Do firms mitigate climate impact on employment? Evidence from US heat shocks

Viral Acharya[1] Abhishek Bhardwaj[2] Tuomas Tomunen[3]

[1]NYU Stern

[2]Tulane University

[3]Boston College

April 2024

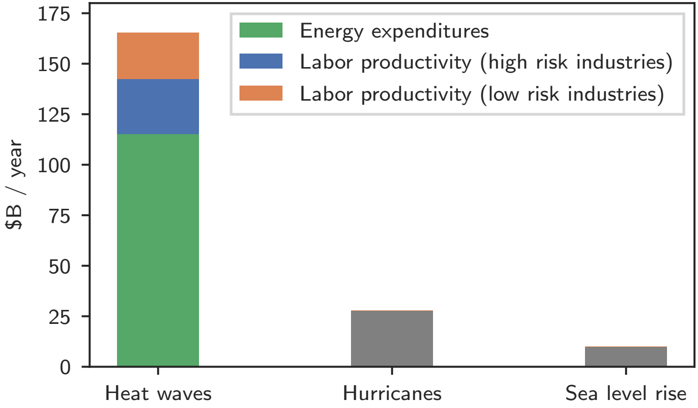
Motivation

"Heat stress is projected to reduce total working hours worldwide by 2.2 per cent and global GDP by US$2,400 billion in 2030. For workers and businesses to be able to cope with heat stress, appropriate policies, technological investments and behavioural change are required."

– International Labor Organization Report (2019)

Heat waves are likely to cause large economic damages

Figure: Estimated climate change damages in the U.S.



Source: Hsiang et al. (2017) and own calculations, Hallegate et al. (2013)

Research questions

1. Do firms adapt to heat shocks by reorganizing their workforce geographically?

2. What factors (firm-specific, region-specific, industry-specific) affect mitigation activity?
   What are the underlying mechanisms?

3. What are the implications for local economies?

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1. Firms experiencing heat shocks:
   - Increase employment in unaffected peer locations, open establishments in new locations

     Takeaway: Firms mitigate impact of heat shocks on aggregate employment but induce spatial redistribution of economic activity

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   - Firms with fewer financial constraints ($\uparrow$ size, $\downarrow$ leverage) & more ESG-oriented investors
   - Industries where workers have higher outdoor exposure

     Takeaway: Firms spend resources to prevent heat-related decline in labor productivity

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3. After facing heat shocks, firms shift workforce:

   From: Counties experiencing more acute, chronic, and compound heat stress

   To: Counties with less projected heat-damage & better economic conditions ($\uparrow$ GDP growth)

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4. After heat shocks materialize, employment growth
   - Decreases in affected county, increases in peer counties (i.e., connected by firm networks)

     Takeaway: Positive employment spillover across counties through firm networks

Related literature

1. Extreme heat and firm performance
   - Addoum et al. (2020), Jin et al. (2021), Addoum et al. (2023), Pankratz et al. (2023), Ponticelli et al. (2023)
   - Extreme heat adversely impacts establishment revenue and costs

2. Firm response to climate shocks
   - Lin et al. (2020), Pankratz and Schiller (2021), Bartram et al. (2022), Castro-Vincenzi (2023)
   - Firms terminate supplier relationships and increase investments in flexible production technologies in response to climate shocks

3. Firms' establishment networks
   - Gabaix (2011), Tate and Yang (2015), Giroud and Mueller (2015, 2019), Gumpert et al. (2022)
   - Establishment networks can propagate economic shock across distant regions

This paper: Firms respond to heat-related profitability shocks by relocating operations

▸ Heat anecdotes

Overview

1. Data
2. Results
   2.1 Impact of heat shocks: Single vs. multi-location firms
   2.2 Firm mitigation: Reallocation to unaffected counties
      2.2.1 Mitigation across firms
      2.2.2 Mitigation across regions
      2.2.3 Mitigation across industries
   2.3 Does mitigation vary by type of shock (acute, spells, chronic)?
   2.4 Other and compound climate hazards
   2.5 Impact of heat shocks on county-level outcomes
   2.6 Does employee-level mitigation and migration explain our results?

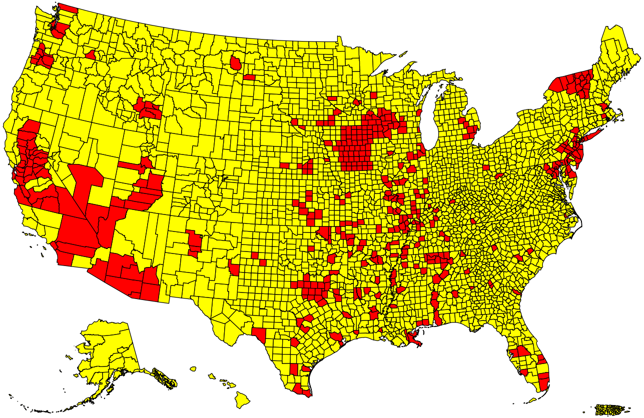
Data: Sources

Data Sources:

1. Establishment-level data: Dun & Bradstreet Global Archive Files (2009 to 2020)
   - Detailed employment data for 50,000 multi-establishment firms across 3,000 counties
2. Heat shocks: Spatial Hazard Events and Losses Database for United States (SHELDUS)
   - County-level data on heat and other climate hazards
3. Other datasets: Current Population Survey (for migration), Compustat (for firm financials), PRISM (for daily temperature data), CRA Analytics (for bank presence), etc.

Data: Realized heat shocks across the U.S.

