Climate Migration and Immobility

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Hélène Benveniste
Postdoctoral Environmental Fellow, Harvard University
@HeleneBenvenist

Climate Change Increases Resource-Constrained Immobility
Climate Change Increases Resource-Constrained Immobility

UCLA Climate Adaptation Research Symposium 2021

Hélène Benveniste    Michael Oppenheimer    Marc Fleurbaey

Center for the Environment & Kennedy School, Harvard University
School of Public and International Affairs, Princeton University
Paris School of Economics, CNRS
Motivation
Migration and Immobility: Two Sides of the Same Coin
Climate Change and International Migration: A Timely Topic

Migration and Immobility: Two Sides of the Same Coin

MOVE

Involuntary Consequence

STAY

Choice
Climate Change and International Migration: A Timely Topic

Migration and Immobility: Two Sides of the Same Coin

Resources

Resource Constraints

MOVE

STAY
Migration and Immobility: Two Sides of the Same Coin

Resources

Resource Constraints

MOVE

STAY

Resource-Constrained Immobility
How much will climate change constrain international migration?
Objectives

Model migration/remittance flows at income quintile level
Include it + income distributions in a climate-economy model
Objectives

Model migration/remittance flows at income quintile level
Include it + income distributions in a climate-economy model

Climate change decreases emigration of lowest income levels
\[ \geq 10\% \text{ in some regions for medium devt/climate scenarios} \]
\[ \leq 20\% \text{ in most regions for pessimistic scenarios} \]
Resource-constrained immobility key in climate-migration

Remittances do not compensate for damages from CC

Populations unable to leave will be extremely vulnerable
Relevant Literature

Involuntary (im)mobility

Empirical evidence of climate change effect on migration

Climate change effect on poverty and inequality

Migration projections in climate change context
Methods
A Model of International Migration and Remittances

Major drivers of international, long-term migration
Major drivers of international, long-term migration

- higher wages, send remittances
- Economic opportunities
A Model of International Migration and Remittances

Major drivers of international, long-term migration

- Economic opportunities: higher wages, send remittances
- Proximity: geographic, cultural
A Model of International Migration and Remittances

Major drivers of international, long-term migration

- Higher wages, send remittances
- Geographic, cultural
- Economic opportunities
- Proximity
- Resources for migrating
- Migration costs
A Model of International Migration and Remittances

Major drivers of international, long-term migration

- Economic opportunities: higher wages, send remittances
- Proximity: geographic, cultural
- Migration costs: resources for migrating

Gravity framework
A Gravity Model at the Income Quintile Level

\[
\text{Origin: } 5 \quad 4 \quad 3 \quad 2 \quad 1 \\
\text{Destination: } 5 \quad 4 \quad 3 \quad 2 \quad 1
\]
A Gravity Model at the Income Quintile Level

Origin

\[ \text{move}_{od,q} \]

5
4
3
2
1

Destination

\[
\begin{align*}
\text{destshare}_{od} & = \beta_0 + \beta_1 \ln(\text{pop}_o) + \beta_2 \ln(\text{pop}_d) + \beta_3 \ln(\text{ypc}_d) + \beta_4 \ln(\text{ypc}_o) + \beta_5 \text{rems}_{od} + \beta_6 \text{remc}_{od} + \beta_7 \ln(\text{dist}_{od}) + \beta_8 \ln(\text{lang}_{od}) + \varepsilon_{odqr} \\
\text{ln}(\text{destshare}_{qr}) & = \gamma_0 + \gamma_1 \ln(\text{ypc}_d) + \gamma_2 \ln(\text{ypc}_o) + \varepsilon_{\prime o d qr}
\end{align*}
\]

population sizes, per capita incomes, distance, language

rems share of migrant’s income sent as remittance, cost

remittances
A Gravity Model at the Income Quintile Level

**Origin**

```
5
4
3
2
1
```

**Destination**

```
5
4
3
2
1
```

\[
\text{move}_{od,q} = \beta_0, q + \beta_1, q \ln (\text{pop}_o, q) + \beta_2, q \ln (\text{pop}_d, q) + \beta_3, q \ln (\text{ypc}_d, \text{ypc}_o, q) + \beta_5, q \epsilon_{rems, od} + \beta_6, q \epsilon_{remc, od} + \beta_4, q \ln (\text{dist}_{od}) + \beta_7, q \ln (\text{lang}_{od}) + \epsilon_{odqr}
\]

\[
\text{destshare}_{od, qr} = \gamma_0, r + \gamma_1, r \ln (\text{ypc}_d, \text{ypc}_o, q) + \epsilon'_{odqr}
\]

Population sizes, per capita incomes, distance, language

Remittances share of migrant's income sent as remittance, cost
A Gravity Model at the Income Quintile Level

\[ \ln(move_{od,q}) = \beta_{0,q} + \beta_{1,q} \ln(pop_{o,q}) + \beta_{2,q} \ln(pop_{d,q}) \]
\[ + \beta_{3,q} \ln\left(\frac{ypc_{d}}{ypc_{o,q}}\right) + \beta_{5,q} \epsilon_{rem_{s,od}} + \beta_{6,q} remc_{od} \]
\[ + \beta_{4,q} \ln(ypc_{o,q}) + \beta_{7,q} \ln(dist_{od}) + \beta_{8,q} \mathbb{1}[lang]_{od} + \epsilon_{odqr} \]

\[ \ln(destshare_{od,qr}) = \gamma_{0,r} + \gamma_{1,r} \ln\left(\frac{ypc_{d}}{ypc_{o,q}}\right) + \epsilon'_{odqr} \]

**pop** population sizes, **ypc** per capita incomes, **distance**, **language**

**rems** share of migrant’s income sent as remittance, **remc** cost

> distribution equation  > remittances
Building a Dataset on Bilateral Migration per Income Level

- Migrants’ education
- Migrants’ income
- Estimation strategy
Building a Dataset on Bilateral Migration per Income Level

- Bilateral migrant stocks
  - World Bank

- Bilateral migrant flows
  - Azose and Raftery 2018
Building a Dataset on Bilateral Migration per Income Level

### Bilateral migrant stocks
- **World Bank**

### Migrant flows per education
- **Shared Socioeconomic Pathways (SSP)**

### Bilateral migrant flows
- **Azose and Raftery 2018**

#### Estimation strategy
- Assume: education correlated with income
- Migrants' income per education same as host
Building a Dataset on Bilateral Migration per Income Level

