Temperature shocks and establishment sales

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Background

- Alarming facts of climate change:
  - Rising temperature
  - Extreme weather
  - Frequent heat waves

- How exposure to extreme temperatures affects U.S. corporate performance
  - How location-specific temperature shocks affect:
    - **establishment-level sales and productivity**
   - firm-level sales, productivity, and profitability

Background

- The impact of temperature on a variety of economic outcomes:
  - negatively affect aggregate output and income
- Channels:
  - Decreased labor supply amid extremely high temperatures, especially in sectors with high climate exposure (e.g., light manufacturing)
  - Agriculture and food-related industries sensitive to temperature extremes.

Hypothesis

- Hypothesis 1: Greater exposure to extreme temperatures will result in lower establishment-level sales.

- Hypothesis 2: Greater exposure to extreme temperatures will result in lower establishment-level productivity.

- Hypothesis 3: The negative effects of greater extreme temperature exposure on sales and productivity will be more pronounced for establishments in industries with high climate exposure, including the agricultural industry.

Data

- Temperature & precipitation:
  - Source: PRISM Climate Group
    - the U.S. Department of Agriculture's official climatological database
    - offer several advantages over other temperature data sources
    - publicly available
  - Content:
    - daily temperatures across 481,631 16-square-kilometer (i.e., 4×4 km.) grids covering the continental United States from 1981 to 2015.
- U.S public firms' geographic footprints:
  - Source: NETS database
  - Content: addresses and information on sales and employment for each U.S. establishment owned by a public company over the period from 1990 to 2015
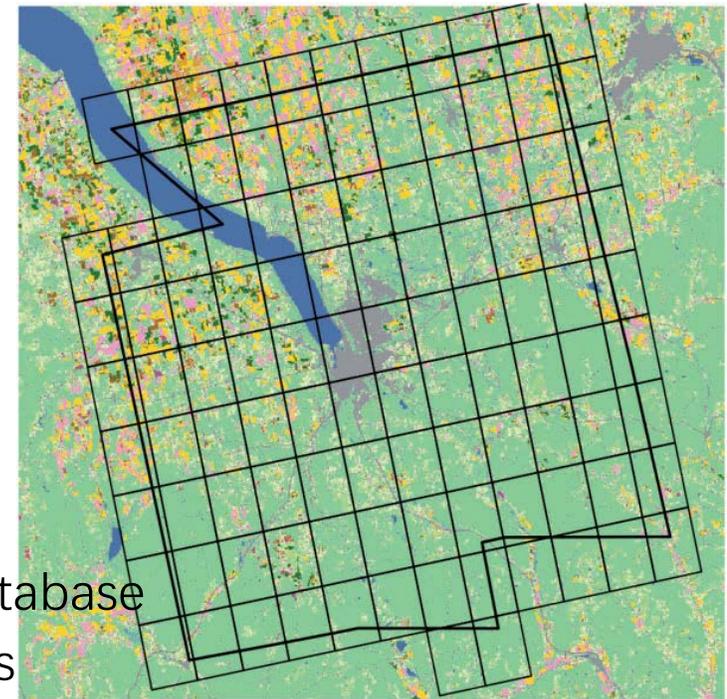
Data

- Firm-level profitability:
  - Source: Compustat
  - Content: quarterly operating income and net income
  - Process: scale these measures by beginning-of-quarter total assets
    take the natural log of one plus the resultant value
- Stock returns around earnings announcements
  - Source: CRSP; Thomson Reuters IBES database
  - Content: common stock prices and returns for firms trading on the AMEX, Nasdaq, and NYSE exchanges
  - Earnings announcement dates

Data: measure temperature exposure

- Average temperature at each establishment location during a given fiscal period
- Define absolute extreme temperature thresholds:
  - Number of days in the fiscal period that temperatures **exceed 30°C / below 0°C**
- Define location and time-specific extreme temperature exposure variables (because the definition of temperature extremes is likely to vary across geographies)
  - number of days that **max (min)** temperatures are **above (below) the 90th (10th) percentile** of the PRISM grid-specific temperature distribution in a given month, and then aggregate over the months in a particular establishment's fiscal period
  - A more stringent definition: 95%, 5%

