Temperature and Growth: A Panel Analysis of the United States

Riccardo Colacito, Bridget Hoffmann and Toan Phan

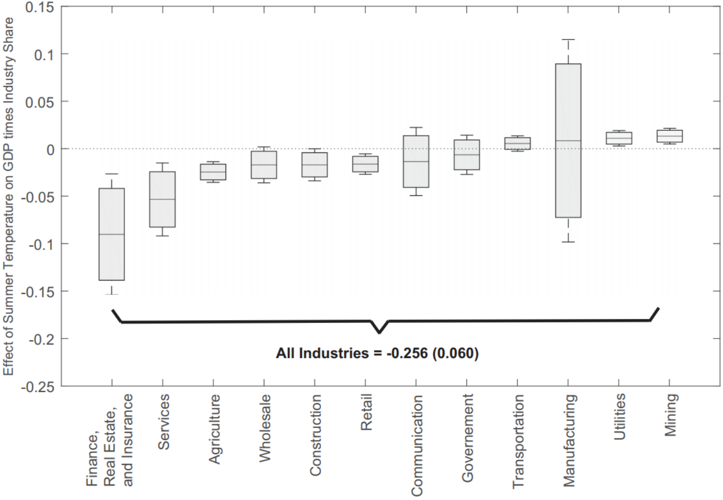
Discussion by:
Danchen Zhao and Shilpi S. Kumar
University of Notre Dame

March 16, 2021

Introduction

- Contribute to this literature by providing comprehensive evidence that rising temperatures do affect U.S. economic activities, at both the aggregate and industry level.
- Overcome existing challenges by exploiting random fluctuations in seasonal temperatures across years and states.
- An increase of 1 Fahrenheit degree in the average summer temperature is associated with a reduction in the annual growth rate of state-level output of 0.15 to 0.25 percentage points
- Rising temperatures could reduce U.S. economic growth by up to one-third over the next century

Introduction



Introduction

- Document that the temperature effects are particularly strong in states with relatively higher summer temperatures, most of which are located in the South.
- However, the authors do not find any evidence that the effect of temperature on GDP in the South is driven by the relatively less developed states.
- Rising summer temperatures have a pervasive effect in the entire cross section of industries, above and beyond the sectors that are traditionally deemed as vulnerable to changing climatic conditions

Data

- Sample Peroid: 1957-2012
- Use daily station-level weather data from the National Oceanic and Atmospheric Administration (NOAA) Northeast Regional Climate Center
- GSP: the value added in production by the labor and capital of all industries located in that state

Benchmark Regression Specification I

Country level: $\Delta y_t = \beta T_t + \rho \Delta y_{t-1} + \alpha + \varepsilon_t$

With seasons: $\Delta y_t = \sum_{s \in \mathcal{S}} \beta_s T_{s,t} + \rho \Delta y_{t-1} + \alpha + \varepsilon_t$

TABLE 1

MAIN RESULTS: EFFECTS OF ANNUAL AND SEASONAL TEMPERATURES ON GSP GROWTH

	Whole Year	Winter	Spring	Summer	Fall
Time series	−0.396	−0.071	−0.027	−0.414	0.042
	(0.382)	(0.179)	(0.334)	(0.385)	(0.287)
Panel analysis	0.006	0.001	0.003	−0.154	0.102
	(0.111)	(0.049)	(0.065)	(0.072)**	(0.055)*
	(0.069)	(0.025)	(0.032)	(0.047)***	(0.040)***
	(0.105)	(0.044)	(0.051)	(0.065)**	(0.054)*

Benchmark Regression Specification II

State level: $\Delta y_{i,t} = \beta T_{i,t} + \rho \Delta y_{i,t-1} + \alpha_i + \alpha_t + \varepsilon_{i,t}$
With season: $\Delta y_{i,t} = \sum_{s \in \mathcal{S}} \beta_s T_{i,s,t} + \rho \Delta y_{i,t-1} + \alpha_i + \alpha_t + \varepsilon_{i,t}$

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Weight: proportion of its GSP relative to the entire country's GDP
Standard error: clustered by year, by state

Growth vs Level Effect

$$\Delta y_{i,t} = \sum_{s\in\mathcal{S}} \beta_s T_{i,s,t} + \underbrace{\sum_{s\in\mathcal{S}} \beta_{\text{lag},s} T_{i,s,t-1}}_{\text{lagged terms}} + \rho\Delta y_{i,t-1} + \alpha_i + \alpha_t + \varepsilon_{i,t}$$

