

Climate Change and Outdoor Labor Market: The Rise of Dropouts of Adult Males

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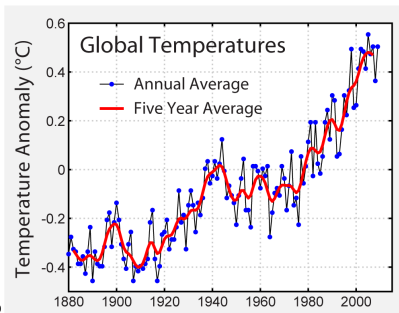
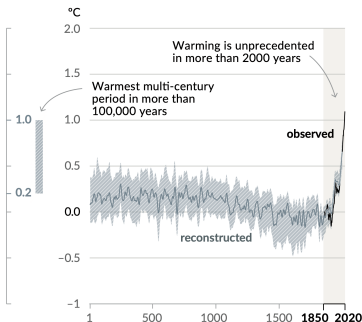
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Background: Global warming

Since the late 1960s, the world has experienced an unprecedented rise in temperature for the 2 millennia. In 5 decades in the U.S., # of hot days ($> 75^{\circ}\text{F}$ (23.9°C)) has increased **by 29.5 days** per year.

- The era of global warming has ended. The era of **global boiling** has arrived." (2023 July, U.N. Secretary-General)

Figure: Global trend of temperature (left: 2 millennia; right: 1880-2020)



Source: IPCC, 2021: Summary for Policymakers. In: Climate Change 2021.

Why care for global warming?

Traditionally, the climate science and env. economics studied damages and adaptations with their prime focus on the **ecosystem and agriculture**.

- agricultural productivity ([Mendelsohn et al. \[1994\]](#); [Deschênes and Greenstone \[2007\]](#)); GDP growth in poor countries([Dell et al. \[2012\]](#))

→ **Recent trend (@COP21): what about effects on humans?**

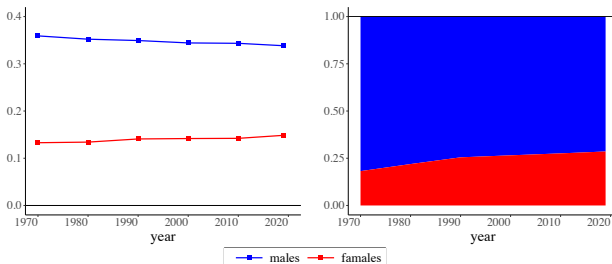
- Extreme weather raises **mortality** ([Barreca et al. \[2016\]](#); [Deschenes and Moretti \[2009\]](#)), **birth weights** ([Deschênes et al. \[2009\]](#)), **crimes** ([Ranson \[2014\]](#))
- Lab studies report harms on **cognitive skills**. ([Seppanen et al. \[2003\]](#))

→ **My idea: what about effects on humans working outdoors?**

Fact: who works outdoors?

Work Context Survey reveals: a consistent third of males ($>$ age 16) work outdoor regularly (at least, weekly). Moreover, 75-80% of outdoor workers are males. Over 85% of outdoor workers do NOT have college degrees.

Figure: The ratio and composition of working outdoor workers by gender
by sex (all sample)



→ **Does climate change nudge male workers to quit jobs, and even exit from the labor market?**

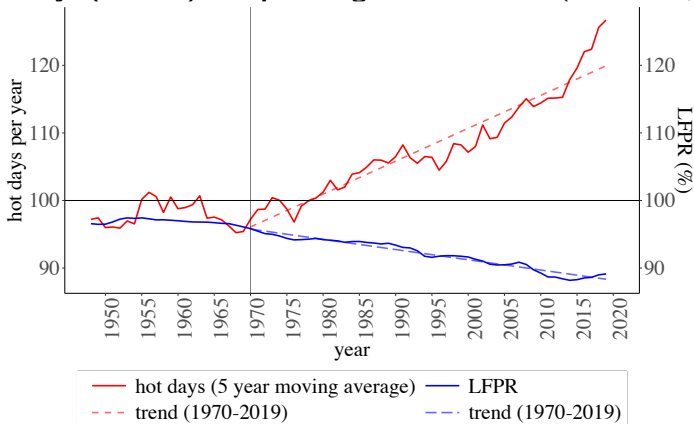
Note: Census, ACS, and Work Context survey at ONET. I construct an indicator where a person regularly works outdoor (cf. at least once a week) for 873 occupations.

Big picture: Global warming and male dropout trend

The onset of warming and declining LFPR roughly coincided around 1970. In OECD countries, LFPR peaked in 1968.

- The U.S. is most serious. (male LFPR: 96.5% (1950) → 89.1%(2019))

Figure: Hot days (> 75°F) and prime-aged male LFPRs (1950-2019, U.S.)



Note: LFPR from BLS. LFPR = emp. rate + unemp. rate. Hot days are 5 year MAs.

