Climate Change, Inequality, and Human Migration

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Teaching Materials
November 8, 2021

The Research Question

What are the potential consequences of Climate Change (CC) for:

- internal and international migration of people
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- the supply of human capital
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when accounting for:

- heterogeneous climatic factors
- detailed geographical representation
- heterogeneous characteristics of individuals

over the 21st century.

Motivation

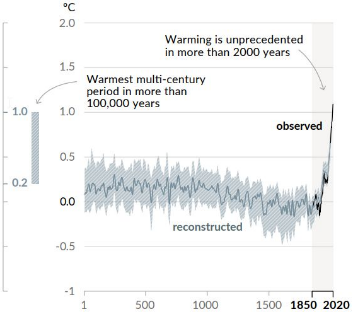

Figure: (Left) Change in global surface temperature, source: IPCC (2021).

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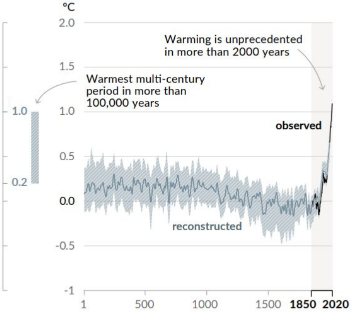


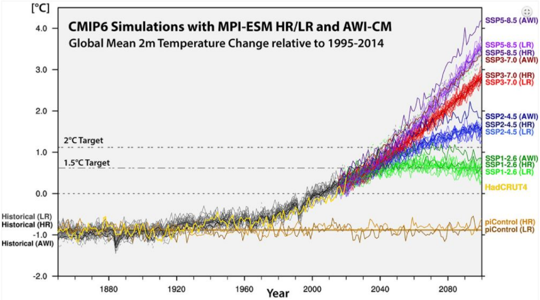
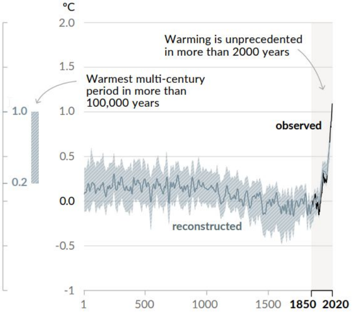
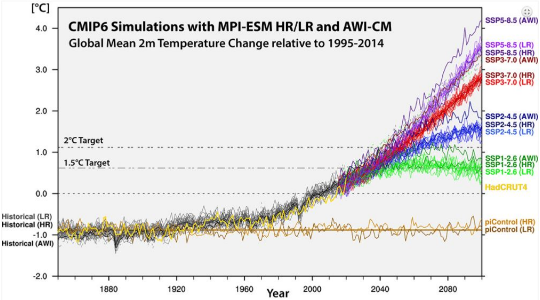


Figure: (Left) Change in global surface temperature, source: IPCC (2021).
(Right) Projected changes in surface temperatures over the 21st century, source: DKRZ





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IPCC 2018 (SR15 CH3):

"Our understanding of the links of global warming to human migration are limited and represent an important knowledge gap."

Literature

Empirical modeling of weather shocks and migration:

- Perch-Nielsen et al. (2008), Piguet et al. (2011), Millock (2015), Berlemann and Steinhardt (2017), Cattaneo et al. (2019), Backhaus et al. (2015), Cai et al. (2016), Coniglio Pesce (2015)

Empirical modeling of climate shocks and migration:

- Beine and Parsons (2015), Marchiori et al. (2012, 2017), Cattaneo and Peri (2016), Peri and Sasahara (2019)

Quantitative theory modeling:

- Dallmann and Millock (2017), Desmet and Rossi-Hansberg (2015), Shayegh (2017), Costinot et al. (2016), Gouel and Laborde (2021), Desmet et al. (2018, 2021), Conte et al. (2021), Alvarez and Rossi-Hansberg (2021), Conte (2021)

I. Geography The world is divided into

- 198 countries, divided into
- 2.319 administrative regions [64 small states], divided into
- +7.100.000 pixels of 5km x 5km per side

Theory - Main Structure

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II. Pixels are characterized by

- sector: either urban (manufacturing) or rural (agriculture)
- population, share of HS workers, wage rates
- CES production function and total factor productivity (TFP)
- climate damage (sector-specific bell-shaped functions as in Desmet and Rossi-Hansberg, 2015)

Theory - Main Structure

III. Climate shocks comprise in pixel-specific factors

SO slow-onset: monthly average temperature levels over 2010-2100

SLR sea level rise: a degree to which a pixel is flooded in 2010-2100

FO fast-onset: intensity and losses generated by FO in 2010-2100

Theory - Main Structure

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IV. Fast-Onset vars are cause economic and utility losses due to

