Climate Tradeoffs: Emission Mitigation Policy, Public Assistance, and Adapting to a Warming Planet

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AERE@ASSA

The New York Times
2024 Brought the World to a Dangerous Warming Threshold. Now What?
Global temperatures last year crept past a key goal, raising questions about how much nations can stop the planet from heating up further.
Global temperatures compared with late-19th-century average
+1.5°C
+1.0
+0.5
2024 average
+1.6°C
Monthly temperature
1940
1960
1980
2000
2020
Source: Copernicus/ECMWF · Note: Temperature anomalies relative to 1850-1900 averages.
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363
By Raymond Zhong and Brad Plumer. Graphics by Mira Rojanasakul. Jan. 9, 2025
The New American
The Cooled
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By Jeff Goodell
Visuals by Tova Katzman
Mr. Goodell has been reporting on climate
Heat Will Kill You First: Life and Death on a S
Aug. 20, 2025
THE WALL STREET JOURNAL.
ets & Finance
Opinion
Arts
Lifestyl
Affect Your
arts of the U.S., according to
climate change
ange is making heat more

Motivation: Adaptation-Mitigation Tradeoff

- Extreme temperatures are dangerous for human health
  - Climate change $\rightarrow$ more extreme heat days
- Air conditioning is an important adaptation to heat exposure
  - Marginal cost of this adaptation: electricity prices
- Adaptation-Mitigation Tradeoff
  - Climate policy (**mitigation**) raises the cost of electricity (**adaptation**)
  - Higher prices could exacerbate health consequences
- *How is the temperature-mortality response function influenced by:*
  - Marginal cost of adaptation (residential electricity prices)
  - Targeted public assistance programs (LIHEAP cooling benefits)

This paper

What we do:

- Spatial border-pair research design: compare adjacent counties across state lines
  - Examine how electricity prices and public assistance influence temperature-mortality fn
- Simulate mortality impacts of future warming and electricity price changes

What we find:

- Higher residential electricity prices exacerbate mortality effects of extreme heat
  - 1-SD increase in price → 0.21 addt'l deaths per 100,000 for an extra 35°C day
- More generous assistance (LIHEAP) has countervailing effect
  - 1-SD increase in LIHEAP cooling benefits → 0.16 fewer addt'l deaths per 100,000
- Higher electricity prices modestly increase projected mortality burden of climate change

Related literature

- Temperature-mortality response function & role of adaptation

  Deschênes and Moretti (2009); Deschênes and Greenstone (2011); Deschênes (2014); Davis and Gertler (2015); Heutel et al. (2021); Carleton et al. (2022); Barreca et al. (2022)

  - Importance of adaptive investments in moderating the health impacts of climate

- Role of energy prices in adaptation; "heat or eat" tradeoff

  Bhattacharya et al. (2003); Beatty et al. (2014); Doremus et al. (2022); He and Tanaka (2023); Chirakijja et al. (2023)

  - Adaptive technologies may be unequally realized due to price/income constraints

- Role of public programs and safety nets that support adaptation

  Mullins and White (2020); Banerjee and Maharaj (2020); Garg et al. (2020); Cohen and Dechezleprêtre (2022); Brewer and Goldgar (2024); Garg et al. (2025)

  - Assistance/adaptation programs may reduce marginal damages of extreme heat

County-month data, 2003–2019

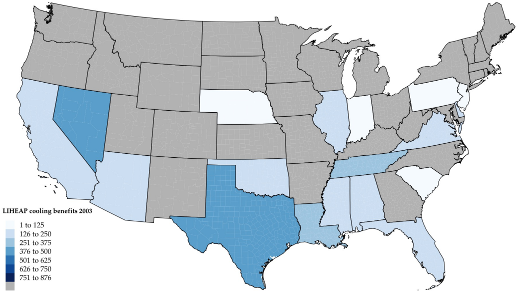
- Mortality: Restricted-use death records (CDC)
  - Combine with annual population counts by age (SEER)
  - Aggregate to county-month level and age-adjust to get rate per 100k
- Electricity prices: county-year prices indexed to state-month price changes (EIA)

  ▸ Details
- Weather: Temperature and precip aggregated from daily 2.5x2.5 mile grid (PRISM)
  - # of days mean temp is in one of 9 bins: $<$0°C, 0–5°, 5–10°C...25–30°, 30-35°, 35°+
- LIHEAP: Admin. for Children and Families' LIHEAP Performance Management Website