1. No effect: $H_0 : \beta_s = \beta_{\mathrm{lag,s}} = 0$
2. Level effect: $H_0 : \beta_s + \beta_{\mathrm{lag,s}} = 0$
3. Growth effect: $H_A : \beta_s + \beta_{\mathrm{lag,s}} \neq 0$

Growth vs Level Effect: Findings

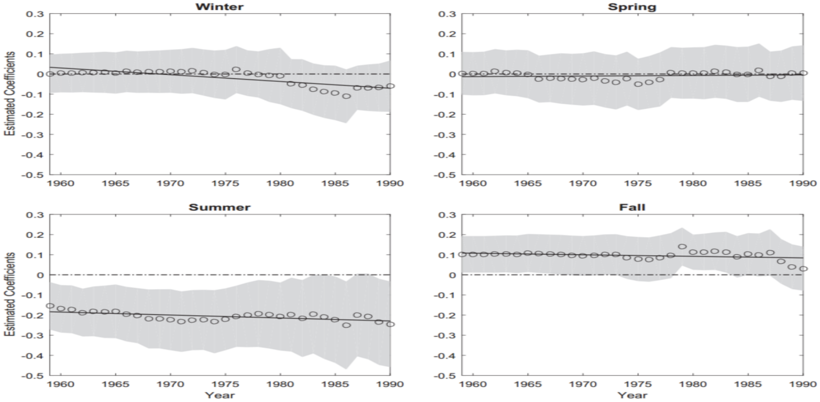
	Winter	Spring	Summer	Fall
Contemporaneous temp.	−0.008	−0.012	−0.170	0.108
	(0.051)	(0.059)	(0.076)**	(0.050)**
	(0.029)	(0.032)	(0.045)***	(0.038)***
	(0.048)	(0.046)	(0.067)**	(0.048)**
One-year lagged temp.	0.004	0.121	−0.153	0.066
	(0.053)	(0.063)*	(0.079)*	(0.060)
	(0.023)	(0.039)***	(0.053)***	(0.029)**
	(0.046)	(0.054)**	(0.075)**	(0.049)
Sum of coefficients	−0.004	0.109	−0.323	0.174
	(0.084)	(0.086)	(0.115)***	(0.077)**
	(0.031)	(0.045)**	(0.077)***	(0.052)***
	(0.075)	(0.068)	(0.108)***	(0.067)***
Wald test's p-value	[0.961]	[0.208]	[0.007]	[0.027]
	[0.893]	[0.018]	[0.000]	[0.002]
	[0.956]	[0.110]	[0.003]	[0.009]

Figure: 1957-2012, weights: GSP shares, se clustered at year & state

Summer and Fall have lasting effect on output growth

Except winter, lags are significant

Stability Across Time



Summer effect is robust, fall effect is not

Economic Mechanism

1. Labor productivity: summer and fall

Economic Mechanism

1. Labor productivity: summer and fall
2. Industry: negatively affects output growth
   - Food services & drinking places
   - Insurance
   - Wholesale
   - Retail
   - Agriculture, forestry, & fishing
   - Utilities and Mining gain

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   - Utilities and Mining gain
3. Region: strong effects on southern states

Economic Mechanism: Labor Productivity

$$\Delta a_{i,t} = \sum_{s\in\mathcal{S}} \beta_s T_{i,s,t} + \rho\Delta a_{i,t-1} + \alpha_i + \alpha_t + \varepsilon_{i,t}$$

	Winter	Spring	Summer	Fall
Productivity	−0.033	−0.020	−0.152	0.132
	(0.067)	(0.065)	(0.087)*	(0.048)***
	(0.041)	(0.031)	(0.049)***	(0.054)**
	(0.055)	(0.028)	(0.063)**	(0.039)***
Employment	0.013	−0.086	0.008	−0.021
	(0.032)	(0.051)*	(0.059)	(0.041)
	(0.015)	(0.051)*	(0.037)	(0.019)
	(0.024)	(0.055)	(0.049)	(0.032)

NOTE: This table reports results for panel regressions of state productivity growth rate on temperatures, using the entire cross section of 50 states and the District of Columbia. Productivity is defined as output over employment in the private sector. All specifications include the lagged dependent variable, state, and year fixed effects. States are weighted in the panel regression by the proportion, averaged over the whole sample, of their GSP relative to that of the whole country. The columns refer to the analysis conducted by regressing jointly on the four seasonal averages. Winter is defined as January–March, spring as April–June, summer as July–September, fall as October–December. Temperatures are in degrees Fahrenheit. The sample is 1990–2011. The standard errors, clustered by year, by state, and by both dimensions, are in parentheses. ***, **, and * denote significance at the 1%, 5%, and 10% levels.