- floods - driven by precipitation in the wettest quarter
- droughts - driven by precipitation in the driest quarter
- storms - driven by temperature in the wettest quarter
- heatwaves - driven by temperature in the hottest quarter
  & the number of days above 25 and 35 degrees

Theory - Main Structure

V. Time starts in 2010, and continues over 2040, 2070, and 2100

- this determines an overlapping generations (OLG) structure
- each person has two stages of life: young (0-30), adult (30-60)
- only adult individuals are economically active
  (all numbers refer to adults only)

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VI. Migration of people is

- modeled endogenously using a RUM model
- determined by skill-specific income, sector-specific prices and pixel-specific congestion externalities
- considered at three spatial scales:
  1. ***international*** migration: across country borders
  2. ***regional*** migration: within a country, across administrative regions
  3. ***local*** migration: within an administrative region, across pixels

Technology and Production

Gross Domestic Product (GDP) in an urban pixel $q \in r \in n$ equals:

$$Y_U(q) = P_U(n) \cdot A_U(q) \cdot (mp_h(r) \cdot h(q) + mp_l(r) \cdot l(q)), \qquad (1)$$

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GDP in a rural pixel $q \in r \in n$ equals:

$$Y_F(q) = P_F(n) \cdot A_F(q) \cdot \left(h(q) + l(q)\right), \tag{4}$$

TFP in a rural pixel $q \in r \in n$ equals:

$$A_F(q) = G_F(q) \cdot \bar{A}_F(r) \tag{5}$$

Damage Due to Climate Change

Quantification follows Desmet and Rossi-Hansberg (2015), who estimate the relationship between T and TFP in agriculture and manufacturing. For $r \in F, U$:

$$G_r(T) = \max\left\{g_{0r} + g_{1r}T + g_{2r}T^2; 0\right\} \tag{6}$$

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$$G_{r,t} = \frac{1}{12} \sum_{m=1}^{12} G_r(T_{m,t}). \tag{7}$$

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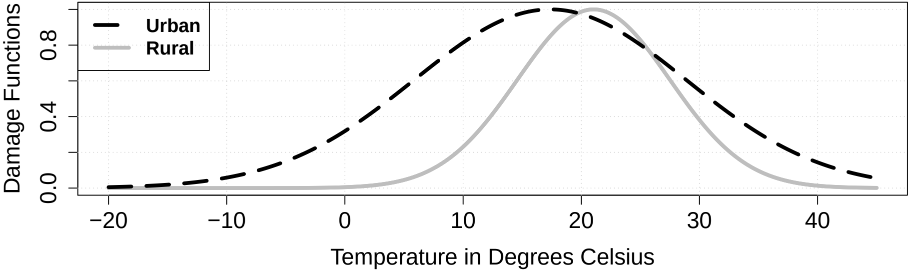

Individuals

Consumption:

$$c = \left(c_F^{\frac{\rho-1}{\rho}} + \theta(n) \cdot c_U^{\frac{\rho-1}{\rho}} \right)^{\frac{\rho}{\rho-1}} \tag{8}$$

Budget constraint:

$$P_F(n) \cdot c_F + P_U(n) \cdot c_U = w \tag{9}$$

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Utility for individual i living in q:

$$u_i(q) = \alpha_i \ln c_i(q) - \delta \ln \left(l(q) + h(q) \right) + \xi_i(q) \tag{10}$$

Note that: $c_i(q) = w_i(q)/P(n)$,
where: $P(n) = \left(P_F(n)^{1-\rho} + \theta(n)^{\rho} \cdot P_U(n)^{1-\rho} \right)^{\frac{1}{1-\rho}}$,
and $P_U(n) = 1$ is a *numeraire*.

Migration

Migrating between $q \in r \in n$ and $q' \in r' \in n'$ induces a utility cost:

$$u_i(q, q') = \ln(1 - x_i) + u_i(q'), \text{ where:} \tag{11}$$

$x_i = x_i(q', q) = x_i(r)$ iff $q' \in r/q$ – region-specific **local** migration cost
$x_i = x_i(r', r)$ iff $q' \in n/r$ – region-pair-specific **regional** migration cost
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Individual prob. of moving from $q \in r \in n$ to $q' \in r' \in n'$ equals:

$$\Pi_i(q, q') = \frac{\exp u_i(q, q')}{\sum_{p \in N} \exp u_i(q, p)} = \Pi_i(q'|r') \cdot \Pi_i(r'|n') \cdot \Pi_i(n'|n) \tag{12}$$

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So each individual faces $n - 1 = 197$ options to move internationally, $r - 1$ options to move internally, 1 option to move locally, and 1 option to stay.