▸ Background on electricity use

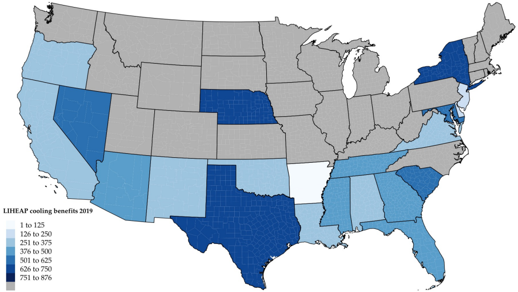
LIHEAP Cooling Benefits

2003



Avg. benefits: \$294 (\$161 w/ 0s)

2019



Avg. benefits: \$461 (\$275 w/ 0s)

▸ Electricity prices

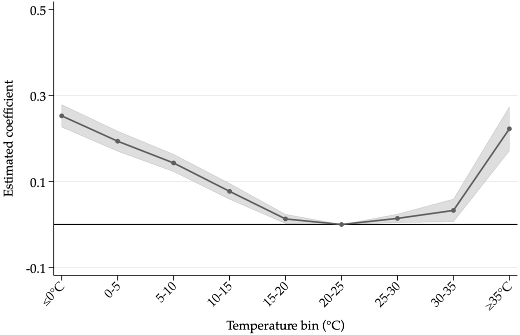
Empirical approach: Temperature-mortality response function

- We first recover temp-mort response function by estimating:

$$Y_{jmy} = \sum_k \beta_k T_{jmyk} + \pi X_{jmy} + \delta_{jm} + \theta_{my} + \mu_{jy} + \varepsilon_{jmy}$$

  - Y_{jmy}: mortality rate (per 100,000) in county j-month m-year y
  - T_{jmyk}: number of days mean temperature is in bin k (omit 20–25°C)
  - X_{jmy}: mean precip; 20–39/40–64/65+ age shares interacted w/ month
  - δ_{jm}, θ_{my}, μ_{jy}: county-month, month-year, county-year FE
    - absorbs variation in seasonal mortality x counties, macro conditions, local changes
    - identified by variation in temp distribution within county/month/year
  - Weight by county pop; cluster on county
- β_k: mortality effect of one addtl day in bin k relative to a 20–25°C day

Temperature-mortality response function



U-shaped relationship consistent w/ other work

(e.g., Deschênes and Greenstone, 2011; Barreca et al., 2016; He and Tanaka, 2023)

Replacing a 20–25°C day with a day:

- Below 0°C → 0.25 addt'l deaths per 100k
- Over 35°C → 0.21 addt'l deaths per 100k

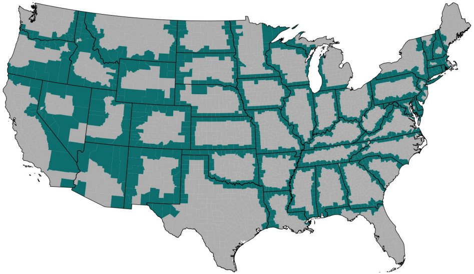
Empirical approach: Price & policy impact on response function

- For each county *on a state border*, estimate:

$$Y_{jmy} = \sum_k \beta_k T_{jmyk} + \sum_k \alpha_k (T_{jmyk} \times L_{sy}) + \sum_k \gamma_k (T_{jmyk} \times P_{jmy})$$
$$+\omega L_{sy} + \phi P_{jmy} + \pi X_{jmy} + \delta_{bm} + \theta_{my} + \mu_{by} + \varepsilon_{jmy}$$

  - Y_{jmy}, T_{jmyk}, X_{jmy}, θ_{my} defined as before
  - L_{sy}: (standardized) LIHEAP cooling benefits in state s in year y
  - P_{jym}: (standardized) price of electricity in county-month-year jmy Details
  - δ_{bm}, μ_{by}: Replace county-month/county-year w/ border-pair-month/border-pair-year FE
  - Weight by county pop times inverse # times in sample; cluster on state-state border pair
- Hypothesis: α_k negative, γ_k positive on extreme heat bins

Border-pair approach



Border counties have:

- Shared climates/temperature shocks
- Different policy regimes and prices

Central identification assumption:

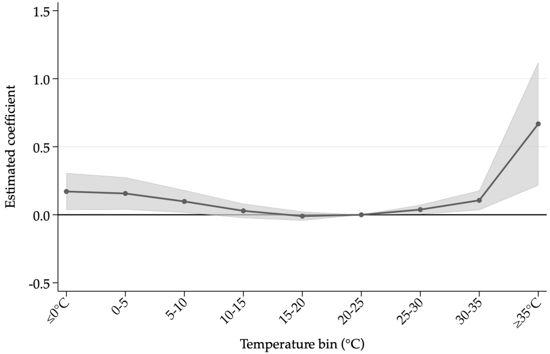
- No confounding variables independently affect temperature-mortality relationship
  - Many borders & years
  - Variation plausibly idiosyncratic x time & space

    ▸ Residualized variation

  - Robust to controlling for cross-border differences in AC adoption, other social ins. programs

Border-pair results: Coefficients on **temperature**

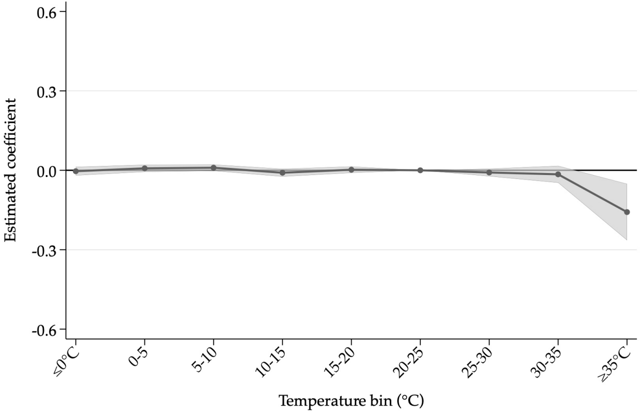
$$Y_{jmy} = \sum_k \beta_k T_{jmyk} + \sum_k \alpha_k \left(T_{jmyk} \times L_{sy}\right) + \sum_k \gamma_k \left(T_{jmyk} \times P_{jmy}\right) + \ldots \varepsilon_{jmy}$$



Border-pair w/ no price/policy vars

Border-pair results: Coefficients on **LIHEAP** interaction

$$Y_{jmy} = \sum_k \beta_k T_{jmyk} + \sum_k \alpha_k (T_{jmyk} \times L_{sy}) + \sum_k \gamma_k (T_{jmyk} \times P_{jmy}) + \ldots \varepsilon_{jmy}$$



1-SD increase in LIHEAP →

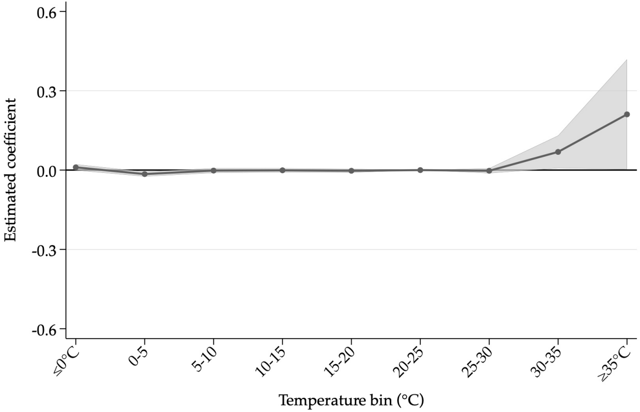
↓ mortality impact of 35°C day by **0.16 per 100k**

Compare to β_{35+}=0.67

▸ 65+ ▸ levels

Border-pair results: Coefficients on **electricity price** interaction

$$Y_{jmy} = \sum_k \beta_k T_{jmyk} + \sum_k \alpha_k \left(T_{jmyk} \times L_{sy} \right) + \sum_k \gamma_k \left(T_{jmyk} \times P_{jmy} \right) + \ldots \varepsilon_{jmy}$$



1-SD increase in price →

↑ mortality impact of addt'l 35°C day by **0.21 per 100k**

Compare to β_{35+}=0.67

▸ 65+ ▸ levels ▸ addt'l controls

Taking stock

- 1-SD increase in electricity prices (2.8¢/kWh) is 22% increase over mean (12.9¢)
  - Average AC/home cooling expenditures: \$299 in 2020 (EIA RECS)
  - 22% increase $\rightarrow$ \$66 annually for avg household
- Avg LIHEAP cooling benefits: \$461 per household (2019)
  - Modest assistance required to "reverse" mortality effect of heat/high prices
  - Assumes prices and LIHEAP benefits affect mortality through equivalent channels (prices)
- In beta: Can we say anything about "optimal" adaptation?

