Economic Evaluation of Climate Change Impacts and Adaptation in the United States: *Comparing Models and Methods*

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Collaborators
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Outline

- Models and methods
- Climate impacts in general equilibrium
- Research extensions
- Database developments

Disclaimer: Views expressed in presentation do not necessarily represent those of the U.S. EPA.

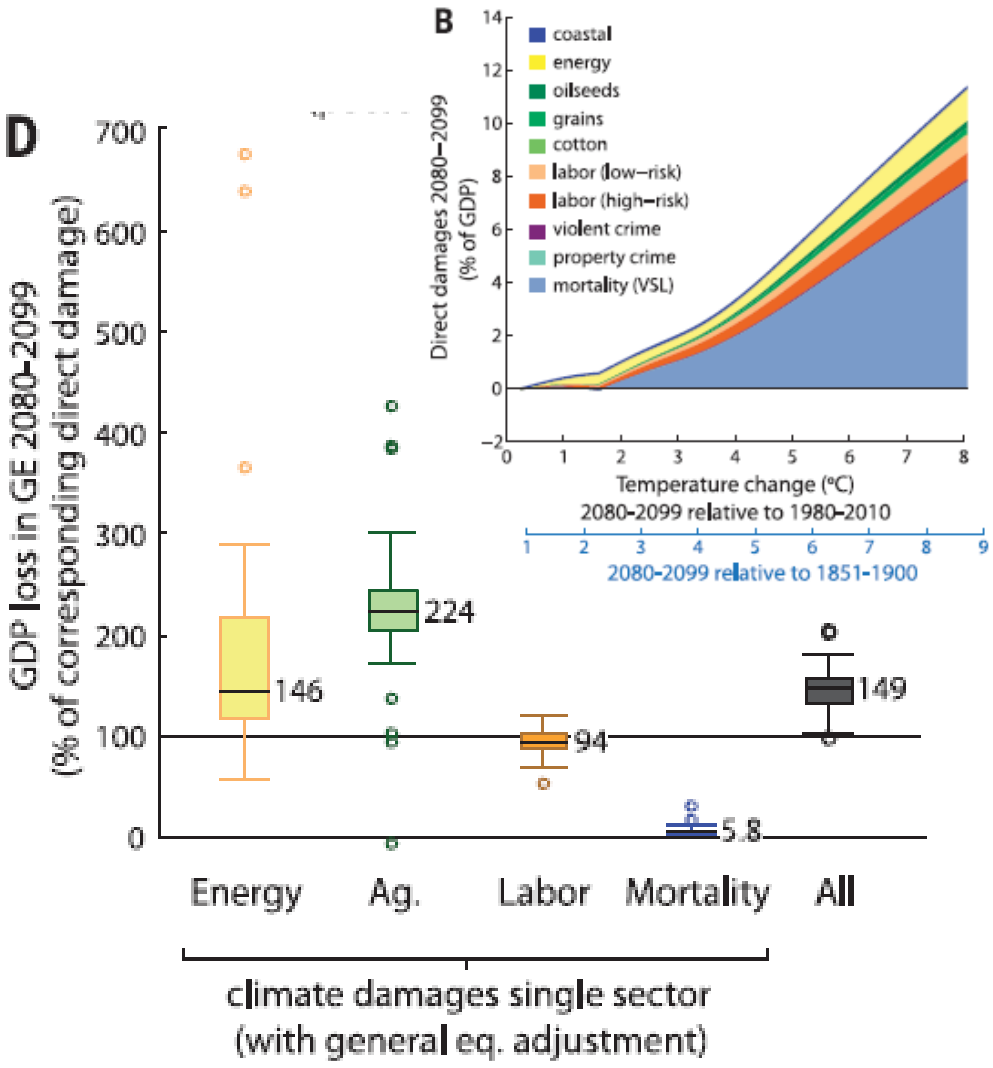
Models and Methods

Objectives of the study

- Introduce bottom-up sectoral climate impacts into a CGE model: MIT's U.S. Regional Energy Policy Model (USREP)
- CGE models provide an consistent accounting and structural framework to
  - evaluate impacts to the broader economy of sectoral shocks
  - examine the interactions across sectors
- Initial phase (this talk)
  - Disaggregate USREP from 12 to 29 regions and extend years from 2050 to 2100
  - Introduce median climate impacts from the Climate Impacts Lab (i.e., Hsiang et. al.) for three impacts: labor, agriculture, and heat mortality
  - Examine the magnitude and incidence of the climate damages within the USREP model

