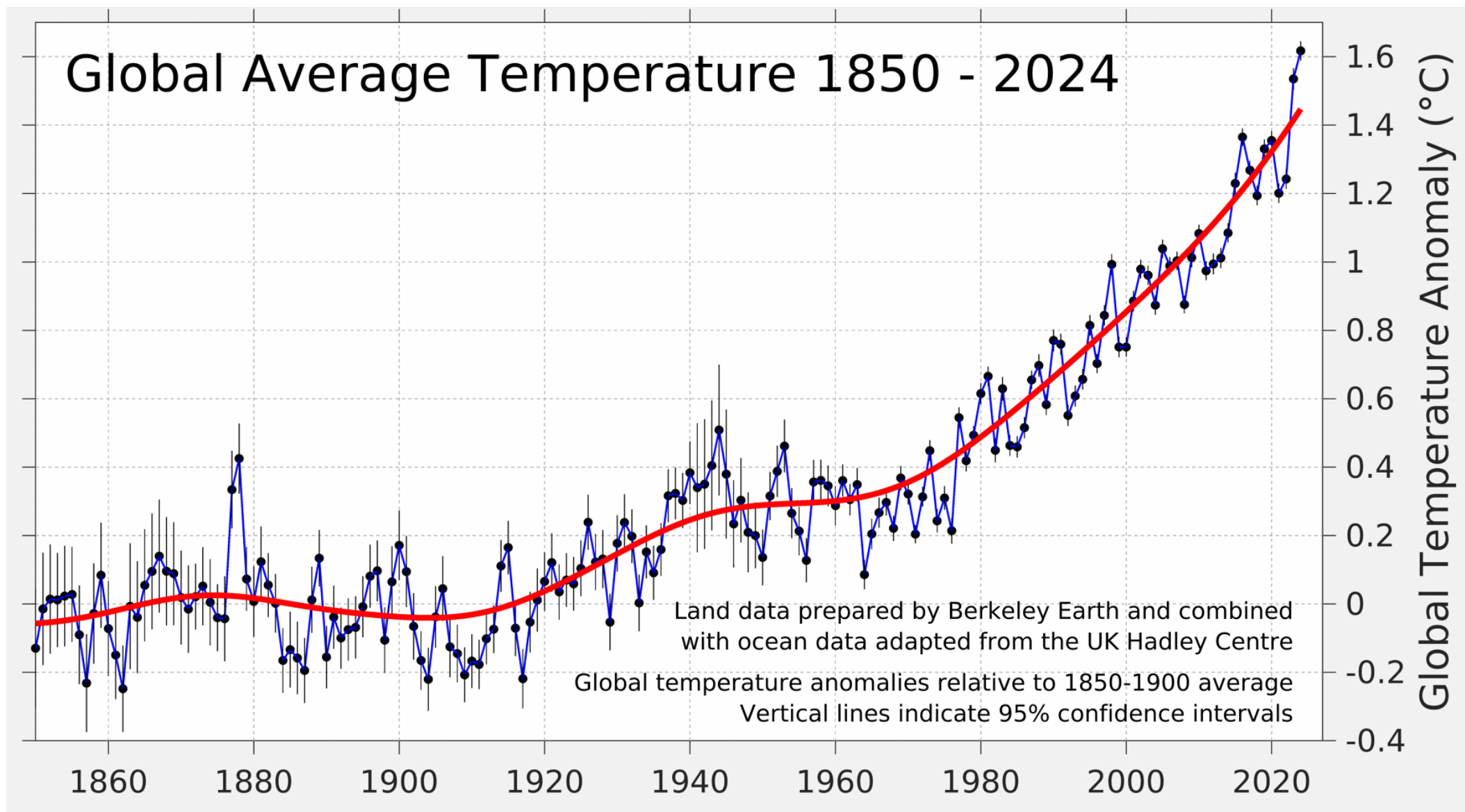


**What do we know about the
economics of climate impacts
and adaptation?**

Ivan Rudik



Climate change is already here

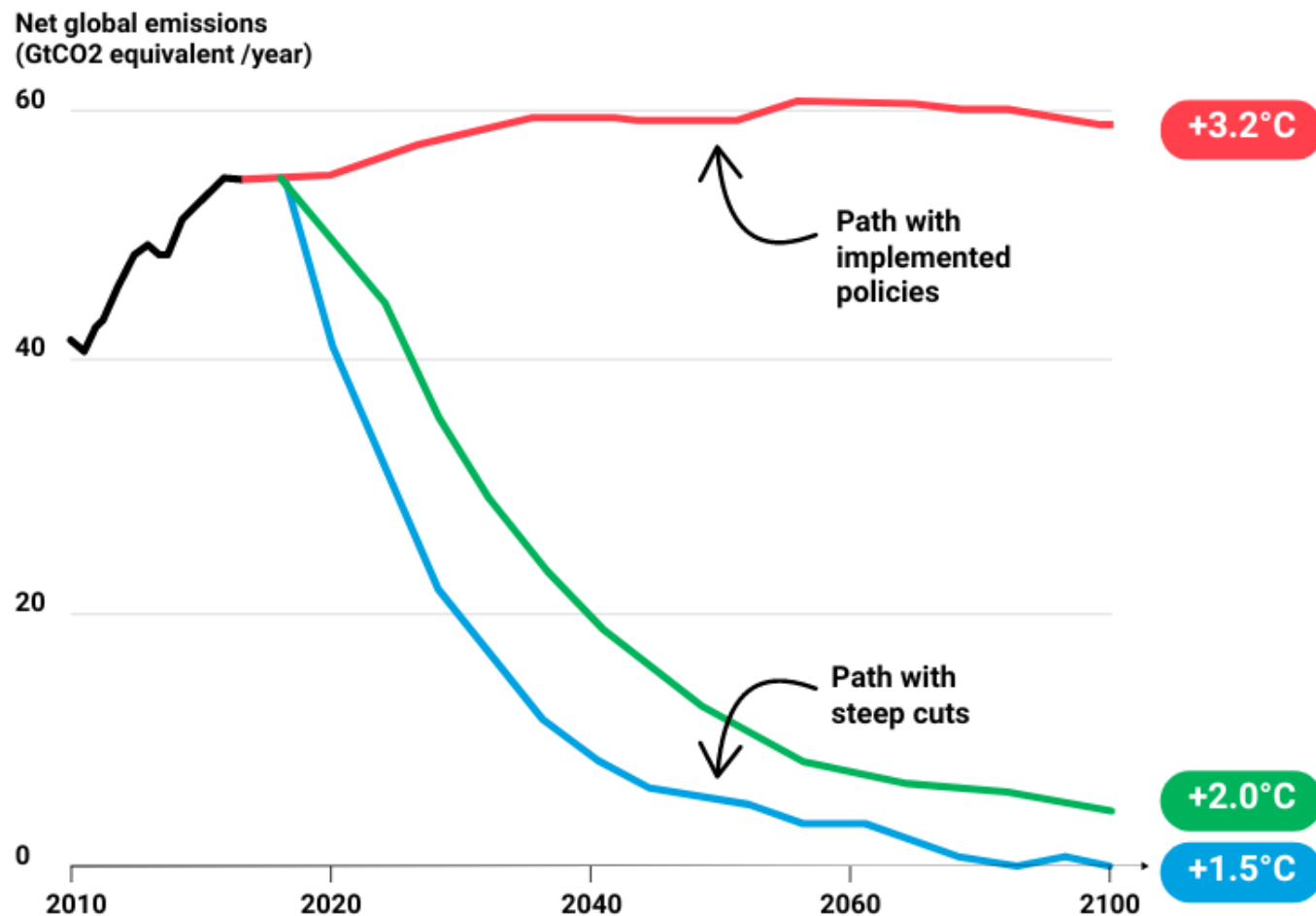


Climate change is going to continue



CLIMATE FACTS

If we act now,
steep cuts to
greenhouse gas
emissions can
limit global
warming



Extreme temperature is unequal across space

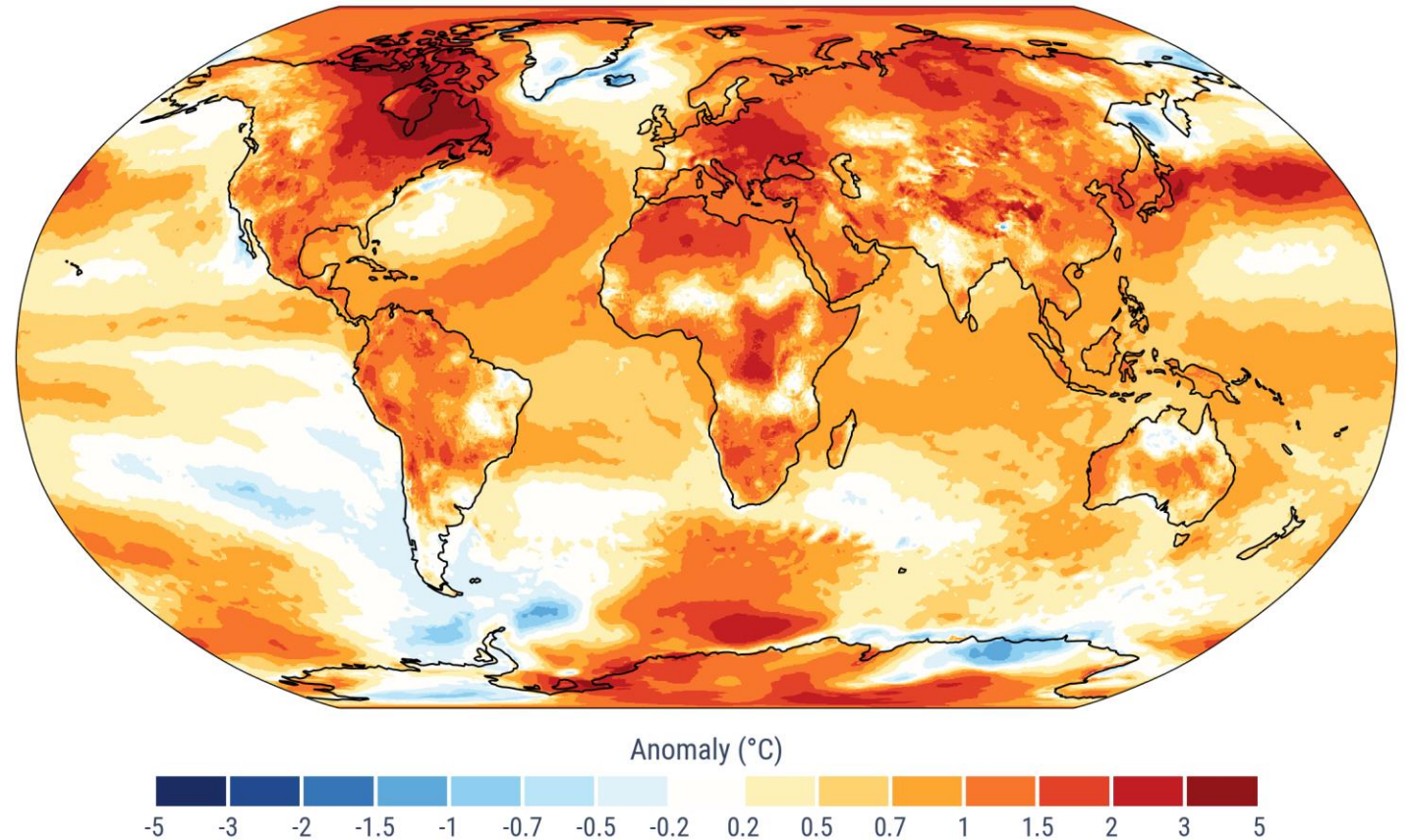
Some places were up to 5°C warmer than the 1991–2020 average!

Note: this is an annual average difference that masks daily extremes and other aspects of climate change