Simulating the mortality impact of climate change

- Combine estimated temp-mortality-price relationship with projections of:
  - Temperature (CCSM4 model, RCP4.5 scenario)
  - Electricity prices (HAIKU model, $50/ton carbon fee)
- Simulate mortality effects of two 2050 scenarios:
  - **Warming only:** RCP4.5 temperature (moderate mitigation)
  - **Climate policy:** RCP4.5 temperature + price increases from $50 carbon fee
- Apply avg. historical effects (β_k and γ_k) to these future temps and prices ▸ More details
  - Assume temperature-mortality-price relationship remains stable
- Abstract from:
  - Local variation in adaptive capacity (e.g., AC penetration)
  - Future adaptation or expansion of programs like LIHEAP
  - Statistical uncertainty in regression estimates

Simulation results

	(1) Warming only	(2) Climate policy	(3) Price effect (2 - 1)
Δmortality rate	4.76	4.86	0.10
Δtotal mortality	19,014	19,427	413

Warming only: RCP4.5 temperature (moderate mitigation)

- 19,014 additional deaths in 2050 due to "intermediate" warming scenario

Climate policy: RCP4.5 temperature + price increases from $50 carbon fee

- 19,427 additional deaths in 2050 due to warming + projected price increases

County-level estimates

Conclusion

- Residential electricity prices shape the mortality impact of extreme heat
  - Higher prices $\rightarrow$ larger mortality effects on hot days
  - LIHEAP assistance has opposing effect
  - Relationships robust to addt'l controls, alt. price construction, lagged variables, etc.
- Simulations show slightly higher mortality under climate policy due to energy prices
- Highlights an **adaptation–mitigation** tension:
  - Mitigation policy may raise the cost of adaptive behavior (e.g., cooling)
- Targeted support can encourage adaptation in a warming world

Thank you!

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Background: Residential electricity consumption

- Households rely on electricity (esp. AC) to adapt to extreme heat
  - Use shaped by outdoor temps, electricity prices, and income
- Descriptive facts from the EIA RECS survey:
  - 20% reduce/forego necessities due to energy bills
  - 15% receive disconnect notices; ∼1% lose power entirely
  - AC use ↑ with hotter weather, ↓ with higher prices
  - Energy assistance participation → lower thermostat temps
- Implications:
  - Higher prices → less cooling/adaptation
    - Energy costs may also crowd out spending on health ("heat or eat")
  - Assistance may reduce energy burdens and support adaptation

Return

Constructing County-Level Electricity Prices

- Electricity prices are only observed at the *state-month-year*
- To construct *county-month-year* prices:
  - Utility-level annual prices from EIA (Forms 861/861S) + monthly state-level changes
- Price in county j, month-year my:

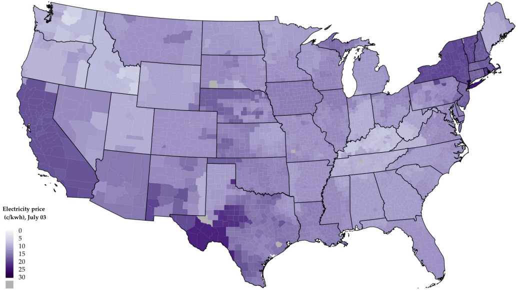
$$P^{\text{elect}}_{jmy} = \omega_{smy} \times \sum_{k \in j} (P_{ky} \times \phi_{ky})$$

  - P_{ky} = Price at utility k in year y (EIA Forms 861/861S)
  - ϕ_{ky} = # of customers served by utility k
  - ω_{smy} = price in state-month-year smy, indexed to January=1
- Assumes intra-annual price changes at the county level follow the state pattern
- All prices are adjusted to constant 2019 dollars using CPI-U

Return

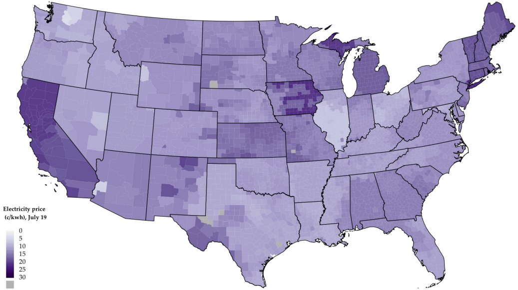
Electricity prices

2003



Avg. price: 14.6 ¢/kWh (2019 dollars)

2019



Avg. price: 13.8 ¢/kWh

◂ Return

Standardization details

1-SD increase in:

- Electricity price=2.8 cents/kilowatt hour
- LIHEAP cooling benefits=$230

Why standardize?