Economy-Wide Climate Impact Analyses

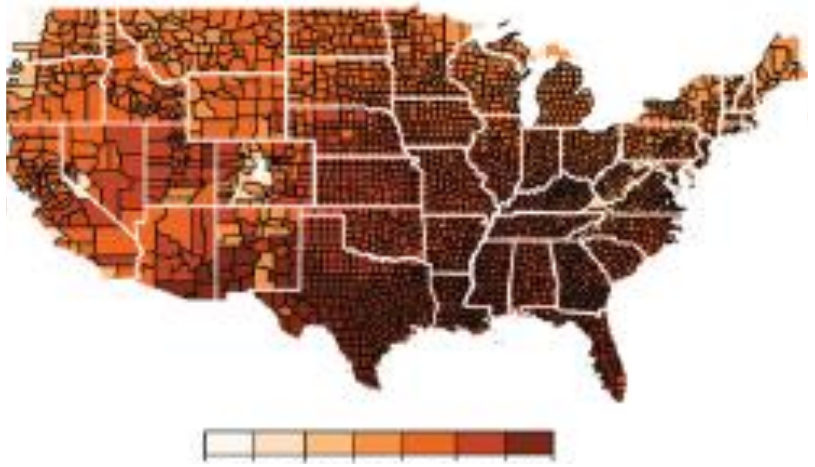
- US - Climate Impacts Lab / American Climate Prospectus
  - RHG-MUSE model
  - 7 sectors: labor, heat mortality, coastal, energy, agriculture, crime
  - Economy-wide impacts are 50% greater than direct damages
  - Heat mortality treated as lost labor
- EU - JRC PESETA I, II, III
  - Static implementation in GEM-E3
  - 6 sectors: labor, heat mortality, coastal, inland flooding, ag
  - Focus on 2 degrees (2030-2040)
  - EU GDP loss ~2%, half coming from heat mortality VSL
- Global - OECD Circle Project
  - ENV-Linkages model
  - Global analysis to 2060
  - Crop yields and labor supply impacts lower GDP by 0.9% and 0.8%



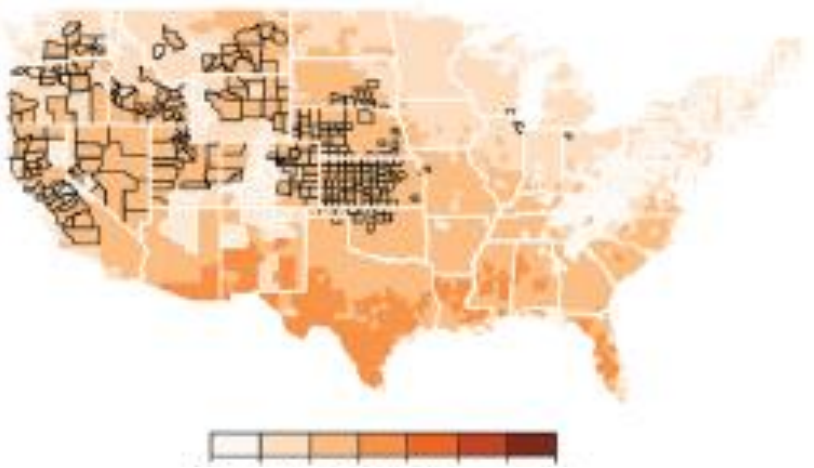
Source: Hsiang et al. Science 2017

Methodology: applying impacts from Hsiang et al.

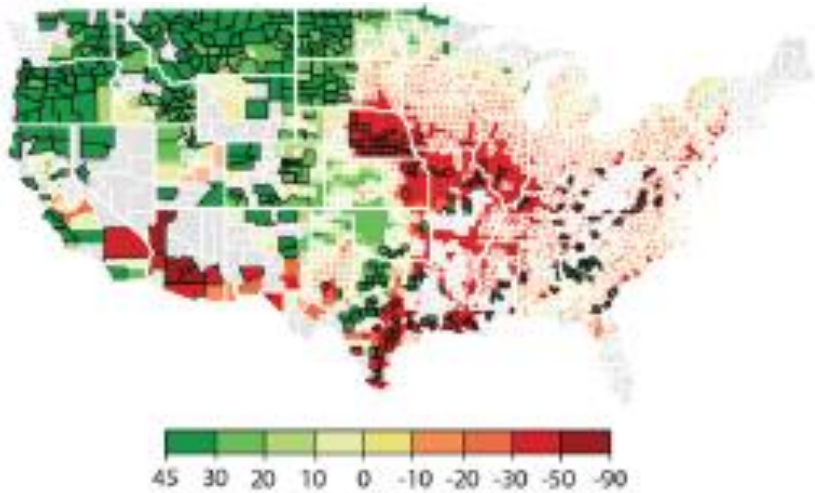
- Apply **median** results from several RCP's, primarily RCP 8.5 and RCP 4.5 for 3 shocks
- **Labor:** productivity shock introduced as an adjustment to labor supply. Low-risk labor applied to services sector.
- **Agriculture:** productivity shock introduced as adjustment to total output (i.e., not land). Impact applied across all crops weighted by output
- **Heat Mortality:** shock introduced as a reduction in the labor/leisure endowment of the representative agent