Bilateral migrant stocks

World Bank

Bilateral migrant flows

Azose and Raftery 2018

Migrant flows per education

Shared Socioeconomic Pathways (SSP)

Migrant flows per income

Assume: education correlated with income
migrant’s income per education same as host

Bilateral migrant flows per income

▶ migrants’ education  ▶ migrants’ income  ▶ estimation strategy
### Estimating gravity equation and migrants’ destination income

#### Migrant flows for origin income quintile

<table>
<thead>
<tr>
<th>Origin quintile 1</th>
<th>Origin quintile 5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Origin population</td>
<td>0.824***</td>
</tr>
<tr>
<td>Destination population</td>
<td>0.719***</td>
</tr>
<tr>
<td>Origin per capita GDP</td>
<td>1.808***</td>
</tr>
<tr>
<td>Ratio of per capita GDP</td>
<td>1.166***</td>
</tr>
<tr>
<td>$N$</td>
<td>24,100</td>
</tr>
<tr>
<td>$R^2$</td>
<td>0.554</td>
</tr>
</tbody>
</table>

#### Migrants share to quintile at destination

<table>
<thead>
<tr>
<th>Destination quintile 1</th>
<th>Destination quintile 5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ratio of per capita GDP</td>
<td>0.142***</td>
</tr>
<tr>
<td>$N$</td>
<td>24,100</td>
</tr>
<tr>
<td>$R^2$</td>
<td>0.251</td>
</tr>
</tbody>
</table>

*p < 0.05, **p < 0.01, ***p < 0.001

Controls: remittance share, remittance cost, distance, language
Including Climate Change Impacts on Resource Deprivation: Migration and Income Distributions in an IAM
Including Climate Change Impacts on Resource Deprivation: Migration and Income Distributions in an IAM

Integrated Assessment Models (IAM)

- emissions
- temperature
- damages
- economy

Regional disaggregation: 16 regions
Version with income quintiles (Dennig et al. 2015)

Immobility: difference in poorest emigrants with vs without CC

IAM modeling
Input scenarios
World regions
Including Climate Change Impacts on Resource Deprivation: Migration and Income Distributions in an IAM

Integrated Assessment Models (IAM)

- Migration
- Economy
- Temperature

- + Income distributions
- + Income distributions
- Emissions
- Damages

Input scenarios
World regions
Including Climate Change Impacts on Resource Deprivation: Migration and Income Distributions in an IAM

Integrated Assessment Models (IAM)

- migration
- + income distributions
- population, income

- economy
- + income distributions
- move, remittances

- temperature
- emissions
- damages

- Input scenarios
- World regions

IAM modeling

Anthoff and Tol 2013
Regional disaggregation: 16 regions
Version with income quintiles (Dennig et al. 2015)
Including Climate Change Impacts on Resource Deprivation: Migration and Income Distributions in an IAM

**FUND** (Anthoff and Tol 2013)

Regional disaggregation: 16 regions

Version with income quintiles (Dennig et al. 2015)

- **Migration**
  - move, remittances
  - + income distributions
  - population, income

- **Economy**
  - + income distributions
  - damages
  - independent of income

- **Temperature**
  - emissions

**Input scenarios**

- IAM modeling
- World regions
Including Climate Change Impacts on Resource Deprivation: Migration and Income Distributions in an IAM

**FUND** (Anthoff and Tol 2013)
Regional disaggregation: 16 regions
Version with income quintiles (Dennig et al. 2015)

**Immobility**: difference in poorest emigrants *with vs without* CC

![Diagram showing the relationship between migration, economy, temperature, emissions, and income distributions.](image)

- **migration** + *income distributions* → **economy** + *income distributions* → **temperature**
- **move, remittances**
- **emissions**
- **population, income**
- **damses**

*independent of income*
Results & Policy Implications
Medium scenario

Pessimistic scenario

Results in poorest quintile, for 2100
Damages Not Compensated by Remittances in the Future

Medium scenario

Pessimistic scenario

Results in poorest quintile

- inequality
- inequality vs original SSP
Damages Not Compensated by Remittances in the Future

Medium scenario

Pessimistic scenario

Results in poorest quintile

- inequality
- inequality vs original SSP
Damages Not Compensated by Remittances in the Future

Medium scenario

Pessimistic scenario

Results in poorest quintile
Climate Change Decreases Mobility for Lowest Income Levels

Medium scenario

Results in poorest quintile, for 2100

*Pink shades: climate change reduces outmigration of poorest populations*
Climate Change Decreases Mobility for Lowest Income Levels

Medium scenario

Pessimistic scenario

Results in poorest quintile, for 2100

*Pink shades: climate change reduces outmigration of poorest populations*
Climate Change Decreases Mobility for Lowest Income Levels

Medium scenario

Pessimistic scenario

Catastrophic damages

Results in poorest quintile, for 2100

*Pink shades: climate change reduces outmigration of poorest populations*
Conclusion & policy relevance

Resource-constrained immobility is not a rare circumstance
Likely to play a substantial role in the climate-migration nexus

Populations unable to leave will be extremely vulnerable
Policies might underestimate CC impacts
Questions?

helenebenveniste@fas.harvard.edu
Appendix
A gravity model at the income quintile level

Migration flows per income quintile at origin

Origin $o$, destination $d$, income quintile $q$ at origin

$$\ln(move_{od,q}) = \beta_{0,q} + \beta_{1,q}\ln(pop_{o,q}) + \beta_{2,q}\ln(pop_{d,q})$$

$$+ \beta_{3,q}\ln\left(\frac{ypc_{d}}{ypc_{o,q}}\right) + \beta_{5,q}\epsilon_{rems,od} + \beta_{6,q}remc_{od}$$

$$+ \beta_{4,q}\ln(ypc_{o,q}) + \beta_{7,q}\ln(dist_{od}) + \beta_{8,q}\mathbb{1}[lang]_{od}$$

$$+ \epsilon_{odqr}$$

with $pop$ quintile population sizes, $ypc$ per capita incomes, $rems$ share of migrant income sent as remittance, cost $remc$, $dist$ distance btw regions, $\mathbb{1}[lang]$ common official language
Distributing migrants over destination income quintiles