Question: Did global warming induce male dropouts?

- 1 Outdoor workers (at agri, construction, transportation) predominantly **underwent exposure to climate change** as “essential workers”.
(→ cost of work outdoors steadily increased)
- 2 Majority of outdoor workers are **less-educated**; fewer outside options in indoor jobs (e.g., office clerks; call center operators; waiters).
(← indoor jobs are more intensive in ICT and/or communication)
- 3 **Residential air conditioners** and other amenities (e.g., **colored TV set**) rapidly spread since the 1960s.
(→ relative cost of working outdoors grew)

Frogs in the boiled “air”?

The effect might look subtle, but is presumably cumulative in the long-run.

- **Mental health:** working outdoors brings discomfort (e.g., sweating with protective wears)
 - ✓ the rise of suicides ([Burke et al. \[2018\]](#)); negative tweets ([Baylis \[2020\]](#)).
- **Physical Health:** working outdoors requires physical and risky operations
 - ✓ **Direct effect:** extra heat and dehydration causes heat-related illnesses (e.g., heat strokes; acute kidney injuries)
 - ✓ **Indirect effect:** Lack of mental alertness causes injuries and even disabilities. ([Park et al. \[2021\]](#))

Data

I assemble a panel of climates (long-run trend of daily weathers) and male LFPRs across CZs during a half century, following [Barreca et al. \[2016\]](#).

- **Climate change**

- ✓ **daily** temperature from nearly 15,000 stations from GHCN-daily from National Climatic Data Center (NCDC). **Hourly** temperature cycle from the U.S. Climate Normals.
- ✓ compute # of **“hot days”** over 75°F (23.9°C); **“cold days”** below 35°F (1.7°C) during 8am-6pm. Using a 5-year average.
- ✓ CZ (instead of counties) most likely captures both temperature of workplaces and commuting routes.

- **LFPR and other covariates**

- ✓ repeated cross-section; Census (1-5% sample; 1970-2000, by decades), and American Community Survey (stacked 2010-11, 2018-19)

Hot days across regions

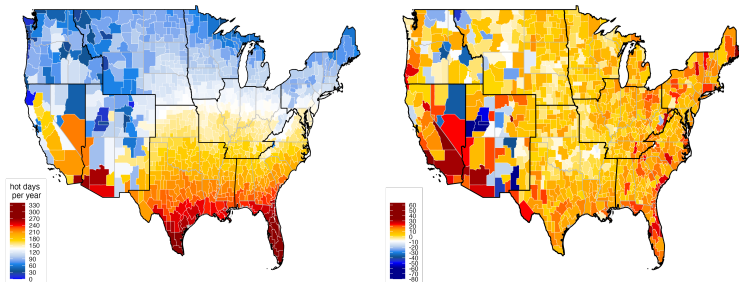
Dramatic spatial variation of climate change, even within states.

(→ Different shocks from automation, ICT or China shocks!)

Figure: Hot days (mean $> 75^{\circ}\text{F}$) across CZs

(level, 2019 (left); change from 1970 to 2019 (right))

Initially hot south areas have increasingly become hotter. Some regions experienced cooling.



Source: Computed from GHCN-daily.

Strategy: “natural” experiment in the U.S. mainland.

Isolate climate effect from other confounders across regions.

- **Variation of analysis** 722 Commuting Zones (**CZs**) $\times$ 4 decades (80, 90, 2000, 2010, 2019)
- **Identification assp.:** Climate change is governed by near-random meteorology.

Empirical model: isolate climate effects

I estimate a model by a panel data regression at CZ i and periods

$I = (\underline{I}, \bar{I}] \in \{(1976, 1980], (1986, 1990], \dots, (2006, 2010], (2015, 2019]\}$:

$$\text{LFPR}_{i,\bar{I}} = \underbrace{\beta^h \text{hd}_{i,I} + \beta^c \text{cd}_{i,I}}_{\text{climate impacts}} + \underbrace{\beta \mathbf{X}_{\bar{I}-1}}_{\text{a vector of pre-period controls}} +$$

$$\underbrace{\delta_i + \delta_I}_{\text{two-way FEs}} + \underbrace{\mathbb{I}(\text{CensusDivision})\bar{I}}_{\text{Census division trend}} + \underbrace{\epsilon_{i,I}}_{\text{clustered by CZs}}$$

- Pre-period covariates $\mathbf{X}_{\bar{I}-1}$ includes a battery of controls:
 - ✓ **Other climate proxies:** humidity; precipitation; snowfall
 - ✓ **Demography:** age; education; race and ethnicity; veterans,
 - ✓ **Industry structure:** industry mix; mean establishment size; HHI
 - ✓ **Regional traits:** poverty ratio; senior ratio ($> \text{age } 65$); population density
 - ✓ **Health & wealth:** disability; personal or family NLI; house rental ratio