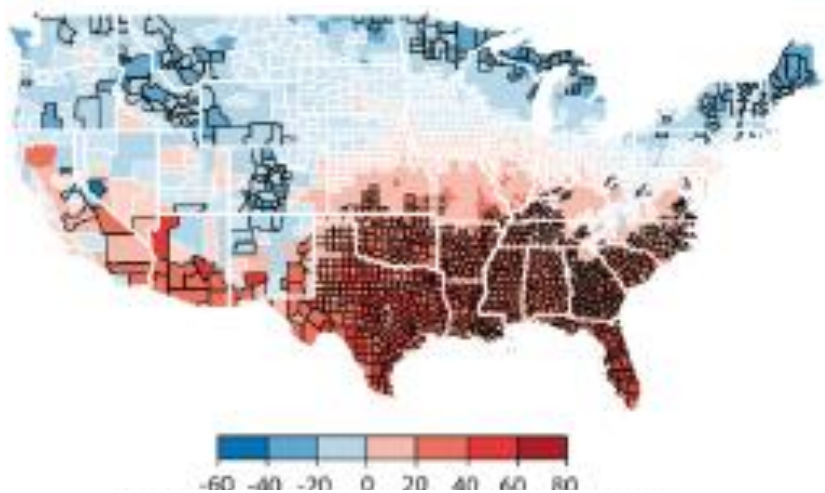
High-risk Labor (0.5% to -3%)



Low-risk Labor (0.5% to -3%)



Agricultural yields (+45 to -99%)



Mortality (chng deaths per 100k -60 to +80)

Median climate damages for RCP8.5 averaged over 2080-2099.

Source: excerpt from Figure 2, Hsiang et al., Science 2017

Caveats and Limitations

- Initial foray looks only at **median impacts** and does not explore the distribution of impacts across the climate models.

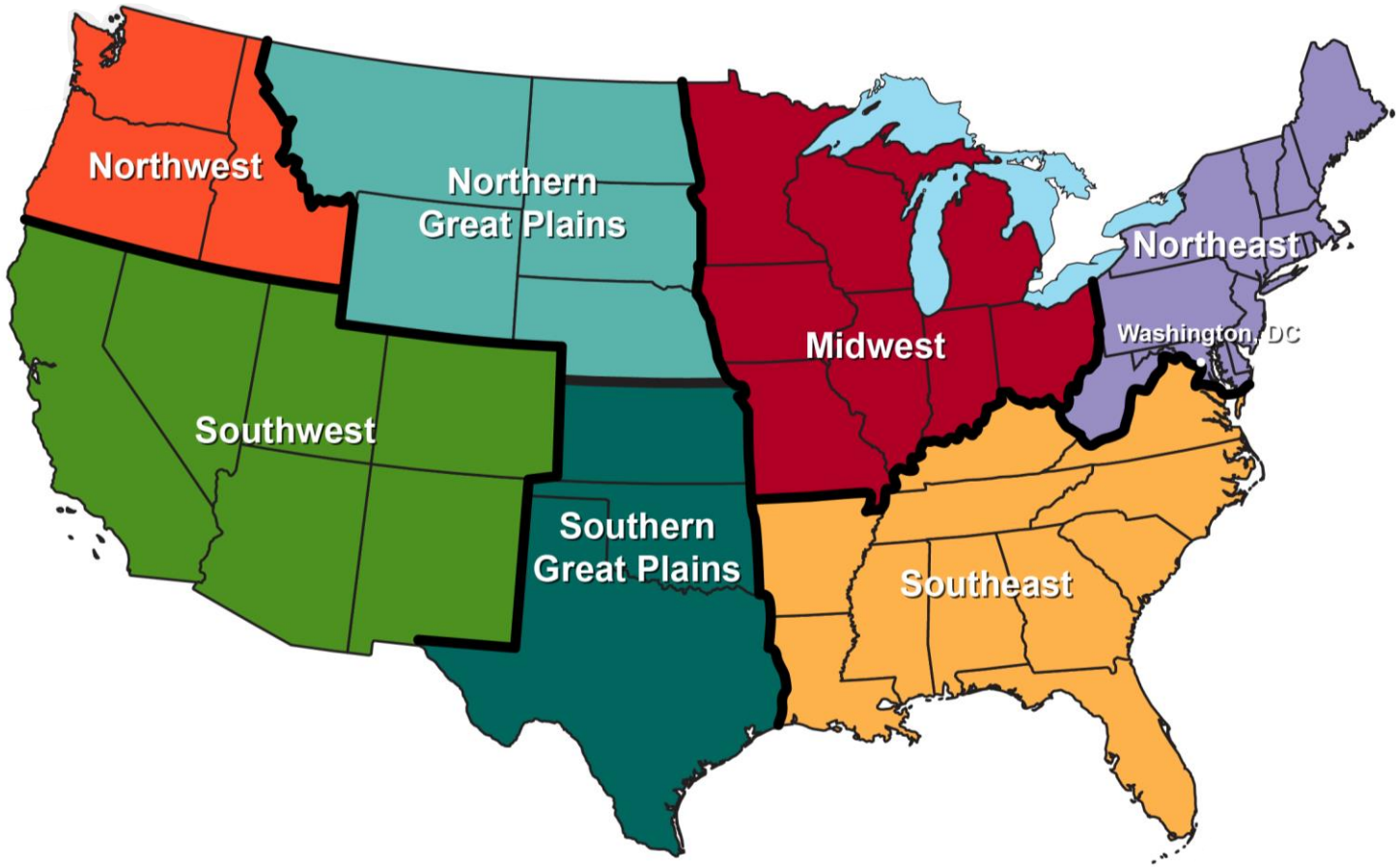
- Adaptation to heat mortality in underlying study is more limited than that reported in recent research, which may inflate the mortality losses. However, the value of statistical life is kept constant (i.e., does not rise the GDP), which understates the losses.