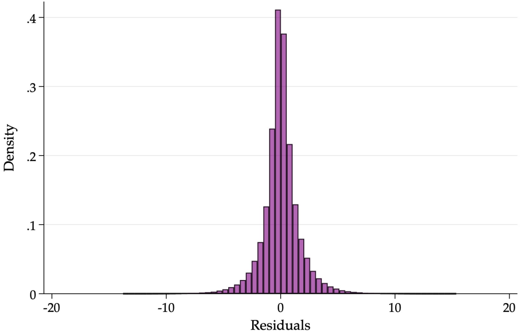
- Provides consistent scale for interpretation across variables in different units
  - γ_k vs. α_k: effect of 1-SD increase in elect. price vs. 1-SD increase in LIHEAP
- Gives uninteracted temp bin coefficients (β_k) a clear interpretation
  - Effect of temp. bin when interacted variables equal zero (i.e., at mean value)
  - Otherwise, β_k measured when electricity prices/LIHEAP=0

Findings similar when using raw dollar or log-transformed values

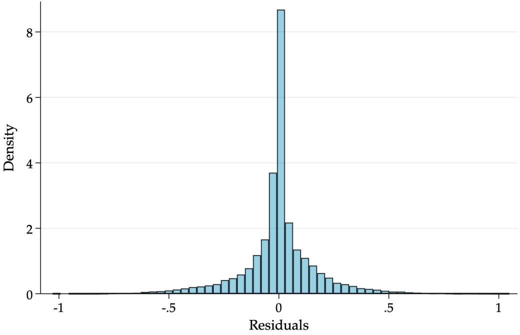
Return

Residualized price/policy distribution

(a) Residential electricity prices



(b) Avg. LIHEAP cooling benefits

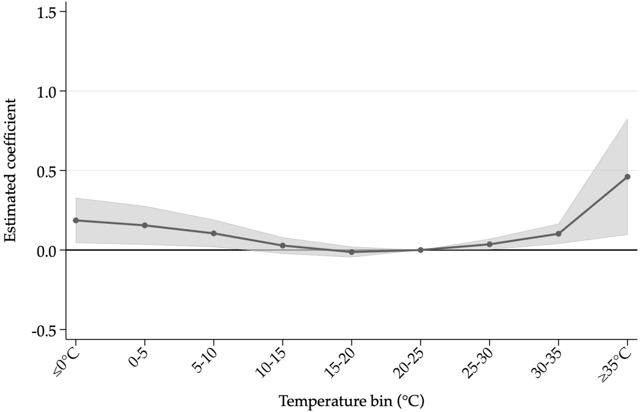


Both variables are residualized on δ_{bm}, θ_{my}, μ_{by}, and X_{jmy}

Return

Border-pair results: Coefficients on **temperature** (no policy/price vars)

$$Y_{jmy} = \sum_k \beta_k T_{jmyk} + \pi X_{jmy} + \delta_{bm} + \theta_{my} + \mu_{by} + \varepsilon_{jmy}$$

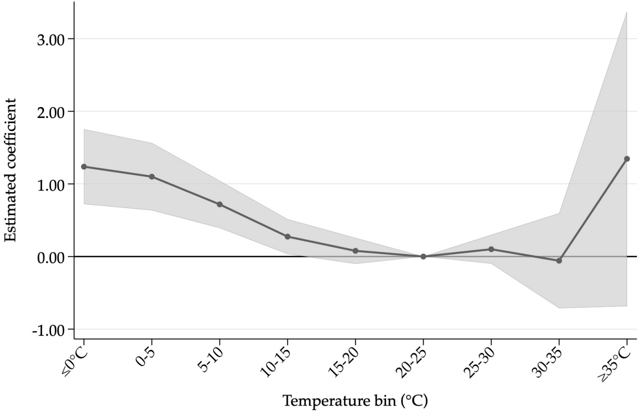


Larger extreme heat effect from border-pair modification (not price/policy variables)

Return

Border-pair results: Coefficients on **temperature (65+)**

$$Y_{jmy} = \sum_k \beta_k T_{jmyk} + \sum_k \alpha_k \left(T_{jmyk} \times L_{sy}\right) + \sum_k \gamma_k \left(T_{jmyk} \times P_{jmy}\right) + ...\varepsilon_{jmy}$$