Key findings

- Hot ($>75^{\circ}\text{F}$ (23.9°C)) and cold days ($<35^{\circ}\text{F}$ (1.7°C))) reduce **LFPR**.
- The harm on LFPR is largest for **the middle-aged (35-44)** and **less-educated**.
- The harm is fueled by pre-period **outdoor exposure**.
- Hot and cold days reduce **salaried emp. rate**.
 - ✓ increased the ratio of **self-employed**, especially working at home and the **unemployed**.
- Hot and cold days **reduced employment rate of outdoor jobs**, but transition to **indoor jobs** is seemingly limited.
- Hot and cold days **hurt real wages** for surviving outdoor jobs.
- **Assessment**: in the 21st century, climate change accounted for **12% of LFPR drop**. In high-school grads (and less), accounted for **18%**.

→ Climate change exacerbates the socioeconomic inequality.

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Baseline result (outcome 1980-2019)

10 hot days reduces LFPR by 0.24 p.p. during 1980-2019. Using discomfort index (including humidity) and limit to non-rainy days enlarges the estimates.

Table: Climate impact on LFPRs (*prime-aged males across CZs; 1980-2019*)

dependent variable: LFPR (percentage point) (prime-aged (25-54) males)					
	(1)	(2)	(3)	(4)	(5)
10 hot days	-0.286 *** (0.065)	-0.294 *** (0.068)	-0.280 *** (0.068)	-0.246 *** (0.066)	-0.239 *** (0.071)
10 cold days	-0.444 *** (0.152)	-0.487 *** (0.153)	-0.498 *** (0.155)	-0.454 *** (0.115)	-0.451 *** (0.122)
pre-period covariates					
climate	Yes	Yes	Yes	Yes	Yes
demography	Yes	Yes	Yes	Yes	Yes
industry structure	No	Yes	Yes	Yes	Yes
labor market	No	No	Yes	Yes	Yes
health and wealth	No	No	No	Yes	Yes
Census division trend	No	No	No	No	Yes
adjusted R-squared	0.863	0.866	0.867	0.880	0.881

Note: *** : $p < 1\%$; Weighted by a pre-period share of prime-aged males. SEs are clustered by CZs.

Exits from salaried workers?

Hot and cold days *reduce* **salaried emp. rate**. (chiefly, outdoor jobs)

- increased the ratio of **self-employed**, especially working at home and the **unemployed**.

Table: Decomposition of LFPR (prime-aged males across CZs; 1980-2019)

	dependent variables (percentage point)							
	LFPR	employment rate			dropout 1-(1)-(7)	unemploy ment	full-time student ratio	self- employed at home
		salaried workers	self- employed	total (2) + (3)				
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
10 hot days	-0.239 *** (0.071)	-0.421 *** (0.112)	0.080 (0.052)	-0.341 *** (0.094)	0.213 *** (0.061)	0.096 * (0.056)	0.031 ** (0.013)	0.054 ** (0.024)
10 cold days	-0.451 *** (0.122)	-0.642 *** (0.210)	0.019 (0.082)	-0.623 *** (0.179)	0.382 *** (0.120)	0.162 * (0.097)	0.079 *** (0.022)	0.082 ** (0.032)
adjusted R-squared	0.880	0.841	0.850	0.852	0.890	0.837	0.690	0.751

Note:*** : $p < 1\%$; ** : $p < 5\%$; * : $p < 10\%$. *Full-controlled, division trend, and two-way FEs. Weighted by a pre-period share of prime-aged males. SEs are clustered by CZs.*

By education subsamples

The effect is **larger** for the less-educated.

Table: Effects by education (prime-aged males across CZs; 1980-2019)

Dependent variable: LFPR (percentage points)					
Panel A: by education (prime-aged (25-54) males)					
	(1)	(2)	(3)	(4)	(5)
	HS dropouts	HS graduates	HS graduates and less ((1)+(2))	some college	college graduates
10 hot days	-0.600 *** (0.193)	-0.246 *** (0.087)	-0.329 *** (0.091)	-0.111 (0.070)	-0.112 * (0.061)
10 cold days	-0.134 (0.292)	-0.012 (0.211)	-0.257 (0.187)	-0.253 ** (0.102)	-0.208 *** (0.069)
adjusted R-squared	0.815	0.868	0.862	0.755	0.699