Surface air temperature anomalies in 2024

Data: ERA5 • Reference period: 1991–2020 • Credit: C3S/ECMWF



PROGRAMME OF
THE EUROPEAN UNION



What do we know about the economics?

Climate change has arrived

What do we know about its economic **impacts** and how we can (and have) already **adapted**?

What role do markets and policy play in blunting or exacerbating the effects of climate change?

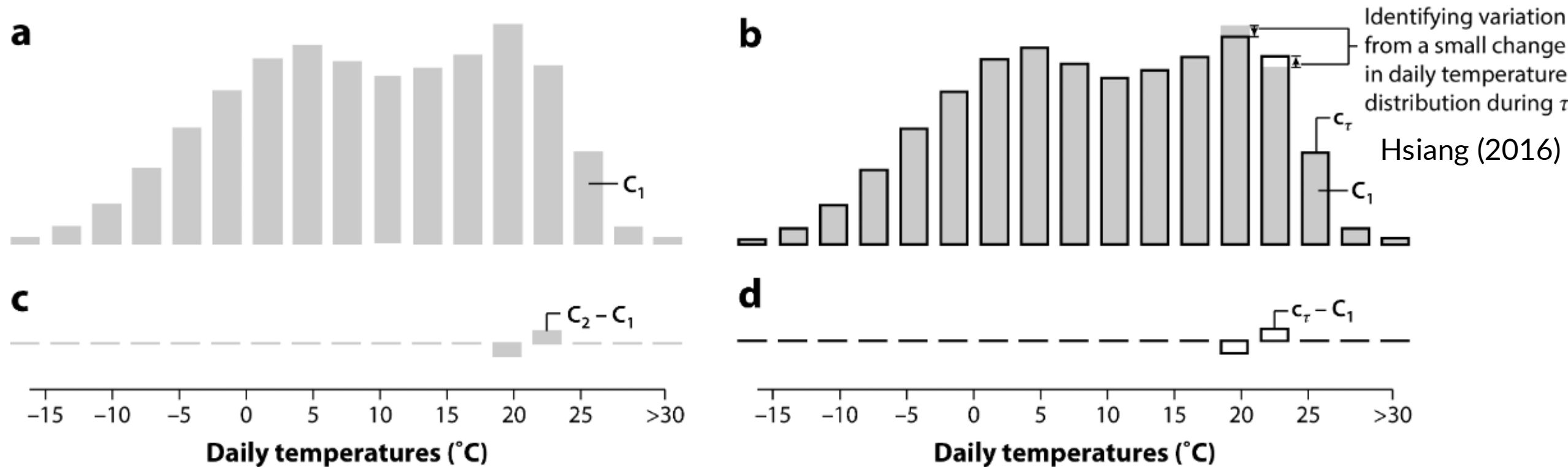
In an hour, I'll only cover a handful of the important points

Why is climate change harmful economically?