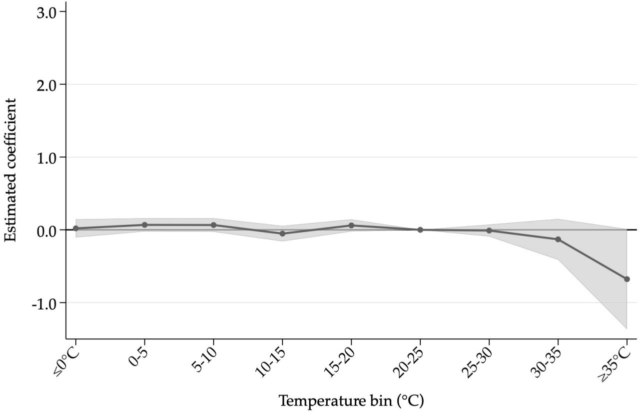


β_{35+}=1.35 (vs. 0.67)

Return

Border-pair results: Coefficients on **LIHEAP** interaction (**65+**)

$$Y_{jmy} = \sum_k \beta_k T_{jmyk} + \sum_k \alpha_k (T_{jmyk} \times L_{sy}) + \sum_k \gamma_k (T_{jmyk} \times P_{jmy}) + ...\varepsilon_{jmy}$$



1-SD increase in LIHEAP →

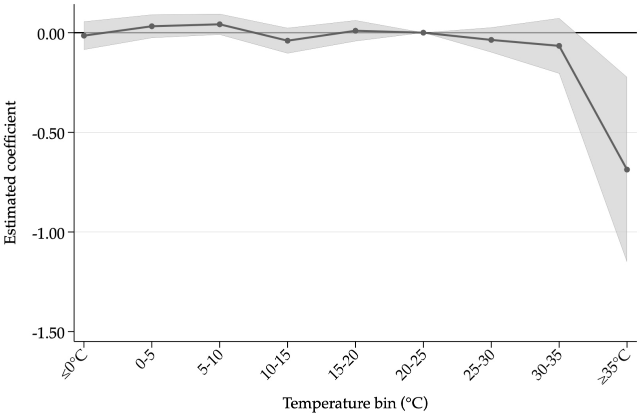
↓ mortality impact of addt'l 35°C day by **0.68 per 100k**

Compare to β_{35+}=1.35

◂ Return

Border-pair results: Coefficients on **LIHEAP** interaction (**levels**)

$$Y_{jmy} = \sum_k \beta_k T_{jmyk} + \sum_k \alpha_k (T_{jmyk} \times L_{sy}) + \sum_k \gamma_k (T_{jmyk} \times P_{jmy}) + ...\varepsilon_{jmy}$$



$1,000 increase in LIHEAP →

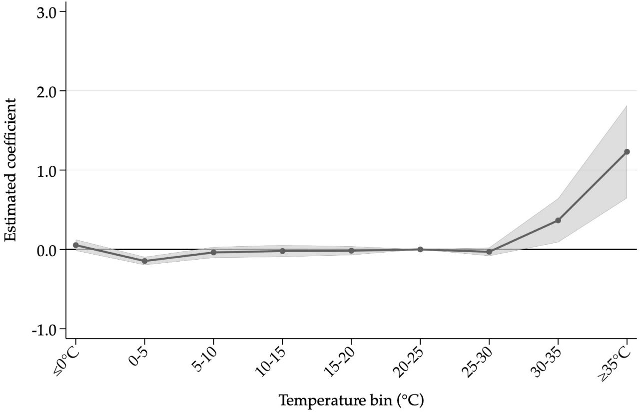
↓ mortality impact of addt'l 35°C day by **0.69 per 100k**

Same as scaling 0.16 from $230 to $1,000

◂ Return

Border-pair results: Coefficients on **electricity price** interaction (**65+**)

$$Y_{jmy} = \sum_k \beta_k T_{jmyk} + \sum_k \alpha_k (T_{jmyk} \times L_{sy}) + \sum_k \gamma_k (T_{jmyk} \times P_{jmy}) + ...\varepsilon_{jmy}$$



