New Perspectives on Climate-Macroeconomics

LSE Environment Week

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September 2025

The state of climate-macro

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- The dominant approach to **climate-macro** has been structural
- Write down **integrated assessment/computable general equilibrium** models to study climate change and policy
  - Extremely important research agenda $\Rightarrow$ how to jointly model climate & economy
  - Culminated in Nordhaus' Nobel Prize
- **Key challenge**: have to discipline key model parameters/objects
  - Climate damage function
  - Abatement cost function
  - Elasticity of substitution between inputs (different energy inputs, capital, labor)
  - …

The state of climate-macro

- Influential literature has exploited variation at the micro level
  - Facilities, firms, regions, countries, ...
  - Credible identification, absorbing potential endogeneity using fixed effects
  - Great to study heterogeneity / speak to certain mechanisms
- **But** estimates micro-elasticities/relative effects $\neq$ macro-elasticities/aggregate effects

  $\Rightarrow$ Missing intercept problem
- In macro: Key object of interest are **macro-elasticities**

Ben Moll's explanation of the missing intercept problem

We want to answer: How does government spending impact output?

- Local government spending: x_{it}, aggregate $X_t = \sum_i x_{it}$
- Local GDP: y_{it}, aggregate $Y_t = \sum_i y_{it}$

We assume the **local relationship**:

$$y_{it} = \alpha + \beta x_{it} + \gamma X_t + \varepsilon_{it}$$

- β: Effect of higher local spending relative to other regions
- γ: Spillovers from aggregate government spending
  - Captures trade, mobility, demand linkages, etc.

Ben Moll's explanation of the missing intercept problem

Aggregate relationship:

$$Y_t = \alpha + (\beta + \gamma)X_t \quad \Rightarrow \quad \Delta Y_t = (\beta + \gamma)\Delta X_t$$

When estimating locally, X_t gets absorbed into intercept

$$y_{it} = \tilde{\alpha}_t + \beta x_{it} + \varepsilon_{it}, \quad \tilde{\alpha}_t = \alpha + \gamma X_t$$

Learnings:

- Cross-sectional variation identifies β, but not γ
- Naive exercise uses cross-sectional β to scale aggregate change: $\Delta Y_t = \beta \cdot \Delta X_t$
- But the true aggregate effect is: $\Delta Y_t = (\beta + \gamma) \cdot \Delta X_t$

Solutions to the missing intercept problem

- In short: need more structure...
- **Dominant approach**: write down structural model to map micro to macro effects
  - Either fully specified model or with sufficient statistics estimable from the data
- **Alternative**: exploit time-series variation to estimate aggregate effect of X_t on Y_t
  - This approach has a lot of promise, especially in the **climate/environment** context
  - Why? Canonical application: identifying the macro effects of monetary policy
  - Challenge: monetary policy systematically responds to economy at high frequency
  - Climate moves more slowly: easier to estimate the effect of temperature on GDP

Outline of this talk

1. Estimating climate damages

2. Estimating abatement costs

3. Updating cost-benefit analyses

Estimating climate damages

Estimating climate damages: Bilal & Känzig (2025)

- Climate change is often portrayed as having **major economic consequences**
- Yet empirical estimates imply **moderate** 1-2% GDP loss per 1°C 5-10 years out
  (Nordhaus 1992, Dell et al. 2012, Burke et al. 2015, Nath et al. 2023, Kotz et al. 2024)
- All focus on within-country, local temperature panel variation

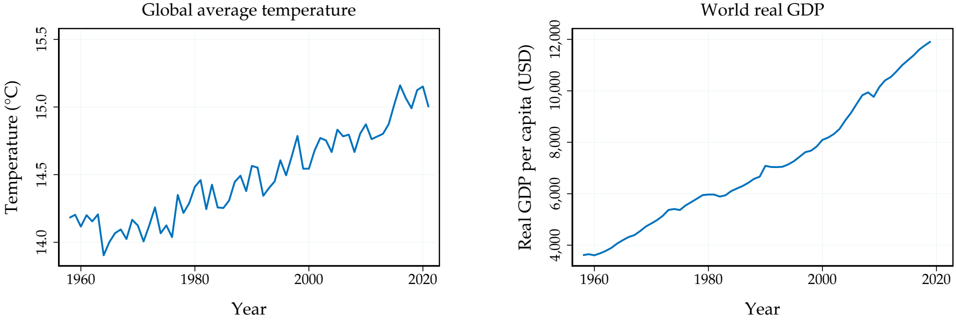
Questions

- Are the economic consequences of climate change moderate at most?
- Or is local temperature a partial representation of climate change?