Data Sources

- Population per pixel: **WorldPop.org**
- Education per pixel: **Inst. for Health Metrics and Eval.**
- Urbanization per pixel: **WorldPop.org**
- GDP per pixel: **Kummu et al. (2020)**
- Administrative regions: **GADM.org**
- International Migration by education: **OECD DIOC**
- Internal migration: **WorldPop.org**, **LFS, Eurostat**, **IPUMSint**
- Fertility and Urbanization Projections: **UN PD**
- Climate variables (SO and FO): **Worldclim.org**
- SLR projections: **Jackson et al. (2016)**
- Elevation: **SEDAC, NASA**
- FO losses data: **SEDAC, NASA** and **EM-DAT**

Calibration Algorithm

Please refer to the Online Appendix

Slow-Onset Factors: Projected Changes in Temp. Levels

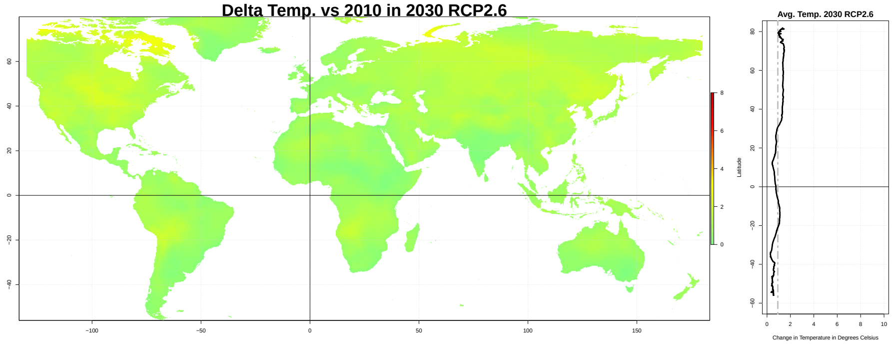
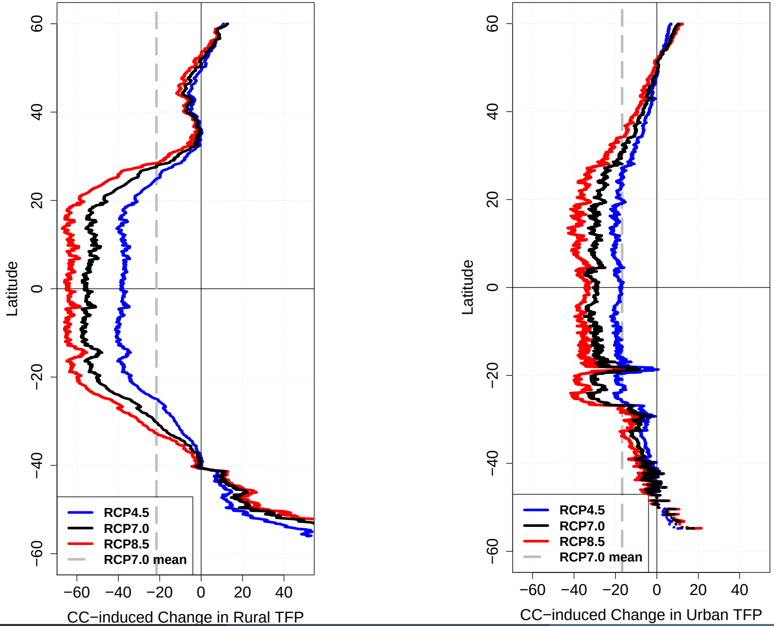
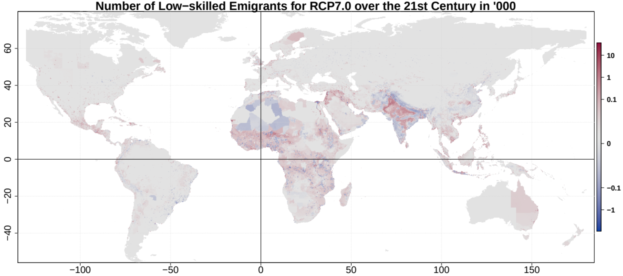