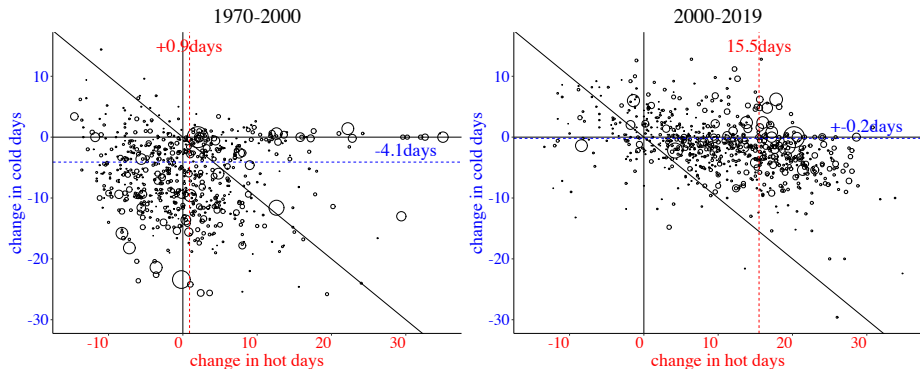
Note: *** : $p < 1\%$; ** : $p < 5\%$; * : $p < 10\%$. Full-controlled, division trend, and two-way FEs. Weighted by a pre-period share of prime-aged males. SEs are clustered by CZs.

Net impacts by climate change (hot vs. cold days)

In 2000-2019, severer warming explains **10-15%** (not *p.p.*) of LFPR drop.

During 1970-2000, milder cooling augmented 3-5% of LFPR drop.

Figure: Δ hot and cold days across CZs in the U.S. (1970-2000 vs. 2000-2019)



Note: Computed from GHCN-Daily. The hot and cold days are 5 year moving-average.

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Outdoor mechanism

Pre-period **outdoor exposure** and **commuting time** fueled adverse effects.

Table: DID-type model (across CZs)

	dependent variables (p.p.) (prime-aged (25-54) males)			
	LFPR	dropout	LFPR	dropout
	(1)	(2)	(3)	(4)
10 hot days	-0.200 ** (0.081)	0.157 ** (0.074)	-0.230 *** (0.085)	0.172 ** (0.080)
10 cold days	-0.290 ** (0.126)	0.212 * (0.116)	-0.037 (0.152)	-0.012 (0.144)
10 hot days × outdoor pre-share	-0.532 *** (0.196)	0.426 ** (0.185)		
10 cold days × outdoor pre-share	0.204 (0.360)	-0.094 (0.326)		
10 hot days × pre-commuting time			-0.234 ** (0.093)	0.215 ** (0.084)
10 cold days × pre-commuting time			-0.325 ** (0.149)	0.336 ** (0.136)
adjusted R-squared	0.948	0.951	0.949	0.953
observations	3,610	3,610	2,888	2,888

Note: *** : $p < 1\%$; ** : $p < 5\%$; * : $p < 10\%$. *Full-controlled, division trend, and two-way FEs. A single pre-period term is dropped from space limit. Weighted by a pre-period share of prime-aged males. SEs are clustered by CZs.*

Homes as cooling shelters?

During 1970-2000, residential ACs and TV sets fueled the climate impact.

Table: Shifting effect by residential amenities

	dependent variables (p.p.) (prime-aged (25-54) males)			
	LFPR	emp rate	unemp rate	LFPR
	(1)	(2)	(3)	(4)
10 hot days	-0.131 (0.085)	0.008 (0.108)	-0.140 ** (0.062)	0.170 (0.135)
10 cold days	-0.496 *** (0.137)	-0.530 *** (0.186)	0.034 (0.117)	-0.439 (0.290)
10 hot days × air conditioner share	-0.165 * (0.099)	-0.398 *** (0.117)	0.233 *** (0.068)	
10 cold days × air conditioner share	-0.094 (0.131)	-0.113 (0.193)	0.019 (0.119)	
10 hot days × TV sets per capita				-0.230 *** (0.061)
10 cold days × TV sets per capita				-0.176 (0.176)
state × year fixed effects	Yes	Yes	Yes	Yes
adjusted R-squared	0.963	0.943	0.886	0.974
observations	2,166	2,166	2,166	642

Note: *** : $p < 1\%$; ** : $p < 5\%$; * : $p < 10\%$. *Full-controlled, division trend, and two-way FEs. A single pre-period term is dropped from space limit. Weighted by pref-period share of prime-aged males. SEs are clustered by CZs.*

Summary: Climate meets labor markets

Throughout the human history, males have enjoyed comparative advantage in working outdoors. The paper suggests that **modern climate change hurt their traditional advantage**.

- **Climate change exacerbates the socioeconomic inequality.**
 - ✓ **non-colleged males** increasingly chooses outdoor jobs
 - ✓ **disadvantaged areas** depend more on outdoor jobs
 - ✓ Outdoor labor market as **hotbeds for dropouts**
- **Not only labor demand, but supply shrinkage are at work.**
 - ✓ *residential* amenities increased opportunity costs of labor.
- **Policy implication: heat regulation** (shading & water; flexible schedule; cool tech wears; currently, at 5 states) could possibly work.

For comments

Thank you for listening. Please feel free to send me a feedback to my email:

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Alternative stories

1. Mobility of workers (e.g., [Peri and Sasahara \[2019\]](#))

- workers might' ve left warming areas.
 - ✓ Excluding the state movers in recent 5 years enlarge the estimates.
- early-retirees might' ve moved to warming areas (e.g. Florida).
 - ✓ warming areas attracted more labor force than non-labor force.