Estimating climate damages: Bilal & Känzig (2025)

- We propose new focus on **global temperature**
- Key **summary statistic** of climate change, used by the IPCC
- Includes **ocean** surface temperature!
- Lots of time-series variation in global temperature unrelated to economic activity
  - Natural climate variability: El Niño, solar cycles, volcanic eruptions, …
- What do we get from this approach?

Global temperature and economic growth



Notes: Global average temperature (including sea surface) from NOAA, world real GDP from PWT

- **Global temperature** and **world GDP** both trending up over our sample
- May bias estimated effects of temperature on output
- Focus on **temperature shocks**

Measuring temperature shocks and tracing their effects

- Use approach by Hamilton (2018) as in Nath et al. (2024) for local temperature
- Estimate **innovation** in global temperature process as forecast error

$$\boldsymbol{T_t^{\text{shock}}} = T_t - (\hat{\beta}_0 + \hat{\beta}_1 T_{t-q} + \ldots + \hat{\beta}_{p+1} T_{t-q-p}),$$

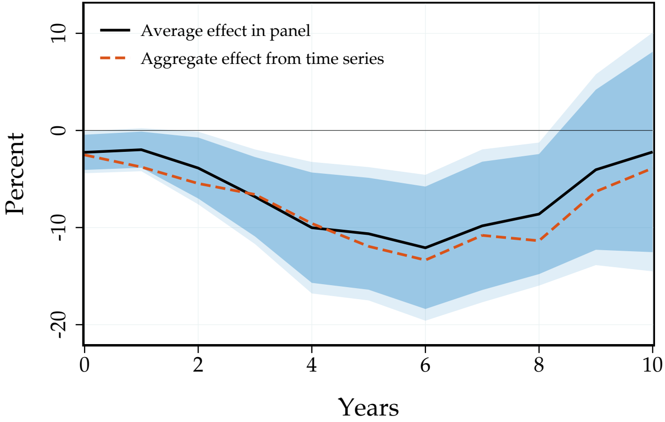
  - Driven by solar cycles, volcanic eruptions, and internal climate variability (e.g. El Niño)
  - Virtually identical results if use HP filter, etc.

- Estimate effects of global temperature shocks using local projections (Jordà et al. 2020)

$$y_{i,t+h} - y_{i,t-1} = \alpha_{i,h} + \boldsymbol{\theta_h} \boldsymbol{T_t^{\text{shock}}} + \mathbf{x}_t' \beta_h + \mathbf{x}_{i,t}' \gamma_h + \varepsilon_{i,t+h}$$

  - $y_{i,t}$ is real GDP per capita of country i
  - $\mathbf{x}_t, \mathbf{x}_{i,t}$ are vectors of global and country-level controls

The impact of a 1°C global temperature shock



Notes: 90 and 95% confidence bands based on Driscoll-Kraay standard errors. GDP per capita data: Penn World Tables for 173 countries, 1960-2019.

Robustness

1. **Omitted variable bias (global)**
   - Stable regardless of macro controls (lagged GDP, oil prices, interest rates, world recessions)
   - Not driven by particular years and robust to jackknife
2. **Reverse causality**
   - Virtually no change after adjusting for feedback from emissions to temperature
3. **External validity**
   - Estimates stable over time (1900-2019, 1985-2019, 1960-2007)
   - Estimates stable by source of global temperature variation (e.g. controlling for El Niño)
4. **Omitted variable bias (regional)**
   - Stable regardless of regional & country controls (regional trends, lagged country GDP)
   - No discernable pre-trends