Figure: Highlighted counties experienced ≥1 hot days



Definition: Hot Days are days when a loss (property, crop, injury, or fatality) occurred from a heat hazard according to SHELDUS

Relation with Temperature-Based Hot Days

Definiting Heat Shocks

Establishment-Level: For firm f, county c, and year t, we define:

$$\text{Own Shock}_{c,t} = \text{Log}(1 + \text{\#Hot Days}_{c,t})$$

$$\text{Peer Shock}_{f,c,t} = \text{Log}(1 + \text{\#Hot Days, Other}_{f,c,t})$$

$$\text{where, \#Hot Days, Other}_{f,c,t} = \sum_{c' \neq c} \frac{\text{Employment}_{f,c',t-2}}{\text{Employment}_{f,c,t-2}} \times \text{\#Hot Days}_{c',t}$$

Firm-Level: For firm f and year t, we define:

$$\text{Firm Shock}_{f,t} = \text{Log}(1 + \#\ \text{Hot Days, Firm}_{f,t}) \tag{1}$$

Summary Statistics

Summary Statistics (Firm-County-Year Panel):

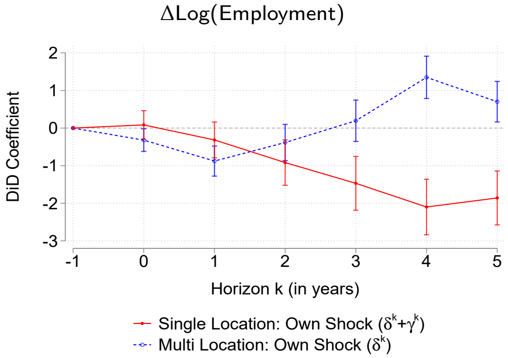
	Mean	SD	5%tile	Median	95%tile
Employment	106	644	2	20	350
# Establishments	2.2	5.5	1	1	6
# Hot Days	.47	3	0	0	2
# Hot Days, Other	1,095	14,730	0	.75	2,787
Own Shock	.12	.47	0	0	1.1
Peer Shock	2.4	2.9	0	.56	7.9

Summary Statistics (Firm-Year Panel):

	Mean	SD	5%tile	Median	95%tile
Single Location	.3	.46	0	0	1
Employment	1,074	8,481	93	233	3,038
# Establishments	21	195	1	5	50
# Hot Days, Firm	.6	3	0	0	3
Firm Shock	.19	.52	0	0	1.4
Entry In New County	.12	.32	0	0	1

Impact of heat shocks: single vs. multi-location firms

$$\Delta \text{Log(Employment)}_{f,t-1\rightarrow t+k} = \gamma^k \times \text{Firm Shock}_{f,t} \times \text{Single Location}_f + \delta^k \times \text{Firm Shock}_{f,t} + \alpha_f + \alpha_t + \varepsilon_{f,t}$$

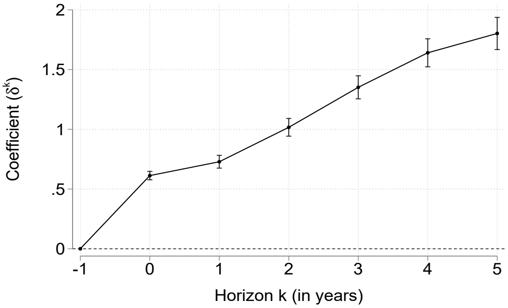


Key Result: One SD increase in firm-shock:

- 0.47% decline in 3-year employment growth for single-location firms
- No significant decline in multi-location firms

2.2. Firm mitigation: Reallocation to unaffected peer counties

$$\Delta \text{Log(Employment)}_{f,c,t-1\to t+k} = \delta^k \times \text{Peer Shock}_{f,c,t} + \alpha_f + \alpha_{c,t} + \varepsilon_{f,c,t}$$



Key Result: Consider a firm with equal employment in two counties (c and c'). Over a 3-year horizon,

- **1 hot day in c'** $\implies$ 0.7% ↑ in employment growth in c
- Mean employment growth in the sample is 2.4%

▸ Robustness - Alternative measures ▸ Robustness - Alternative FE ▸ Robustness - Number of Establishments ▸ Robustness - Temperature-Based Shocks

2.2. Firm mitigation: Reallocation to new counties

$$\text{Entry In New County}_{f,t} = \gamma \times \text{Firm Shock}_{f,t-1} + \alpha_f + \alpha_t + \varepsilon_{f,t}$$

	Entry In New County $\times$ 100					
	Overall	Low Heat damage/GDP	Low Energy damage/GDP	Low Labor damage/GDP (high-risk)	Low Labor damage/GDP (low-risk)	Low Chronic Heat Stress
Firm Shock	0.177*	0.252***	0.241***	0.201**	0.284***	0.169*
	(0.092)	(0.077)	(0.077)	(0.079)	(0.075)	(0.086)
Firm FE	✓	✓	✓	✓	✓	✓
Year FE	✓	✓	✓	✓	✓	✓
Observations	540,874	540,874	540,874	540,874	540,874	540,874
$\bar{y}$	8.833	6.411	6.329	6.415	5.873	7.328
Adj. R^2	0.270	0.244	0.245	0.243	0.236	0.251

Key Result: One SD increase in firm-shock:

- 0.09 pp increase in the probability of entering a new county
- Effect is stronger when the new county has lower projected heat-related damages (according to SEAGLAS)

Hypotheses (heterogeneity of mitigation)

1. Understanding the mechanisms:
   - Is the mitigating response stronger in the case of
     - Heat-exposed firms?
     - (Towards) Counties less exposed to heat stress?
     - Industries with workers at risk of injuries or fatalities due to heat stress?
   - Primary alternative candidate: Employee-, rather than Employer-, level mitigation
     - Is mitigation stronger for larger firms vis-à-vis smaller firms, within-county vs across-counties?
     - Is there inward migration of workers to benefiting counties?

Hypotheses (heterogeneity of mitigation)

2. Understanding costs and benefits to firms from mitigation:
   - Is the mitigating response stronger in the case of
     - Firms with management/shareholders keen/incentivized to address climate change?
     - Less-leveraged firms as they focus on long-term resilience rather than short-term gains?
     - (Towards) Counties with more competitive rather than concentrated labor markets?
     - (Towards) Nearby counties due to the cost of breaking firm relationships with clients and customers?
     - Economic times when resilience costs easier to incur?