2. Product market channel

- Climate change hurt agriculture thus, suppresses incomes at farms.
 - ✓ Agriculture accounts for less than 1% of GDP and 1.5% of employment in the U.S. (leading developed economy)
 - ✓ Excluding agriculture-intensive regions does not affect the estimates.

Where does the money for dropouts come from?

Non-labor income has to be higher than the subsistence level.

- Rising living with parents (In 2021, 1/3 in adults aged 18-34).
(→ saves housing rent. U.S. houses typically have an empty kids room.)
- Intrafamily transfer from parents ([Binder and Bound \[2019\]](#)) or spouses
- Welfare benefit as a “subsidy for dropping out”
 - ✓ Rise of disability insurance benefit ([Parsons \[1980\]](#))
 - ✓ Poverty measures (e.g. social security income; food stamp)

→ These fall-back options appear to be only substantial for **developed economies in the post war period**.

Literature: males' labor supply

None spans **long enough** to reconcile the half-century global phenomenon.

- **Labor demand drivers:** computerization (1990s); robots (1980s?); ([Acemoglu and Restrepo \[2020\]](#)); China shock (2001-) ([Autor et al. \[2014\]](#)) and offshoring (1980s?)
- **Labor supply drivers:** disability insurance ([Parsons \[1980\]](#)); health ([Krueger \[2017\]](#)); computer game technology ([Aguilar et al. \[2021\]](#))

→ Provide a new climate perspective on the debate.

Literature: closest papers on temperature-labor nexus

- **Establishment-level studies**

- ✓ **labor demand adaptation**: small manufacturing plants exit ([Ponticelli et al. \[2023\]](#)); labor reallocation ([Acharya et al. \[2023\]](#))
- ✓ **labor productivity (partly absenteeism)**: manufacturing in India ([Somanathan et al. \[2021\]](#)); China ([Chen and Yang \[2019\]](#))

→ My paper addresses **labor supply** using individual data.

- **time allocation**: work time & outdoor leisure↓ and indoor leisure↑ ([Graff Zivin and Neidell \[2014\]](#))

→ My paper studies **labor market attachment** instead of **daily reactions** from extreme weathers.

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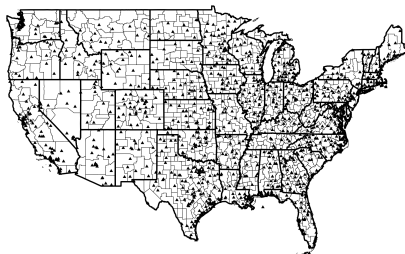
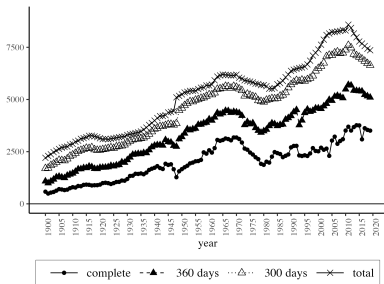
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Daily weather big data

Daily weather (max & min temperature and precipitation) big data comes from 2,000-3,000 stations, recorded by GHCN-Daily.

- I take an inverse-distance weighted average of **10 closest station records within 100km from CZ popu. centroids.**

Figure: stations recording temperature (1900-2019); distribution (2019)



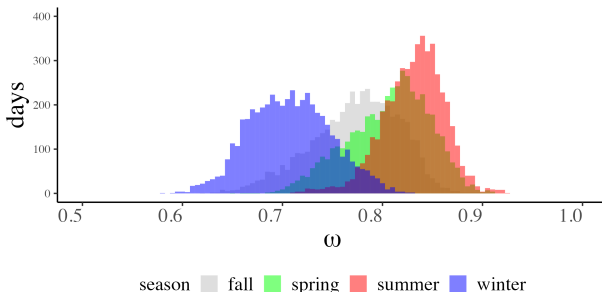
Source: GHCN-Daily from NOAA (National Oceanic and Atmospheric Administration).

Construct a daily mean temperature

I compute a daily mean temperature as $T_d = \omega T_{max} + (1 - \omega) T_{min}$.

- ① Convention of literature: $\omega = 0.5$. (**underestimates** the temperature faced by workers, especially in the summer.)
- ② **Biz hour (8AM-6PM) temperature:** $\omega_{week, month}^l$ I compute a weekly CZ-specific ω by **mean hourly temperature** data during 1981-2010 across 408 stations (Climate Normals dataset).