Let's first look at micro-level evidence of the impacts of daily temperature on individuals and firms:

- Labor supply
- Productivity
- Mortality
- Mental health

Changes in daily average temperature



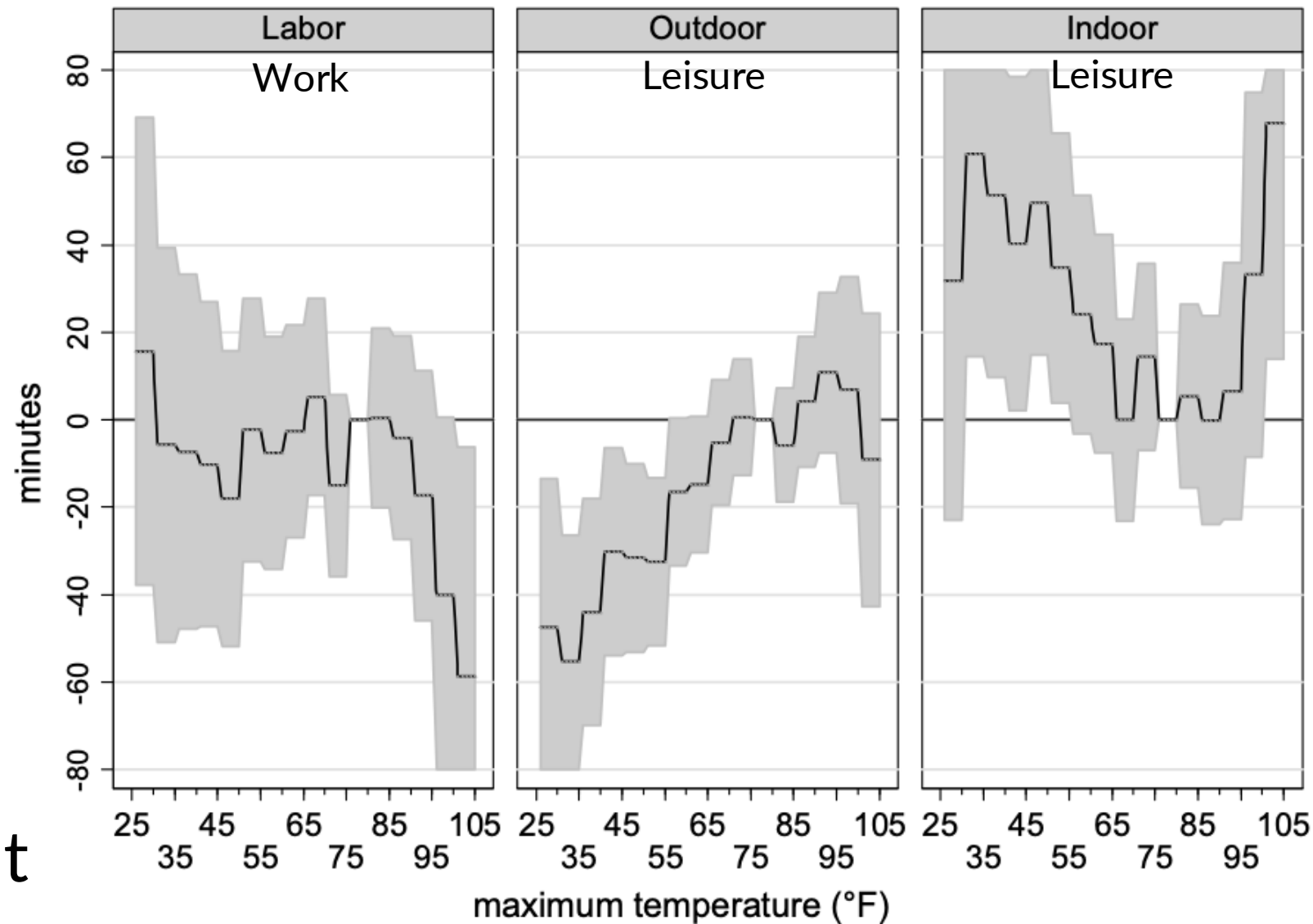
To keep things simple we will look at only impacts of changes in daily temperature

If one day of the year typically at 75°F was instead 95°F, what happens to mortality rates in Monroe County?

Does temperature affect work and leisure?