- Decreased cold mortality reported in Hsiang et al. was not found to be significant in a separate work published as part of the CIRA study.

- A single, aggregated agricultural sector masks differential impacts on particular crops and cannot represent important interactions in the sector (e.g., substitution between crops and livestock).

US National Climate Assessment Regions

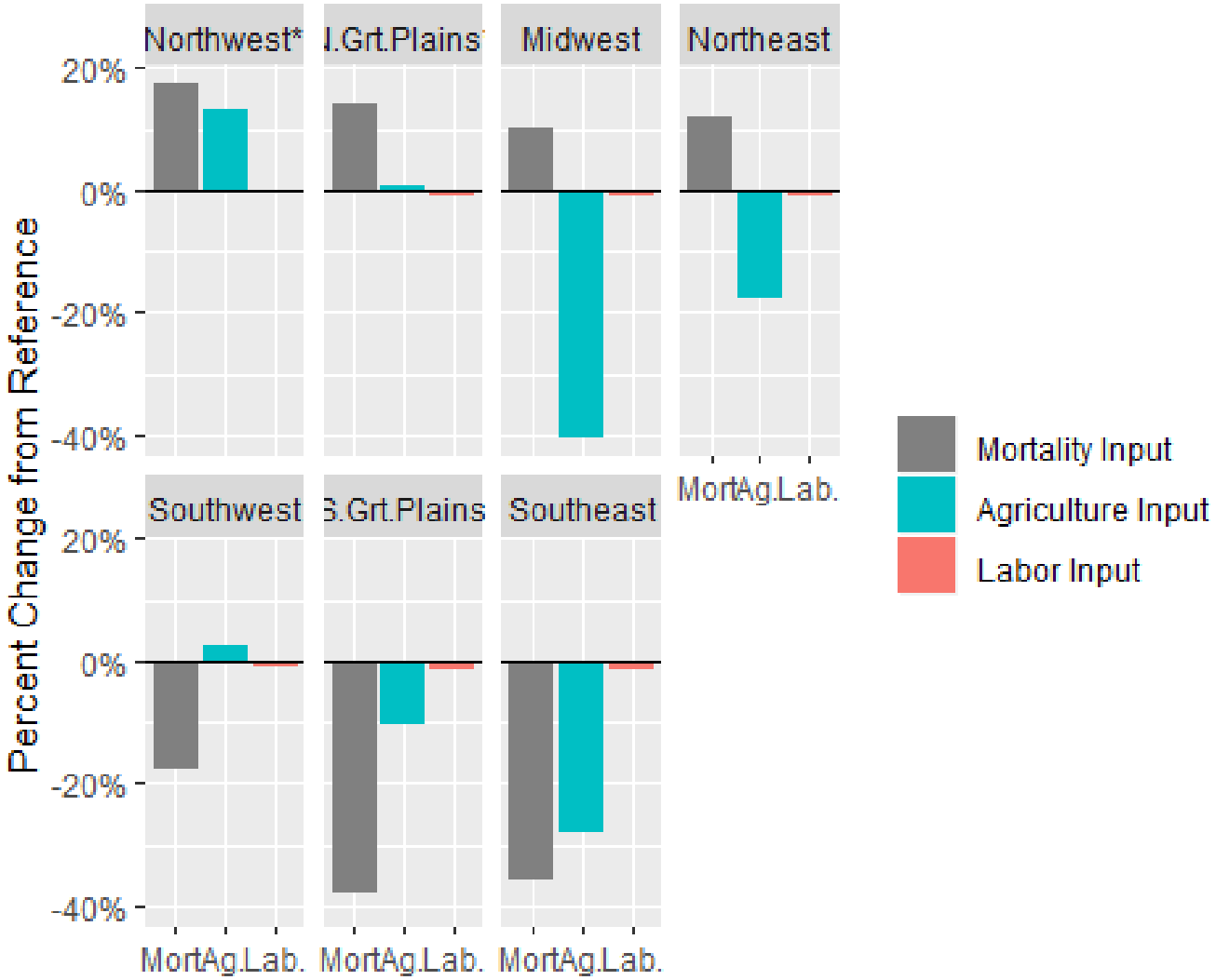
- Results reported at national and NCA region levels



Regional Input Shocks and GDP Output for RCP8.5 in 2100

- Heat mortality exhibits a difference in sign and magnitude between the northern and southern regions.
- The agricultural productivity shock is strongly negative in the Midwest and Southeast. The Northwest, and to a lesser extent the Southwest, experience a positive shock.
- The labor productivity shock is quite small in comparison to the other shocks in percentage terms.