3. Descriptive inquiries:
   - Acute, chronic heat stress; Other physical climate risks; Compound physical climate risks

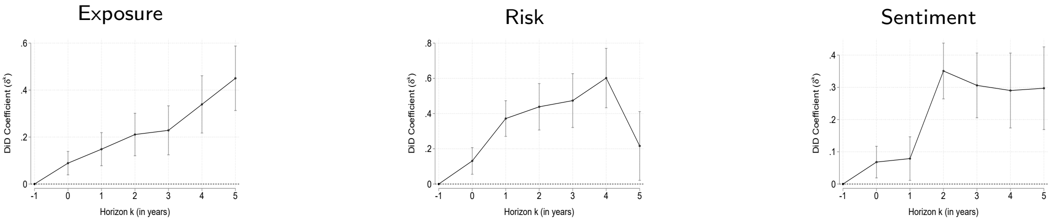
2.2.1. Mitigation across firms

Mitigation is higher when:

- Exposure, Risk, and Sentiment towards climate change is higher

Definitions: Following Sautner et al. (2023),

- Exposure is the overall frequency of climate change bi-grams in earnings call transcript
- Risk corresponds to bi-grams associated with risk-related words
- Sentiment corresponds to bi-grams associated with positive/negative tone words

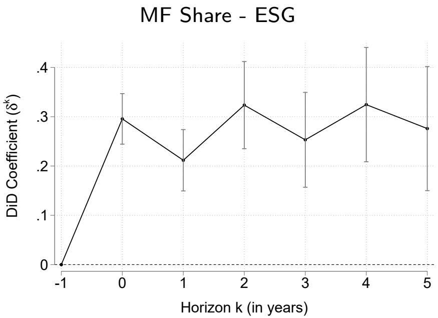


Key Result: Employment reallocation to unaffected counties is higher in firms more exposed and sensitive to climate change factors

2.2.1. Mitigation across firms (contd.)

Mitigation is higher when:

- Shareholding of ESG-classified mutual funds is higher
- **Definition**: We follow ESG classification of Cohen et al. (2021)



Key Result: Employment reallocation to unaffected counties is higher if firm's mutual fund investors are ESG-oriented

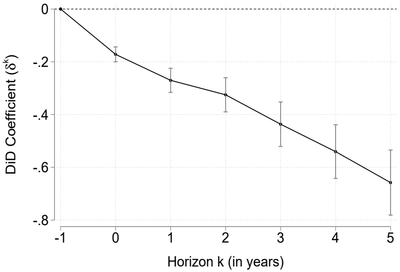
2.2.1. Heterogeneity across firms: Firm financials

	ΔLog(Employment)$_{t-1,t+k}$ $\times$ 100				
	k=+2	k=+2	k=+2	k=+2	k=+2
Peer Shock	0.263***	2.016***	1.972***	2.002***	0.672
	(0.066)	(0.083)	(0.087)	(0.095)	(0.856)
Large Firm	-11.377***				-12.162***
	(0.295)				(0.830)
Large Firm × Peer Shock	1.091***				1.401*
	(0.066)				(0.849)
Low Leverage		-0.275			-0.701
		(0.565)			(0.586)
Low Leverage × Peer Shock		0.533***			0.534***
		(0.091)			(0.094)
High Z-Score			0.525		-0.467
			(0.506)		(0.558)
High Z-Score × Peer Shock			0.305***		0.117
			(0.070)		(0.082)
High Profitability				6.645***	7.461***
				(0.563)	(0.595)
High Profitability × Peer Shock				0.176**	0.047
				(0.080)	(0.091)
Firm FE	✓	✓	✓	✓	✓
County × Year FE	✓	✓	✓	✓	✓
Sample	Full D&B	Compustat	Compustat	Compustat	Compustat
Observations	4,015,976	463,256	463,256	463,256	463,256
$\bar{y}$	2.424	4.206	4.206	4.206	4.206
Adj. R^2	0.043	0.035	0.035	0.036	0.036

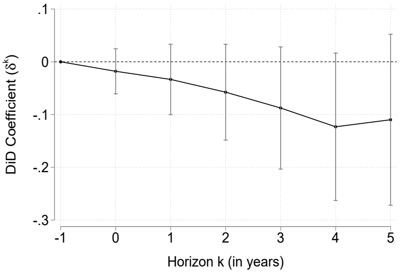
2.2.2. Mitigation across regions

$$\Delta\text{Log(Employment)}_{f,c,t-1\to t+k} = \delta^k \times \text{Peer Shock}_{f,c,t} \times \text{County Characteristic}_{c,t} + \gamma^k \text{Peer Shock}_{f,c,t} + \alpha_f + \alpha_{c,t} + \varepsilon_{f,c,t}$$

High Employment HHI



High Non-Compete Enforceability



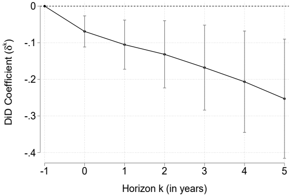
Key Result: Employment reallocation to unaffected counties is higher if their labor markets are competitive

2.2.2. Mitigation across regions (contd.)

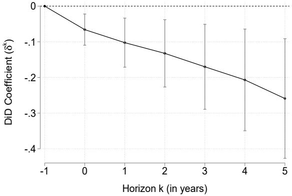
$$\Delta\text{Log(Employment)}_{f,c,t-1\to t+k} = \delta^k \times \text{Peer Shock}_{f,c,t} \times \text{County Characteristic}_{c,t} + \gamma^k \text{Peer Shock}_{f,c,t} + \alpha_f + \alpha_{c,t} + \varepsilon_{f,c,t}$$

Definitions: Exposure measures from SEAGLAS (Hsiang et al., 2017)

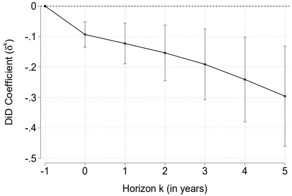
Heat Damage/GDP



Energy Damage/GDP



Labor Damage/GDP



Key Result: Employment reallocation to unaffected counties is higher if they have lower exposure to heat-related damage

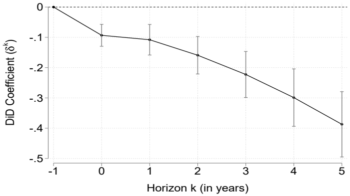
2.2.2. Mitigation across regions (contd.)