Empirical tests

Estimate the effect of temperature exposure on establishment-level sales:

$$sales_{i,j,t} = \theta_i + \theta_{j,t} + \rho T_{i,t} + \gamma P_{i,t} + \varepsilon_{i,j,t}$$

- Run a panel regressions at the annual and quarterly frequencies
  - Regress the **natural log of sales** on each temperature exposure variable
- Include **precipitation** over the fiscal period as a **control** (e.g. Dell, Jones, and Olken 2012, 2014)
  - Include **industry-time fixed effects** to control for broad trends in industry sales growth
  - Include **establishment fixed effects** in all specifications to identify the causal effect of temperature exposure using random and exogenous variation in the distribution of heat around each firm's mean exposure over a fiscal period

Findings: Establishment level

- Population average effect of temperature exposure on establishment-level sales growth is zero at both the annual and quarterly frequencies.
  - Mean temperature
  - Absolute extreme temperature
  - Relative extreme temperature

- **Sufficient samples**: nonresults are driven by point estimates with small economic magnitudes, and not by imprecise estimates resulting from large standard errors.

	A. Annual frequency			
	(1)	(2)	(3)	(4)
Mean temperature	0.0011			
	(0.37)			
Days above 30°C		0.0001		
		(1.20)		
Days below 0°C		0.0002		
		(0.80)		
Days above 90th pctl			0.0001	
			(0.91)	
Days below 10th pctl			0.0000	
			(−0.22)	
Days above 95th pctl				0.0001
				(0.65)
Days below 5th pctl				−0.0001
				(−0.49)
Precipitation	−0.0006	−0.0004	−0.0005	−0.0006
	(−1.16)	(−0.68)	(−0.99)	(−1.15)
Establishment FE	Yes	Yes	Yes	Yes
Estab–calendar qtr FE	No	No	No	No
Time-industry FE	Yes	Yes	Yes	Yes
Adj. R^2	.915	.915	.915	.915
No. observations	1,385,344	1,385,344	1,385,344	1,385,344
No. establishments	167,623	167,623	167,623	167,623

Findings: Establishment level

- Examine whether sales nonresults are potentially driven by establishments **scaling labor inputs** in order to smooth output
  - Replace sales with productivity in baseline regressions
  - Productivity: ratio of sales to number of employees
- Result: No evidence that temperature exposures are significant drivers of **worker productivity**
  - consistent across our different temperature exposure variables and extends to both the annual and quarterly frequencies.

Findings: Establishment level

- Examine whether establishments in certain **sectors** of the economy exhibit climate sensitivity that differs from the population average
  - Define an indicator for establishments that are in the **heat-sensitive industries**: agriculture; forestry, fishing, and hunting; mining; construction; manufacturing; and transportation and utilities.
  - Reestimate baseline specifications with an interaction between this indicator (dummy variable) and the temperature exposure variables
- Result: generally unresponsive to temperature shocks, except:
  - Abnormally cold days: small but statistically significant increase in sales
  - Small but statistically significant interaction effects between the heat-sensitive industry indicator and precipitation levels