Summer & Fall temperature affects GSP growth through productivity growth not employment growth

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Summer & Fall temperature affects GSP growth through productivity growth not employment growth

Supporting empirical evidence from automobile, garment industry and cognitive performance etc

Economic Mechanism: Industry

12 industry group according to BEA, pre and post 1997

$$\Delta y_{i,t}^{j} = \beta_{\text{summer}}^{j} \, T_{i,\text{ summer },t} + \rho \Delta y_{i,t-1}^{j} + \alpha_i + \alpha_t + \varepsilon_{i,t}$$

Economic Mechanism: Industry

12 industry group according to BEA, pre and post 1997

$$\Delta y^j_{i,t} = \beta^j_{\text{summer}}\ T_{i,\text{ summer },t} + \rho \Delta y^j_{i,t-1} + \alpha_i + \alpha_t + \varepsilon_{i,t}$$

Findings: Table 4 from paper

Industry: negatively affects output growth

- Food services & drinking places
- Insurance
- Wholesale
- Retail
- Agriculture, forestry, & fishing

Utilities and Mining gain

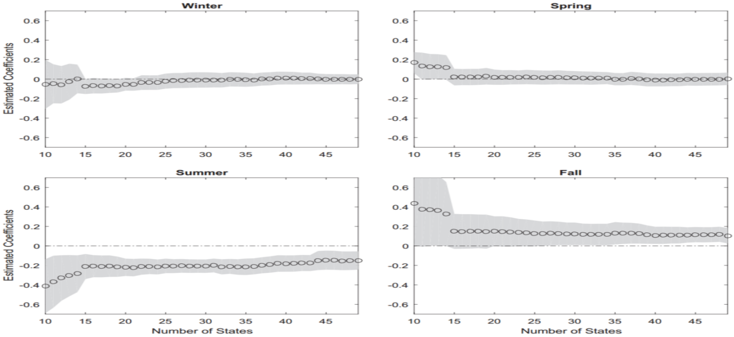
Economic Mechanism: Regional Analysis

Regions: North, South, Midwest, West (U.S. Census Bureau

	Winter	Spring	Summer	Fall
North	0.329	0.065	0.240	−0.255
	(0.173)*	(0.296)	(0.257)	(0.233)
	(0.238)	(0.176)	(0.232)	(0.184)
	(0.216)	(0.233)	(0.235)	(0.186)
South	−0.087	0.152	−0.326	0.571
	(0.167)	(0.159)	(0.163)**	(0.194)***
	(0.077)	(0.087)*	(0.085)***	(0.063)***
	(0.142)	(0.130)	(0.129)**	(0.157)***
Midwest	0.010	−0.158	0.043	−0.116
	(0.089)	(0.144)	(0.162)	(0.128)
	(0.055)	(0.104)	(0.075)	(0.068)*
	(0.074)	(0.125)	(0.130)	(0.112)
West	−0.000	−0.155	0.028	−0.006
	(0.096)	(0.143)	(0.154)	(0.167)
	(0.060)	(0.077)**	(0.145)	(0.162)
	(0.056)	(0.097)	(0.153)	(0.174)

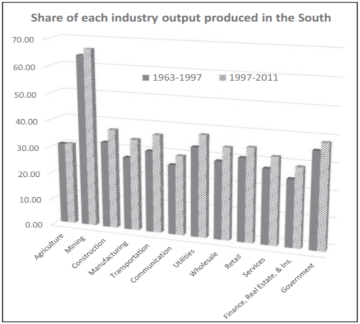
GSP in Southern states: summer and fall temperatures, other states not affected

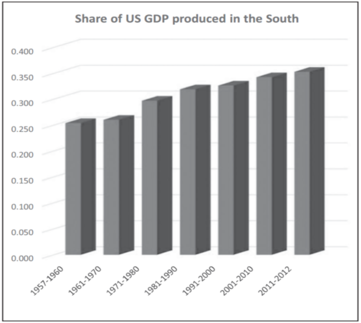
Economic Mechanism: Temperature Sorted



Non-linearity in the impact of rising temperatures

Economic Mechanism: Share of Southern States





Additional Results: Development and Temperature

Define development levels according to the Human Development Index (HDI).

