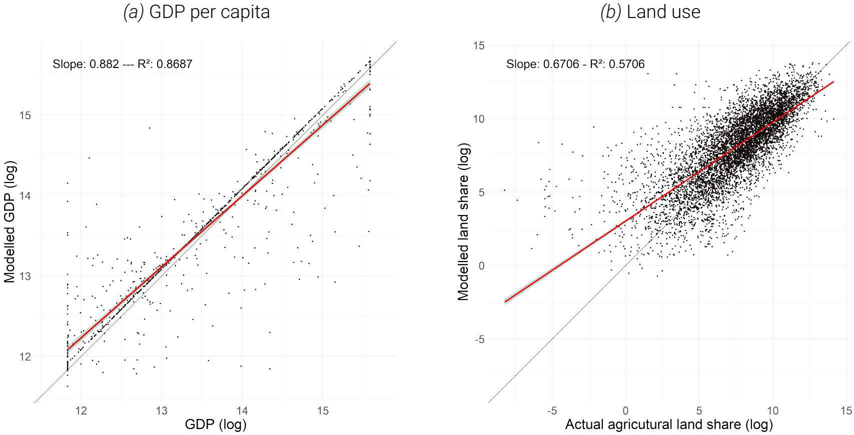
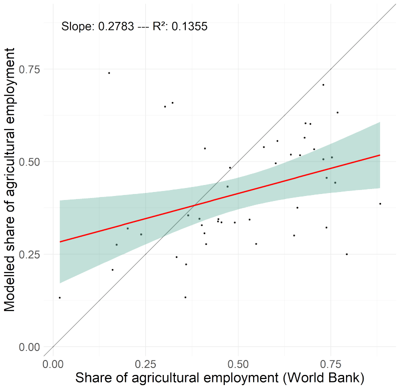


Figure: Model fit with real data

Model fit

(a) Agricultural employment



(b) Productivity gap

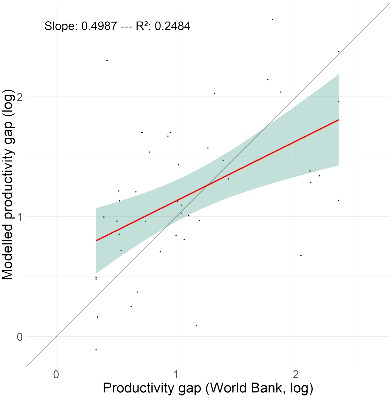


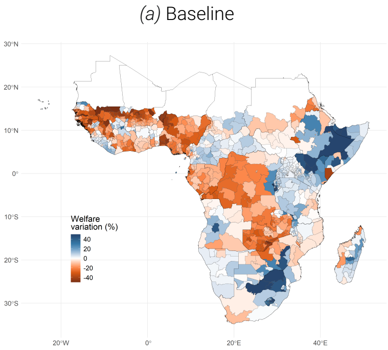
Figure: Model fit with real data

Main Results

Table: The Economy in 2080 under RCP8.5 relative to no Climate Change

		(1) Baseline	(2) No budget constraint
Climate migration (M)	$\Delta N_i \| \Delta N_i > 0$	29.56	83.72
Net trapped workers (M)	$\Delta N_{b,i}$	30.70	—
Real income pc change (%)	Δv_i	-4.06	-2.77
Non-ag. emp. change (%)	ΔN_i^M	-0.62	-2.68
Welfare change (%)	ΔW_i	-2.62	-1.84

Results — Spatial distribution



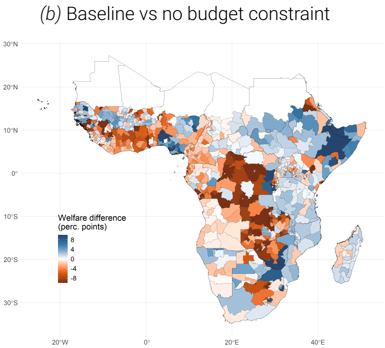


Figure: The distributional impact of climate change on welfare according to the inclusion of liquidity constraint