Figure: Δ Average Temperature in RCP2.6-8.5 1850-1900 in 2040-2100

Slow-Onset Factors: Damage due to Temperature



Fast Onset Factors: Emigration by Pixels



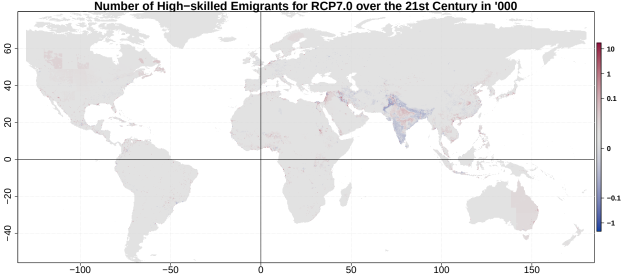
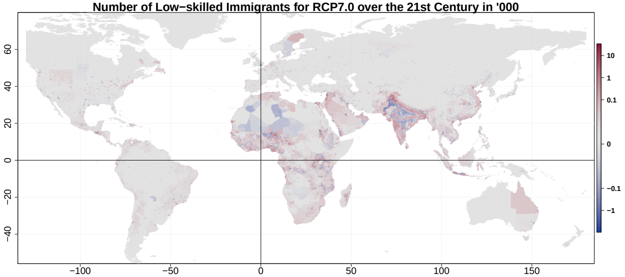
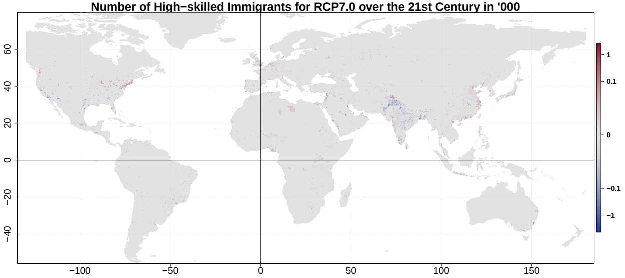


Figure: Emigration of LS (top) and HS (bottom) Persons by Pixel

Fast Onset Factors: Immigration by Pixels





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Slow-Onset Factors: Temperature Distribution

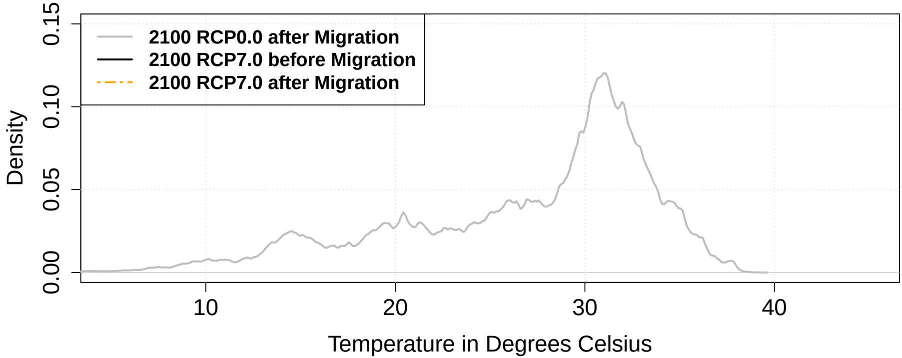

Figure: Population-Weighted Distribution of Global Temperature Levels in 2100

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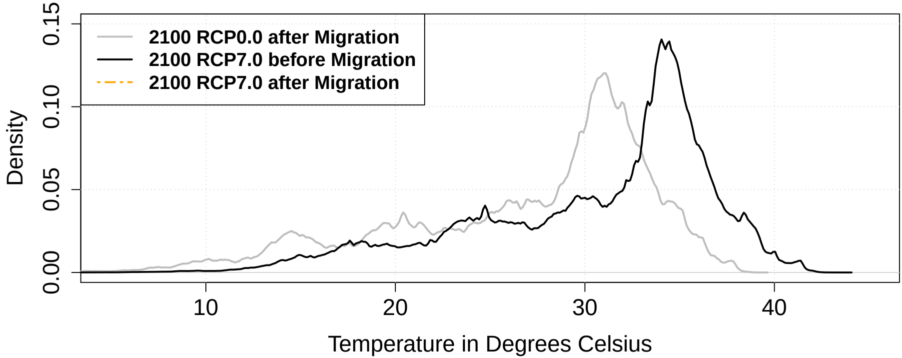

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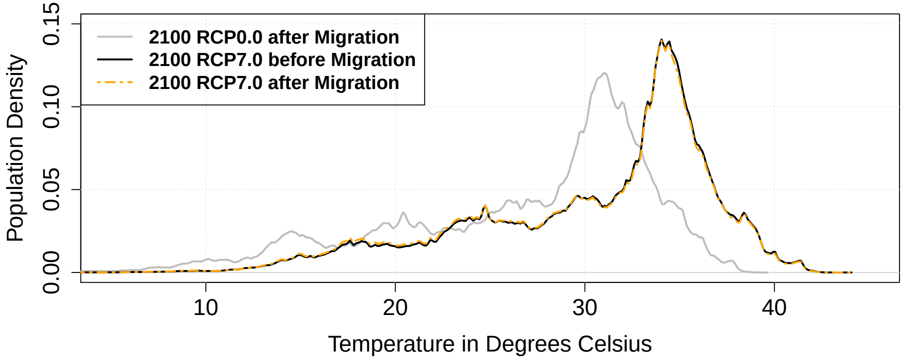