Regional input shock by sector and change in GDP (output)



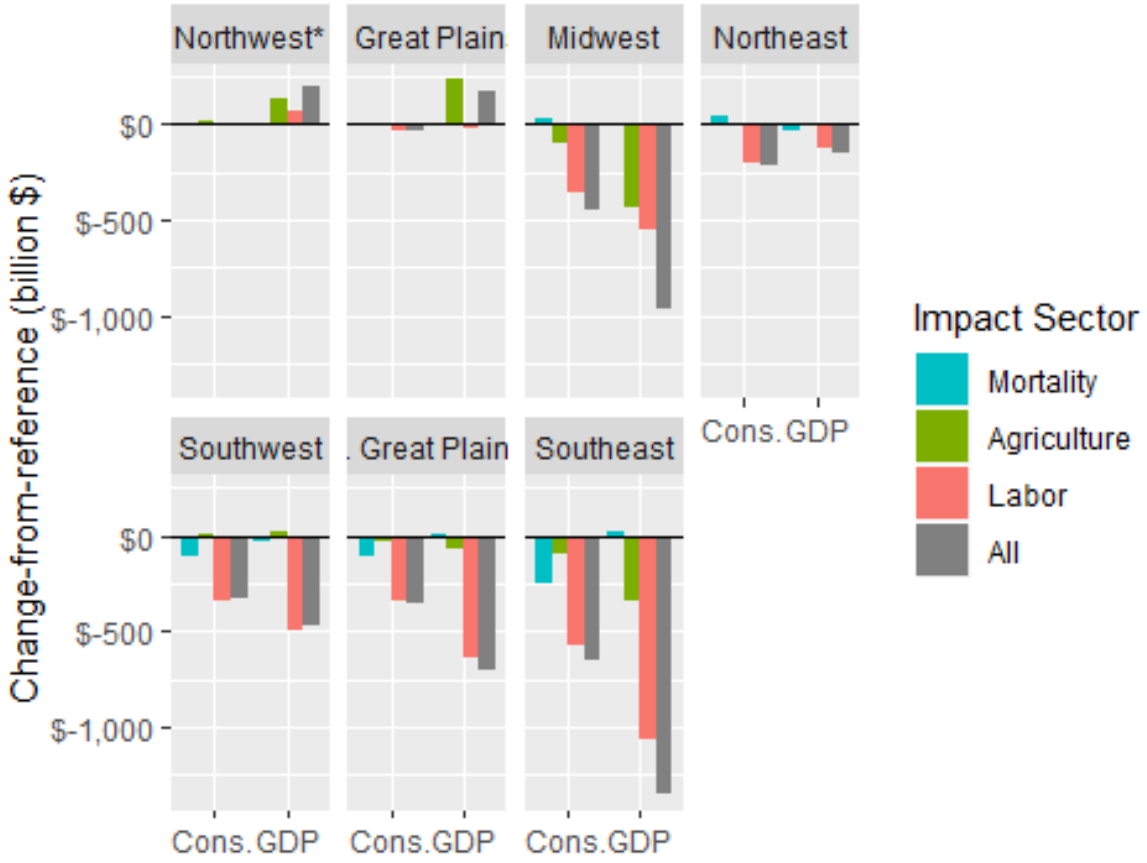
Preliminary results. Not for citation or quotation.