$$\Delta \text{Log(Employment)}_{f,c,t-1\to t+k} = \delta^k \times \text{Peer Shock}_{f,c,t} \times \text{High Economic Stress}_{c,t}$$
$$+ \gamma^k \text{Peer Shock}_{f,c,t} + \alpha_f + \alpha_{c,t} + \varepsilon_{f,c,t}$$

Definitions:

– High economic stress: Negative growth in real GDP during $t-1$

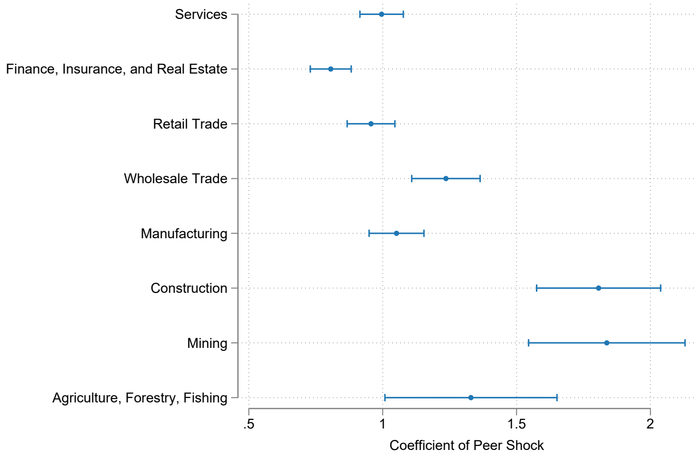
High economic stress



Key Result: Employment reallocation to unaffected counties is higher if they have lower economic stress

Distance | Bank presence | Own County Characteristics

2.2.3. Mitigation across industries



Key Result: Employment reallocation to unaffected counties is higher if workers are more exposed to physical heat

2.2.3. Mitigation across industries

$$\Delta\text{Log(Employment)}_{f(i),c,t-1\rightarrow t+k} = \delta^k \times \text{Peer Shock}_{f(i),c,t} \times \text{Industry Characteristic}_{i,t-1} + \gamma^k \text{Peer Shock}_{f(i),c,t} + \alpha_{f(i)} + \alpha_{c,t} + \varepsilon_{f(i),c,t}$$

Definitions:

- Teleworking: Dingel and Neiman (2020) classification based on feasibility of remote work
- Tradable: geographical concentration-based classification of Mian and Sufi (2014)

	ΔLog(Employment)$_{t-1,t+k} \times 100$					
	k=+0	k=+1	k=+2	k=+3	k=+4	k=+5
Peer Shock	0.453***	0.783***	1.099***	1.436***	1.760***	2.002***
	(0.023)	(0.032)	(0.044)	(0.055)	(0.068)	(0.077)
Telework × Peer Shock	0.222***	-0.078***	-0.116***	-0.119***	-0.164***	-0.271***
	(0.018)	(0.023)	(0.030)	(0.035)	(0.041)	(0.043)
Peer Shock	0.624***	0.710***	1.004***	1.333***	1.620***	1.779***
	(0.018)	(0.028)	(0.039)	(0.051)	(0.061)	(0.069)
Non-Tradable × Peer Shock	-0.077***	0.122***	0.088**	0.130***	0.148***	0.174***
	(0.020)	(0.029)	(0.038)	(0.047)	(0.055)	(0.059)
Observations	5,556,578	4,727,432	4,015,976	3,379,161	2,797,759	2,267,637
$\bar{y}$	0.770	1.785	2.424	3.213	3.899	4.748
Firm FE	✓	✓	✓	✓	✓	✓
County × Year FE	✓	✓	✓	✓	✓	✓

2.3. Does mitigation vary by type of shock (acute)?

$$\Delta\text{Log(Employment)}_{f,c,t-1\rightarrow t+k} = \delta^k \times \text{Peer Shock (Type)}_{f,c,t} + \alpha_f + \alpha_{c,t} + \varepsilon_{f,c,t}$$

Definitions:

– Acute stress: peer shock calculated using hot days with non-zero property damage

	ΔLog(Employment)$_{t-1,t+k} \times 100$					
	k=+0	k=+1	k=+2	k=+3	k=+4	k=+5
Panel (a): Heat stress (baseline)						
Peer Shock	0.612***	0.728***	1.017***	1.352***	1.640***	1.803***
	(0.018)	(0.027)	(0.038)	(0.049)	(0.060)	(0.069)
Panel (b): Acute heat stress						
Peer Shock (Damages)	0.708***	0.920***	1.546***	1.822***	2.113***	2.014***
	(0.021)	(0.031)	(0.049)	(0.057)	(0.063)	(0.068)
Observations	5,556,578	4,727,432	4,015,976	3,379,161	2,797,759	2,267,637
$\bar{y}$	0.770	1.785	2.424	3.213	3.899	4.748
Firm FE	✓	✓	✓	✓	✓	✓
County × Year FE	✓	✓	✓	✓	✓	✓

2.3. Does mitigation vary by type of shock (spells)?

$$\Delta \text{Log(Employment)}_{f,c,t-1\to t+k} = \delta^k \times \text{Peer Shock (Type)}_{f,c,t} + \alpha_f + \alpha_{c,t} + \varepsilon_{f,c,t}$$

Definitions:

- Heat spells: peer shock calculated using hot days that occurred in a consecutive spell of three or more days

	ΔLog(Employment)$_{t-1,t+k} \times 100$					
	k=+0	k=+1	k=+2	k=+3	k=+4	k=+5
Panel (a): Heat stress (baseline)						
Peer Shock	0.612***	0.728***	1.017***	1.352***	1.640***	1.803***
	(0.018)	(0.027)	(0.038)	(0.049)	(0.060)	(0.069)
Panel (c): Heat spells						
Peer Shock (Spells)	0.594***	0.675***	0.937***	1.257***	1.540***	1.674***
	(0.017)	(0.025)	(0.035)	(0.045)	(0.054)	(0.062)
Observations	5,556,578	4,727,432	4,015,976	3,379,161	2,797,759	2,267,637
$\bar{y}$	0.770	1.785	2.424	3.213	3.899	4.748
Firm FE	✓	✓	✓	✓	✓	✓
County × Year FE	✓	✓	✓	✓	✓	✓