Figure: Distribution of weekly temperature weight ω across seasons



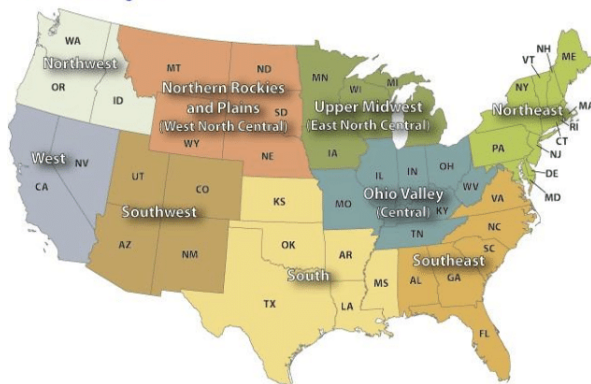
Note: Average in a single week in 4 weeks within each month recorded by one station.

Definition: Climate region

The U.S. includes 9 climate regions from tropical one to deserts.

Table: Annual hot days by climate regions (1970-2019)

U.S. Climate Regions

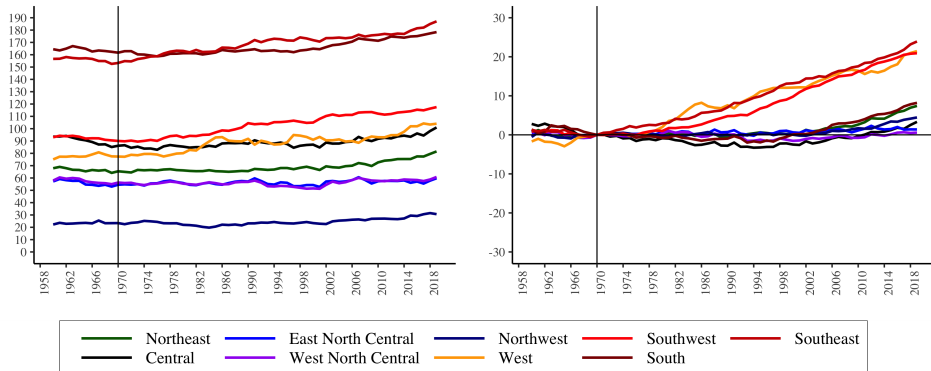


Source: National Centers for Environmental Information (NCEI); NOAA

Climate change by climate region

When climate is measured by hot days, hot regions are increasingly getting hotter.

Table: Annual hot days across climate regions (1970-2019)



Source: Computed from GHCN-daily.

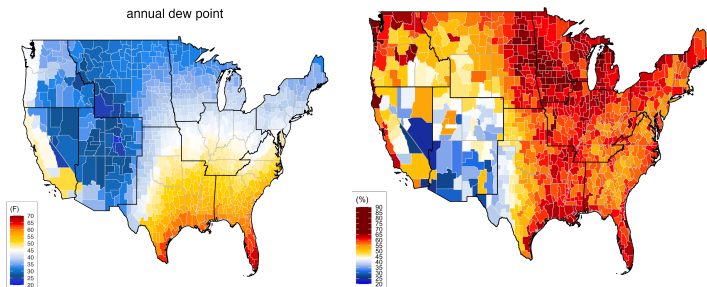
Humidity

Humidity is *lower* in the **west area** close to mountains and *higher* in the **east area** near the Mexican gulf.

- **Daily relative humidity** is computed from a dew point and mean temperature through a standard meteorological formula.

Figure: Humidity across CZs (2019)

annual relative humidity

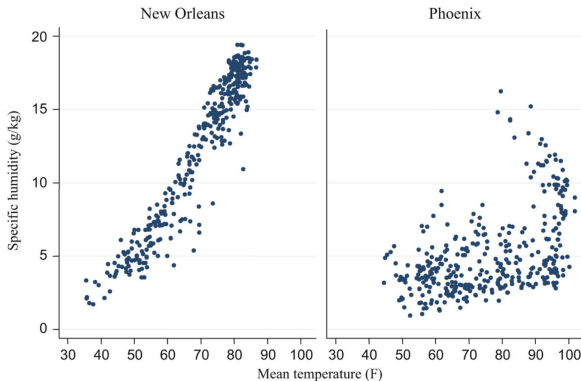


Source: Computed from Global Summary of the Day (GSoD).

Examples: Outlier cities

New Orleans in Louisiana is *much more humid* than Phenix in Arizona with comparable temperature. (→ **discomfort in summer** is much different.)

Figure: Distribution of mean daily temperature and humidity (2002 only)

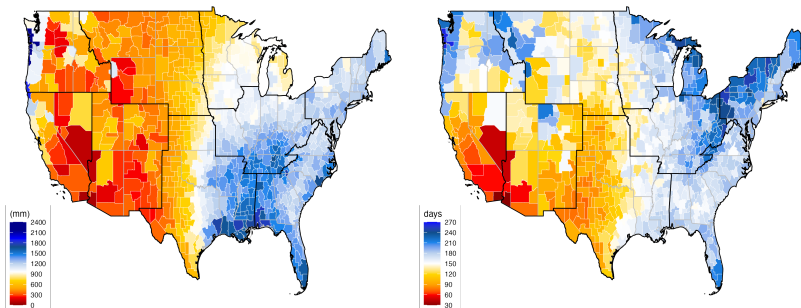


Source: Barreca (2012); Humidity is a specific humidity (g/kg).