Share of migrants per income quintile at destination

Income quintile $r$ at destination

$$\ln(\text{destshare}_{od,qr}^*) = \gamma_{0,r} + \gamma_{1,r} \ln \left( \frac{\text{ypc}_d}{\text{ypc}_o,q} \right) + \varepsilon'_{odqr}$$

$$\text{destshare}_{od,qr} = \frac{\text{destshare}_{od,qr}^*}{\sum_r \text{destshare}_{od,qr}^*}$$

Number of migrants per location $\times$ quintile pair

$$\text{move}_{od,qr} = \text{destshare}_{od,qr} \left( \sum_r 1 \right) \text{move}_{od,q}$$
Other key aspects of international migration

Remittances

\[ \ln(\text{rems}_{od}) = \alpha_0 + \alpha_1 \ln(\text{ypc}_o) + \alpha_2 \ln(\text{ypc}_d) + \alpha_3 \text{remc}_{od} + \epsilon_{od} \]

1st generation migrants send remittances, their whole life

Migrants stay in same income quintile over time at destination

\[ \text{rem}_{o,q} = \sum_d \text{stock}_{od,qr} \times \text{ypc}_{d,r} \times \text{rems}_{od} \times (1 - \text{remc}_{od}) \]
\[ - \sum_p \text{stock}_{po,sq} \times \text{ypc}_{o,q} \times \text{rems}_{po} \times (1 - \text{remc}_{po}) \]

Risk of dying while attempting to migrate

\[ \text{deadmig}_{o,q} = 1_{q \leq 3} \sum_d \text{riskd}_{od} \times \text{move}_{od,qr} \]
\[ \text{deadmigcost}_{o,q} = 1_{q \leq 3} \sum_d \text{riskd}_{od} \times \text{move}_{od,qr} \times \max(\text{VSL}_d, \text{VSL}_o) \]
Migrants’ education levels in SSP projections
Migrants’ income levels in 2010-2015
Estimation strategy

Population, average income levels
  World Development Indicators, World Bank

Income distributions

Remittances flows and costs
  World Bank remittance matrices
  Remittance Prices Worldwide

Estimation by OLS at country level
  Separately for each origin quintile for gravity model
  Separately for each destination quintile for distribution
### Estimation of gravity equation

#### Bilateral migrant flows for a given origin income quintile

<table>
<thead>
<tr>
<th></th>
<th>qorig1</th>
<th>qorig2</th>
<th>qorig3</th>
<th>qorig4</th>
<th>qorig5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Origin population</td>
<td>0.824***</td>
<td>0.809***</td>
<td>0.792***</td>
<td>0.807***</td>
<td>0.805***</td>
</tr>
<tr>
<td>Destination population</td>
<td>0.719***</td>
<td>0.717***</td>
<td>0.719***</td>
<td>0.718***</td>
<td>0.720***</td>
</tr>
<tr>
<td>Origin per capita GDP</td>
<td>1.808***</td>
<td>1.760***</td>
<td>1.865***</td>
<td>1.834***</td>
<td>1.808***</td>
</tr>
<tr>
<td>Ratio of per capita GDP</td>
<td>1.166***</td>
<td>1.174***</td>
<td>1.170***</td>
<td>1.166***</td>
<td>1.153***</td>
</tr>
<tr>
<td>Residuals for share of income</td>
<td>-0.002</td>
<td>-0.002</td>
<td>-0.001</td>
<td>-0.000</td>
<td>0.001</td>
</tr>
<tr>
<td>Distance between countries</td>
<td>-1.100***</td>
<td>-1.081***</td>
<td>-1.099***</td>
<td>-1.086***</td>
<td>-1.120***</td>
</tr>
<tr>
<td>Common official language</td>
<td>1.433***</td>
<td>1.490***</td>
<td>1.422***</td>
<td>1.436***</td>
<td>1.320***</td>
</tr>
<tr>
<td>$N$</td>
<td>24,100</td>
<td>24,100</td>
<td>24,100</td>
<td>24,100</td>
<td>24,100</td>
</tr>
<tr>
<td>$R^2$</td>
<td>0.554</td>
<td>0.540</td>
<td>0.549</td>
<td>0.545</td>
<td>0.543</td>
</tr>
</tbody>
</table>

*p < 0.05, **p < 0.01, ***p < 0.001
**Estimation of migrants income levels at destination**

<table>
<thead>
<tr>
<th>Ratio of per capita GDP</th>
<th>qdest1</th>
<th>qdest2</th>
<th>qdest3</th>
<th>qdest4</th>
<th>qdest5</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0.142***</td>
<td>0.073***</td>
<td>0.027</td>
<td>0.023</td>
<td>-0.149***</td>
</tr>
<tr>
<td>$N$</td>
<td>24,100</td>
<td>24,100</td>
<td>24,100</td>
<td>24,100</td>
<td>24,100</td>
</tr>
<tr>
<td>$R^2$</td>
<td>0.251</td>
<td>0.100</td>
<td>0.006</td>
<td>0.012</td>
<td>0.281</td>
</tr>
</tbody>
</table>

*p < 0.05, **p < 0.01, ***p < 0.001*
Estimation of remittance share

Data: World Bank, 2017

\[ \ln(\text{rems}_{od}) = \alpha_0 + \alpha_1 \ln(\text{ypc}_o) + \alpha_2 \ln(\text{ypc}_d) + \alpha_3 \text{remc}_{od} + \epsilon_{od} \]

<table>
<thead>
<tr>
<th>Share of income sent as remittance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Destination per capita GDP</td>
</tr>
<tr>
<td>Ratio of per capita GDP</td>
</tr>
<tr>
<td>Cost of sending remittances</td>
</tr>
</tbody>
</table>

\[ *p < 0.05, **p < 0.01, ***p < 0.001 \]

\[ N = 10,430 \]

\[ R^2 = 0.133 \]
Calibration of other migration parameters

How long migrants stay in region

Life expectancy: SSP projections, country level
Age when migrating: SSP2 2020, country education 5-yr age

Cost of sending remittances

$remc_{od}$: total cost in %, 2017 (RPW World Bank)

Risk of dying while attempting to migrate

$riskd_{od}$: data on missing migrants 2014-2018 (IOM)
Incorporating residuals from gravity estimation