Climate Impacts

Regional impacts on Consumption and GDP

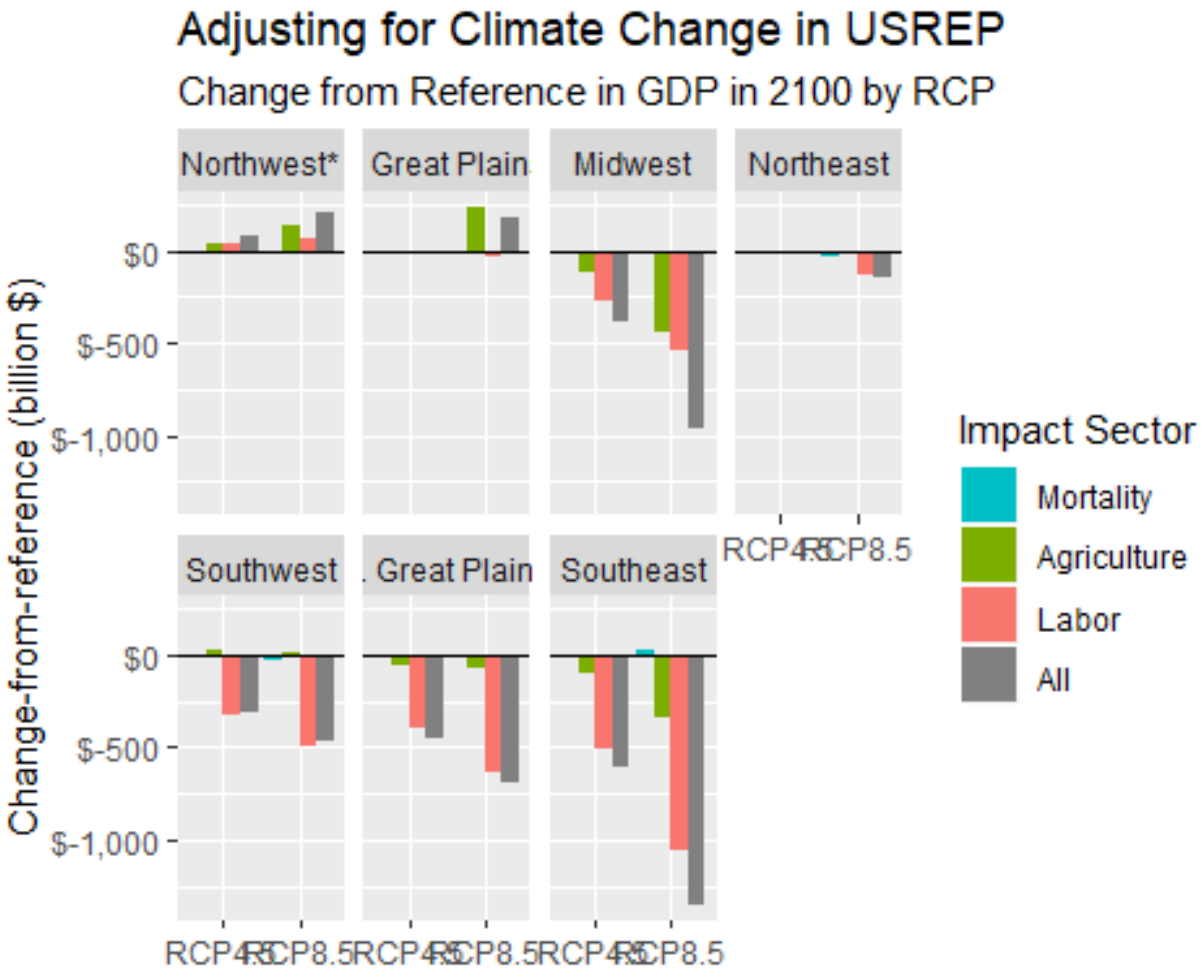
- In 2100 under RCP 8.5, labor productivity losses lower consumption by almost $1.7 trillion (2.5%) and GDP by $2.7 trillion (2.9%).
- Agricultural impacts lower consumption and GDP by $200 billion (0.3%) and $500 billion (0.5%) , respectively.
- Heat mortality effects lower consumption by $400 billion (0.6%), but have much less of an effect on GDP.
- When all impacts are introduced simultaneously, the consumption effects are less than the sum of the separate effects. GDP is roughly additive.