Figure: Population-Weighted Distribution of Global Temperature Levels in 2100

Slow-Onset Factors: Migration Pressures

Table: Climate-Induced Migration Over the 21st Century [in million People]

Scenario:	Local '40	'70	'00	∑	Regional '40	'70	'00	∑	International '40	'70	'00	∑
RCP8.5 SO	-0.9	-3.5	-4.5	**-8.9**	-1.1	-3.9	-5.9	**-10.9**	3.2	8.9	13.5	**25.6**
RCP7.0 SO	-0.7	-2.6	-3.3	**-6.6**	-0.9	-3.2	-4.8	**-8.9**	2.5	6.3	8.9	**17.7**
RCP4.5 SO	-0.6	-1.9	-2.0	**-4.5**	-0.9	-2.4	-3.0	**-6.3**	2.5	4.8	5.7	**13.0**

Sea Level Rise: Flooding by Pixels

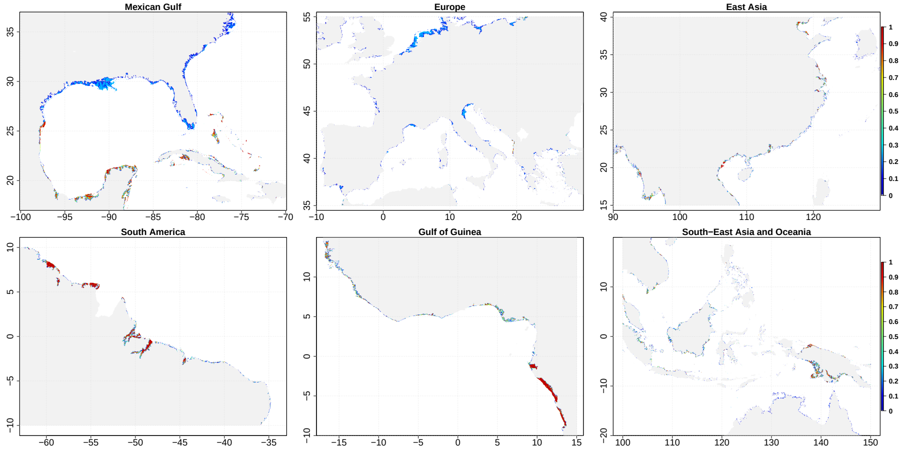

Figure: Coastal Flooding by Pixels and by Intensity under RCP7.0

Sea Level Rise: Aggregates of Forced Displacement

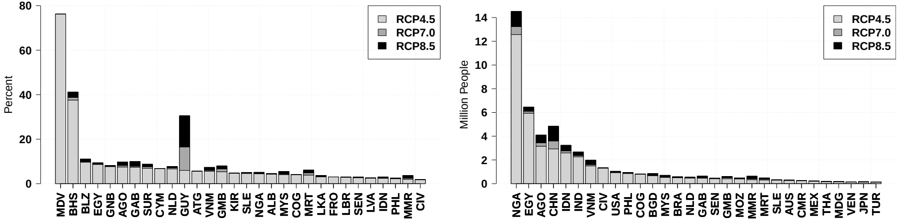

Figure: Flooded (Forcibly Displaced) People as Percent and in Millions

Sea Level Rise: Migration Pressures

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RCP8.5 SO	-0.9	-3.5	-4.5	**-8.9**	-1.1	-3.9	-5.9	**-10.9**	3.2	8.9	13.5	**25.6**
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RCP8.5 SO & SLR	4.0	-0.4	-1.8	**1.8**	5.9	0.2	-0.9	**5.2**	8.5	11.6	16.4	**36.5**
RCP7.0 SO & SLR	4.2	0.2	-1.0	**3.4**	6.1	0.5	-0.4	**6.1**	7.8	8.8	11.4	**28.0**
RCP4.5 SO & SLR	4.2	0.9	-0.1	**5.0**	6.1	1.1	0.9	**8.1**	7.8	7.1	8.0	**22.9**