Climate-sensitive sectors

	A. Sales			
	(1)	(2)	(3)	(4)
Mean temperature	0.0012			
	(0.38)			
× Heat-sensitive ind.	0.0000			
	(−1.62)			
Days above 30°C		0.0001		
		(0.80)		
× Heat-sensitive ind.		0.0001		
		(0.55)		
Days below 0°C		0.0000		
		(−1.38)		
× Heat-sensitive ind.		0.0005		
		(1.91)		
Days above 90th pctl			0.0000	
			(0.56)	
× Heat-sensitive ind.			0.0000	
			(−0.21)	
Days below 10th pctl			0.0000	
			(−1.75)	
× Heat-sensitive ind.			0.0003	
			(1.66)	
Days above 95th pctl				0.0000
				(0.17)
× Heat-sensitive ind.				−0.0001
				(−0.50)
Days below 5th pctl				0.0000
				(−1.93)
× Heat-sensitive ind.				0.0006
				(2.06)
Precipitation	−0.0489	0.0423	−0.0016	−0.0016
	(−0.08)	(1.16)	(−0.06)	(−0.05)
× Heat-sensitive ind.	0.0026	0.0037	0.0034	0.0035
	(1.74)	(2.44)	(2.35)	(2.35)
Establishment FE	Yes	Yes	Yes	Yes
Time-industry FE	Yes	Yes	Yes	Yes
Adj. R^2	.915	.915	.915	.915
No. observations	1,385,344	1,385,344	1,385,344	1,385,344
No. establishments	167,623	167,623	167,623	167,623

Findings: Firm level

- Take the **sales-weighted** average of mean temperature levels experienced at each of the firm's establishments

- For the absolute and relative temperature exposure variables, compute the **sales-weighted** average number of days spent above or below each of the cutoffs across each firm's establishments

- Nonresults

- Exception: extreme cold temperature has a small but statistically significant population average effect on firm sales
  - Concentrated in energy sector: extreme cold driving up heating demand and leading to higher Energy sector sales

Findings: Firm level

- **Profitability**: operating income, net income, and earnings announcement returns as dependent variables
- Operating income and net income:
  - natural log of 1 plus ratio of operating income/net income to total asset
- Earning announcement returns:
  - AR from [0, +3] window surrounding announcement
- Insignificant

Robustness checks

- How the results are affected by alternative standard error adjustments
- and potentially heterogeneous temperature sensitivities in relatively warmer and cooler area of the United States

Robustness check: accounting for spatial correlation

- PRISM weather data are spatially interpolated for grid points between observed weather stations

- Unobservable determinants of sales may be spatially correlated

- So errors are likely to be highly correlated for geographically proximate establishments, which may not be properly accounted for in the standard double-clustering approach employed in the baseline tests.

Robustness check: accounting for spatial correlation

- A modified Conley approach
- Compare two sets of t-statistics:
  - calculated using standard errors adjusted for clustering, both by the firm and across time
  - calculated using standard errors adjusted for both spatial correlation, following the method of Conley (1999), and time-series correlation using the method of Newey and West (1987)
- Double-clustering approach is more conservative
- Both approaches imply statistically weak effects
- Overall, the standard double-clustering approach in the baseline results does not seem to understate standard errors

Robustness check: Adaptation

- Establishments in relatively **hotter areas** of the United States may exhibit temperature sensitivity that differs from their counterparts located in cooler parts of the country

- Split the sample of establishments into two subsamples based on average temperatures

- Define a warmer location **indicator variable** that equals 1 for the set of establishments in the top half of average temperatures experienced and include this variable as an interaction with each of our temperature exposure variables.

- Limited evidence in support of an adaptation story

Conclusion

- At both the annual and quarterly frequencies, we find that the effects of temperature shocks are economically small and statistically insignificant, including among industries identified as heat sensitive in prior literature

- Similar nonresults at the firm level (sales, productivity & earnings)

- Our study focuses on establishments owned by **publicly listed firms** in the United States, a group likely to have the resources to withstand extreme weather.

  - Consistent with the study of temperature impact on developing and richer countries

Contribution

- Document the effect of abnormal temperature exposures on establishment sales and productivity, as well as firm-level sales, productivity, and profitability.

- Determinants of establishment-level sales and productivity

Further study

- Though population average treatment effects that are close to zero, certain sectors of the U.S. economy may be more vulnerable to temperature shocks

- Sector-specific sensitivities also may be time dependent, showing up only during certain months or seasons

- Whether key market participants, such as analysts and investors, understand these relationships