

# Economic Costs of Climate Change

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# Motivation and Research Question

- Global temperature likely to increase by at least 2°C by mid- to late-21<sup>st</sup> century and extreme weather events are likely to be more frequent
- Higher temperature lowers agricultural activity and total factor productivity
- Mixed evidence of temperature affecting aggregate firm sales

**How do changes in temperature affect firm sales?**

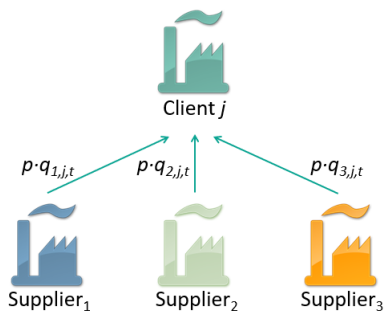
# Empirical Challenge

## Temperature may affect **both supply and demand** for a firm's products

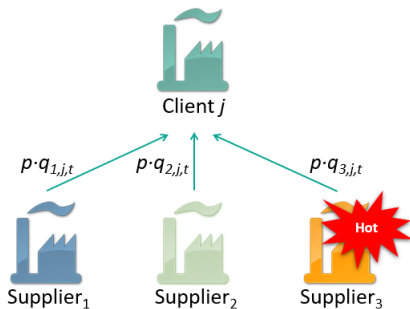
Use production networks as laboratory:

- 1 Changes in temperature are **exogenous** to individual firms' activities
- 2 Suppliers in different locations are **differently exposed** to changes in temperature
- 3 We compare changes in sales of suppliers to the **same client** in the **same year**

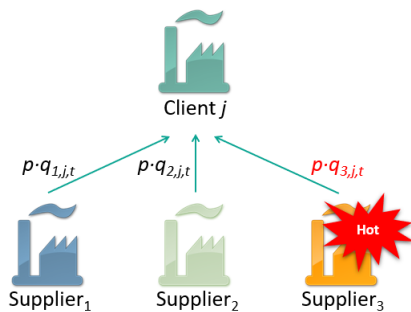
# Identification



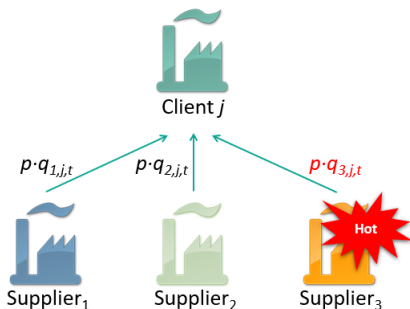
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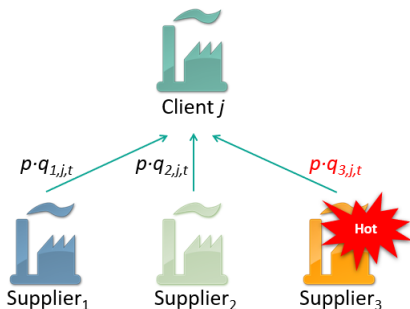
# Empirical Specification



$$\Delta \ln(\text{Sales})_{ijt} = \beta_1 \Delta \text{Temp}_{it} + \beta_2 \overline{\text{Pr}cp}_{it} + \gamma X_{it-1} + \delta_{jt} + \epsilon_{ijt}$$

$$\Delta \text{Temp}_{it} = \overline{\text{Temp}}_{it} - \overline{\text{Temp}}_{it-1}$$

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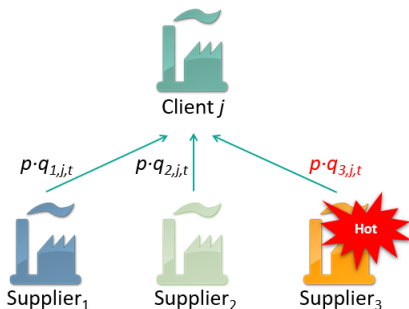