Results — Aggregated results

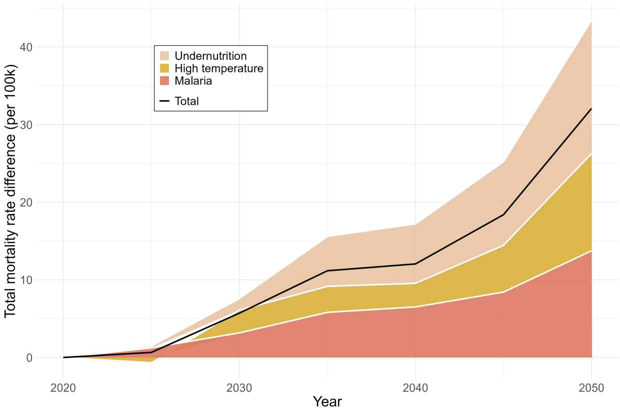


Figure: Climate change induced mortality over time

Results — Spatial distribution

(a) Malaria *(b)* Undernutrition *(c)* High temperature

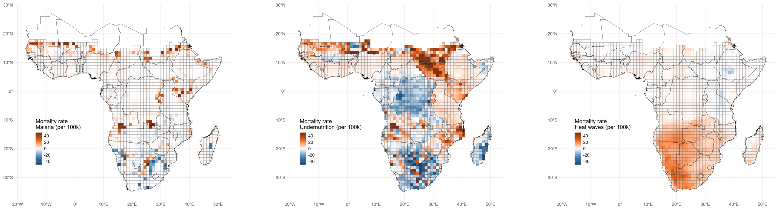


Figure: Spatial distribution of mortality by channel

Results — Mortality drivers

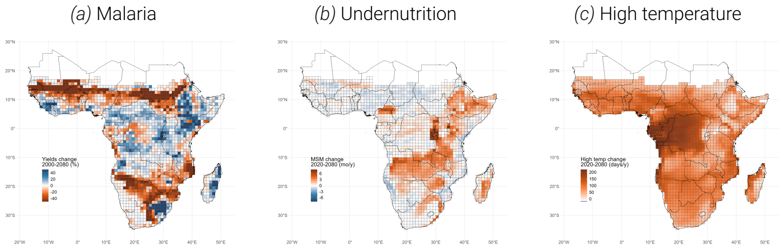


Figure: Drivers of mortality channel

Heat waves mortality (old people)

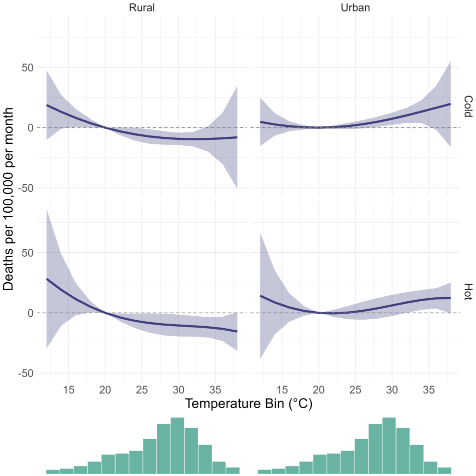


Figure: High temperature impact on mortality (60 years old and older)

0-15 years old 15-60 years old

Heat waves mortality (young people)

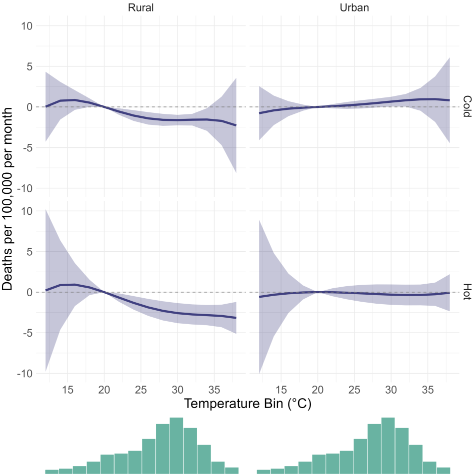


Figure: High temperature impact on mortality (0-15 years old)

60+ years old 15-60 years old

Back

Heat waves mortality (adults)

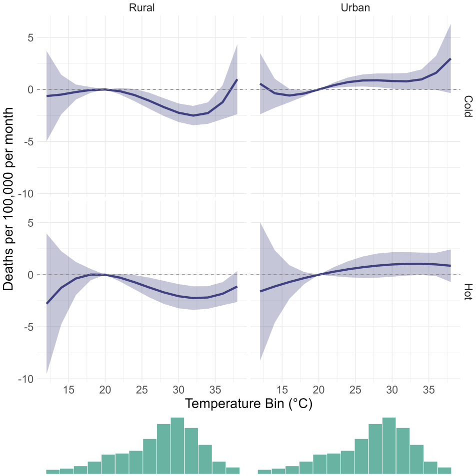


Figure: High temperature impact on mortality (15-60 years old)

0-15 years old 60+ years old

Back

Malaria

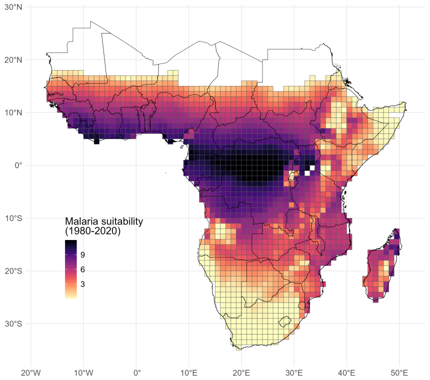


Figure: Malaria suitability map

Protein consumption

Crop	Calories (millions)	Share	Crop	Calories (millions)	Share
Maize	1,872.16	16.54%	Oil palm fruit	469.47	4.15%
Cassava	1,530.87	13.52%	Yams	392.59	3.47%
Rice	1,123.89	9.93%	Groundnuts	372.98	3.30%
Wheat	871.59	7.70%	Millet	324.72	2.87%
Livestock products	641.26	5.67%	Banana	308.94	2.73%
Sorghum	610.25	5.39%	Other cereals	259.12	2.29%
Sugar cane	557.18	4.92%	Other	1,984.40	17.53%