Fast Onset Factors: Utility and TFP Losses

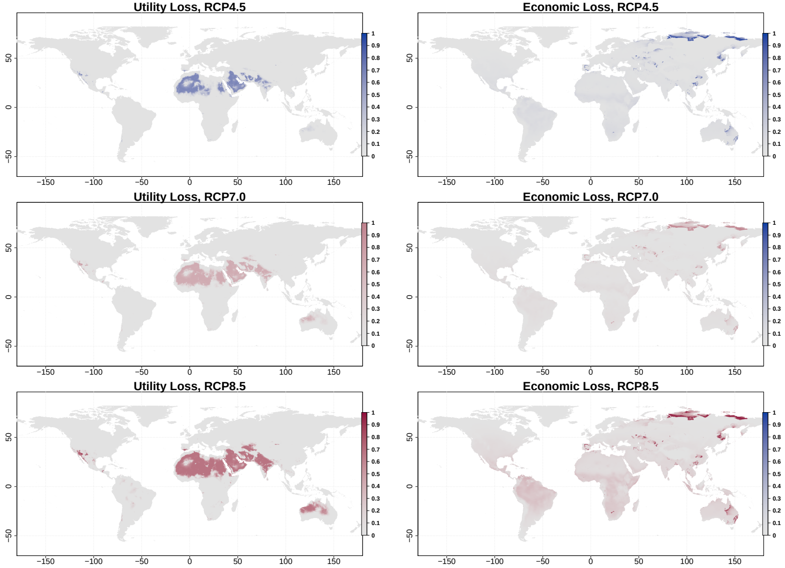

Figure: Utility and TFP Losses Due to Fast-Onset Factors in 2100

Fast Onset Factors: Migration Pressures

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Scenario:	Local				Regional				International			
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RCP8.5 SO	-0.9	-3.5	-4.5	**-8.9**	-1.1	-3.9	-5.9	**-10.9**	3.2	8.9	13.5	**25.6**
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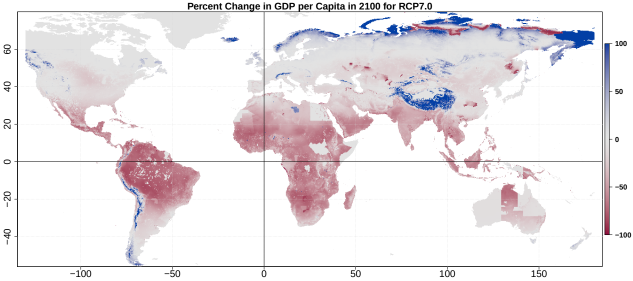
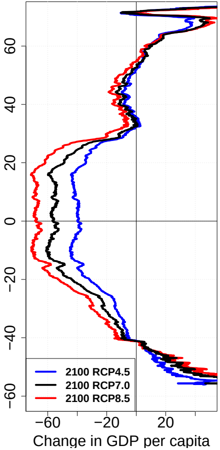
RCP8.5 SO & SLR & FO	3.4	-3.5	-10.0	**-10.2**	5.8	3.3	4.0	**13.1**	15.1	29.4	49.7	**94.1**
RCP7.0 SO & SLR & FO	3.7	-1.9	-6.1	**-4.3**	5.6	2.2	2.3	**10.1**	11.8	16.8	28.2	**56.8**
RCP4.5 SO & SLR & FO	3.7	-0.9	-3.0	**-0.3**	5.7	2.0	1.5	**9.3**	11.5	11.9	13.2	**36.6**

Fast Onset Factors: Change in GDP per Capita



(a) Change in GDP per Capita in RCP7.0 in 2100...



(b) ...by Latitudes

Fast Onset Factors: Change in Population

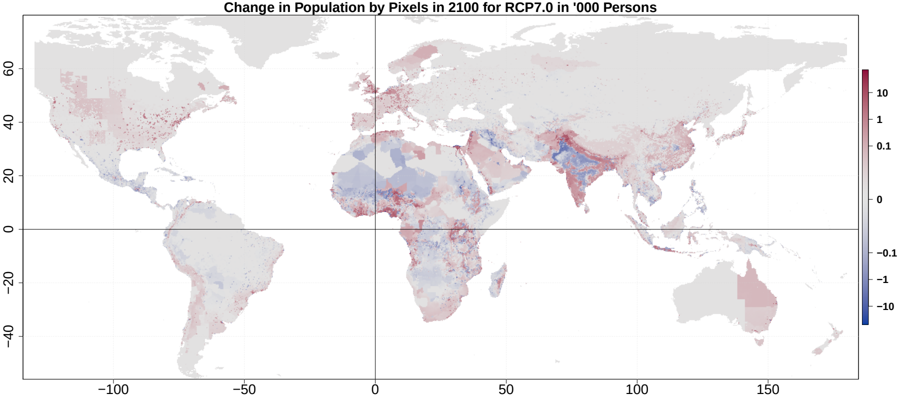
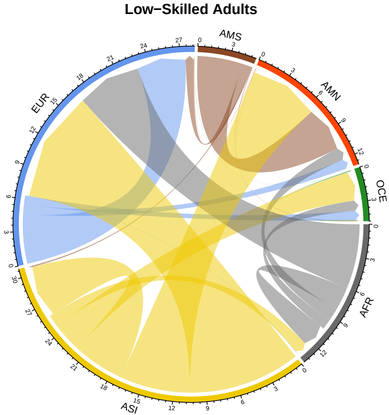
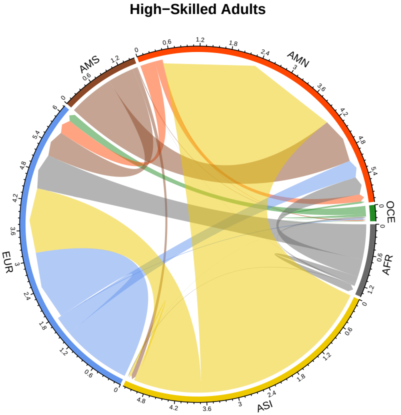