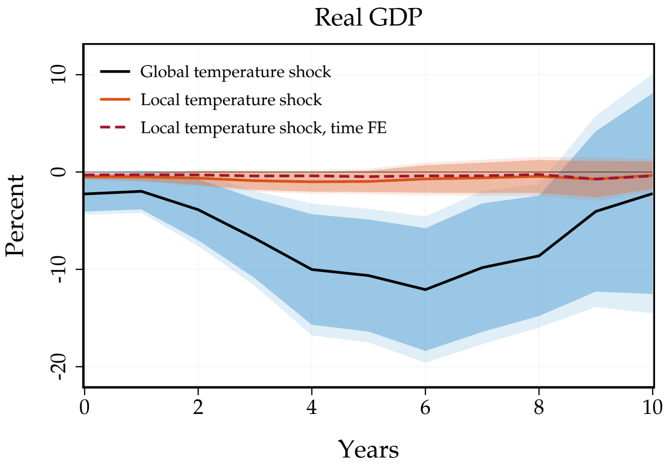
Global vs. local temperature shocks

- How do **global** temperature shocks compare to **local** country-level temperature shocks?
  - Virtually **all previous work** uses **local** temperature shocks
- To maximize comparability, estimate responses using
  - Same specification
  - Same data
- Just replace global temperature shock with **local temperature shock**

$$y_{i,t+h} - y_{i,t-1} = \alpha_{i,h} + (\ \delta_{t,h} +\ )\ \theta_h \boldsymbol{T_{i,t}^{\text{shock}}} + \mathbf{x}_t' \beta_h + \mathbf{x}_{i,t}' \gamma_h + \varepsilon_{i,t+h}$$

  - Without and with time fixed effects

Impact of global vs. local temperature shocks

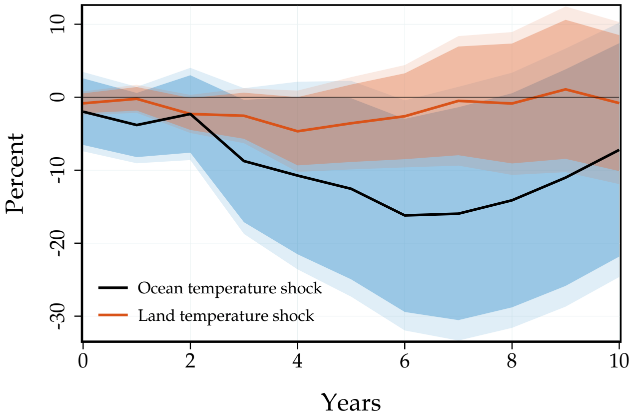


Notes: Point estimate with 90 and 95% confidence bands based on Driscoll-Kraay SE

Why is global temperature different?

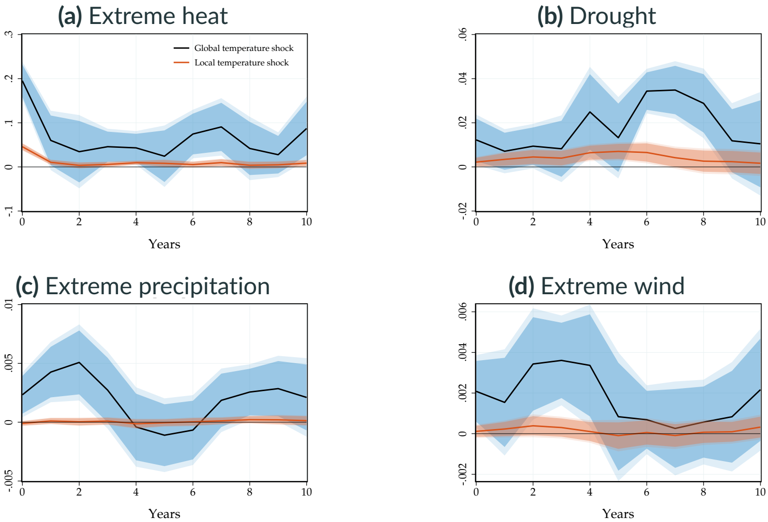
- Conjecture that **global temperature is fundamentally different** from local temperature
- Global temperature: better **summary statistic** of state of climate system
- Includes **ocean surface temperatures**
- Better captures the frequency, intensity, and distribution of extreme weather events
- Captures correlated nature of local shocks and spillovers