Capture each migration corridor’s specificity

$$move_{od,qr}^* = move_{od,qr} + \varepsilon_{odqr}$$
<table>
<thead>
<tr>
<th>Name</th>
<th>Countries</th>
</tr>
</thead>
<tbody>
<tr>
<td>USA</td>
<td>United States of America</td>
</tr>
<tr>
<td>Canada</td>
<td>Canada</td>
</tr>
<tr>
<td>Western Europe</td>
<td>Andorra, Austria, Belgium, Cyprus, Denmark, Finland, France, Germany, Greece, Iceland, Ireland, Italy, Liechtenstein, Luxembourg, Malta, Monaco, Netherlands, Norway, Portugal, San Marino, Spain, Sweden, Switzerland, United Kingdom</td>
</tr>
<tr>
<td>Japan and South Korea</td>
<td>Japan, South Korea</td>
</tr>
<tr>
<td>Australia and New Zealand</td>
<td>Australia, New Zealand</td>
</tr>
<tr>
<td>Central and Eastern Europe</td>
<td>Albania, Bosnia and Herzegovina, Bulgaria, Croatia, Czech Republic, Hungary, FYR Macedonia, Poland, Romania, Slovenia, Yugoslavia</td>
</tr>
<tr>
<td>Former Soviet Union</td>
<td>Armenia, Azerbaijan, Belarus, Estonia, Georgia, Kazakhstan, Kyrgyzstan, Latvia, Lithuania, Moldova, Russia, Tajikistan, Turkmenistan, Ukraine, Uzbekistan</td>
</tr>
<tr>
<td>Middle East</td>
<td>Bahrain, Iran, Iraq, Israel, Jordan, Kuwait, Lebanon, Oman, Qatar, Saudi Arabia, Syria, Turkey, United Arab Emirates, West Bank and Gaza, Yemen</td>
</tr>
<tr>
<td>Central America</td>
<td>Belize, Costa Rica, El Salvador, Guatemala, Honduras, Mexico, Nicaragua, Panama</td>
</tr>
<tr>
<td>South America</td>
<td>Argentina, Bolivia, Brazil, Chile, Colombia, Ecuador, French Guiana, Guyana, Paraguay, Peru, Suriname, Uruguay, Venezuela</td>
</tr>
<tr>
<td>South Asia</td>
<td>Afghanistan, Bangladesh, Bhutan, India, Nepal, Pakistan, Sri Lanka</td>
</tr>
<tr>
<td>Southeast Asia</td>
<td>Brunei, Cambodia, East Timor, Indonesia, Laos, Malaysia, Myanmar, Papua New Guinea, Philippines, Singapore, Taiwan, Thailand, Vietnam</td>
</tr>
<tr>
<td>China plus</td>
<td>China, Hong Kong, North Korea, Macau, Mongolia</td>
</tr>
<tr>
<td>North Africa</td>
<td>Algeria, Egypt, Libya, Morocco, Tunisia, Western Sahara</td>
</tr>
</tbody>
</table>
IAM Modeling

- Population
  - Pop
  - Dead

- Emissions
  - Emissions
  - Income
  - Temp

- Climate
  - Pop
  - Dead MIG

- Impact 1
  - Econ Loss

- Impact 12
  - Econ + Non Econ Loss

- Impact Death Morb

- Impact Aggregation

- SCC
IAM Input Scenarios

Population
- Socio Economic
  - GDP per cap growth
  - inequality growth
  - energy intensity evolution
  - carbon intensity evolution

Emissions

Climate

Impact 1
- Impact 12
  - Impact
  - Death Morb

Impact Aggregation

Avoid double counting of migration

SCC
IAM Input Scenarios

- **Population**
  - Population growth, *Implicit mig*
  - GDP per cap growth, *Implicit mig*
  - Inequality growth, *Implicit mig*
  - Emissions growth, *Implicit mig*
  - Energy intensity evolution, *Implicit mig*
  - Carbon intensity evolution, *Implicit mig*

- **Emissions**
- **Impact 1**

- **Economic**
  - Socio-Economic growth

- **Climate**
  - Climate change
  - Impact 12
  - Impact Death Morb

- **Impact Aggregation**

- **SCC**
IAM Input Scenarios

Population
  - pop growth, Zero mig

Socio Economic
  - GDP per cap growth, Zero mig
  - inequality growth, Zero mig

Emissions
  - energy intensity evolution, Zero mig
  - carbon intensity evolution, Zero mig

Climate
  - Impact 1

Impact 12
  - Impact
  - Death Morb

Impact Aggregation

Migration

Avoid double counting of migration back

SCC
IAM Input Scenarios

Avoid **double counting** of migration
The Shared Socioeconomic Pathways: Migration Assumptions

Sources: O’Neill et al. 2017, KC and Lutz 2017
Versions of SSP for Zero Migration

Population projections
Demographic model of population dynamics by KC 2020

GDP projections
Similar gravity model with explicit remittances

Energy consumption and GHG emissions projections
Assume climate policies, innovation, consumption not affected
Unaffected path along GDP per capita

Gini coefficients based on Rao et al. 2019
Migration-driven changes in education levels, public spending
Gini → income quintiles: lognormal distribution
Income quintiles → Gini: Lorenz curve
Extending SSP Scenarios for Input in FUND

<table>
<thead>
<tr>
<th>Period</th>
<th>Population growth</th>
<th>GDP per capita growth</th>
<th>Inequality growth</th>
<th>Energy intensity of GDP growth</th>
<th>Carbon intensity of energy growth</th>
<th>Carbon price</th>
</tr>
</thead>
<tbody>
<tr>
<td>2015-2100</td>
<td>Linearize from 5-year periods to yearly values</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2100-2300</td>
<td>Linear decline to 0 in 2200, then constant</td>
<td>Linear decline reaching 0</td>
<td>Fixed at 2090-2100 rate if &lt; 0 in 2100, otherwise linear decline reaching 0</td>
<td>0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2300-3000</td>
<td>Steady state: growth rates = 0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Emissions & Energy Consumption & Carbon Prices Scenarios

Development scenarios: Shared Socioeconomic Pathways (SSP) + Climate scenarios: Representative Concentration Pathways (RCP)