2.3. Does mitigation vary by type of shock (chronic)?

$$\Delta \text{Log(Employment)}_{f,c,t-1\to t+k} = \delta^k \times \text{Peer Shock (Type)}_{f,c,t} + \alpha_f + \alpha_{c,t} + \varepsilon_{f,c,t}$$

Definitions:

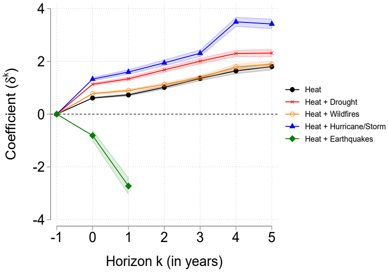
– Chronic stress: peer shock calculated using hot days occurring in counties s in the top quintile of the distribution of the number of hot days during the 1960-2008 period

	ΔLog(Employment)$_{t-1,t+k} \times 100$					
	k=+0	k=+1	k=+2	k=+3	k=+4	k=+5
Panel (a): Heat stress (baseline)						
Peer Shock	0.612***	0.728***	1.017***	1.352***	1.640***	1.803***
	(0.018)	(0.027)	(0.038)	(0.049)	(0.060)	(0.069)
Panel (d): Chronic heat stress						
Peer Shock (Chronic)	0.771***	0.885***	1.196***	1.555***	1.824***	2.012***
	(0.021)	(0.030)	(0.041)	(0.053)	(0.063)	(0.074)
Observations	5,556,578	4,727,432	4,015,976	3,379,161	2,797,759	2,267,637
$\bar{y}$	0.770	1.785	2.424	3.213	3.899	4.748
Firm FE	✓	✓	✓	✓	✓	✓
County × Year FE	✓	✓	✓	✓	✓	✓

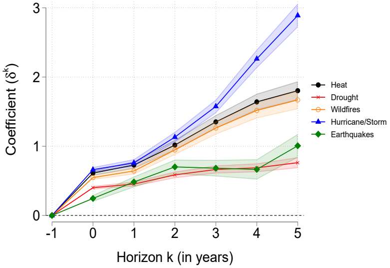
2.4. Other and compound climate hazards

$$\Delta \text{Log(Employment)}_{f,c,t-1\to t+k} = \delta^k \times \text{Peer Shock (Type)}_{f,c,t} + \alpha_f + \alpha_{c,t} + \varepsilon_{f,c,t}$$

Combined with heat hazard



Single hazard

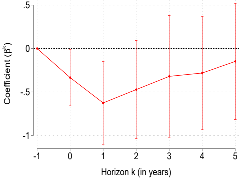


Key Result: Employment reallocation is stronger in response to compound shocks. Firms handle all forms of climate risks.

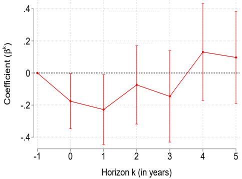
2.5. Impact of heat shocks on county-level outcomes (Own Shock)

$$\Delta Y_{c,t-1\to t+k} = \beta \times \text{Own Shock}_{c,t} + \alpha_c + \alpha_t + \varepsilon_{c,t}$$

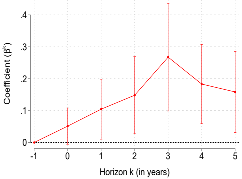
ΔLog(Employment)



ΔLog(# Establishments)



ΔEmployment HHI



Economic Magnitudes (3 year period):

- 1% ↑ in Own Shock $\implies$ 0.7% ↓ in employment growth, 0.3% ↓ in establishment growth, 0.13% ↑ in HHI growth
- 1% ↑ in Peer Shock $\implies$ 6.9% ↑ in employment growth, 1.2% ↑ in establishment growth, 0.4% ↑ in HHI growth

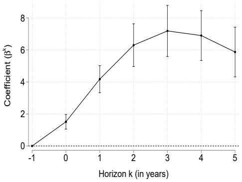
Key Result: Heat shocks lead to lower employment and establishment growth, higher concentration

▸ Reallocation across firms

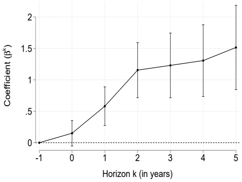
2.5. Impact of heat shocks on county-level outcomes (Peer Shock)

$$\Delta Y_{c,t-1\to t+k} = \beta \times \text{Peer Shock}_{c,t} + \alpha_c + \alpha_t + \varepsilon_{c,t}$$

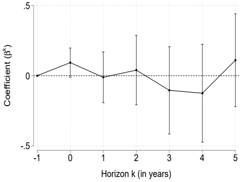
ΔLog(Employment)



ΔLog(# Establishments)



ΔEmployment HHI



Economic Magnitudes (3 year period):

- 1% $\uparrow$ in Own Shock $\implies$ 0.7% $\downarrow$ in employment growth, 0.3% $\downarrow$ in establishment growth, 0.13% $\uparrow$ in HHI growth
- 1% $\uparrow$ in Peer Shock $\implies$ 6.9% $\uparrow$ in employment growth, 1.2% $\uparrow$ in establishment growth, 0.4% $\uparrow$ in HHI growth

Key Result: Heat shocks lead to higher employment and establishment growth in peer counties

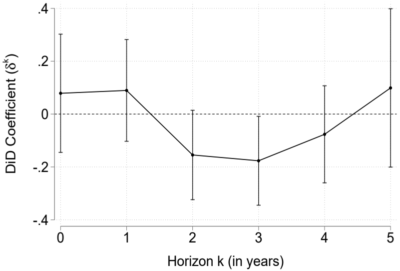
Census Results

2.6. Does employee-level mitigation and migration explain our results?

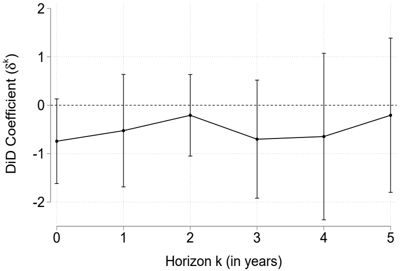
$$\text{In-Migration}_{h,c,t} = \gamma^k \times \text{Shock}_{c,t-k} + \alpha_D + \alpha_c + \alpha_t + \epsilon_{w,c,t}$$