Change in consumption and GDP in 2100 for RCP 8.5



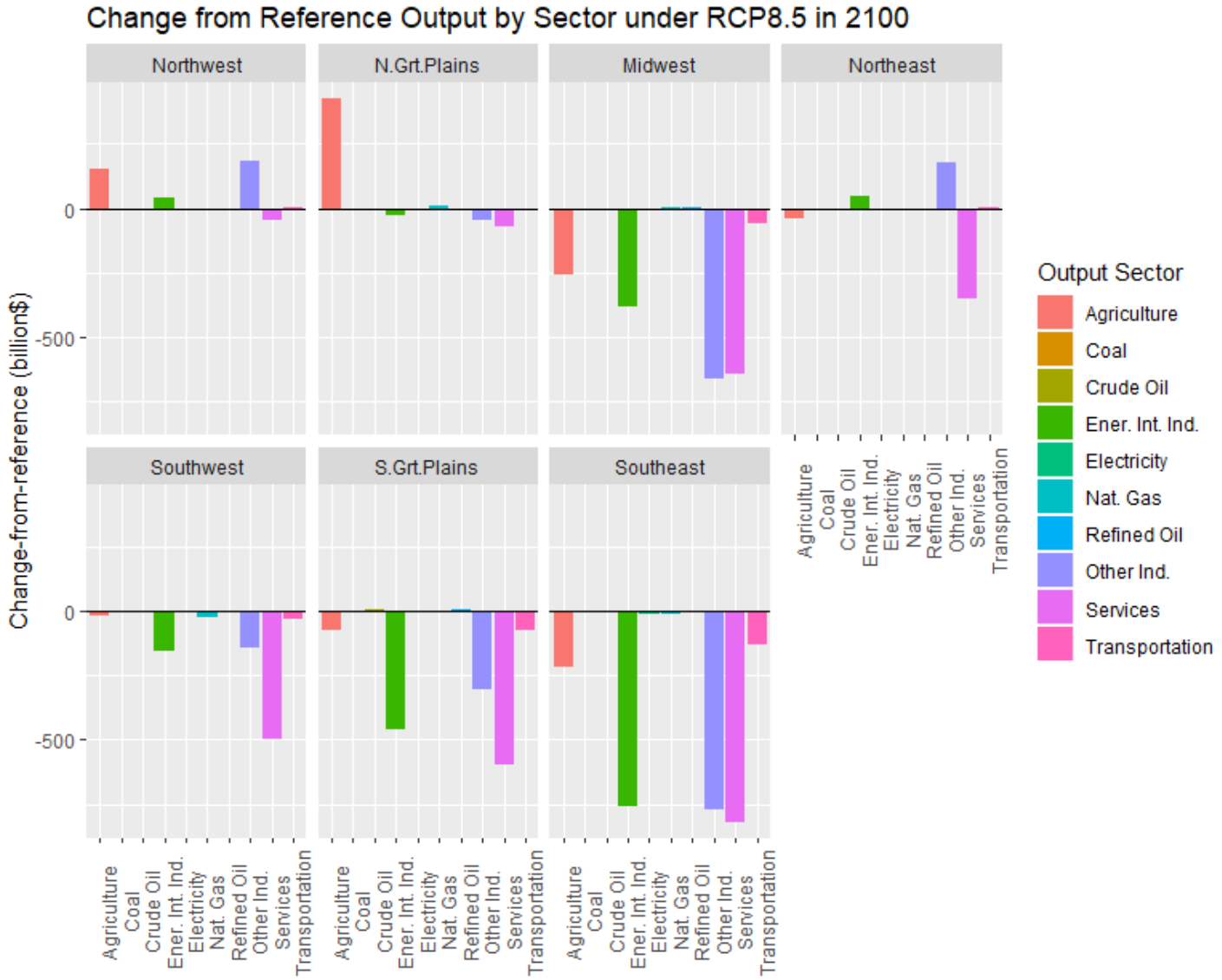
Regional impact differences across RCPs

- Impacts are substantially lower under RCP 4.5 than RCP 8.5 with some regional variation.
- Impacts across the Northwest, Northern Great Plains, and Northeast are minimal under RCP 4.5.
- The impacts in the Midwest, Southwest, and Southeast are reduced by roughly 50%.
- Reductions in the Southern Great Plains are only 30%.



Impact on Sectoral output by region with “All” shocks

- The largest impacts in absolute terms, in 2100 under RCP 8.5 are in Services, Other Industries, Energy Intensive Industries, and Agriculture.
  - Services, Other Industries, and Energy Intensive Industries all use significant intermediate inputs which makes them more susceptible to the labor productivity shock.
- The aggregate national effects on output miss important regional shifts.
  - Positive effects on output in some northern regions for agriculture, energy intensive, and other industries.



Preliminary results. Not for citation or quotation.

Extensions

Extension 1 – Introduce sectoral impacts covered in CIRA

- Introduce detailed sectoral impacts from bottom-up models into USREP.
- Detailed bottom-up, sectoral data enables improved representation in a CGE framework
  - Break-out of impacts by inputs (e.g., capital, labor, and energy) is possible.
  - This is particularly relevant for coastal adaptation which requires substantial capital investment to mitigate losses.
  - Spatial detail only limited by bottom-up model.

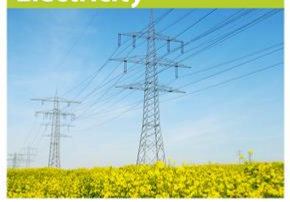
Health

- **Air Quality**
- **Aeroallergens**
- **Extreme Temperature Mortality**
- **Labor**
- **West Nile Disease**
- **Harmful Algal Blooms**
- **Domestic Migration**

Infrastructure

- **Roads**
- **Bridges**
- **Rail**
- **Alaska Infrastructure**
- **Urban Drainage**
- **Coastal Property**

Electricity



- **Electricity Demand and Supply**

Water Resources

- **Inland Flooding**
- **Water Quality**
- **Winter Recreation**

Agriculture

- **Domestic Yields and Welfare Effects**
- **U.S. and Global Agriculture Interactions**

Ecosystems

- **Coral Reefs**
- **Shellfish**
- **Freshwater Fish**
- **Wildfire**
- **Carbon storage**

