Regional Economic Impacts from Climate Change-Induced Migration in the U.S.

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College Park, Maryland
March 15, 2013
Outline

- Motivation
- Research Questions
- Approach
- Data
- Methodology (RUM and CGE)
- Results
- Conclusions
- Future Directions
Motivation

- A few studies examine climate change impacts on location choice in terms of mean climate (Timmins, 2007; Sinha and Cropper, 2009), but no study has examined impacts of climate extremes.

- Previous studies on climate change and valuation have not considered factors such as the climate of one’s place of birth, age, and mobility, which may lead to preference heterogeneity.

- Previous studies focus on limited markets and ignore interactions across different sectors in the regional economies (Timmins, 2007).

- Previous studies that couple a CGE model with a micro-simulation model are limited to a reduced-form empirical analysis (Peichil, 2008; Bohringer and Rutherford, 2006; Aaberge, 2004).
Research Questions

- What are the effects of climate change on residential location choices in the US in terms of extremes?

- How would changes in residential location choices due to climate change affect regional economies?
Research Approach

- Econometric Model: Residential Sorting Model (RUM)
- Convergence
- Population Shares (Labor supply)
- Aggregation
- Regional US Computable General Equilibrium (CGE Model)
- Wage Rates Disaggregation
Data

- Main dataset: Integrated Public Use Microdata Sample (IPUMS)
  - Demographic characteristics of 2,117,136 households located in 281 Metropolitan Statistical Areas (MSAs) in the year 2000

- MSA-specific characteristics are from different data sources
  - Observed climate data: National Climate Data Center (NCDC)
  - Amenity and recreation data: U.S. Census

- Projected climate data: Ed Maurer’s downscaled data—provided by Rob Nicholas from Department of GeoSciences at the Pennsylvania State University (ensemble average across 16 climate models under the A2 scenario from 2056 to 2065).

- Minnesota IMPLAN group (MIG): it consists of state-level social accounting matrices (SAMs) for the United States in 2010.

- Population projections: U.S. Census
Metropolitan Statistical Areas (MSA)
(281 MSAs identified from IPUMs data in the U.S.)
Methodology: Sorting Model- Tiebout sorting

- Empirical model: residential sorting—random utility model (RUM) (Bayer and Timmins, 2005)
- Indirect utility:

\[
\ln U_{ij} = \beta_1 \ln \hat{I}_{ij} + \sum_{q \in Q} \beta_{HH_{ij}}^x (HH_{ij}^q \times X_j) + \beta_m M_{ij} - \beta_h \ln \hat{\rho}_j + \beta_z \ln Z_j + \beta_C C_j + \xi_j + \eta_{ij}
\]

\(\hat{I}_{ij}\) Predicted income for household \(i\) possibly living in one of the 281 MSA \(j\)

\(HH_{ij}^q\) Demographic characteristics of the household \(i\)

\(X_j\) Extreme hot days, extreme cold days, mobility pattern, wage rates associated with MSA \(j\)

\(M_{ij}\) Whether MSA \(j\) is outside the head of household \(i\)'s birth region

\(\hat{\rho}_j\) Housing price index for MSA \(j\)

\(Z_j\) MSA-specific attributes associated with MSA \(j\)

\(C_j\) Climate variables associated with MSA \(j\)
Methodology: Sorting Model (RUM)

- Indirect utility:
  \[ \ln U_{ij} = \ln V_{ij} + \eta_{ij} \]
  \[ = \beta_I \ln \hat{I}_{ij} + \sum_{q \in Q} \beta_{HHq}^x (HH_i^q \times X_j) + \beta_m M_{ij} - \beta_h \ln \hat{\rho}_j + \beta_z \ln Z_j + \beta_c C_j + \xi_j + \eta_{ij} \]
  
- Break into two stages:

1. 1\textsuperscript{st} Stage (multinomial logit)
   \[ lI = \sum_j \sum_i Y_{ij} \ln (P(\ln U_{ij} > \ln U_{ik} \ \forall j \neq k)) \quad P_{ij}(\ln U_{ij} > \ln U_{ik} \ \forall j \neq k) = \frac{e^{\ln V_{ij}}}{\sum_j e^{\ln V_{iq}}} \]

2. 2\textsuperscript{nd} Stage (Region Fixed Effects with IV)
   \[ \Theta_j + \beta_h \ln \hat{\rho}_j = \beta_z \ln Z_j + \beta_c C_j + \beta_{pop} POP_j + \xi_j \]
MSAs and Extreme Hot Days
MSAs and Extreme Cold Days
MSAs and Extreme Precipitation
Five Regions
Projections of Population Shares Across Regions in the RUM