Definition: In-Migration$_{w,c,t}$ is an indicator that equals one if any member of the household h residing in county c in year t migrated into their current location for a work-related reason during the previous year

Own shock



Peer shock



Conclusion

- Evidence suggests that
  - Heat shocks impact local counties and small firms

    BUT

  - Multi-establishment firms relocate workers away from impacted locations to their unaffected, less exposed, locations
  - In a manner consistent with firm-level costs and benefits of mitigation
  - Particularly for acute, chronic and compound climate stress
- Open questions
  - Are mitigating firms more resilient to FUTURE stress?
  - How much does mitigation help in the aggregate to insulate economy against climate change?
- Next steps
  - Further disentangle worker-driven and firm-driven reallocation (job postings)
  - Within-firm mitigation across occupational groups

Heat Is Costing the U.S. Economy Billions in Lost Productivity

From meatpackers to home health aides, workers are struggling in sweltering temperatures and productivity is taking a hit.

NYT (7/31/2023)

ECONOMY

Weeks of Extreme Heat Strain Small Businesses and Economy

Infrastructure holds up but risk of failure rises as hot weather persists

WSJ (7/15/2023)

Heat Wave Intensifies Energy Crisis in Europe

Natural-gas prices surge to a record, and electricity prices rally as high temperatures spur bidding war for the fuel

WSJ (8/16/2022)

China's worst heatwave in 60 years is forcing factories to close

CNN (8/16/2022)

We ask: do firms respond to these heat-related profitability shocks by relocating?

Back

Determinants of SHELDUS Heat Shock

$$\#\text{ Hot Days}_{c,t} = \#\text{ Days}(\text{T}\geq 99\text{Pctile})_{c,t} + \alpha_c + \alpha_t + \varepsilon_{c,t}$$

	# Hot Days			
# Days(T≥99Pctile)	0.116***	0.117***	0.109***	0.066***
	(0.003)	(0.005)	(0.006)	(0.006)
# Days(T≥99Pctile)				0.076***
× High Social Vulnerability/Low Resilience				(0.009)
County FE		✓	✓	✓
Year FE			✓	✓
Observations	113,763	113,763	113,763	113,763
$\bar{y}$	0.728	0.728	0.728	0.728
Adj. R^2	0.014	0.022	0.082	0.083

Key Result:

- Positive correlation between temperature-based hot days and SHELDUS hot days
- Association is stronger when the county has high social risk according to FEMA

Back

Robustness: Alternative measures of Peer Shock

Definitions:

- Peer Shock, $\text{Alt}_{f,c,t}$ is the lagged-employment-weighted number of hot days across all the peer counties of c where firm f has employment in year t
- Peer Shock, $(\text{Est-Wt})_{f,c,t}$ is the total number of peer hot days weighted by the number of establishments in the peer county (relative to those in county c)
- Peer Shock, $(\text{Eq-Wt})_{f,c,t}$ is the equal-weighted average of hot days in peer counties.
- Peer Shock, $(\text{Top Tercile})_{f,c,t}$ indicates that the peer shock lies in the top tercile of the distribution.

	ΔLog(Employment)$_{t-1,t+k} \times 100$					
	k=+0	k=+1	k=+2	k=+3	k=+4	k=+5
Peer Shock, Alt	0.701***	0.449***	0.322***	0.731***	1.123***	1.092***
	(0.058)	(0.073)	(0.090)	(0.110)	(0.136)	(0.150)
Peer Shock, (Est-Wt)	0.304***	0.031*	0.080***	0.229***	0.378***	0.388***
	(0.014)	(0.017)	(0.022)	(0.028)	(0.034)	(0.038)
Peer Shock, (Eq-Wt)	0.154**	0.518***	0.903***	0.899***	0.947***	0.645***
	(0.068)	(0.095)	(0.109)	(0.131)	(0.146)	(0.136)
Peer Shock (Top Tercile)	1.718***	1.895***	2.747***	3.823***	4.642***	5.317***
	(0.087)	(0.136)	(0.187)	(0.245)	(0.307)	(0.359)
Firm FE	✓	✓	✓	✓	✓	✓
County × Year FE	✓	✓	✓	✓	✓	✓
Observations	5,521,381	4,697,477	3,990,510	3,357,697	2,779,954	2,253,138
$\bar{y}$	0.769	1.782	2.420	3.208	3.892	4.740
Adj. R^2	0.010	0.026	0.040	0.055	0.072	0.090

Back

Robustness: Alternative fixed effects and clustering

	ΔLog(Employment)$_{t-1,t+k}$ $\times$ 100					
	k=+0	k=+1	k=+2	k=+3	k=+4	k=+5
Panel (a)						
Firm$\times$Year and County$\times$Year FE						
Peer Shock	1.171***	2.093***	2.893***	3.598***	4.172***	4.785***
	(0.030)	(0.051)	(0.072)	(0.092)	(0.112)	(0.129)
Firm and County$\times$Industry$\times$Year FE						
Peer Shock	0.807***	1.069***	1.494***	1.995***	2.360***	2.640***
	(0.025)	(0.039)	(0.055)	(0.070)	(0.089)	(0.105)
County$\times$Year FE						
Peer Shock	0.277***	0.394***	0.486***	0.602***	0.741***	0.890***
	(0.010)	(0.016)	(0.021)	(0.027)	(0.033)	(0.040)
Double clustering at County and Firm level						
Peer Shock	0.612***	0.728***	1.017***	1.352***	1.640***	1.803***
	(0.038)	(0.049)	(0.066)	(0.083)	(0.098)	(0.104)
Firm $\times$ Year FE	✓	✓	✓	✓	✓	✓
County $\times$ Year FE	✓	✓	✓	✓	✓	✓
Observations	5,514,632	4,688,481	3,980,139	3,346,619	2,768,822	2,242,546
$\bar{y}$	0.763	1.777	2.413	3.199	3.880	4.724
Adj. R^2	0.087	0.091	0.093	0.095	0.099	0.101