If temperature affects workers, it should be reflected in hours worked

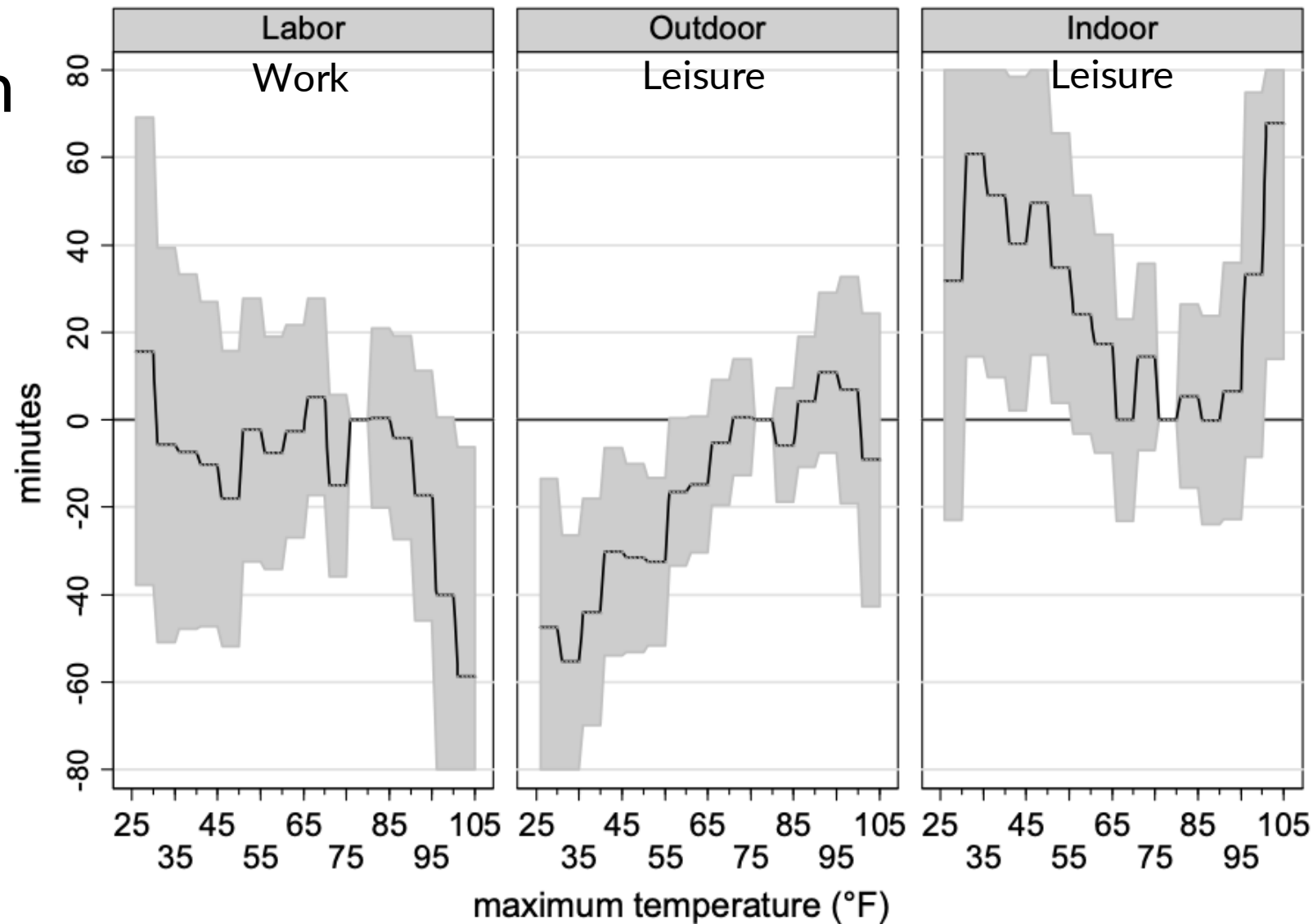
If temperature affects the relative value of outdoor amenities, it should be reflected in out time inside versus



Hot temperatures reduce US labor supply

A day at 100°F results in an hour less work compared to a day at 75°F

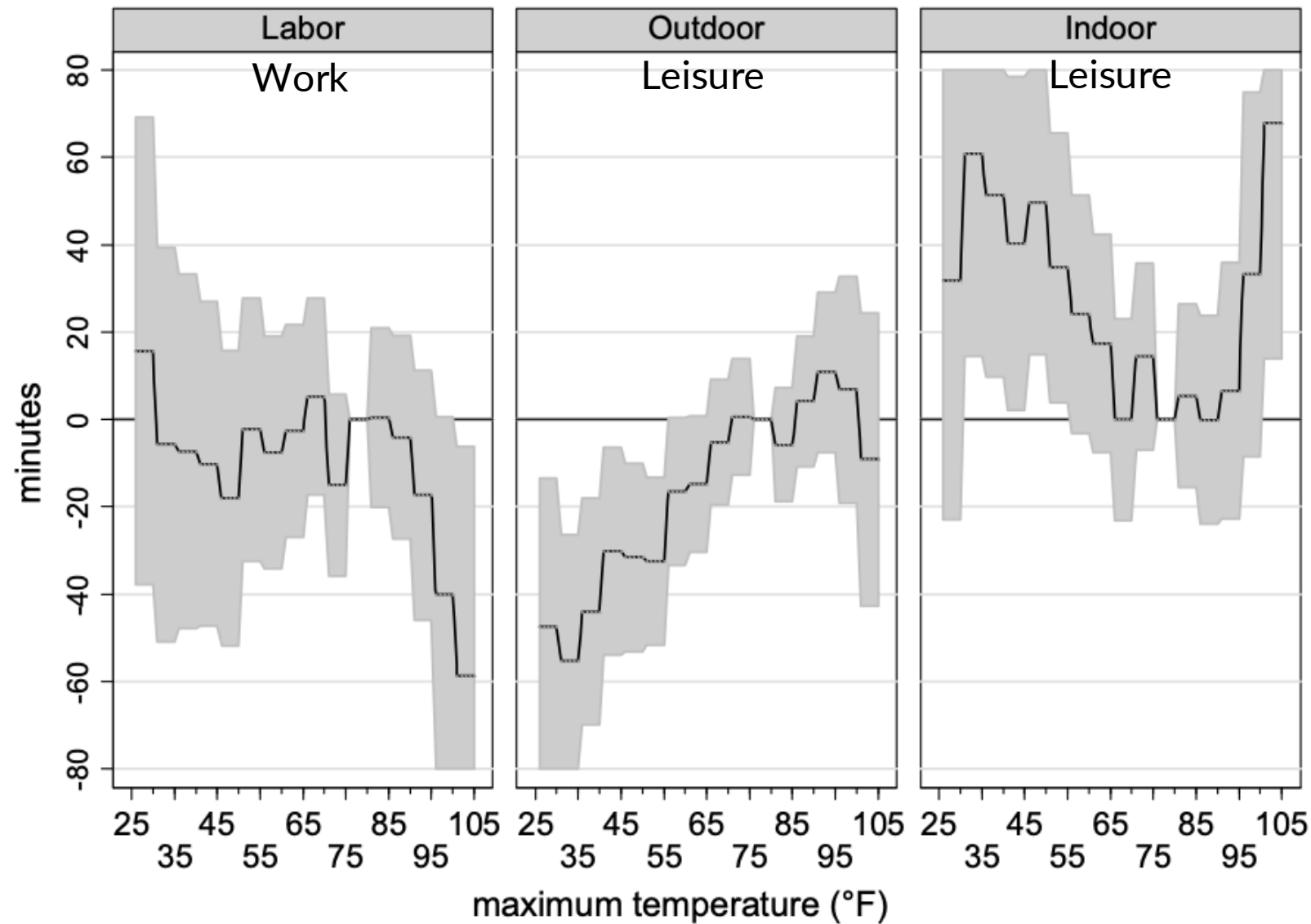
This is for **high-risk** industries: ag, construction, manufacturing, etc



Hot temperatures reduce US labor supply

What do people
substitute toward with
this time?