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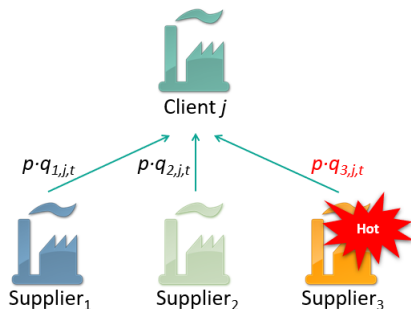
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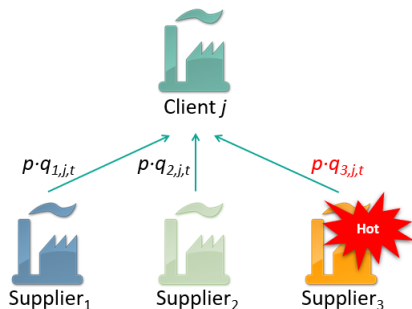
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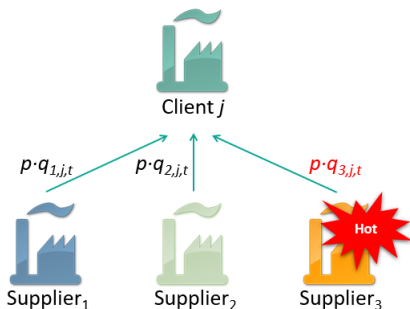
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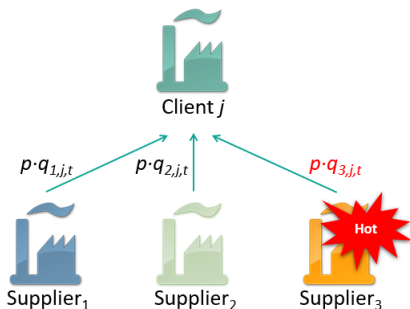
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# Overview of Results

- A 1°C increase in average daily temperature leads to a 1.2% to 1.9% decrease in inter-firm sales
- **Economic mechanisms:**
  - Labour supply and productivity
  - Financial constraints and adaptability
  - Switching costs
- Extreme heat (cold) events have a larger negative impact: -6.2% to -8.0% (-31.3% to -35.7%)

# Contribution

- Heat reduces productivity and/or firm performance (Graff-Zivin and Kahn (2016), Chen, Huynh and Zhang (2018) and Colmer, Martin, Muuls and Wagner (2019) and Pankratz and Schiller (2019))
- Heat has no effect on sales, productivity, or profitability (Addoum, Ng, and Ortiz-Bobea (2020))

**We estimate the impact of local temperature on firm supply, controlling for demand shocks**

# Data

- Compustat Segments: Client-supplier pairs in the US (2000-2015)
  - Main clients ( $\geq 10\%$  sales)
  - Purchases from main clients represent more than 30% of suppliers' total sales
- Weather variables:
  - PRISM Climate Group: Daily temperature ( $^{\circ}\text{C}$ ) and precipitation (mm);  $4 \times 4$  km grid in continental US; interpolated from nearby weather stations
  - National Oceanic and Atmospheric Administration (NOAA): Extreme weather events
  - Aggregated to headquarters county and fiscal year level



# Summary Statistics

- Unit of analysis: supplier-client-year.
- 12,439 observations, of which:
  - 1,856 unique suppliers
  - 419 unique clients
  - 700 observations per year on average
  - 5 suppliers per client per year on average
- Key summary statistics

	Mean	Median	S.Dev.	# Obs.
$\Delta \ln Sales$	0.0159	0.0363	0.5081	12,439
$Temp$	13.7013	13.2761	4.2085	12,439
$\Delta Temp$	-0.0013	0.0364	0.8520	12,439
Cold Events	0.0007	0	0.0269	12,439
Heat Events	0.0053	0	0.1261	12,439

## Baseline Results

	(1)	(2)	(3)	(4)	(5)	(6)
$\Delta Temp$	-0.012*	-0.013*	-0.017**	-0.014*	-0.014*	-0.019**
	(0.085)	(0.072)	(0.023)	(0.069)	(0.052)	(0.015)
<i>Prcp</i>				-0.007	-0.008	-0.009
				(0.236)	(0.166)	(0.124)
Controls	✓	✓	✓	✓	✓	✓
Observations	12,439	12,439	12,439	12,439	12,439	12,439
R <sup>2</sup>	0.298	0.302	0.333	0.298	0.302	0.334
Client-Yr FE	✓	✓	✓	✓	✓	✓
Industry FE		✓			✓	
Ind-Yr FE			✓			✓
Cluster	County	County	County	County	County	County

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# Economic Mechanisms

**Labour supply and productivity**

**Financial constraints and adaptability**

**Switching costs**

# Labour Supply and Productivity

## **Labour supply and productivity:**

- Negative effect of temperature should be more pronounced for labor-intensive or heat-sensitive firms

## Financial constraints and adaptability

## Switching costs

# Labour Supply and Productivity

	(1)	(2)	(3)	(4)	(5)	(6)
	Mfg	Non-Mfg	Heat Sensitive	Non-Heat Sensitive	High Labor Intensity	Low Labor Intensity
$\Delta Temp$	-0.022** (0.025)	0.011 (0.635)	-0.023** (0.011)	0.034 (0.141)	-0.022** (0.047)	-0.007 (0.659)
$Prcp$	-0.010 (0.180)	-0.024** (0.020)	-0.013** (0.043)	-0.008 (0.575)	0.007 (0.331)	-0.019* (0.062)
Controls	✓	✓	✓	✓	✓	✓
Client-Yr FE	✓	✓	✓	✓	✓	✓
Ind-Yr FE	✓	✓	✓	✓	✓	✓
Obs	8,557	3,031	10,218	1,416	5,452	5,432
R <sup>2</sup>	0.319	0.447	0.342	0.449	0.419	0.381