Back

Robustness: Alternative outcome

	ΔLog(# Establishments)$_{t-1,t+k} \times 100$					
	k=+0	k=+1	k=+2	k=+3	k=+4	k=+5
Peer Shock	0.133***	0.022***	0.039***	0.110***	0.178***	0.198***
	(0.006)	(0.007)	(0.009)	(0.012)	(0.016)	(0.018)
Firm FE	✓	✓	✓	✓	✓	✓
County $\times$ Year FE	✓	✓	✓	✓	✓	✓
Observations	5,556,578	4,727,432	4,015,976	3,379,161	2,797,759	2,267,637
$\bar{y}$	0.554	1.211	1.520	1.918	2.305	2.759
Adj. R^2	0.021	0.044	0.064	0.086	0.114	0.144

Back

Reallocation with Temperature-Based Shocks

$$\Delta\text{Log(Employment)}_{f,c,t-1\to t+k} = \delta^k \times \text{Peer Shock (T}\geq\text{99Pctile)}_{f,c,t} + \alpha_f + \alpha_{c,t} + \varepsilon_{f,c,t}$$

Definition: $\#$ Days(T$\geq$99Pctile)$_{c,t}$: Number of days in year t when the average temperature in county c was above its 99th percentile value from 1982 to 2020

	$\Delta\text{Log(Employment)}_{t-1,t+k} \times 100$					
	k=+0	k=+1	k=+2	k=+3	k=+4	k=+5
Peer Shock (T$\geq$99Pctile)	0.452***	0.779***	1.115***	1.448***	1.825***	2.053***
	(0.014)	(0.022)	(0.031)	(0.042)	(0.051)	(0.057)
Firm FE	✓	✓	✓	✓	✓	✓
County $\times$ Year FE	✓	✓	✓	✓	✓	✓
Observations	5,093,577	4,293,786	3,605,427	2,985,655	2,422,352	1,908,354
$\bar{y}$	0.807	1.238	1.731	2.287	2.796	3.379
Adj. R^2	0.013	0.026	0.043	0.061	0.081	0.098

Key Result:

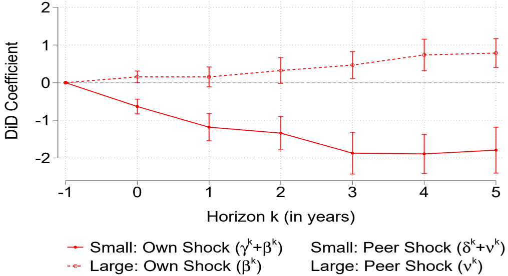
– Response to temperature-based shocks is similar as that to SHELDUS-based shocks

Back

2.2.1. Heterogeneity across firms: Firm size

$$\Delta \text{Log(Employment)}_{f,c,t-1\rightarrow t+k} = \gamma^k \times \text{Own Shock}_{c,t} \times \text{Small Firm}_f + \beta^k \times \text{Own Shock}_f$$
$$+ \delta^k \times \text{Peer Shock}_{f,c,t} \times \text{Small Firm}_f + \nu^k \times \text{Peer Shock}_f + \alpha_f + \alpha_t + \alpha_c + \varepsilon_{f,c,t}$$

Definition: Small firm: Average employment ≤ 250 (sample median)



Key Result: Consider a firm with equal employment in two counties – c and c'. Over 3-year horizon, **1 hot day in** c' $\implies$ Employment growth

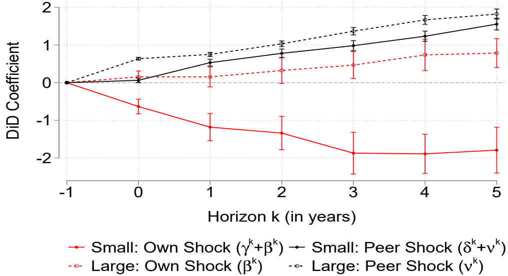
- in c': 0.9% $\downarrow$ in small firms and 0.2% $\uparrow$ in large firms
- Mean employment growth in the sample is 2.4%

Back

2.2.1. Heterogeneity across firms: Firm size

$$\Delta \text{Log(Employment)}_{f,c,t-1\to t+k} = \gamma^k \times \text{Own Shock}_{c,t} \times \text{Small Firm}_f + \beta^k \times \text{Own Shock}_f$$
$$+ \delta^k \times \text{Peer Shock}_{f,c,t} \times \text{Small Firm}_f + \nu^k \times \text{Peer Shock}_f + \alpha_f + \alpha_t + \alpha_c + \varepsilon_{f,c,t}$$

Definition: Small firm: Average employment ≤ 250 (sample median)



Key Result: Consider a firm with equal employment in two counties – c and c'. Over 3-year horizon, **1 hot day in** c' $\implies$ Employment growth

- in c': 0.9% ↓ in small firms and 0.2% ↑ in large firms
- in c: 0.5% ↑ in small firms and 0.7% ↑ in large firms
- Mean employment growth in the sample is 2.4%

Back

Heterogeneity across firms: Firm size

$$\Delta\text{Log(Employment)}_{f,c,t-1\to t+k} = \gamma^k \times \text{Own Shock}_{c,t} \times \text{Small Firm}_f + \delta^k \times \text{Own Shock}_{c,t} \times \text{Single Location}_f + \beta^k \times \text{Own Shock}_{c,t} + \text{FE} + \varepsilon_{f,c,t}$$

	$\Delta\text{Log(Employment)}_{t-1,t+k} \times 100$			
	k=+2	k=+2	k=+2	k=+2
Own Shock	-0.005	0.355**		
	(0.126)	(0.173)		
Small Firm × Own Shock		-1.745***	-1.737***	-1.686***
		(0.375)	(0.379)	(0.357)
Single Location × Own Shock				-0.801
				(0.607)
Firm FE	✓	✓	✓	✓
County FE	✓	✓		
Year FE	✓	✓		
County × Year FE			✓	✓
Observations	4,106,771	4,106,771	4,106,632	4,106,632
$\bar{y}$	2.618	2.618	2.618	
Adj. R^2	0.052	0.052	0.050	0.050