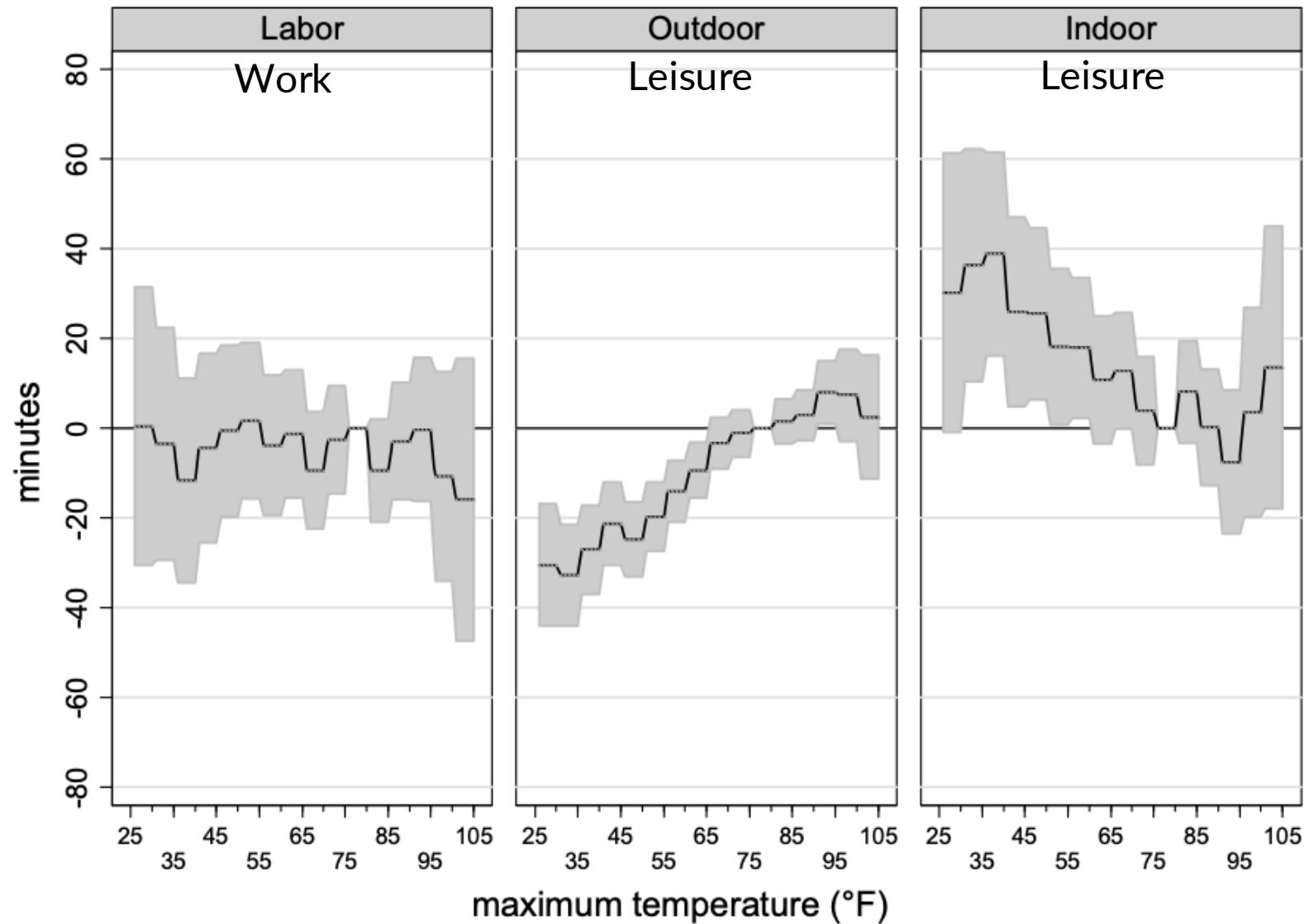
Indoor leisure!



Hot temperatures don't reduce labor supply

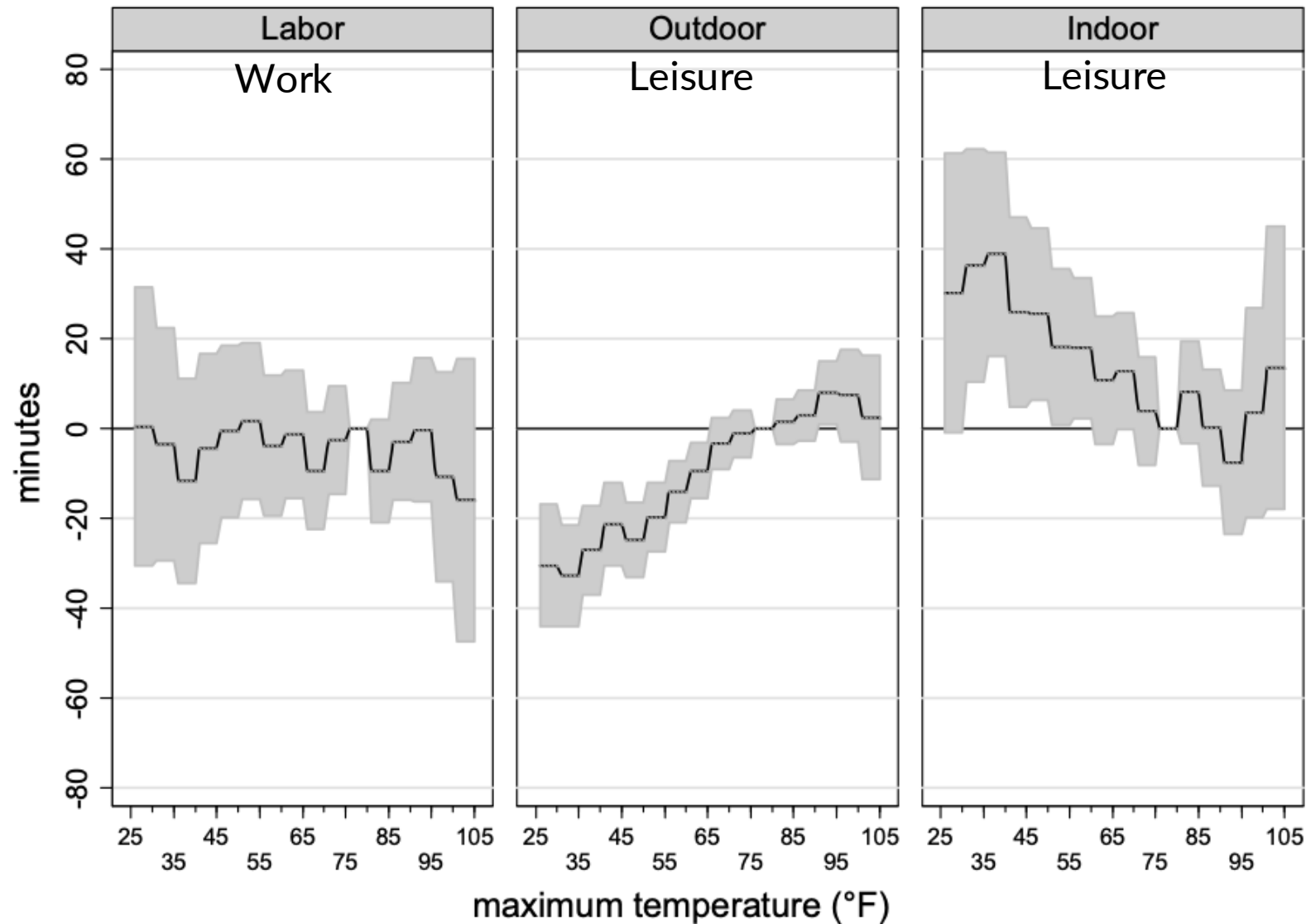
A day at 100°F results in
~0 hours less work
compared to a day at
75°F

This is for **low-risk**
industries: services,
finance, public admin



Hot temperatures don't reduce labor supply

But we still see
substitution between
indoor and outdoor
leisure for cold days



Does temperature reduce indoor Indian worker productivity?