Figure: Change in Population in RCP7.0 in 2100 in ’000 People

Fast Onset Factors: Migration Paths



(a) LS Migration under RCP7.0 in 2100



(b) HS Migration under RCP7.0 in 2100

Policy Discussion: Impact on Income Distribution

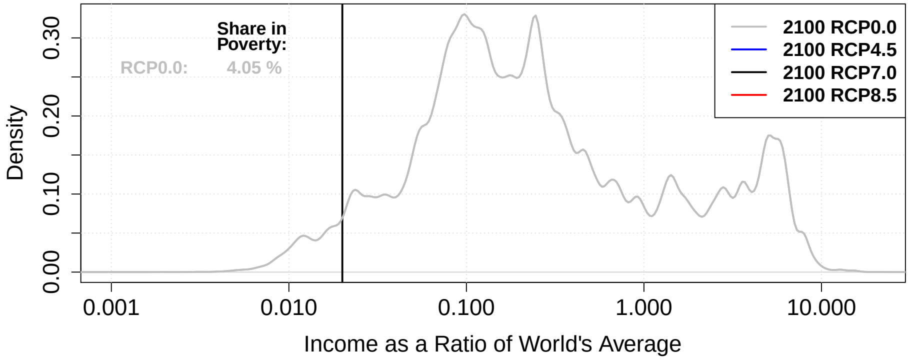
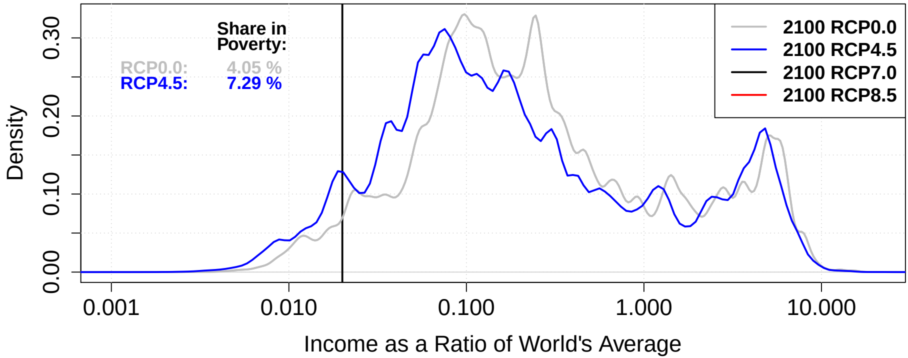


Figure: Population-Weighted Distributions of Income in 2100

Policy Discussion: Impact on Income Distribution



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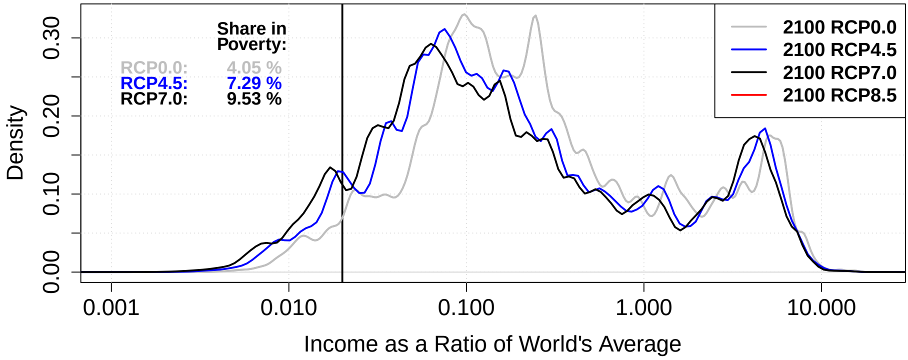