Selected scenarios

Source: O’Neill et al. (2016). CMIP6 data: Gidden et al. (2019)
Global Carbon Prices

Global carbon prices for each SSP-RCP as input in FUND → ensures consistent mitigation costs

Source: IIASA SSP Database
Producing results for a range of specifications

Quantifying climate change-related immobility
Difference in poorest emigrants for runs with vs without CC

Damages distribution onto income quintiles
Damages proportional, indep., inversely prop. to income

Input scenarios of future development & climate change
Five SSP-Representative Concentration Pathways (RCP)
SSP2-RCP4.5 (medium), SSP3-RCP7.0 (pessimistic)

Damages functional form & calibration
Specification with catastrophic damages (Weitzman 2012)
Income profiles of migrants
Income profiles of migrants
Income profiles of migrants for all damage elasticities
Income profiles of migrants for SSP3-RCP7.0
Cumulative number of migrants living abroad
Net migration per income quintile
Net remittances per income quintile
Results in quintile 1, for 2100, for SSP2-RCP4.5
Damages as shocks on poorest populations for SSP2-RCP4.5
Damages as shocks on poorest populations for SSP3-RCP7.0
Within-region inequality

Damage elasticity affects inequality only in a few regions
Within-region Gini coefficients vs original SSP
CC effect on immobility for SSP2-RCP4.5
CC effect on immobility for SSP3-RCP7.0
CC effect on numbers of migrants per income quintile
Immobility with catastrophic damages for SSP2-RCP4.5
Immobility with catastrophic damages for SSP3-RCP7.0
Immobility when damages proportional to income
Immobility when damages inversely prop. to Income
## Robustness check: gravity with other migration dataset

### Derivation from stocks to flows using Abel 2018

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<tbody>
<tr>
<td>Origin population</td>
<td>0.716***</td>
<td>0.698***</td>
<td>0.684***</td>
<td>0.702***</td>
<td>0.709***</td>
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<tr>
<td>Destination population</td>
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<td>0.721***</td>
<td>0.722***</td>
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*p < 0.05, **p < 0.01, ***p < 0.001
Robustness check: gravity with income minus remittances

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<tbody>
<tr>
<td>Origin population</td>
<td>0.824***</td>
<td>0.809***</td>
<td>0.792***</td>
<td>0.807***</td>
<td>0.805***</td>
</tr>
<tr>
<td>Destination population</td>
<td>0.719***</td>
<td>0.717***</td>
<td>0.719***</td>
<td>0.718***</td>
<td>0.720***</td>
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<tr>
<td>Origin per capita GDP no rem</td>
<td>1.808***</td>
<td>1.760***</td>
<td>1.865***</td>
<td>1.833***</td>
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<td>Ratio of per capita GDP</td>
<td>1.166***</td>
<td>1.174***</td>
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<td>1.153***</td>
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<td>-0.002</td>
<td>-0.001</td>
<td>-0.000</td>
<td>0.001</td>
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<td>-1.100***</td>
<td>-1.081***</td>
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<td>1.490***</td>
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*p < 0.05, **p < 0.01, ***p < 0.001
Robustness check: gravity with quadratic origin income

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<tbody>
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<td>0.830***</td>
<td>0.810***</td>
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<td>0.810***</td>
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<tr>
<td>Destination population</td>
<td>0.720***</td>
<td>0.718***</td>
<td>0.720***</td>
<td>0.719***</td>
<td>0.722***</td>
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<tr>
<td>Origin per capita GDP</td>
<td>-0.151</td>
<td>-0.466</td>
<td>-0.826</td>
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<td>-4.977*</td>
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<tr>
<td>Origin per capita GDP squared</td>
<td>0.128**</td>
<td>0.135*</td>
<td>0.155*</td>
<td>0.229**</td>
<td>0.350***</td>
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<tr>
<td>Ratio of per capita GDP</td>
<td>1.176***</td>
<td>1.182***</td>
<td>1.177***</td>
<td>1.176***</td>
<td>1.165***</td>
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<td>0.001</td>
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<tr>
<td>(R^2)</td>
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<td>0.545</td>
<td>0.554</td>
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\*p < 0.05, \**p < 0.01, \***p < 0.001
Robustness check: gravity with cubic origin income

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<tr>
<td>Origin population</td>
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<td>0.829***</td>
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<td>0.723***</td>
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<td>Origin per capita GDP</td>
<td>2.281</td>
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<td>Origin per capita GDP squared</td>
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<td>-1.522</td>
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<td>Origin per capita GDP cubed</td>
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<td>0.062</td>
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<td>0.064</td>
<td>0.076</td>
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<td>Ratio of per capita GDP</td>
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<td>1.183***</td>
<td>1.178***</td>
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<td>1.164***</td>
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<td>$R^2$</td>
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<td>0.547</td>
<td>0.556</td>
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<td>0.558</td>
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* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$
Robustness check: gravity with ratio of average per capita incomes

<table>
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<th>qorig3</th>
<th>qorig4</th>
<th>qorig5</th>
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<tbody>
<tr>
<td>Origin population</td>
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<td>0.820***</td>
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<td>0.786***</td>
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<td>Destination population</td>
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<td>0.710***</td>
<td>0.715***</td>
<td>0.717***</td>
<td>0.718***</td>
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<tr>
<td>Origin per capita GDP</td>
<td>1.449***</td>
<td>1.546***</td>
<td>1.753***</td>
<td>1.805***</td>
<td>1.806***</td>
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<tr>
<td>Ratio of per capita GDP</td>
<td>1.065***</td>
<td>1.130***</td>
<td>1.156***</td>
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<td>1.087***</td>
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<td>0.004</td>
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<td>-1.169***</td>
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<td>1.537***</td>
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<td>24,100</td>
<td>24,100</td>
<td>24,100</td>
<td>24,100</td>
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<tr>
<td>$R^2$</td>
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<td>0.547</td>
<td>0.545</td>
<td>0.533</td>
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*p < 0.05, **p < 0.01, ***p < 0.001
Robustness check: gravity with ratio of specific per capita incomes

