The Economic Effects of Climate Change in Dynamic Spatial Equilibrium

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Spatial-Environment Reading Group – UChicago

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Introduction – Motivation

- Goal : measure the welfare and distributional impact of climate change, both in the US and in the world
  1. Develop a dynamic-spatial equilibrium model
  2. Build a dynamic envelope theorem method (reduce form)

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  - Heterogeneous impact across countries and sectors
  - Input-Output linkages (across sectors)
  - Trade (across countries)
  - Labor reallocations
  - Migrations

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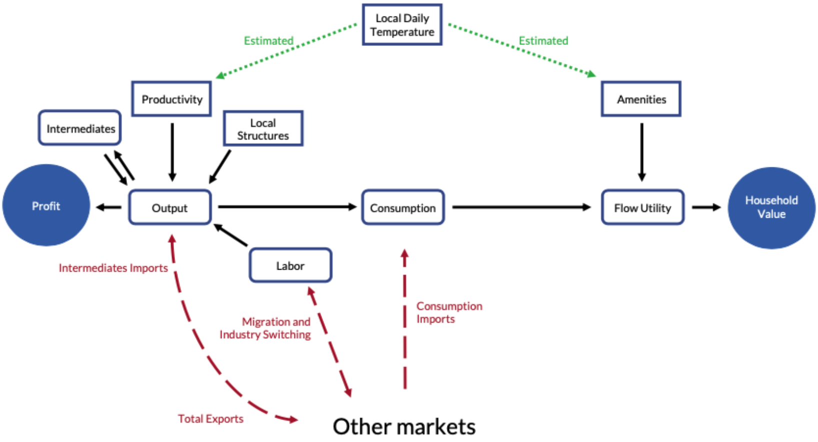
  - Input-Output linkages (across sectors)
  - Trade (across countries)
  - Labor reallocations
  - Migrations
- Main results :
  - Warming reduces US welfare by 4% and global welfare by over 20%
  - Amplification due to realistic features
  - Market adaptation : small but trade and labor reallocation complementary

Graphical Representation



Household, migration and labor reallocation

- Household welfare working in industry k and in country n

$$U\left(C_{n,t}^{k}, B_{n,t}\right) = \log\left(B_{n,t} C_{n,t}^{k}\right) \qquad B_{n,t} = \bar{B}_{n,t} \exp\left(f\left(\mathbf{T_{n,t}}; \zeta_{\mathbf{B}}\right)\right)$$

  - $C_{n,t}^{k}$ Cobb-Douglas across sectors $c_{n,t}^{ks}$ & $c_{n,t}^{ks}$ CES across varieties ξ. Consuming wage/price index $C_{n,t}^{k} = w_{n,t}^{k} / P_{n,t}$
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- Migration decisions to move to country $n \rightarrow i$ and reallocate in the industry $s \rightarrow k$
  - Receive $V_{i,t+1}^{s}$ discounted of a fixed cost μ_{ni}^{ks} and shocks $\nu\epsilon_{i,t}^{s} \sim T1EV$, Yields :

$$\pi_{ni,t}^{ks} = \frac{\exp\left[\left(\beta V_{i,t+1}^{s} - \mu_{ni}^{ks}\right)/\nu\right]}{\sum_{l=1}^{N}\sum_{h=0}^{K} \exp\left[\left(\beta V_{l,t+1}^{h} - \mu_{nl}^{kh}\right)/\nu\right]}$$

Production and I-O Linkages

- In sector k, IO linkages : production $q^k_{n,t}$, cost $x^k_{i,t}$ Cobb-Douglas :

$$q^k_{n,t} = z^k_{n,t}\left[\left(H^k_n\right)^{\psi^k}\left(L^k_{n,t}\right)^{1-\psi^k}\right]^{\gamma^k_n}\prod_{s=1}^{K}\left(M^{ks}_{n,t}\right)^{\gamma^{ks}_n}, \quad x^k_{n,t} = \kappa^k_n\left[\left(r^k_{n,t}\right)^{\psi^k}\left(w^k_{n,t}\right)^{1-\psi^k}\right]^{\gamma^k_n}\prod_{s=1}^{K}\left(P^s_{n,t}\right)^{\gamma^{ks}_n}$$