Most economic activity happens indoors, presumably insulated from the outdoor temperature

Do outdoor temperatures matter for indoor manufacturing production?

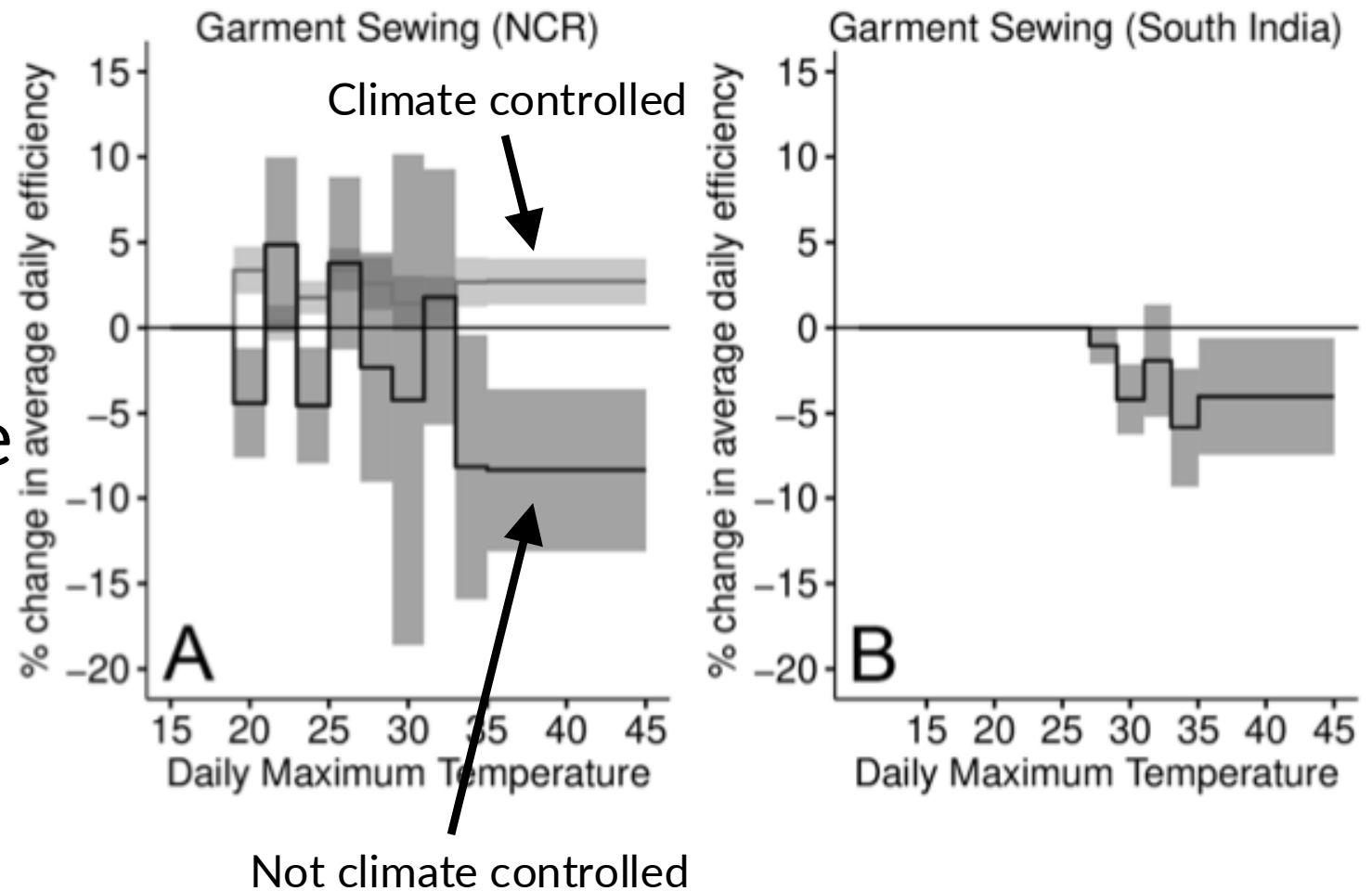
If so, we should see temperatures associated with measures of worker productivity

Hot temperatures reduce Indian manufacturing productivity

Workers produce less in factories when it's extremely hot outside

But **not** if there is climate control (AC) installed

AC is one adaptation strategy



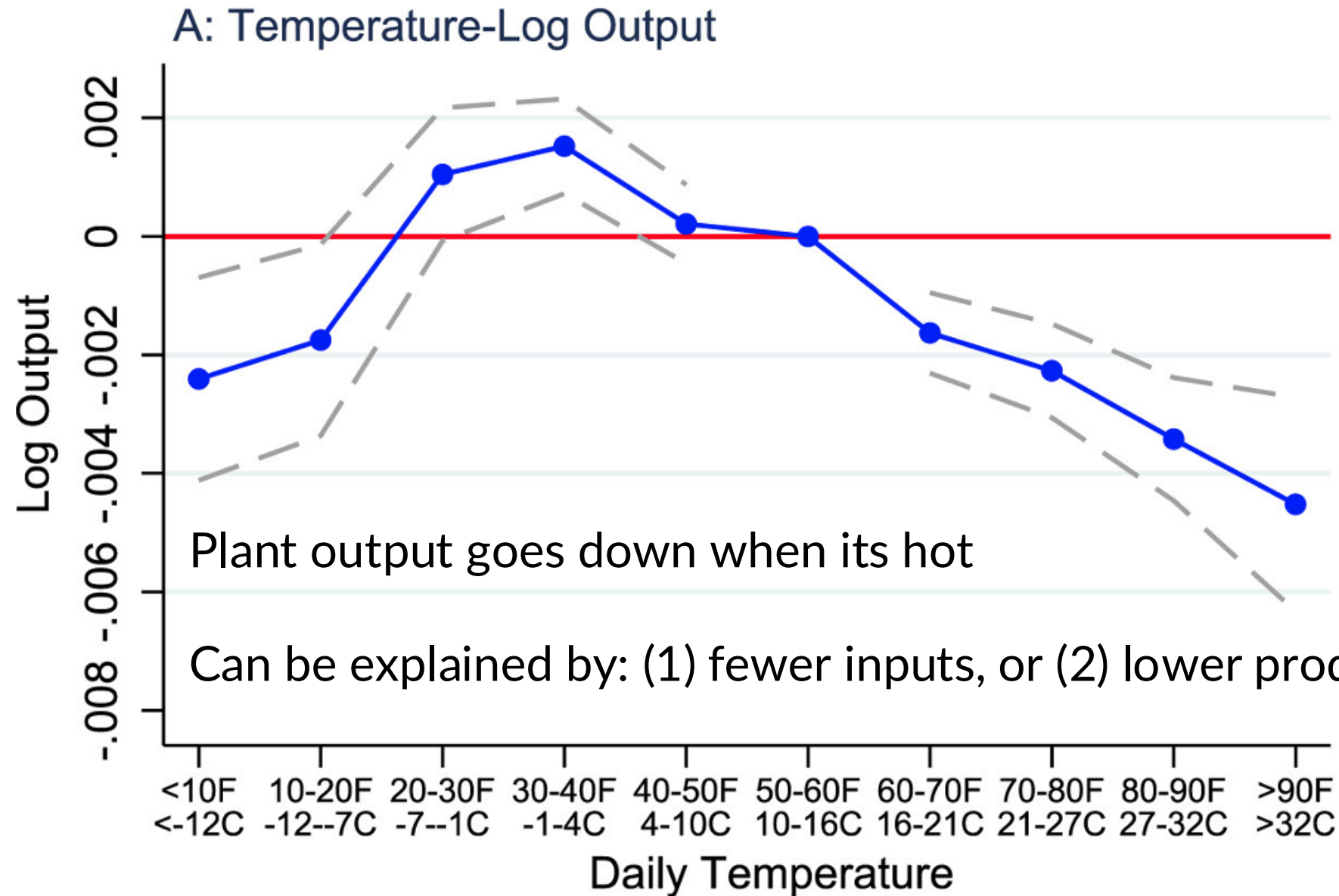
Does temperature reduce indoor Chinese worker productivity?