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<th>qorig3</th>
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<th>qorig5</th>
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<tbody>
<tr>
<td>Origin population</td>
<td>0.811***</td>
<td>0.797***</td>
<td>0.779***</td>
<td>0.795***</td>
<td>0.794***</td>
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<td>Destination population</td>
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<td>0.703***</td>
<td>0.705***</td>
<td>0.704***</td>
<td>0.706***</td>
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<tr>
<td>Origin per capita GDP</td>
<td>1.381***</td>
<td>1.327***</td>
<td>1.430***</td>
<td>1.399***</td>
<td>1.375***</td>
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<td>0.788***</td>
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<td>0.777***</td>
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<tr>
<td>$R^2$</td>
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<td>0.502</td>
<td>0.511</td>
<td>0.507</td>
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* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$
### Robustness check: gravity with gini coefficients

Bilateral migrant flows for a given origin income quintile

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<th>qorig3</th>
<th>qorig4</th>
<th>qorig5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Origin population</td>
<td>0.819***</td>
<td>0.805***</td>
<td>0.790***</td>
<td>0.807***</td>
<td>0.817***</td>
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<tr>
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<td>0.733***</td>
<td>0.732***</td>
<td>0.732***</td>
<td>0.732***</td>
<td>0.732***</td>
</tr>
<tr>
<td>Origin per capita GDP</td>
<td>1.809***</td>
<td>1.746***</td>
<td>1.832***</td>
<td>1.791***</td>
<td>1.751***</td>
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<tr>
<td>Ratio of per capita GDP</td>
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<td>1.127***</td>
<td>1.126***</td>
<td>1.122***</td>
<td>1.122***</td>
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<td>Gini at origin</td>
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<td>0.687</td>
<td>0.069</td>
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<td>-1.883</td>
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<td>Gini at destination</td>
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<td>-0.000</td>
<td>0.000</td>
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<tr>
<td>Distance between countries</td>
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<td>-1.069***</td>
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<td>-1.051***</td>
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<td>1.598***</td>
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<td>24,100</td>
<td>24,100</td>
<td>24,100</td>
<td>24,100</td>
</tr>
<tr>
<td>$R^2$</td>
<td>0.517</td>
<td>0.502</td>
<td>0.511</td>
<td>0.507</td>
<td>0.505</td>
</tr>
</tbody>
</table>

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$
Environmental Shocks and the Decision to Migrate
Environmental Shocks and the Decision to Migrate

Timothy Foreman

King’s College London & EIEE

September 8, 2021
Background

World Bank
Motivation

Khartoum, Sudan 2007
Main Contributions

▶ Using micro-level census data to assess the impact of climate on migration patterns, both within and across countries
  – Show that long-term trends in temperature and precipitation impact migration across West Africa
  – Dust exposure decreases migration in this context, differing from others
Recent literature

Air pollution & migration

▶ Chen et al. (2017); Bayer et al. (2009)

Dust storm & air pollution impacts

▶ Ai and Polenske (2008); Graff Zivin and Neidell (2012); Hornbeck (2012); Hanna and Oliva (2015); Aragon et al. (2016); Arthi (2018); Birjandi-Feriz and Yousefi (2018)

Climate & Migration

▶ Beine and Parsons (2016); Cattaneo and Peri (2016); Missirian and Schlenker (2017)
Dust data

- Modern-Era Retrospective Analysis for Research and Applications, Version 2 (MERRA-2) assimilated Aerosol Optical Depth
  - $0.5^\circ \times 0.625^\circ$, daily resolution

- Concern: picking up other aerosols
West African Monsoon
West African Monsoon
Migration Data

- IPUMS-International
  - 10% sample of census data from many countries, standardized to the degree possible
Two Pieces

- First: Consider international migration based on censuses in the destination countries, use information on where respondents lived in prior years

- Second: Consider intranational migration across regions using census data from Burkina Faso and Senegal
Empirical Model- International Migration

\[ Y_{ijt} = \beta_O D_{it} + \psi_O T_{it} + \eta_O P_{it} \\
\quad + \beta_D D_{jt} + \psi_D T_{jt} + \eta_D P_{jt} \\
\quad + \phi_{ij} + \alpha_t + \epsilon_{ijt} \]

- \( Y_{ijt} \) = Migration from \( i \) to \( j \) in year \( t \)
- \( D_{it} \) is the population-weighted average dust exposure over origin country \( i \) in year \( t \)
- \( T_{it} \) is the population-weighted average temperature over origin country \( i \) in year \( t \)
- \( P_{it} \) is the population-weighted average precipitation over origin country \( i \) in year \( t \)
- \( \phi_{ij}, \alpha_t \) allow for country pair fixed effects, year fixed effects
- \( \epsilon_{ijt} \) allowed to be correlated within the origin country over time, standard errors clustered at origin country
Endogeneity in dust measurement

- Locally emitted dust
- Instrument using the Bodélé Depression
- Identifying assumption: Bodélé dust is uncorrelated with economic activity except through its effects on dust over the countries of interest
Dust Transport
# Results

<table>
<thead>
<tr>
<th>VARIABLES</th>
<th>(1) Migration rate</th>
<th>(2) Migration rate</th>
<th>(3) Migration rate</th>
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<td>-260.075</td>
<td>-258.851</td>
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<tr>
<td></td>
<td>(167.124)</td>
<td>(163.755)</td>
<td>(159.753)</td>
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<td>(15.384)</td>
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<tr>
<td>Pair FE</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>First stage F-stat</td>
<td>322.9</td>
<td>289.9</td>
<td>291.9</td>
</tr>
<tr>
<td>Year trend</td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Country-year trend</td>
<td></td>
<td></td>
<td>X</td>
</tr>
</tbody>
</table>