Precipitation

Humidity is heavily shaped by precipitation. **East region** has larger annual precipitation and rainy days due to the U.S. geography. **West region** near desserts (especially, California) suffers from droughts and even forest fires.

Figure: Precipitation across CZs (average in 2000-2019)
annual precipitation rainy days



Source: Computed from GHCN-daily.

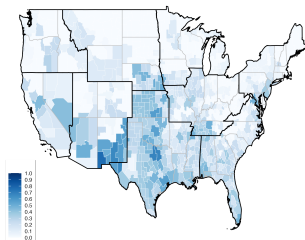
Spread of Air conditioner

Hotter regions experience **faster adoption rates** of ACs. ([Biddle \[2008\]](#))

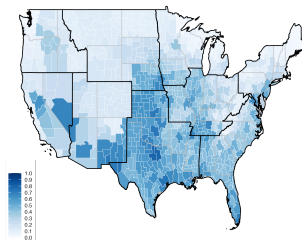
(→ the relative cost expanded even more quickly in hot areas.

Figure: Fraction of households with residential ACs (1960-1980)

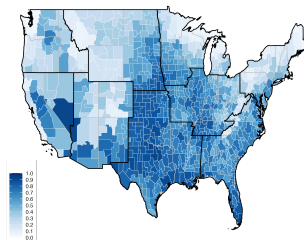
1960



1970



1980



Note: Census of Households, 1970 and 1980. Extrapolation by an author based on [Barreca et al. \[2016\]](#).

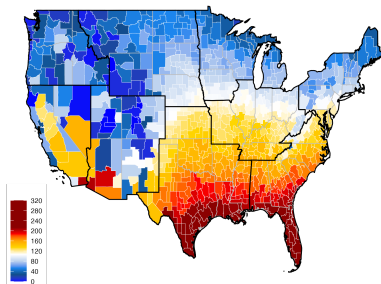
Do workers avoid discomfort?

DI is a function of temperature and relative humidity. Uncomfortable days have $DI > 75$. (A majority of people feels uncomfortable)

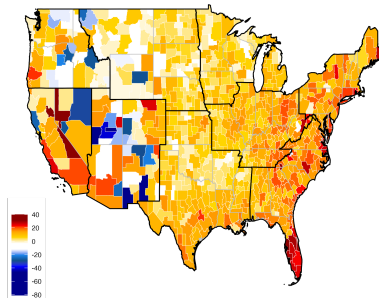
- The West or Southwest regions are comparably hot, but less uncomfortable compared to the Southeast or South.

Figure: Discomfort index across CZs

uncomfortable days
(2010-2019 average)



change in 1970-2019



Source: Computed from GHCN-daily.

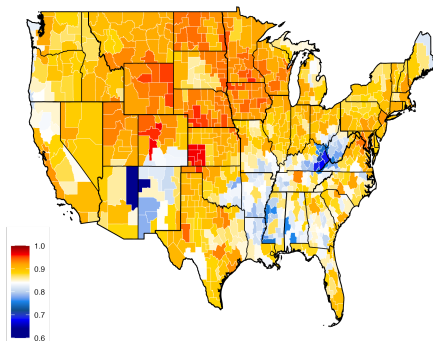
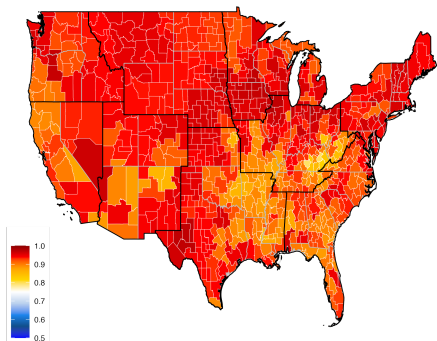
LFPR of prime-aged males

Male LFPR significantly *dropped*, especially in the Southeast and South. Over 90% of prime-aged male dropouts do not have college degrees.

Figure: LFPR of males across Commuting Zones (1970 vs. 2019)

1970

2019

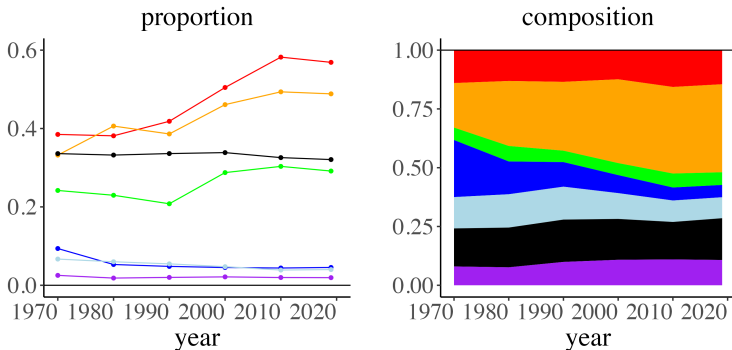


Note: Bold line is a climate zone from NOAA.