Is this just an Indian story?

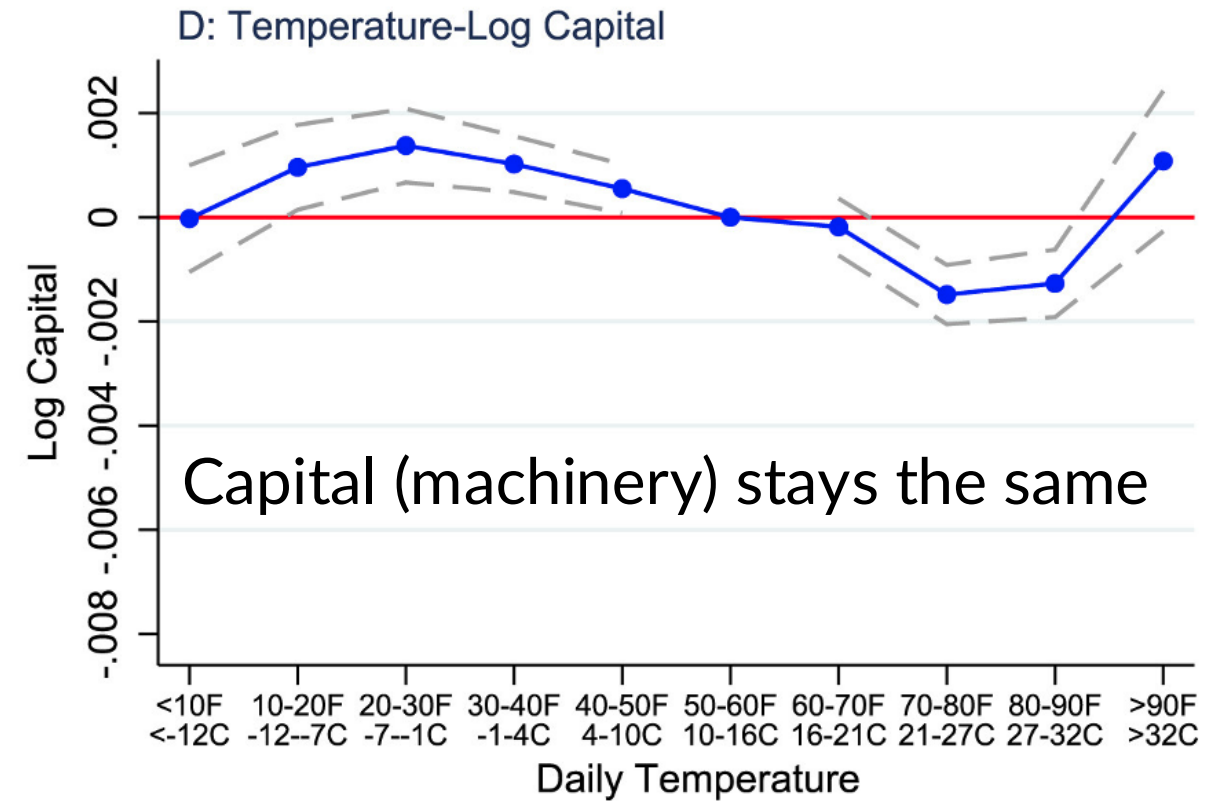
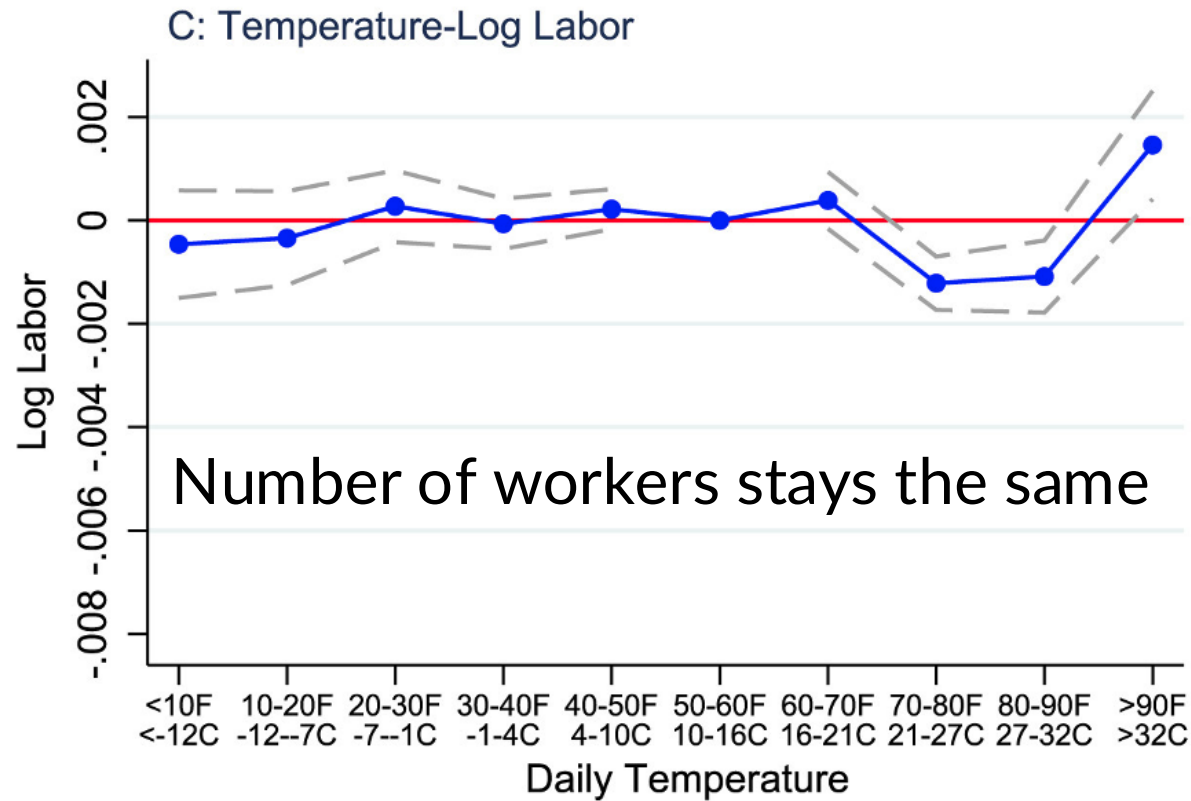
Is it just a garment manufacturing story?