- Probability that household \( i \) chooses MSA \( j \) is:

\[
P_{ij,t=2065} (\ln U_{ijt} > \ln U_{ikt}) \forall j \neq k = \frac{e^{\beta_1 \ln \hat{i}_{ijt} + \sum_{q=1}^{q} \beta_q^T (H_q \times T_q^j) + \beta_{Edu}^W (EDU_i \times W_j^t) + \beta_{M_{ijt}} + \Theta_{jt}}}{\sum_{l=1}^{L} e^{\beta_1 \ln \hat{i}_{ilt} + \sum_{q=1}^{q} \beta_q^T (H_q \times T_q^l) + \beta_{Edu}^W (EDU_i \times W_l^t) + \beta_{M_{ilt}} + \Theta_{lt}}}
\]

where

\[
\Theta_{jt} = \beta_Z \ln Z_{jt} + \beta_W \ln W_j^t + \beta_t C_{jt} + \zeta_{jt}
\]

- Aggregate the probability at regional level:

\[
P_{r,t=2065} = \sum_{j \in r} \left( \text{WEIGHT}_{jt} \times P_{jt} \right) = \sum_{j \in r} \left( \frac{\text{pop}_{jt}}{\text{pop}_{rt}} \times \frac{1}{N} \sum_{i=1}^{N} P_{ijt} \right)
\]
Regional U.S. CGE model

- Develop a recursive dynamic inter-regional CGE model based on the modeling framework of Rausch and Rutherford (2006) and Sue Wing (2007).

- Sectors:
  - Aggregate 440 IMPLAN sectors to 30 sectors.

- Regions:
  - Define 5 regions that capture climate variation across climate zones while reflecting regional economic activities.

- Time Period:
  - Calibrate the model based on 2010 IMPLAN social accounting matrices (SAMs)
  - Solve for equilibrium results at 1-year step until 2065.
Model Structure

- Four economic agents: consumers, producers, government, and the foreign sector.

- Conditions for achieving competitive general equilibrium:
  1) Market clearing: supply equals demand
  2) Zero profit
  3) Income balance
  4) Total investment is equal to total savings
CGE-Scenarios

- Baseline scenario: business as usual (BAU)
  - Saving rate /0.057/ (source: BLS 2010)
  - Population projection (source: U.S. Census)
  - Labor productivity growth rate /0.025/
  - Capital quality growth rate /0.025/
  - Multifactor productivity growth rate /0.025/
  - Autonomous energy efficiency improvement (AEEI) /0.02/

- Climate Change-Induced Migration scenario with exogenous wages (w/o iteration between the RUM and CGE models)

- Climate Change-Induced Migration Scenario with endogenous wages (w/ iteration)
Incorporating Empirical Results into the CGE Model

- Endogenize labor wages

**CGE**

- Growth Rate of Wages

\[ LS_{r,t=2065} = q_{r,t=2065}^L \times (POP_{t=2065}^{Census} \times P_{r,t=2065}^{CGE-MIG}) \]

\[ YL_{r,t=2065} = PL_{r,t=2065}^{MIG} \times LS_{r,t=2065} \]

\[ W_{r,t=2065}^{MIG} = W_{r,t=2010}^{BLS} \times (1 + \frac{PL_{r,t=2065}^{MIG}}{PGDF_{r,t=2065}^{MIG}}) \]

\[ W_{j_\ell,t=2065}^{MIG} = W_{j_\ell,t=2000}^{MIG} + \left[ W_{r,t=2065}^{MIG} - W_{r,t=2000}^{MIG} \right] \]

**RUM**

- Regional Population shares

\[ P_{r,t=2065}^{CGE-MIG} = P_{r,t=2065}^{CGE-BAU(Census)} \times \left( \frac{P_{r,t=2065}^{RUM-MIG}}{P_{r,t=2065}^{RUM-BAU}} - 1 \right) \]

\[ P_{r,t=2065}^{RUM-MIG} = \sum_{j_\ell} \left[ WEIGHT_{j_\ell} \times P_{j_\ell} (C_{C_{j_\ell}}; W_{MIG_{j_\ell,t=2065}}^{MIG}, \ldots) \right] \]
Results: Population Shares by Region under Different Scenarios (CGE results)

<table>
<thead>
<tr>
<th>Regions</th>
<th>CGE-BAU (population share projection from U.S. Census) (2065)</th>
<th>CGE-MIG w/o iterations (2065)</th>
<th>CGE-MIG w/ iterations (2065)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Northeast</td>
<td>0.1248</td>
<td>0.1841</td>
<td>0.1314</td>
</tr>
<tr>
<td>Midwest</td>
<td>0.1410</td>
<td>0.1106</td>
<td>0.1434</td>
</tr>
<tr>
<td>South</td>
<td>0.4623</td>
<td>0.4185</td>
<td>0.4474</td>
</tr>
<tr>
<td>West</td>
<td>0.1372</td>
<td>0.1379</td>
<td>0.1343</td>
</tr>
<tr>
<td>California</td>
<td>0.1347</td>
<td>0.1489</td>
<td>0.1434</td>
</tr>
</tbody>
</table>
## Results: Top 10 Industries based on Regional Shares of Output

**Changes in Industrial Output Shares by Region**  
(Climate Change-Induced Migration Scenario w/ Iteration vs. BAU scenario-% difference)