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- Firms as in Eaton Kortum : firm productivity with Fréchet distribution :

$$z^k_n \sim \mathcal{F}^k_{n,t}(z) = \exp(-Z^k_{n,t}\, z^{-\theta^k})$$

- Climate damage on productivity :

$$Z^k_{n,t} = \bar{Z}^k_{n,t}\exp\left(g\left(\mathbf{T_{n,t}};\zeta^{\mathbf{k}}_{\mathbf{Z}}\right)\right)$$

  - g and $\zeta_{\mathbf{Z}}$ to be estimated with trade flows

Trade

- Trade a la Eaton Kortum : ships from country i to n in industry k at iceberg cost $\tau^k_{ni,t}$

$$p^k_{n,t}(\xi) = \min_{1 \leq i \leq N} \left\{ \frac{\tau^k_{ni,t} x^k_{i,t}}{z^k_{i,t}(\xi)} \right\} \qquad \lambda^k_{ni,t} = \frac{X^k_{ni,t}}{X^k_{n,t}} = \frac{Z^k_{i,t}\left(x^k_{i,t}\tau^k_{ni,t}\right)^{-\theta^k}}{\sum_l Z^k_{l,t}\left(x^k_{l,t}\tau^k_{nl,t}\right)^{-\theta^k}}$$

- Closing the model :
  - Good and market clearing in each market (n, k)
  - Trade imbalances allowed with opposite financial flows from capitalists

Estimation of climate impact

- Trade Flows Identify Effects on Local Productivity

$$\log\left(\frac{X^k_{ni,t}}{X^k_{nn,t}}\right) = \left[g\left(\mathbf{T}_{i,t};\zeta^k_{\mathbf{Z}}\right) - g\left(\mathbf{T}_{n,t};\zeta^k_{\mathbf{Z}}\right)\right] - \theta^k \log\left(\tau^k_{ni,t}\right) + \zeta_{\mathbf{X}}\mathbf{X_t} + \rho^k_t + \varphi^k_{ni} + \varepsilon^k_{ni,t}$$

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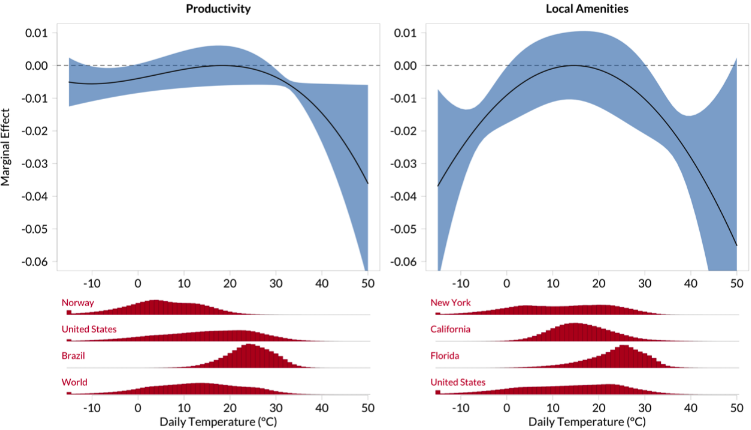
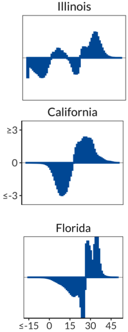
- Migration Shares Identify Effects on Local Amenities

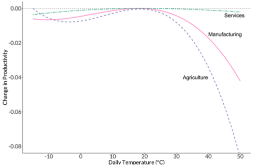
$$\log\left(\frac{\pi^{ks}_{ni,t}}{\pi^{kk}_{nn,t}}\right) = \frac{\beta}{\nu}\left[f\left(\mathbf{T}_{i,t+1};\zeta_{\mathbf{B}}\right) - f\left(\mathbf{T}_{n,t+1};\zeta_{\mathbf{B}}\right)\right] + \frac{\beta}{\nu}\log\left(\frac{\omega^s_{i,t+1}}{\omega^k_{n,t+1}}\right) + \beta\log\left(\frac{\pi^{ks}_{ni,t+1}}{\pi^{ss}_{ii,t+1}}\right) + \delta^k_t + \varphi^k_{ni} + \varepsilon^{ks}_{ni,t}$$