$$\Delta y_{i,t} = \sum \left(\beta_s T_{i,s,t} + \delta_s T_{i,s,t} \cdot I\left[HDI_i\right]\right) + \rho \cdot \Delta y_{i,t-1} + \alpha_i + \alpha_t + \varepsilon_{i,t}$$

Additional Results: Development and Temperature

TABLE 6

EFFECTS OF SEASONAL TEMPERATURE BY DEVELOPMENT LEVEL

	Winter	Spring	Summer	Fall
Panel A: South				
β_s	−0.111	0.139	−0.375	0.585
	(0.188)	(0.185)	(0.179)**	(0.203)***
	(0.069)	(0.116)	(0.090)***	(0.065)***
δ_s	0.053	0.068	0.131	−0.042
	(0.072)	(0.136)	(0.120)	(0.124)
	(0.046)	(0.111)	(0.064) **	(0.060)
Panel B: U.S.				
β_s	0.005	−0.008	−0.155	0.099
	(0.049)	(0.065)	(0.075)**	(0.052)*
	(0.026)	(0.032)	(0.050)***	(0.040)**
δ_s	−0.031	0.121	0.003	0.036
	(0.055)	(0.106)	(0.113)	(0.111)
	(0.043)	(0.075)	(0.063)	(0.059)

NOTE: Results of estimating equation (11). HDI is an indicator equal to 1 for states with HDI value less than or equal to 4.5. The sample is 1957–2012. Standard errors are in parentheses. The first set of standard errors is clustered by year and the second set of standard errors is clustered by state. ***, **, and * denote significance at the 1%, 5%, and 10% levels.

Additional Results: Development and Temperature

- The results reported in Table 6 are likely driven by the different industrial composition of more and less developed states in the South, with GSP in states with higher development more highly concentrated in industries exposed to summer.
- These results likely differ from those reported in the literature because even U.S. states that are considered less developed are still well above the poverty line, according to the most common measures of poverty.

Future Projections

They employ temperature projections obtained from the Climate Wizard to (http://ClimateWizard.org) developed by Girvetz et al. (2009) Projected Impacts:

$$E[\Delta GDP] = \sum_{s \in \{\text{ summer, fall }\}} E\left[\Delta T_s\right] \times \hat{\beta}_s$$

Additional Results: Development and Temperature

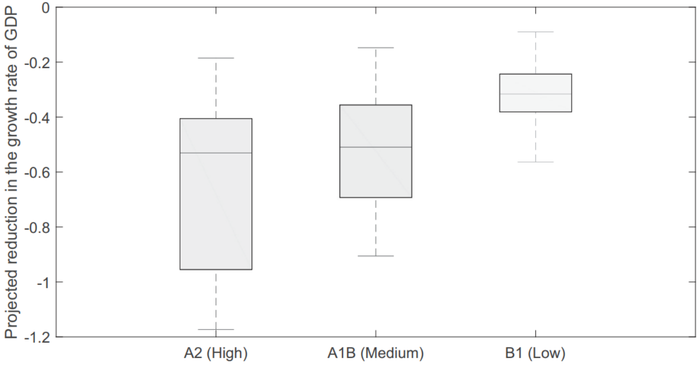


FIG. 6. Projected Reduction in the Growth Rate of GDP for the Period 2070–2099 under Three Emission Scenarios.

NOTE: For each scenario, the bottom and top lines denote the minimum and maximum projected impact, the bottom and top of the rectangle are the first and third quartiles of the distribution of projected impacts, while the horizontal line within the rectangle is the median projected impact.

Additional Results: Robustness Tests

The results are robust to:

- Alternative panel weights
- Alternative GSP measures
- Alternative definitions of seasons
- Alternative temperature data
- Spatial correlation, controlling for precipitation, excluding AR(1), excluding Alaska and Hawaii.

Conclusion

They find that an increase in the average summer temperature has a significant and robust negative effect on GSP growth.
They also find a positive, albeit weaker and less robust, effect of an increase in the average fall temperature.

First, models that estimate the damage of climate change should account for the heterogeneous effects that rising temperatures have on the cross-section of industries.
Second, these models should explicitly model the effects of seasonal temperatures on labor productivity and other economic variables.

Comments

- A simple and executable framework.
- Robust Results.
- Consistent with the literature.
- Will regional heterogeneous effects induce labor and capital flows?