<table>
<thead>
<tr>
<th></th>
<th>NE</th>
<th>MW</th>
<th>SO</th>
<th>WE</th>
<th>CA</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Insurance</td>
<td>2.43%</td>
<td>Grains and oilseeds</td>
<td>Poultry and eggs</td>
<td>Other mining</td>
</tr>
<tr>
<td>2</td>
<td>Pulp paper</td>
<td>2.61%</td>
<td>Other animal production</td>
<td>Oil gas</td>
<td>Forestry</td>
</tr>
<tr>
<td>3</td>
<td>Services</td>
<td>3.57%</td>
<td>Beef</td>
<td>Coal</td>
<td>Fruits vegetables nuts</td>
</tr>
<tr>
<td>4</td>
<td>Water and sewage</td>
<td>3.77%</td>
<td>Dairy</td>
<td>Chemicals</td>
<td>Other agric</td>
</tr>
<tr>
<td>5</td>
<td>Construction</td>
<td>3.74%</td>
<td>Primary metals</td>
<td>Heat air conditioner</td>
<td>Wood products</td>
</tr>
<tr>
<td>6</td>
<td>Natural gas distribution</td>
<td>2.73%</td>
<td>Rubber plastics</td>
<td>Forestry</td>
<td>Dairy</td>
</tr>
<tr>
<td>7</td>
<td>Coal</td>
<td>3.98%</td>
<td>Electricity</td>
<td>Other crops</td>
<td>Beef</td>
</tr>
<tr>
<td>8</td>
<td>Electricity</td>
<td>2.21%</td>
<td>Pulp paper</td>
<td>Wood products</td>
<td>Nonmetallic metals</td>
</tr>
<tr>
<td>9</td>
<td>Rubber plastics</td>
<td>3.26%</td>
<td>Insurance</td>
<td>Construction</td>
<td>Services</td>
</tr>
<tr>
<td>10</td>
<td>Primary metals</td>
<td>3.68%</td>
<td>Furniture</td>
<td>Electricity</td>
<td>Construction</td>
</tr>
</tbody>
</table>
Results: Changes in Macroeconomic Indicators (Climate Change-Induced Migration vs. BAU % difference)

Table 1 (results w/o iterations)

<table>
<thead>
<tr>
<th>Region</th>
<th>GDP</th>
<th>Consumption</th>
<th>Investment</th>
<th>Government</th>
<th>Net exports</th>
</tr>
</thead>
<tbody>
<tr>
<td>Northeast</td>
<td>29.06%</td>
<td>30.00%</td>
<td>31.00%</td>
<td>1.66%</td>
<td>35.07%</td>
</tr>
<tr>
<td>Midwest</td>
<td>-14.71%</td>
<td>-14.69%</td>
<td>-14.86%</td>
<td>-0.75%</td>
<td>-21.53%</td>
</tr>
<tr>
<td>South</td>
<td>-6.37%</td>
<td>-6.38%</td>
<td>-6.22%</td>
<td>-0.15%</td>
<td>-8.93%</td>
</tr>
<tr>
<td>West</td>
<td>0.05%</td>
<td>0.25%</td>
<td>0.71%</td>
<td>0.31%</td>
<td>-0.93%</td>
</tr>
<tr>
<td>California</td>
<td>6.25%</td>
<td>6.50%</td>
<td>7.34%</td>
<td>0.68%</td>
<td>6.04%</td>
</tr>
</tbody>
</table>

Table 2 (results w/ iterations)

<table>
<thead>
<tr>
<th>Region</th>
<th>GDP</th>
<th>Consumption</th>
<th>Investment</th>
<th>Government</th>
<th>Net exports</th>
</tr>
</thead>
<tbody>
<tr>
<td>Northeast</td>
<td>3.41%</td>
<td>3.52%</td>
<td>3.65%</td>
<td>0.23%</td>
<td>4.15%</td>
</tr>
<tr>
<td>Midwest</td>
<td>1.07%</td>
<td>1.09%</td>
<td>1.17%</td>
<td>0.12%</td>
<td>1.41%</td>
</tr>
<tr>
<td>South</td>
<td>-2.11%</td>
<td>-2.14%</td>
<td>-2.13%</td>
<td>-0.10%</td>
<td>-2.80%</td>
</tr>
<tr>
<td>West</td>
<td>-1.46%</td>
<td>-1.46%</td>
<td>-1.44%</td>
<td>-0.02%</td>
<td>-1.94%</td>
</tr>
<tr>
<td>California</td>
<td>4.01%</td>
<td>4.11%</td>
<td>4.40%</td>
<td>0.29%</td>
<td>4.35%</td>
</tr>
</tbody>
</table>
Conclusions

- People’s preferences for temperature extremes are heterogeneous.
- The population share in the Northeast increases, while the population share in the South drops under changes in climate.
- The size of labor-intensive industries (e.g. service) increases in the Northeast, while labor-intensive sectors shrink in the South.
- Wage effects dominate climate effects in location decisions.
- Ignoring feedback from the equilibrium labor market leads to biased results in simulating economic impacts.
Future Directions

- Endogenize housing prices
- Welfare analysis
- Multiple impacts and mutual interactions among different impacts
Questions?

Thank you!!!!

Questions can be emailed to: quf101@psu.edu