  - Both with PPML and parameters calibrated : $\beta = 0.98, \nu = 2.02$, $\theta^k =$ c.f. Caliendo Parro (2015)

Estimation of climate impact

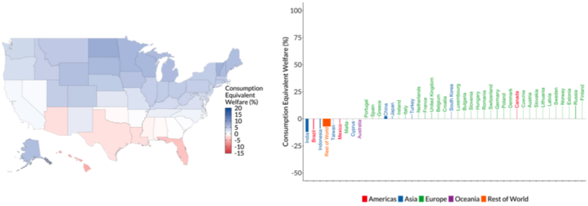




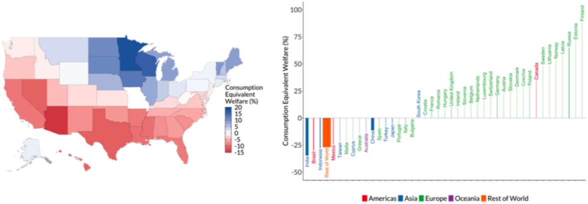


Welfare

Basic model structure with no market-based adaptation



Full model structure with market-based adaptation



Results – welfare impact of different channels

Table 1: US welfare contribution of model attributes relative to the base model.

	United States		Global	
	Without Market Adaptation	With Market Adaptation	Without Market Adaptation	With Market Adaptation
Basic Structure Welfare	**1.9%**	**2.3%**	**-4.9%**	**-5.5%**
Add Input-Output Linkages	-0.9pp	-0.9pp	+1.2pp	+0.4pp
Add Amenities	-6.2pp	-6.5pp	-18pp	-17.9pp
Add Forward-Looking US Households	+0pp	+0.2pp	+0pp	+0pp
Add Industry Heterogeneity	-0.9pp	-1.1pp	+2.9pp	+3.2pp
Add Daily Temperature	-4.6pp	-5.3pp	-4.3pp	-4.2pp
Add All	-5.9pp	-5.4pp	-16.2pp	-16.2pp

Table 2: US welfare contribution of adaptation through trade, migration, and industry switching: 2015–2100.

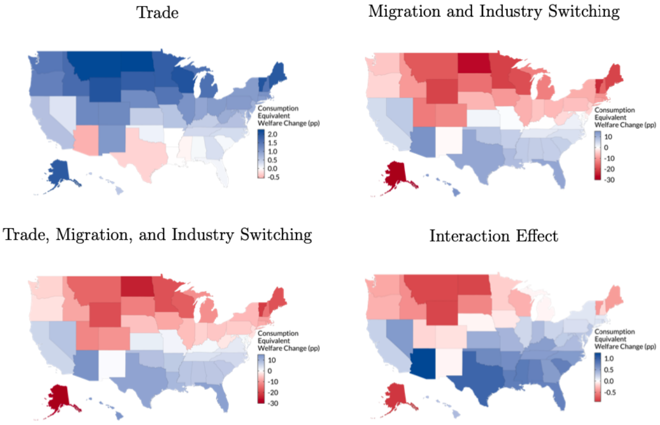
Full Structure Welfare	Add Trade Adjustments	Add Migration and Industry Switching	Add All
-4.064%	+0.668pp	+0.004pp	+1.004pp

Other results on market adaptation

- Migration / labor outflows from southern states ($\sim 1.5 - 2\%$)
- Increase in employment in manufacturing and agriculture, because US less negatively affected than the rest of the world.
- Trade affects south negatively
- Migration and industry switching hurts the north because of inflows, depressing wages
- Complementarity Trade, Migration and Labor reallocation

Results – welfare impact of different channels

Figure 7: Welfare value of adaptation mechanisms: 2015–2100.



Estimating Welfare Impacts – A reduced form approach

- Recall the migration share expression :

$$\pi_{ni,t}^{ks} = \frac{\exp\left[\left(\beta V_{i,t+1}^{s} - \mu_{ni}^{ks}\right)/\nu\right]}{\sum_{l=1}^{N}\sum_{h=0}^{K}\exp\left[\left(\beta V_{l,t+1}^{h} - \mu_{nl}^{kh}\right)/\nu\right]}$$