Table: Calories per agricultural products in Sub-Saharan Africa

Results —Distribution

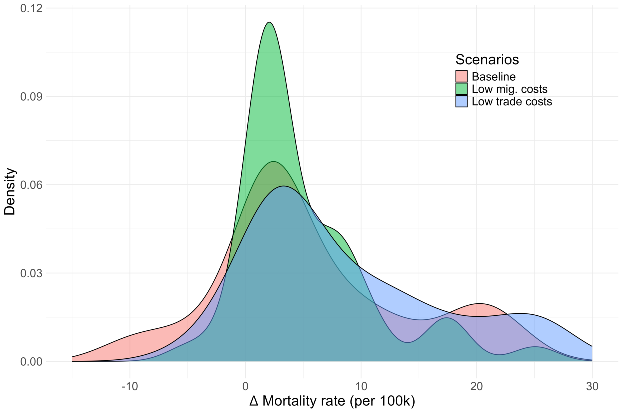


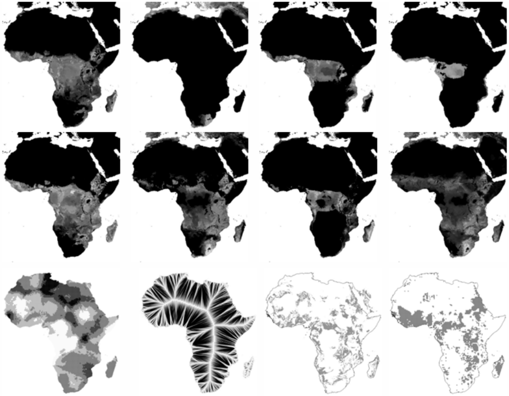
Figure: Country distribution of mortality under RCP8.5 relative to no Climate Change

Results — Policies

	(1) Baseline	(2) Low trade costs	(3) Low mig. costs
Total mortality (per 100k)	9.56	12.27	8.95
— Undernutrition	5.19	7.69	1.94
— Malaria	4.76	8.60	3.34
— Heat waves	3.19	3.35	4.77
Welfare change (%)	-0.23	-0.27	-0.08
Migration (M)	10.61	11.25	14.22
Non-ag. emp. change (%)	-0.25	0.43	-1.67

Table: Results in 2050 under RCP8.5 relative to no Climate Change for different policy scenarios

Gold suitability correlation



Notes: each map represents the following variables, going left to right and top to bottom [we include in bracket the Pearson pairwise correlation between the gold suitability data and each variable] : suitability for banana [0.25], barely [-0.10], cocoa [0.15], coconut [0.04], coffee [0.27], sunflower [0.14], tea [0.17] or tobacco [0.16], prevalence of high temperatures over the study period [-0.12], distance to coast [0.00], geology-based gold suitability [0.70], and man-made ASgM records [0.37].

Figure: Core cells characteristics. Source: Girard et al. (2022)

Gold suitability example

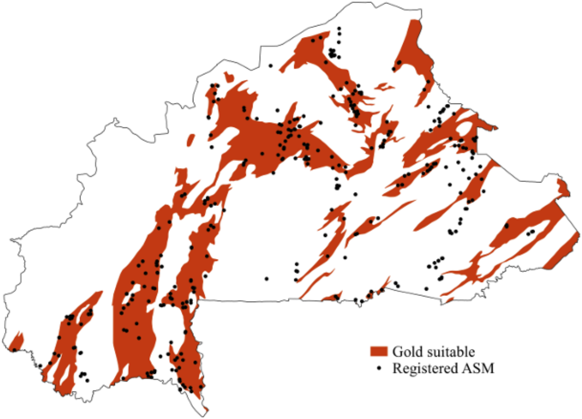
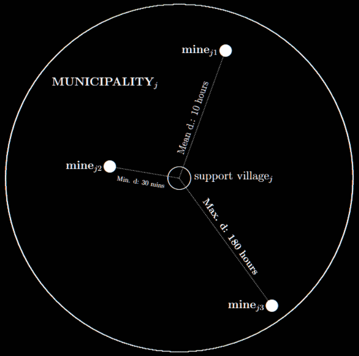


Figure: Artisanal mining in Burkina Faso. Source: Girard et al. (2022)

Support village



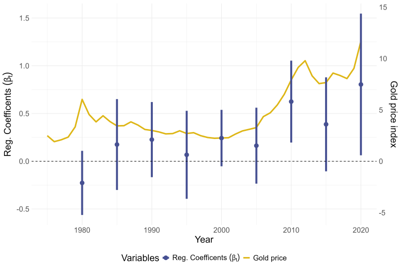
Notes: This figure presents the structure of a typical municipality. A municipality is composed of land, one support village (the historical village agglomeration in which households live), and mines—mines are located where minerals were discovered, which often does not correspond to the historical village agglomeration. The figure also reports the minimum, average, and maximum distance between the support village to a mining site, recorded in walking hours—most of the time mining sites are only accessible by foot, and passing first by the support village.

Figure: The structure of mining areas. Source: Sanchez de la Sierra (2020)

Results - Dynamic

Figure: Artisanal mining and urbanization — Dynamic

(a) Urban population (log)



(b) Cities