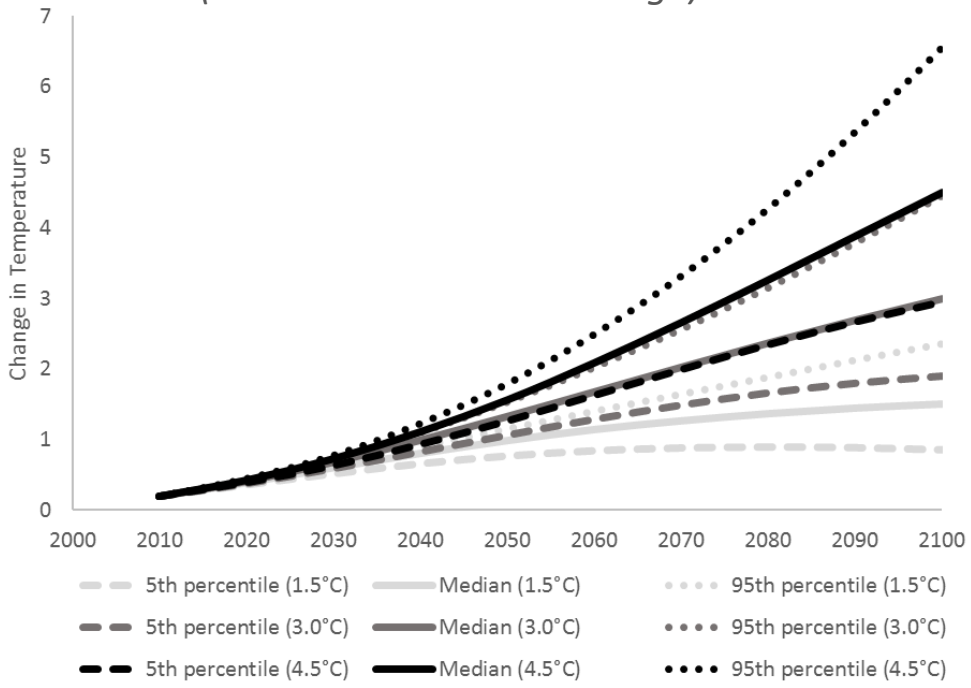
Many important impacts are not included in the modeling framework. Future work will expand and deepen the sectors covered.

Extension 2 – Introduce damages from reduced-form models

- Reduced-form damage functions were developed for 15 CIRA sectors based on CIRA 2.0 results at the NCA-region level as functions of temperature, precipitation, population, and GDP.
  - Publication forthcoming in REEP: "*Climate damage functions for estimating the economic impacts of climate change in the United States*" by Neumann, Wilwerth, Martinich, McFarland, Sarofim, and Yohe.
- Projected damages were developed for three end-of-century temperature targets (1.5, 3.0, and 4.5 C) for median, 5th and 95th moments to capture uncertainty in climate system and damage functions.

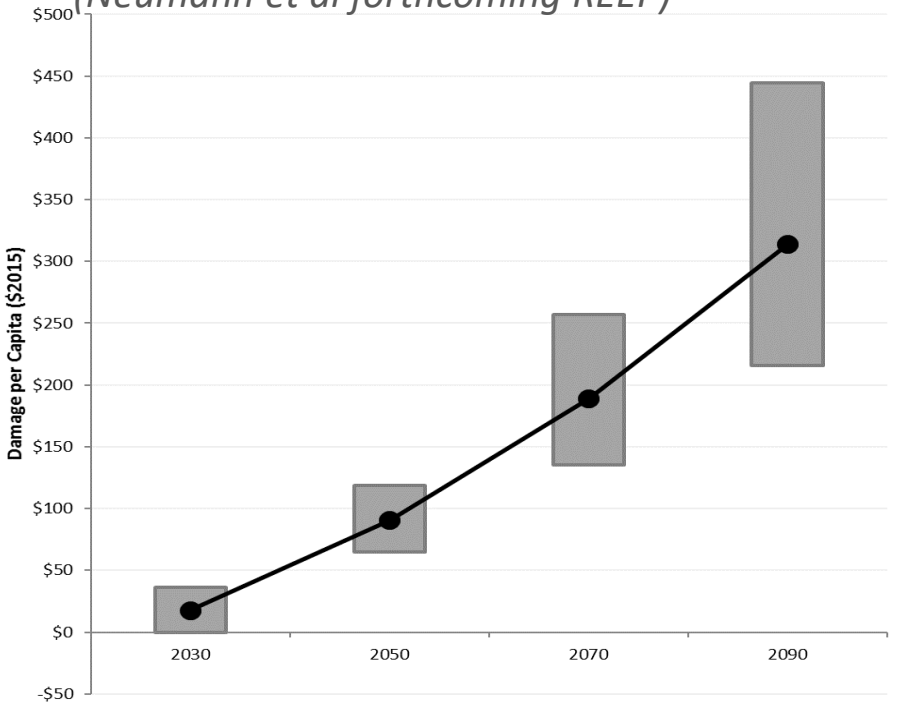
Trajectories of Global Mean Temperatures

(Yohe 2017 Climatic Change)



Estimated Economic Damage Uncertainty Range - Labor Sector in S. Grt Plains Region

(Neumann et al forthcoming REEP)



Database developments

- State-level GHG emissions consistent with national inventory
  - 1990 to present
- Non-CO2 GHG Marginal Abatement Cost Curves
  - Projections and Abatement Curves to 2050
- Potential areas:
  - Agriculture
  - Forestry

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