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- This is the solution of the problem of a representative agent problem :

$$V^{k}_{n,t} = \max_{\{\pi^{ks}_{ni,t}\}^{N}_{i,s}} U^{k}_{n,t} + \sum_{i=1}^{N}\sum_{s=0}^{K}\pi^{ks}_{ni,t}\left[\beta V^{s}_{i,t+1} - \mu^{ks}_{ni}\right] - \nu\sum_{i=1}^{N}\sum_{s=0}^{K}\pi^{ks}_{ni,t}\log\pi^{ks}_{ni,t} \qquad \text{s.t} \sum_{i=1}^{N}\sum_{s=0}^{K}\pi^{ks}_{ni,t} = 1 \quad \forall n, i, k, s, t$$

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- Taking the Lagrangian and using the Envelope theorem, we obtain :

$$\frac{\partial V^{k}_{n,t}}{\partial \mathbf{C}_{n,t+1}} = \underbrace{\sum_{i=1}^{N}\sum_{s=0}^{K}\underbrace{\frac{\partial \mathcal{L}^{k}_{n,t}}{\partial \pi^{ks}_{ni,t}}}_{=0}\frac{\partial \pi^{ks}_{ni,t}}{\partial \mathbf{C}_{n,t+1}}}_{\text{indirect effect }=0} + \underbrace{\sum_{s=0}^{N}\sum_{=0}^{K}\frac{\partial \mathcal{L}^{k}_{n,t}}{\partial V^{s}_{i,t+1}}\frac{\beta\partial V^{s}_{i,t+1}}{\partial \mathbf{T}_{n,t+1}}\underbrace{\frac{\partial \mathbf{T}_{i,t+1}}{\partial \mathbf{C}_{i,t+1}}}_{=1}}_{\text{direct effect}} = \sum_{s=0}^{N}\sum_{=0}^{K}\pi^{ks}_{ni,t}\beta\frac{\partial V^{s}_{i,t+1}}{\partial \mathbf{T}_{n,t+1}}$$

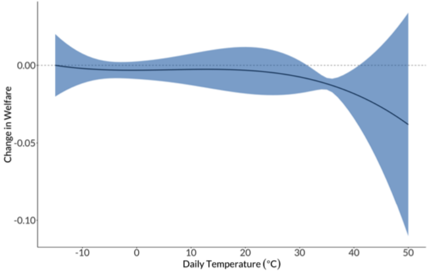
Estimating Welfare Impacts – A reduced form approach

- Rewriting the migration flow

$$\log \pi^{ks}_{ni,t} = \frac{\beta}{\nu} V^{s}_{i,t+1} - \frac{1}{\nu}\mu^{ks}_{ni} \underbrace{- \sum_{l=1}^{N}\sum_{h=0}^{K} \exp\left[\left(\beta V^{h}_{l,t+1} - \mu^{kh}_{nl}\right)/\nu\right]}_{=\widetilde{\delta}^{k}_{n,t}}$$

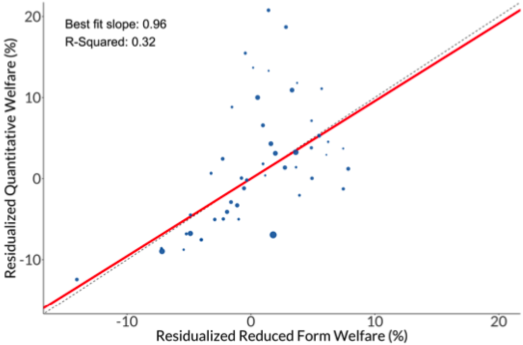
- yields the estimation equation :

$$\log \pi^{ks}_{ni,t} = \frac{\beta}{\nu} h\left(\mathbf{T}_{i,t+1}; \zeta_{\mathbf{D}}\right) + \delta^{k}_{n,t} + \varphi^{ks}_{ni} + \varepsilon^{ks}_{ni,t}$$



Estimating Welfare Impacts – Comparison Reduced Form

Figure 9: Reduced form welfare versus structural welfare.



Conclusion

- Develop two approaches for evaluating the economic impact of climate change
- Main result : market adaptation is significant :
  - Can account for close to 10% of southern states
  - Trade and labor reallocation complementary, otherwise, trade adjustments alone are regressive (South worse off)
- New way of estimating climate damage
  - Effect on productivity well identified with trade data
  - Effect on utility using migration flows, controlling for wages
- Importance of heterogeneity