Robust standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1
Precipitation

Estimated response in migration to a change in precipitation, same year

Migrants per million population

SPI

Predicted response
## Results

<table>
<thead>
<tr>
<th>VARIABLES</th>
<th>(1) Migration rate</th>
<th>(2) Migration rate</th>
<th>(3) Migration rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dust exposure, 5 years</td>
<td>-305.354</td>
<td>-290.614*</td>
<td>-290.640*</td>
</tr>
<tr>
<td></td>
<td>(187.676)</td>
<td>(174.455)</td>
<td>(174.664)</td>
</tr>
<tr>
<td>Temperature, 5 years</td>
<td>0.475</td>
<td>0.553</td>
<td>0.578</td>
</tr>
<tr>
<td></td>
<td>(0.438)</td>
<td>(0.463)</td>
<td>(0.407)</td>
</tr>
<tr>
<td>SPI, 5 years</td>
<td>-64.715</td>
<td>-111.668</td>
<td>-113.217</td>
</tr>
<tr>
<td></td>
<td>(59.283)</td>
<td>(81.338)</td>
<td>(80.598)</td>
</tr>
<tr>
<td>Excess SPI, 5 years</td>
<td>-267.356</td>
<td>-217.714</td>
<td>-210.609</td>
</tr>
<tr>
<td></td>
<td>(214.402)</td>
<td>(192.400)</td>
<td>(168.577)</td>
</tr>
<tr>
<td>Drought SPI, 5 years</td>
<td>82.527</td>
<td>155.631</td>
<td>157.779</td>
</tr>
<tr>
<td></td>
<td>(80.486)</td>
<td>(115.298)</td>
<td>(114.181)</td>
</tr>
<tr>
<td>Observations</td>
<td>453</td>
<td>453</td>
<td>453</td>
</tr>
<tr>
<td>R-squared</td>
<td>0.015</td>
<td>0.150</td>
<td>0.150</td>
</tr>
<tr>
<td>Pair FE</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>First stage F-stat</td>
<td>645.8</td>
<td>602.3</td>
<td>600.8</td>
</tr>
<tr>
<td>Year trend</td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Country-year trend</td>
<td></td>
<td></td>
<td>X</td>
</tr>
</tbody>
</table>

Robust standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1
Precipitation

Estimated response in migration to a change in precipitation, last 5 years

- Migrants per million population
- SPI

- Predicted response
## Results

<table>
<thead>
<tr>
<th>VARIABLES</th>
<th>Senegal</th>
<th>Burkina Faso</th>
</tr>
</thead>
<tbody>
<tr>
<td>Temperature</td>
<td>0.041</td>
<td>0.000</td>
</tr>
<tr>
<td></td>
<td>(0.024)</td>
<td>(0.003)</td>
</tr>
<tr>
<td>SPI</td>
<td>-0.139</td>
<td>-0.006</td>
</tr>
<tr>
<td></td>
<td>(0.233)</td>
<td>(0.010)</td>
</tr>
</tbody>
</table>

| Observations | 1,272,466 | 3,123,562 |
| R-squared    | 0.011     | 0.006     |
| Year FE      | X         | X         |

Robust standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1
## Results

<table>
<thead>
<tr>
<th>VARIABLES</th>
<th>(1) Senegal</th>
<th>(2) Burkina Faso</th>
</tr>
</thead>
<tbody>
<tr>
<td>Temperature (5 year mean)</td>
<td>0.126**</td>
<td>0.000</td>
</tr>
<tr>
<td></td>
<td>(0.060)</td>
<td>(0.003)</td>
</tr>
<tr>
<td>SPI (5 year mean)</td>
<td>-0.060</td>
<td>-0.006</td>
</tr>
<tr>
<td></td>
<td>(0.096)</td>
<td>(0.010)</td>
</tr>
<tr>
<td>Observations</td>
<td>1,272,466</td>
<td>3,123,562</td>
</tr>
<tr>
<td>R-squared</td>
<td>0.010</td>
<td>0.006</td>
</tr>
<tr>
<td>Year FE</td>
<td>X</td>
<td>X</td>
</tr>
</tbody>
</table>

Robust standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1
Over Time- Dust
Conclusions & Future Work

- Climate has long-term effects on migration, but little contemporaneously
- Dust exposure is a contributing factor
- The time dynamics are an important part of regional migration
- Will explore individual characteristics to determine who is moving
Stephanie Lackner
Assistant Professor, IE University
@slackner0

Population Movement Response to Hurricane Exposure - Tracked with Cellphone GPS Location Data
Population Movement Response to Hurricane Exposure - Tracked With Cellphone GPS Location Data

Stephanie Lackner\textsuperscript{1}, Michael Oppenheimer\textsuperscript{2}, and Elmira Kalhor\textsuperscript{2}

\textsuperscript{1}IE University, stephanie.lackner@ie.edu
\textsuperscript{2}Princeton University

Climate Adaptation Research Symposium
September 8, 2021
Mobility and Migration

• Mobility during warning phase
• Mobility during storm
• Evacuation
• Displacement
• Migration
• Short/medium/long-term changes in mobility
Literature

- Interdisciplinary
- Migration after extreme events (e.g. Black et al. (2013), Cattaneo et al. (2019))
- Hurricane Katrina (e.g. Paxson & Rouse (2008), Fussell et al. (2009), Deryugina (2017))
- GPS Data (e.g. Bengtsson et al. (2011), Lu et al. (2012), Lu et al. (2016), Yabe (2019), Boas et al. (2020), Acosta (2020))
Hurricane Harvey

“Harvey [...] rapidly intensified into a category 4 hurricane [...] before making landfall along the middle Texas coast. The storm then stalled [...] dropping historic amounts of rainfall [...] Harvey is the second-most costly hurricane in U.S. history [...] at least 68 people died”

Source: National Hurricane Center Tropical Cyclone Report Hurricane Harvey (AL092017)
**TIMELINE**

8/17  tropical storm
8/24  first hurricane warning issued
8/26  first landfall
8/31  all tropical storm warnings discontinued
Data

- GPS Data from PlaceIQ (private location intelligence provider)
- Hurricane Harvey Data
  - FEMA Flood Depths Grid Data
  - FEMA Building Damage Data
- ACS5 2016 census tract data
Activity During Harvey
Daily Activity
**Device Level Data Set**

**Summary**
- Ca. 500,000 devices
- Ca. 55,000,000 device-days
- July 2017 – October 2018

**Usual Location (“home”)**
- Centroid of visits in most visited ZIP codes
- Census tract data
- Average flooding in census tract
Distance from Usual Location
Distance from Usual Location
FLOOD
POVERTY
FLOOD
OWNER OCCUPIED
Regression Analysis

\[ Y_{i,t} = \alpha_i + T_t \times CT_i + \varepsilon_{i,t} \]

