The Economic Geography of Global Warming

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Global warming is a **protracted, global,** phenomenon with **heterogeneous local effects**

Standard climate models use loss functions relating aggregate economic outcomes to climate variables

- Fail to incorporate behavioral responses, and therefore economic adaptation
- Ignore the vast spatial heterogeneity in climate damages

We propose and quantify a spatial and dynamic assessment model

- Emphasizing the role of **economic adaptation through migration, trade, and innovation**
Model Characteristics

- We extend the spatial growth model in Desmet et al. (2018)
  - Add natality, energy, carbon cycle, and local temperature effect on amenities and productivities
  - Quantify using $1^\circ \times 1^\circ$ G-Econ data on population and income in 2000
  - Set trade and mobility frictions to match gravity and net migration flows
  - Natality depends on income and temperature
Local Temperature Down-scaling

- We let $T_{t+1}(r) = T_t(r) + g(r) \cdot (T_{t+1} - T_t)$

  - where $g(\cdot)$ is a function of latitude, longitude, elevation, distance to coast, distance to ocean, distance to water, vegetation density and albedo
Damage Functions

- Invert fundamental amenities and productivities consistent with observed data (1990, 1995, 2000, 2005)

- Estimate damage function given by

\[
\text{Log-Amenity}_t(r) = \sum_{j=1}^{J} \delta^b_j \cdot T_t(r) \cdot \mathbb{1}\{T_t(r) \in T_j\} + \nu(r) + \nu_t(s_j) + \varepsilon_t(r)
\]

\[
\text{Log-Productivity}_t(r) = \sum_{j=1}^{J} \delta^a_j \cdot T_t(r) \cdot \mathbb{1}\{T_t(r) \in T_j\} + \delta^z \cdot Z(r) + \nu_t(s_j) + \varepsilon_t(r)
\]
Fossil and Clean Energy Costs

1. Fossil fuel extraction cost $f(\cdot)$

Data from Bauer et al. (2016)
Cost has asymptote at total $\text{CO}_2$ reserves

2. Set initial productivities to match fossil and clean energy use

3. Set relative fossil and clean technology growth to match historical $\text{CO}_2$ emissions and clean energy use
Baseline Scenario: CO2 Emissions and Global Temperature

![Graphs showing CO2 emissions and global temperature over time](image-url)

- **CO2 emissions (GtCO2/year)**
  - Model
  - IPCC (RCP 8.5)
  - IPCC (RCP 6.0)

- **Global temperature (°C) relative to pre-industrial level**
  - Model
  - IPCC (RCP 8.5)
  - IPCC (RCP 6.0)
Baseline Scenario: Amenities and Productivities

Amenities 2200: relative to no warming

Productivities 2200: relative to no warming

worst-scenario
Baseline Scenario: Global and Local Population

![Graph of Global Population](image1)

![Map of Population Density 2200 Relative to No Warming](image2)
Baseline Scenario: Welfare Cost of Global Warming

Welfare: baseline relative to no warming

welfare, worst-scenario
real GDP, baseline
real GDP, worst-scenario

Average = 0.945
Std dev = 0.043
Baseline Scenario: Uncertainty about Damage Functions
Baseline Scenario: Uncertainty about Damage Functions

**PDV real GDP: baseline relative to no warming**

- Low 95%
- Benchmark
- High 95%

**Welfare: baseline relative to no warming**

- Low 95%
- Benchmark
- High 95%
Adaptation: Migration

Welfare, DiD: baseline relative to no warming and $m_2(t)^{1.25}$

Welfare: baseline relative to no warming

- Benchmark
- $m_2(t)^{1.125}$, exog temp
- $m_2(t)^{1.125}$, endog temp
- $m_2(t)^{1.25}$, exog temp
- $m_2(t)^{1.25}$, endog temp

real GDP
Adaptation: Trade

Welfare, DiD: baseline relative to no warming and $(r,s)^2$

Welfare: baseline relative to no warming

- Benchmark
- $(r,s)^{1.5}$, exog temp
- $(r,s)^{1.5}$, endog temp
- $(r,s)^{2}$, exog temp
- $(r,s)^{2}$, endog temp

real GDP
Adaptation: Innovation

Welfare, DiD: baseline relative to no warming and $0.5 \cdot \frac{\gamma_f}{\xi}$