Back

County-level results using QCEW data

$$\Delta Y_{c,t-1\rightarrow t+k} = \beta \times \text{Shock}_{c,t} + \alpha_c + \alpha_t + \varepsilon_{c,t}$$

	Panel (A): ΔLog(Employment)$_{t-1,t+k} \times 100$					
	k=+0	k=+1	k=+2	k=+3	k=+4	k=+5
Own Shock	0.136*	0.167	0.169	0.068	0.220	0.239
	(0.073)	(0.121)	(0.153)	(0.175)	(0.179)	(0.152)
Peer Shock	0.602***	0.931**	1.422**	1.716**	1.685**	1.129*
	(0.188)	(0.442)	(0.669)	(0.874)	(0.854)	(0.585)
	Panel (B): ΔLog(Establishments)$_{t-1,t+k} \times 100$					
	k=+0	k=+1	k=+2	k=+3	k=+4	k=+5
Own Shock	-0.002	0.036	0.009	0.171	0.088	0.148
	(0.060)	(0.106)	(0.141)	(0.158)	(0.150)	(0.133)
Peer Shock	0.325**	0.688***	0.741**	0.897***	0.898**	1.138***
	(0.128)	(0.227)	(0.299)	(0.344)	(0.350)	(0.367)
County FE	✓	✓	✓	✓	✓	✓
Year FE	✓	✓	✓	✓	✓	✓
Observations	30,412	27,339	24,276	21,212	18,153	15,087
$\bar{y}$	0.585	1.191	1.748	2.262	2.886	3.465
Adj. R^2	0.071	0.184	0.305	0.441	0.588	0.708

Back

2.2.2. Mitigation across varying distance from the shock

$$\Delta\text{Log(Employment)}_{f,c,t-1\to t+k} = \sum_{(d_1,d_2)} \delta^k_{(d_1,d_2)} \times \text{Peer Shock}_{f,c,t,(d_1,d_2)} + \alpha_f + \alpha_{c,t} + \varepsilon_{f,c,t}$$

	ΔLog(Employment)$_{t-1,t+k} \times 100$					
	k=+0	k=+1	k=+2	k=+3	k=+4	k=+5
Peer Shock$\leq$100	0.485***	0.682***	0.911***	1.075***	1.186***	1.332***
	(0.038)	(0.054)	(0.069)	(0.085)	(0.094)	(0.108)
Peer Shock$\in$(100,250]	0.361***	0.451***	0.588***	0.738***	0.832***	0.842***
	(0.027)	(0.037)	(0.047)	(0.060)	(0.074)	(0.087)
Peer Shock$\in$(250,500]	0.253***	0.261***	0.368***	0.480***	0.537***	0.545***
	(0.018)	(0.026)	(0.035)	(0.046)	(0.055)	(0.065)
Peer Shock$\in$(500,750]	0.385***	0.430***	0.592***	0.784***	0.903***	0.970***
	(0.018)	(0.027)	(0.037)	(0.051)	(0.061)	(0.071)
Firm FE	✓	✓	✓	✓	✓	✓
County × Year FE	✓	✓	✓	✓	✓	✓
Observations	5,527,471	4,698,487	3,988,344	3,353,575	2,774,744	2,247,523
$\bar{y}$	0.763	1.776	2.413	3.200	3.882	4.731
Adj. R^2	0.011	0.027	0.040	0.055	0.071	0.088

Back

Impact of county characteristics (affected county)

$$\Delta\text{Log(Employment)}_{f,c,t-1\rightarrow t+k} = \sum_{\text{Type}} \delta^{k,\text{Type}} \times \text{Peer Shock}^{\text{Type}}_{f,c,t} + \alpha_f + \alpha_{c,t} + \varepsilon_{f,c,t}$$

	ΔLog(Employment)$_{t-1,t+k} \times 100$					
	k=+0	k=+1	k=+2	k=+3	k=+4	k=+5
Panel (A): Community Risk						
Peer Shock	0.111***	0.299***	0.416***	0.728***	0.771***	0.782***
	(0.025)	(0.038)	(0.045)	(0.060)	(0.070)	(0.078)
Peer Shock (High Vulnerability/Low Resilience)	0.592***	0.509***	0.706***	0.723***	1.011***	1.184***
	(0.026)	(0.036)	(0.048)	(0.055)	(0.069)	(0.087)
Panel (B): Unionization						
Peer Shock	0.306***	0.477***	0.679***	1.093***	1.301***	1.620***
	(0.019)	(0.031)	(0.047)	(0.062)	(0.076)	(0.092)
Peer Shock (High Union Membership)	0.383***	0.315***	0.419***	0.312***	0.411***	0.216**
	(0.023)	(0.034)	(0.049)	(0.058)	(0.072)	(0.086)
Firm FE	✓	✓	✓	✓	✓	✓
County-Year FE	✓	✓	✓	✓	✓	✓
Observations	5,556,578	4,727,432	4,015,976	3,379,161	2,797,759	2,267,637
$\bar{y}$	0.770	1.785	2.424	3.213	3.899	4.748
Adj. R^2	0.012	0.027	0.042	0.057	0.075	0.093

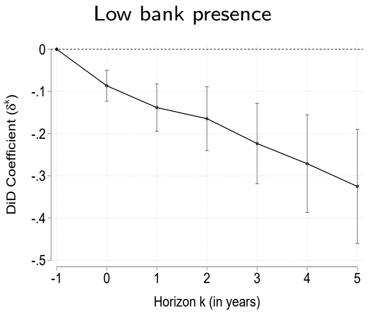
Back

2.2.2. Mitigation across regions

$$\Delta \text{Log(Employment)}_{f,c,t-1\to t+k} = \delta^k \times \text{Peer Shock}_{f,c,t} \times \text{Low bank presence}_{c,t} + \gamma^k \text{Peer Shock}_{f,c,t} + \alpha_f + \alpha_{c,t} + \varepsilon_{f,c,t}$$

Definitions:

- Low bank presence: Below median credit availability



Key Result: Employment reallocation to unaffected counties is lower if they have weaker credit availability

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