- \( T_t \): Timing (6 separate periods)
- \( CT_i \): Census tract characteristics
|                | Robust Coef. | Std. Err. | t    | P>|t| | [95% Conf. Interval] |
|----------------|-------------|-----------|------|-----|---------------------|
| max_distance_t-d |             |           |      |     |                     |
| timing          |             |           |      |     |                     |
| August 24-25    | 16.03654    | .4166596  | 38.49| 0.000| 15.2199            | 16.85318|
| August 26-27    | 44.23695    | .6013688  | 73.56| 0.000| 43.05829           | 45.41562|
| August 28-31    | 27.47719    | .3558762  | 77.21| 0.000| 26.77968           | 28.17469|
| September       | 18.54044    | .1446854  | 128.14| 0.000| 18.25687           | 18.82402|
| after September | 44.74033    | .1166784  | 383.45| 0.000| 44.51164           | 44.96901|
| _cons           | 60.81715    | .0969976  | 627.00| 0.000| 60.62703           | 61.00726|
| max_distance_to_d   | Robust Coef. | Std. Err. | t     | P>|t|   | [95% Conf. Interval] |
|---------------------|--------------|-----------|-------|--------|---------------------|
| timing              |              |           |       |        |                     |
| August 24–25        | 17.6805      | .4787398  | 36.93 | 0.000  | 16.74219 18.61881   |
| August 26–27        | 47.59634     | .6932226  | 68.66 | 0.000  | 46.23765 48.95503   |
| August 28–31        | 29.59836     | .4100922  | 72.17 | 0.000  | 28.79459 30.40213   |
| September           | 19.4031      | .1661491  | 116.78| 0.000  | 19.07745 19.72875   |
| after September     | 46.09998     | .1341613  | 343.62| 0.000  | 45.83703 46.36293   |
| flooding            | 0            | (omitted) |       |        |                     |
| timing#c.flooding   |              |           |       |        |                     |
| August 24–25        | -7.183298    | .9707489  | -7.40 | 0.000  | -9.085931 -5.280665 |
| August 26–27        | -14.77129    | 1.387654  | -10.64| 0.000  | -17.49105 -12.05154 |
| August 28–31        | -9.201179    | .823676   | -11.17| 0.000  | -10.81555 -7.586803 |
| September           | -3.78949     | .3373715  | -11.23| 0.000  | -4.450726 -3.128253 |
| after September     | -5.944983    | .2712262  | -21.92| 0.000  | -6.476576 -5.413389 |
| _cons               | 60.82649     | .0969832  | 627.19| 0.000  | 60.63641 61.01658   |
| max_distance_to_d   | Robust Coef. | Robust Std. Err. | t     | P>|t| | [95% Conf. Interval] |
|---------------------|--------------|------------------|-------|------|----------------------|
| timing              |              |                  |       |      |                      |
| August 24–25        | 20.35002     | .6744662         | 30.17 | 0.000 | 19.02809             | 21.67195 |
| August 26–27        | 55.46899     | .9556933         | 58.04 | 0.000 | 53.59586             | 57.34211 |
| August 28–31        | 28.44357     | .5641532         | 50.42 | 0.000 | 27.33785             | 29.54929 |
| September after September | 16.33467 | .2312555         | 76.63 | 0.000 | 15.88132             | 16.78783 |
| timing#flooding     |              |                  |       |      |                      |
| August 24–25#1      | -8.679985    | 1.36666          | -6.35 | 0.000 | -11.35859            | -6.08138 |
| August 26–27#1      | -18.2857     | 1.952196         | -9.37 | 0.000 | -22.1193            | -14.45947 |
| August 28–31#1      | -9.170367    | 1.145872         | -8.00 | 0.000 | -11.41624            | -6.9245  |
| September#1         | -1.277367    | .4735432         | -2.70 | 0.007 | -2.205495            | -.3492397 |
| after September #1  | -1.861781    | .3784813         | -4.92 | 0.000 | -2.603591            | -1.119971 |
| timing#c.mv_black_alone |          |                  |       |      |                      |
| August 24–25        | -18.53514    | 3.293567         | -5.72 | 0.000 | -24.88457            | -12.1857 |
| August 26–27        | -66.74212    | 4.636644         | -12.02 | 0.000 | -64.82958            | -40.65466 |
| August 28–31        | 7.73922      | 2.738602         | 2.83  | 0.005 | 2.371658             | 13.10678 |
| September           | 21.24377     | 1.083697         | 19.60 | 0.000 | 19.11976             | 23.36777 |
| after September     | 27.54978     | .9070207         | 30.37 | 0.000 | 25.77205             | 29.3275  |
| timing#flooding#c.mv_black_alone |         |                  |       |      |                      |
| August 24–25#1      | 8.199828     | 7.982850         | 1.04  | 0.300 | -7.300127            | 23.69978 |
| August 26–27#1      | 17.30828     | 11.44929         | 1.51  | 0.131 | -5.131916            | 39.74847 |
| August 28–31#1      | 2.221445     | 6.575643         | 0.34  | 0.735 | -10.66658            | 15.10947 |
| September#1         | -16.36781    | 2.574519         | -6.36 | 0.000 | -21.41377            | -11.32185 |
| after September #1  | -28.74592    | 2.064901         | -13.92 | 0.000 | -32.79305            | -24.69879 |
| _cons               | 60.84307     | .9970068         | 627.20 | 0.000 | 60.65294             | 61.0332  |
Main Regression Results

• Average distance increased by about 55km during Harvey.
• Still up by 16km in September 2017 and increases to 42km afterward.
• Less evacuation/distance from more flooding affected census tracts. Particularly during Harvey (-18km).
• Less evacuation/distance from black census tracts during Harvey (55km). More distance after Harvey.
Results

• Increased mobility pre-landfall phase of Harvey.
• Vulnerability related to race and socio-economic characteristics stronger factors than direct exposure.
• Pre-Harvey 29% of devices were active in the 10-100 km range from their usual location. During Harvey, only about 20%. Recovered quickly and increased to 33% by early September, increasing further into 2018.
• Pre-Harvey 5% of devices were active more than 100 km from their usual location. During Harvey it was 15%, and it went down to 6% by September 10.
Up next – 10:45am-12:15pm PT

SESSION 2.1
International Lessons on Climate Adaptation

SESSION 2.2
Before the Storm: Responses to Forecasts

SESSION 2.3
Quantifying and Minimizing the Impacts of Wildfires

SESSION 2.4
Proactive Planning for Resilient and Equitable Communities
Thanks for tuning in!