Fact: outdoor workers by sectors

Agriculture and **construction** accounts for the half. **Transportation and service sectors** has the second largest share.

Figure: The ratio and composition of outdoor workers by sectors
outdoor workers

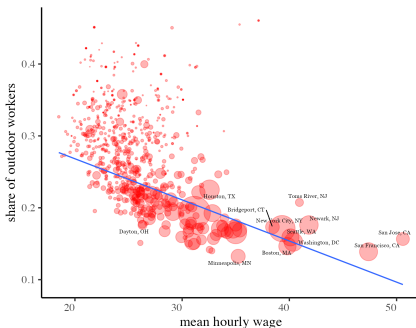
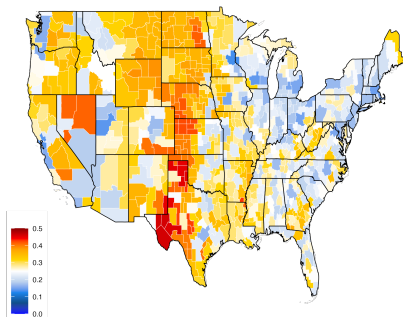


Note: Computed from IPUMS of Census and ACS. The outdoor worker regularly operates outdoors at least once a week identified by a Work Context Survey from the O*NET.

Regional dependency on outdoor jobs

Poorer regions rely more on outdoor jobs.

Figure: Share of outdoor jobs across regional labor markets (2019)



Note: IPUMS of ACS 2017-2019 (for 2019). The outdoor worker regularly operates outdoors at least once a week identified by a Work Context Survey from the O*NET.

1 Introduction

2 Empirical results

3 Mechanism

4 A1: Theory

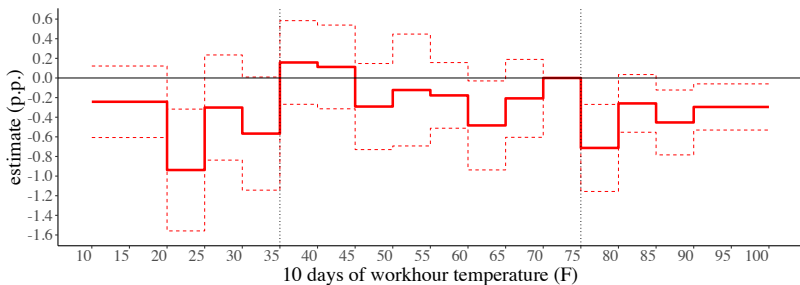
5 A2: Data

6 A3: Analysis

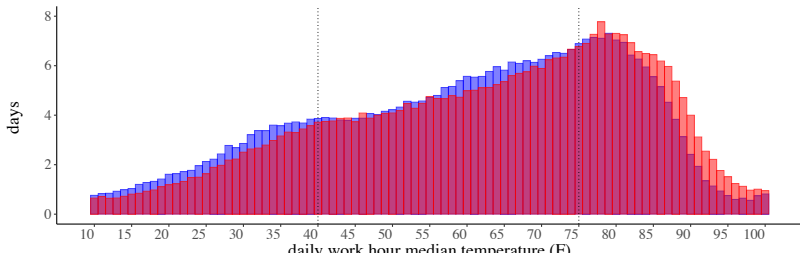
Flexible bin estimates (males; 1970-2019)

I use 75°F (23.9°C) and 35°F (1.7°C) as thresholds for hot days and cold days.

Table: Climate impact on male LFPRs (across CZs; a benchmark is 70-75F.)



1980s vs. 2010s



Does climate change hurt work preference?

For prime-aged males in 2017, **negative effects** were found on all work-related questions. (Sharper for less-educated. Not observed for prime-aged females.)

Table: Climate effects on work preference (2017; World Value Survey)

	dependent variable: work-related values (prime-aged males, 2017; normalized value (0-1))				
	work is important	non- working is lazy	work is a duty	work should always comes first	hard work improves life
	(1)	(2)	(3)	(4)	(5)
10 hot days	-1.00 *** (0.37)	-1.02 *	-2.03 *** (0.62)	-1.20 (0.94)	-2.09 ** (0.89)
10 cold days	4.07 ** (1.88)	-0.73 (3.43)	3.57 (5.72)	6.53 (4.60)	-4.31 (3.65)
state fixed effects	Yes	Yes	Yes	Yes	Yes
Observations	671	668	668	669	669

Note: *** : $p < 1\%$; ** : $p < 5\%$; * : $p < 10\%$. Weighted by a sample weight.

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