1-SD increase in price →

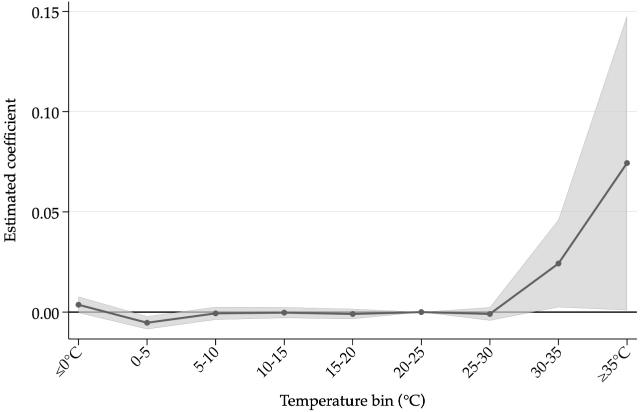
↑ mortality impact of addt'l 35°C day by **1.23 per 100k**

Compare to β_{35+}=1.35

Return

Border-pair results: Coefficients on **electricity price** interaction (**levels**)

$$Y_{jmy} = \sum_k \beta_k T_{jmyk} + \sum_k \alpha_k \left(T_{jmyk} \times L_{sy} \right) + \sum_k \gamma_k \left(T_{jmyk} \times P_{jmy} \right) + ...\varepsilon_{jmy}$$



1¢/kWh increase in price →

↑ mortality impact of addt'l 35°C day by **0.07 per 100k**

Same as scaling 0.21 from 2.8¢ to 1¢

Return

Control for initial AC adoption; state-level policies (3 temp bins)

	(1)	(2)	(3)	(4)
	Mortality rate per 100,000			
$\leq$ 0°C	0.049*	0.031	0.031	0.039*
	(0.026)	(0.024)	(0.024)	(0.023)
$\geq$ 30°C	0.155***	0.168***	0.181***	0.166***
	(0.028)	(0.026)	(0.027)	(0.026)
LIHEAP (L_{sy})$\times \leq$ 0°C	0.005	0.004	0.005	0.007
	(0.005)	(0.005)	(0.007)	(0.006)
LIHEAP (L_{sy})$\times \geq$ 30°C	-0.034***	-0.035***	-0.037***	-0.031***
	(0.012)	(0.012)	(0.012)	(0.011)
Price (P_{jmy})$\times \leq$ 0°C	0.008*	0.008*	0.012***	0.013***
	(0.005)	(0.005)	(0.004)	(0.005)
Price (P_{jmy})$\times \geq$ 30°C	0.078***	0.079***	0.086***	0.065***
	(0.030)	(0.029)	(0.024)	(0.019)
δ_{bm}, θ_{my}, μ_{by}, X_{jmy}	✓	✓	✓	✓
Baseline AC adoption		✓	✓	✓
Medicaid transfers			✓	✓
SNAP transfers				✓

*** p<0.01, ** p<0.05, * p<0.1

◂ Return

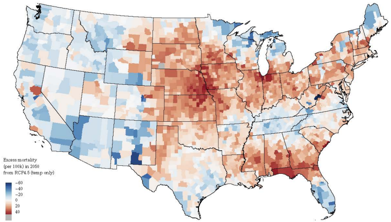
Simulation details

- Temp projections from CCSM4 (RCP4.5) and elect. prices from HAIKU ($50 carbon fee)
  - Division-level price effect defined as carbon scenario – reference, standardized
- For each county-month:
  - Count projected number of days in each temp bin vs. 20–25°C bin (reference)
  - Compute differences in bin counts between 2050 and 2020
  - Aggregate to annual county-level change in relative bin counts
- Apply regression coefficients from border-pair estimates:
  - "Warming only:" Apply β_k (temp–mortality effects) to relative change in bin counts
  - "Climate policy:" Apply β_k & γ_k (bin $\times$ price)
- Convert predicted change in mortality rate to *expected number of deaths* using county population projections (Hauer and CIESIN, 2020)

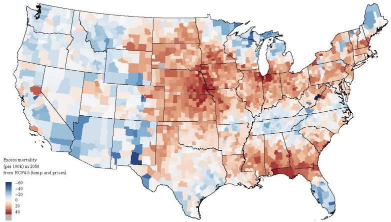
Return

Simulation results: County-level estimates

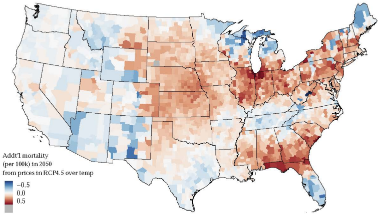
Warming only



Climate policy



Difference



◂ Return