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# Financial Constraints and Adaptability

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## Financial constraints and adaptability:

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## Switching costs

# Financial Constraints and Adaptability

	(1)	(2)	(3)	(4)
	High % LT Debt Maturing	Low % LT Debt Maturing	Non-Rated	Rated
$\Delta Temp$	-0.038*** (0.015)	0.005 (0.751)	-0.031*** (0.003)	0.024 (0.109)
Obs	3,892	3,842	8,775	2,776
R <sup>2</sup>	0.438	0.430	0.347	0.488
	(5)	(6)	(7)	(8)
	Low Assets	High Assets	Single Segment	Conglomerate
$\Delta Temp$	-0.042** (0.006)	0.001 (0.900)	-0.021** (0.020)	-0.003 (0.873)
Obs	5,529	5,528	9,034	2,060
R <sup>2</sup>	0.386	0.436	0.356	0.490
Controls	✓	✓	✓	✓
Client-Yr FE	✓	✓	✓	✓
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# Switching Costs

## Labour supply and productivity:

- Negative effect of temperature should be more pronounced for labor-intensive or heat-sensitive firms

## Financial constraints and adaptability:

- Negative effect of temperature should be more pronounced for firms with financial constraints and less operating flexibility

## Switching costs:

- Negative effect of temperature should be more pronounced for firms selling standardized goods and client-supplier pairs with weaker relationships



# Switching Costs

	(1) Std Goods	(2) Non-Std Goods	(3) No Patents	(4) Has Patents	(5) High Distance	(6) Low Distance
$\Delta Temp$	-0.036* (0.099)	-0.017* (0.092)	-0.019* (0.064)	-0.012 (0.464)	-0.029* (0.084)	0.017 (0.222)
$Prcp$	-0.035*** (0.002)	0.003 (0.667)	-0.019*** (0.010)	0.011 (0.415)	0.011 (0.183)	-0.015 (0.294)
Controls	✓	✓	✓	✓	✓	✓
Client-Yr FE	✓	✓	✓	✓	✓	✓
Ind-Yr FE	✓	✓	✓	✓	✓	✓
Obs	7,232	3,103	9,907	2,537	3,341	3,315
R <sup>2</sup>	0.348	0.288	0.355	0.412	0.425	0.419

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Controls	✓	✓	✓	✓	✓	✓
Client-Yr FE	✓	✓	✓	✓	✓	✓
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# Robustness

- Alternative weather controls
  - Postcode level weather variables
  - Quadratic weather variables
  - Changes in precipitation
- State level standard error clusters
- 3-digit SIC industry fixed effects
- Placebo test

# Additional Tests

- What about extreme weather events?
- What about extensive margin?

# Extreme Weather

	(1)	(2)	(3)	(4)	(5)	(6)
Heat	-0.062** (0.024)	-0.064** (0.020)	-0.080** (0.024)			
Cold				-0.313*** (0.006)	-0.333*** (0.004)	-0.357*** (0.003)
Temp	-0.016 (0.156)	-0.015 (0.168)	-0.020* (0.078)	-0.016 (0.146)	-0.016 (0.157)	-0.021* (0.071)
Prcp	0.007 (0.620)	0.006 (0.650)	0.007 (0.617)	0.006 (0.631)	0.006 (0.661)	0.007 (0.632)
Controls	✓	✓	✓	✓	✓	✓
Obs.	12,413	12,413	12,413	12,413	12,413	12,413
R <sup>2</sup>	0.323	0.327	0.358	0.323	0.327	0.358
Client-Yr FE	✓	✓	✓	✓	✓	✓
County FE	✓	✓	✓	✓	✓	✓
Industry FE		✓			✓	
Ind-Yr FE			✓			✓

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Cold				-0.313*** (0.006)	-0.333*** (0.004)	-0.357*** (0.003)
Temp	-0.016 (0.156)	-0.015 (0.168)	-0.020* (0.078)	-0.016 (0.146)	-0.016 (0.157)	-0.021* (0.071)
Prcp	0.007 (0.620)	0.006 (0.650)	0.007 (0.617)	0.006 (0.631)	0.006 (0.661)	0.007 (0.632)
Controls	✓	✓	✓	✓	✓	✓
Obs.	12,413	12,413	12,413	12,413	12,413	12,413
R <sup>2</sup>	0.323	0.327	0.358	0.323	0.327	0.358
Client-Yr FE	✓	✓	✓	✓	✓	✓
County FE	✓	✓	✓	✓	✓	✓
Industry FE		✓			✓	
Ind-Yr FE			✓			✓