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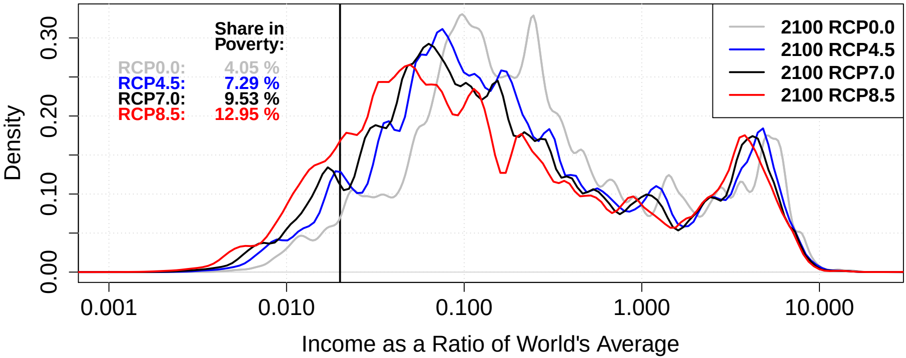

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Policy Discussion: Migration Policies and Conflicts

Three scenarios considered (including RCP7.0 SO, SLR, and FO):

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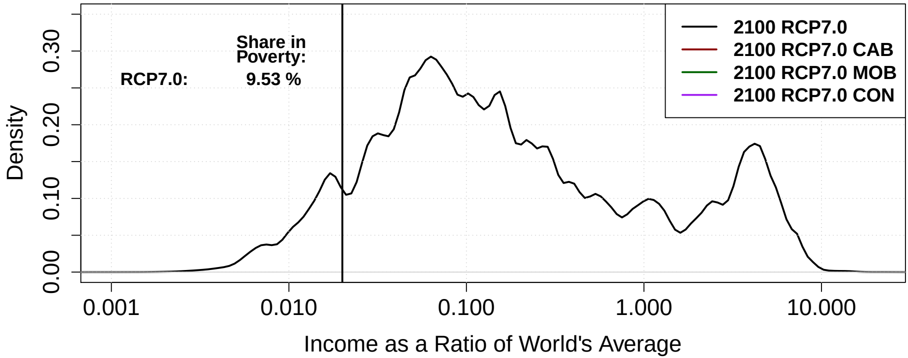
CON Conflict: 10-20% loss in GDP in 20 countries with food price $\uparrow\uparrow$
$\rightarrow$ all types of migration up by 33%

Policy Discussion: Impact on Income Distribution



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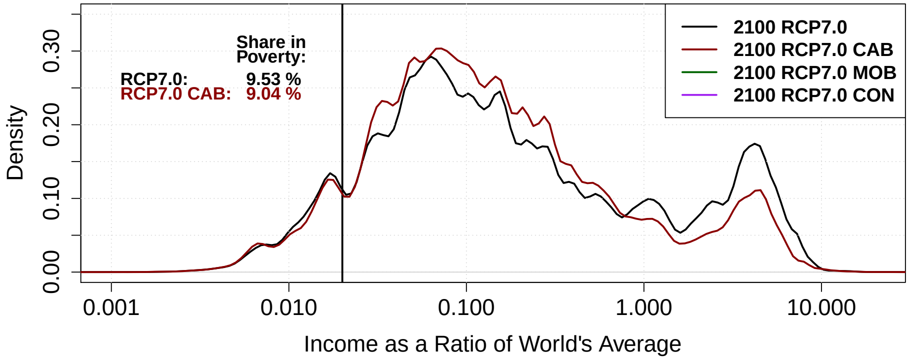

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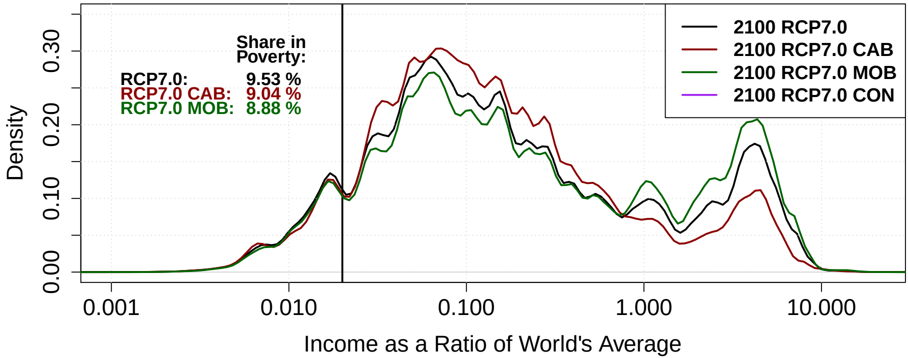

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Conclusions

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Policy Discussion:

- closing/boosting migration has little impact on extreme poverty
- reduce emissions to minimize the chances of worst case scenarios
- reach the 2 degree goal (CO_2 neutrality by 2050)

Thanks

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