Oceans drive global temperature effects

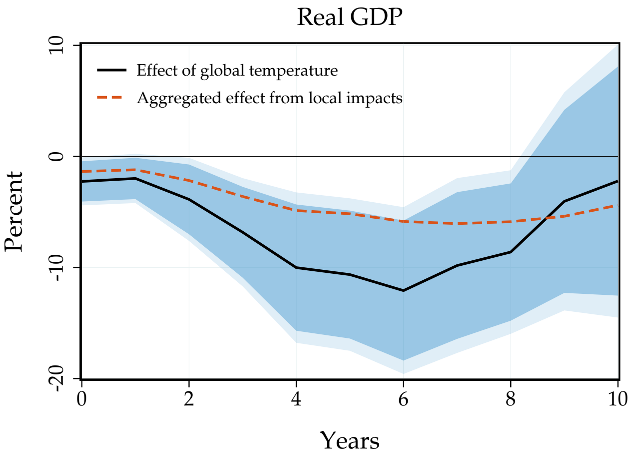


Notes: joint estimation of the impact of ocean and land temperatures. 90 and 95% confidence intervals.

Damaging extreme events correlate strongly with global temperature



Extreme events help rationalize the impact of global temperature

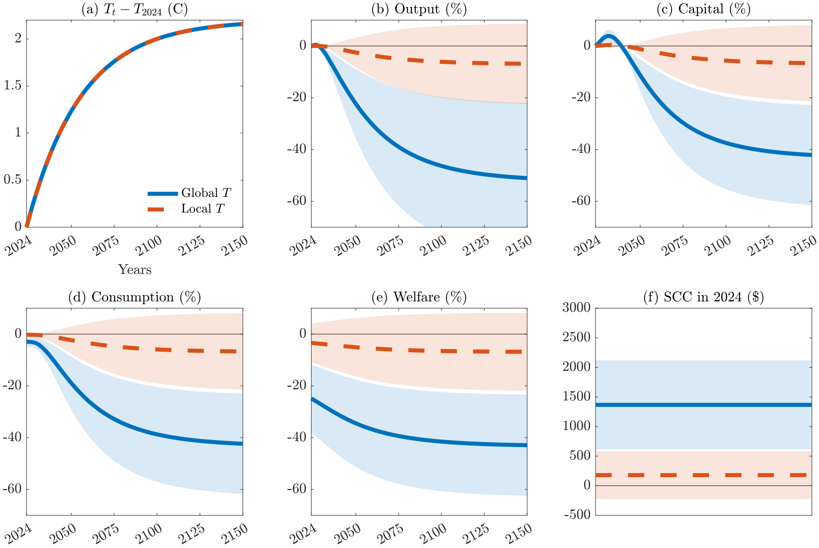


Notes: predicted effect on GDP based on aggregating local impacts. Interact frequency response of extremes to global temperature with estimated damages of extremes. 90 and 95% confidence intervals.

A simple climate-economy model

- Use the **neoclassical growth model**
  - Damage function: temperature reduces aggregate productivity
  - Includes lagged effects
- **Estimate damage function** by matching estimated output responses in the data
  - Characterize **identification in model**
  - Estimation accounts for internal persistence of temperature
- Use estimated model to perform **counterfactual** analyses and estimate **SCC**
  - Consider business-as-usual scenario with additional 2°C warming by 2100
  - Use climate sensitivity from state-of-the-art climate models

The impact of climate change



Updating damage estimates

- Global temperature shocks have large economic effects
  - 1°C global temperature causes **12%** decline in world GDP vs. **1%** for local temperature
- Why? **Geophysical** explanation:
  - **Global** temperature estimates driven by **ocean temperature**, not **land temperature**
  - **Global** temp shocks predict damaging **extreme events**: explain 2/3 of direct estimate
  - **Local** temperature shocks do not
- Global temperature shocks imply large **SCC** and **welfare costs** of climate change
  - Use reduced-form impacts to estimate damage functions in IAM and infer long-run effects
  - **SCC** $\geq$ **\$1,300/tCO2** for global temperature vs. $\leq$ **\$180/tCO2** for local temperature
  - Adding 2°C to 2024 temperature by 2100 implies a **25% welfare loss**

Estimating abatement costs

Carbon pricing across the globe

- Looming **climate crisis** put climate change at **top** of the **global policy agenda**
- **Carbon pricing** increasingly used as a tool to mitigate climate change **but:**
- **Little known** about effects on **emissions** and the **economy** in practice
  - Effectiveness?
  - Short-term economic costs?
  - Distributional consequences?
- With $>$20 years of practical experience in carbon pricing, what does the data say?