Welfare: baseline relative to no warming

- Benchmark
- $0.5 \cdot \frac{\gamma_f}{\xi}$, exog temp
- $0.5 \cdot \frac{\gamma_f}{\xi}$, endog temp
- $0.667 \cdot \frac{\gamma_f}{\xi}$, exog temp
- $0.667 \cdot \frac{\gamma_f}{\xi}$, endog temp

real GDP
Carbon Taxes

- Carbon tax of 50% equals 37 usd/tCO$_2$; similar to maximum in EU Emissions Trading Scheme
- Carbon tax of 200% equals 146 usd/tCO$_2$; similar to Swedish Tax
Carbon Taxes: Dynamic Effects

- Aggregate gains depend on discount factor and BGP growth rate

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<thead>
<tr>
<th></th>
<th>PDV of real GDP</th>
<th>Welfare</th>
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<tbody>
<tr>
<td></td>
<td>BGP gr</td>
<td>$\beta=0.965$</td>
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<tr>
<td>$\tau=0%$</td>
<td>3.043%</td>
<td>1</td>
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<td>$\tau=50%$</td>
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<td>$\tau=200%$</td>
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Carbon Taxes: Local Effects

Welfare, carbon tax 200%: relative to no carbon tax

real GDP
Carbon Taxes with Abatement

- Perfect and cost-less abatement technology in 2100
- With abatement, carbon tax not only flattens the temperature curve but reduces total emissions significantly
With abatement, carbon tax results in same current cost but much larger welfare gains in the future

- For $\tau = 200\%$ and $\beta = 0.969$, welfare gains from carbon tax double
Clean Energy Subsidies: Local Effects

Welfare, clean subsidy 75%: relative to no clean subsidy

dynamic effects  real GDP
Conclusions

- We develop an economic spatial growth model of global warming
  - Accounts for adaptation through trade, migration, innovation
- Estimate impact of temperature on fundamentals
  - Heterogeneous spatial effect of temperature for amenities and productivities
- Large heterogeneity in climate damages over space
  - From welfare losses of 15% to gains of 14%
  - On average, welfare losses of 6%
  - Large role of adaptation, particularly migration
- Carbon taxes create trade-off between present and future benefit
  - Large disagreement across regions
  - Highly effective only in combination with future abatement technology
Thank You
Estimation: Temperature
Worst-Scenario: Amenities and Productivities

Amenities 2200: relative to no warming

Productivities 2200: relative to no warming
Worst-Scenario: Welfare Cost of Global Warming
Baseline Scenario: Real GDP Cost of Global Warming
Worst-Scenario: Real GDP Cost of Global Warming
Adaptation: Migration and Real GDP

![Graph showing PDV real GDP, DiD: baseline relative to no warming and m_2(r)^{1.25}](image1.png)

![Graph showing Real GDP: baseline relative to no warming](image2.png)
Adaptation: Trade and Real GDP

PDV real GDP, DiD: baseline relative to no warming and $\langle r, s \rangle^2$

Real GDP: baseline relative to no warming

- Benchmark
- $\langle r, s \rangle^{1.5}$, exog temp
- $\langle r, s \rangle^{1.5}$, endog temp
- $\langle r, s \rangle^2$, exog temp
- $\langle r, s \rangle^2$, endog temp
Adaptation: Innovation and Real GDP

PDV real GDP, DiD: baseline relative to no warming and $0.5\cdot\gamma_1/\xi$

Real GDP: baseline relative to no warming

- Benchmark
- $0.5\cdot\gamma_1/\xi$, exog temp
- $0.5\cdot\gamma_1/\xi$, endog temp
- $0.667\cdot\gamma_1/\xi$, exog temp
- $0.667\cdot\gamma_1/\xi$, endog temp

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Carbon Taxes: Energy Price

Log Price CO2 - Log Price clean energy, 2000

CO2 emi 2001, carbon tax 200%: relative to no carbon tax
Carbon Taxes: Energy Price

Total energy 2001, carbon tax 200%: relative to no carbon tax

Price energy 2001: carbon tax 200% relative to no carbon tax

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Carbon Taxes: Population

Global population

Population 2001, carbon tax 200%: relative to no carbon tax
Carbon Taxes: Population

Global population

Population 2200, carbon tax 200%: relative to no carbon tax
Carbon Taxes: Local Real GDP

[Map and bar chart showing the impact of carbon taxes on local real GDP]

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Clean Energy Subsidies: Dynamic Effects

Real GDP: relative to no clean subsidy

Welfare: relative to no clean subsidy

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<td>$s=75%$</td>
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Clean Energy Subsidies: Local Real GDP

[Map and graph showing the impact of clean energy subsidies on real GDP, with color-coded regions and a histogram of the relative GDP changes.]