# Extreme Weather

	(1)	(2)	(3)	(4)	(5)	(6)
Heat	-0.062** (0.024)	-0.064** (0.020)	-0.080** (0.024)			
Cold				-0.313*** (0.006)	-0.333*** (0.004)	-0.357*** (0.003)
Temp	-0.016 (0.156)	-0.015 (0.168)	-0.020* (0.078)	-0.016 (0.146)	-0.016 (0.157)	-0.021* (0.071)
Prcp	0.007 (0.620)	0.006 (0.650)	0.007 (0.617)	0.006 (0.631)	0.006 (0.661)	0.007 (0.632)
Controls	✓	✓	✓	✓	✓	✓
Obs.	12,413	12,413	12,413	12,413	12,413	12,413
R <sup>2</sup>	0.323	0.327	0.358	0.323	0.327	0.358
Client-Yr FE	✓	✓	✓	✓	✓	✓
County FE	✓	✓	✓	✓	✓	✓
Industry FE		✓			✓	
Ind-Yr FE			✓			✓

# Termination of Relationships

	(1)	(2)	(3)	(4)	(5)	(6)
$\Delta Temp$	-0.004 (0.241)	-0.004 (0.227)	-0.004 (0.220)	-0.005 (0.177)	-0.005 (0.114)	-0.006 (0.115)
Prcp				✓	✓	✓
Observations	23,193	23,193	23,193	23,193	23,193	23,193
R <sup>2</sup>	0.427	0.440	0.455	0.427	0.440	0.455
	(7)	(8)	(9)	(10)	(11)	(12)
Extreme Heat	0.034 (0.104)	0.038* (0.084)	0.044 (0.192)			
Extreme Cold				0.041 (0.582)	0.044 (0.552)	0.061 (0.491)
Observations	23,179	23,179	23,178	23,179	23,179	23,178
R <sup>2</sup>	0.478	0.486	0.501	0.478	0.486	0.500
Controls	✓	✓	✓	✓	✓	✓
Client-Yr FE	✓	✓	✓	✓	✓	✓
Industry FE		✓			✓	
Ind-Yr FE			✓			✓

# Termination of Relationships

	(1)	(2)	(3)	(4)	(5)	(6)
<i>ΔTemp</i>	<b>-0.004</b> (0.241)	<b>-0.004</b> (0.227)	<b>-0.004</b> (0.220)	<b>-0.005</b> (0.177)	<b>-0.005</b> (0.114)	<b>-0.006</b> (0.115)
Prcp				✓	✓	✓
Observations	23,193	23,193	23,193	23,193	23,193	23,193
R <sup>2</sup>	0.427	0.440	0.455	0.427	0.440	0.455
	(7)	(8)	(9)	(10)	(11)	(12)
Extreme Heat	0.034 (0.104)	0.038* (0.084)	0.044 (0.192)			
Extreme Cold				0.041 (0.582)	0.044 (0.552)	0.061 (0.491)
Observations	23,179	23,179	23,178	23,179	23,179	23,178
R <sup>2</sup>	0.478	0.486	0.501	0.478	0.486	0.500
Controls	✓	✓	✓	✓	✓	✓
Client-Yr FE	✓	✓	✓	✓	✓	✓
Industry FE		✓			✓	
Ind-Yr FE			✓			✓

# Termination of Relationships

	(1)	(2)	(3)	(4)	(5)	(6)
$\Delta Temp$	-0.004 (0.241)	-0.004 (0.227)	-0.004 (0.220)	-0.005 (0.177)	-0.005 (0.114)	-0.006 (0.115)
Prcp				✓	✓	✓
Observations	23,193	23,193	23,193	23,193	23,193	23,193
R <sup>2</sup>	0.427	0.440	0.455	0.427	0.440	0.455
	(7)	(8)	(9)	(10)	(11)	(12)
<b>Extreme Heat</b>	<b>0.034</b> (0.104)	<b>0.038*</b> (0.084)	<b>0.044</b> (0.192)			
<b>Extreme Cold</b>				<b>0.041</b> (0.582)	<b>0.044</b> (0.552)	<b>0.061</b> (0.491)
Observations	23,179	23,179	23,178	23,179	23,179	23,178
R <sup>2</sup>	0.478	0.486	0.501	0.478	0.486	0.500
Controls	✓	✓	✓	✓	✓	✓
Client-Yr FE	✓	✓	✓	✓	✓	✓
Industry FE		✓			✓	
Ind-Yr FE			✓			✓

# Conclusion

- We identify the effects of local temperature on firm supply, controlling for unobserved changes in demand
- Economic mechanisms:
  - Labour supply and productivity
  - Financial constraints and adaptability
  - Switching costs
- Extreme weather events are more disruptive
- Limited effects on extensive margin

Thank you!