Estimating the impacts of carbon pricing: Känzig (2025)

- **Challenge**: carbon prices are not set in a vacuum
  - Policymakers respond to macroeconomic developments when deciding on climate policy
  - Cap-and-trade prices are market prices driven by demand & supply
- Identification challenge more acute for cap-and-trade prices
- But: **institutional** features allow for credible identification of carbon price impacts
  - Cap-and-trade regulates quantity, establishes **market price** for carbon
  - Liquid **futures markets** on allowances
  - Regulations in the market **changed** considerably over time
  - Isolate **exogenous** variation by measuring carbon price change in **tight window** around **policy events**

EU carbon price

Regulatory events

- Collected **comprehensive list** of **regulatory update** events
  - Decisions of European Commission
  - Votes of European Parliament
  - Judgments of European courts
- Of interest in this paper: regulatory news on the **supply of allowances**
  - National **allocation plans**
  - **Auctions**: timing and quantities
  - Use of international credits
- **Identified 114** relevant **events** from 2005-2019

High-frequency identification

- **Idea**: Identify carbon policy surprises from changes in EUA futures price in tight window around regulatory event

$$\text{CPSurprise}_d = \frac{F_d^{\text{carbon}} - F_{d-1}^{\text{carbon}}}{P_{d-1}^{\text{elec}}}$$

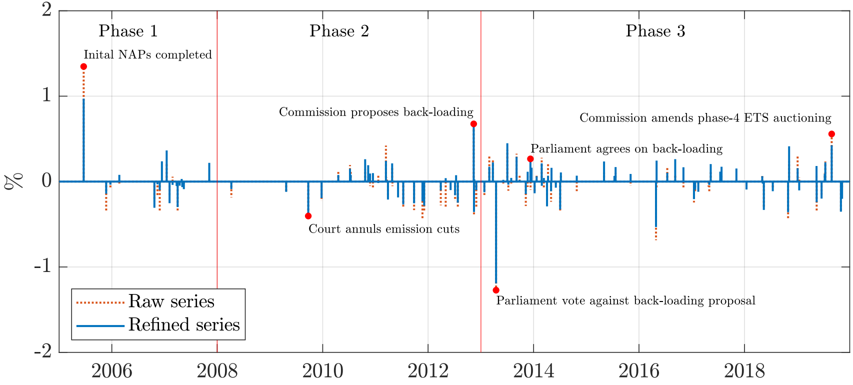
where $F_{t,d}$ is log settlement price of the EUA front contract on event day d in month t

- Purge from potential predictability from macro- & financial variables, $\text{CPSurprise}_d^{\perp}$

- Aggregate surprises to **monthly** series

$$CPSurprise_t^{\perp} = \begin{cases} CPSurprise_{t,d}^{\perp} & \text{if one event} \\ \sum_i CPSurprise_{t,d_i}^{\perp} & \text{if multiple events} \\ 0 & \text{if no event} \end{cases}$$

Carbon policy surprises



Econometric framework

- **Carbon policy surprise series** has good properties but still imperfect measure

  $\Rightarrow$ Use it as an **instrument** to estimate dynamic causal effects on variables of interest

- For estimation I rely on VAR techniques given the short sample

- **Identifying assumptions**:

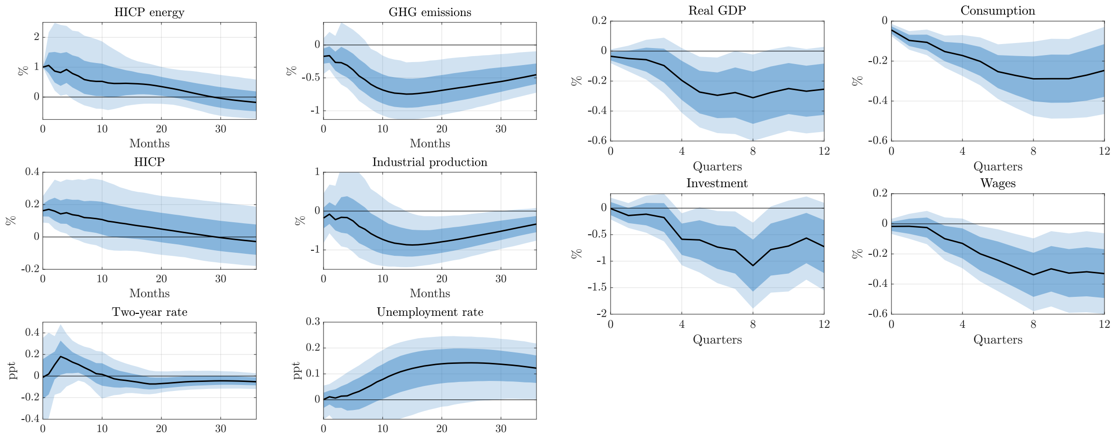
$$\mathbb{E}[z_t \varepsilon_{1,t}] = \alpha \neq 0 \qquad \text{(Relevance)}$$

$$\mathbb{E}[z_t \boldsymbol{\varepsilon}_{2:n,t}] = \mathbf{0}, \qquad \text{(Exogeneity)}$$

$$\mathbf{u}_t = \mathbf{S}\boldsymbol{\varepsilon}_t \qquad \text{(Invertibility)}$$

- Use **carbon policy surprise series** as *external instrument* for **energy price**

The aggregate effects of carbon pricing



Notes: The solid line is the point estimate and the dark and light shaded areas are 68 and 90% confidence bands

Revisiting marginal abatement cost

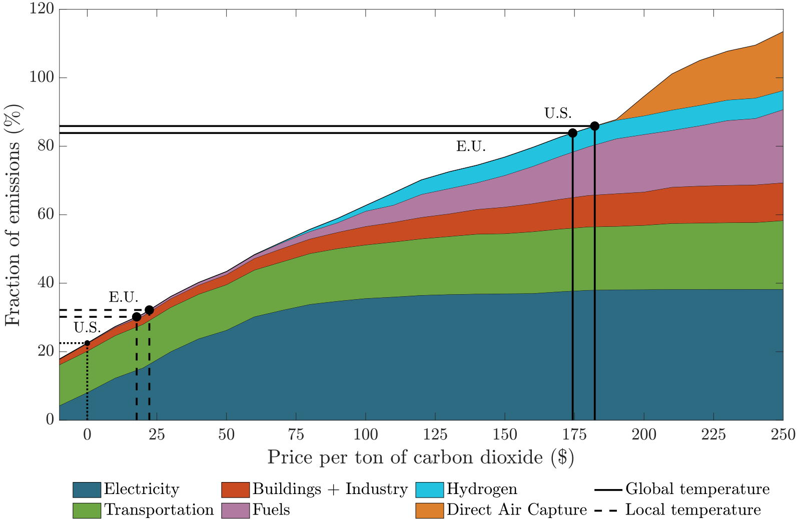
- Back-of-the-envelope estimate based on impulse responses gives **MAC** of $\approx$ €107/tCO_2
- Higher than many engineering estimates & avg. ETS price over the sample $\approx$ €12/tCO_2
  - Market prices do **not internalize** GE effects via prices, consumption, employment
  - Higher economy-wide costs of decarbonization
- Important implications for **cost-benefit analyses**

Updating cost-benefit analyses

Updating cost-benefit analyses: Bilal & Känzig (AEAPP, 2025)

- Most large-scale decarbonization policies in IRA cost $\approx$**\$80/tCO2** (Bistline et al. 2023)
  - Below traditional **worldwide** SCC estimates, e.g. **\$180/tCO2** with **local temperature**
  - But higher than **US-only** Domestic Cost of Carbon, e.g. **\$35/tCO2** with **local temperature**
  - So **unilateral, non-cooperative** policy is **not cost-effective**
- Our estimates with **global temperature** entirely **reverse this trade-off**
  - Even the **US-only** Domestic Cost of Carbon is $\geq$ **\$200/tCO2**
  - Higher than the cost of decarbonization
  - So **unilateral, non-cooperative** decarbonization policy becomes **cost-effective**

Carbon policy surprises



Thank you!