Let's look at China and across **all** manufacturing firms

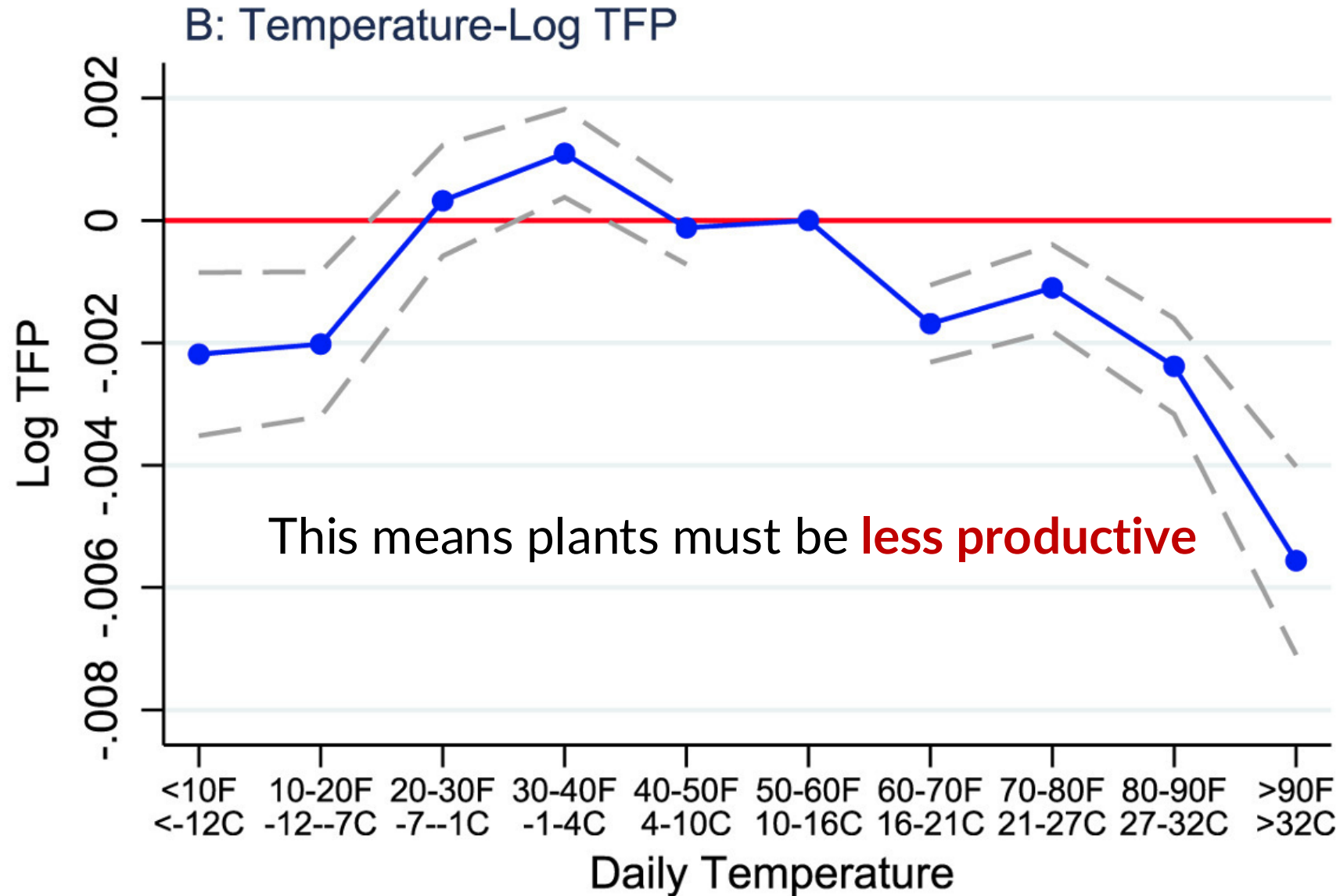
Hot temperatures reduce Chinese manufacturing productivity



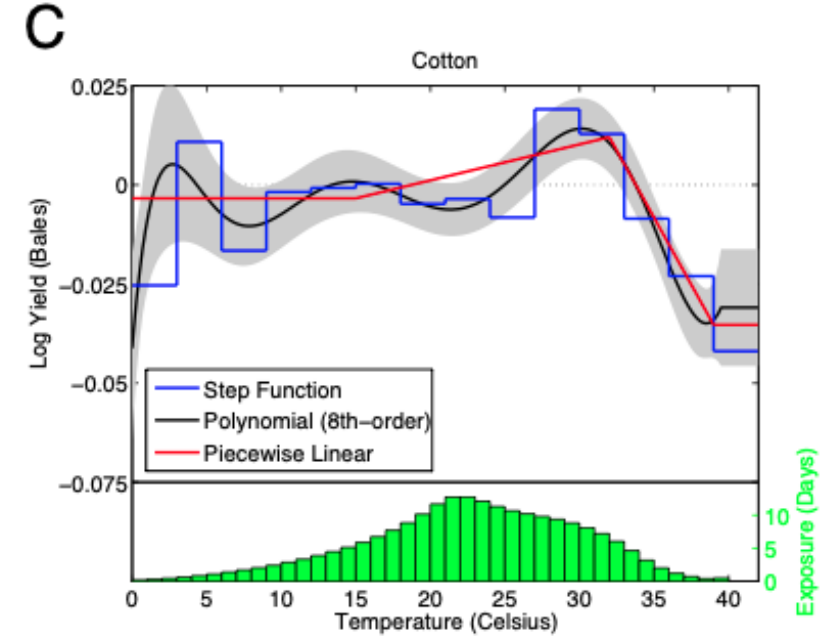
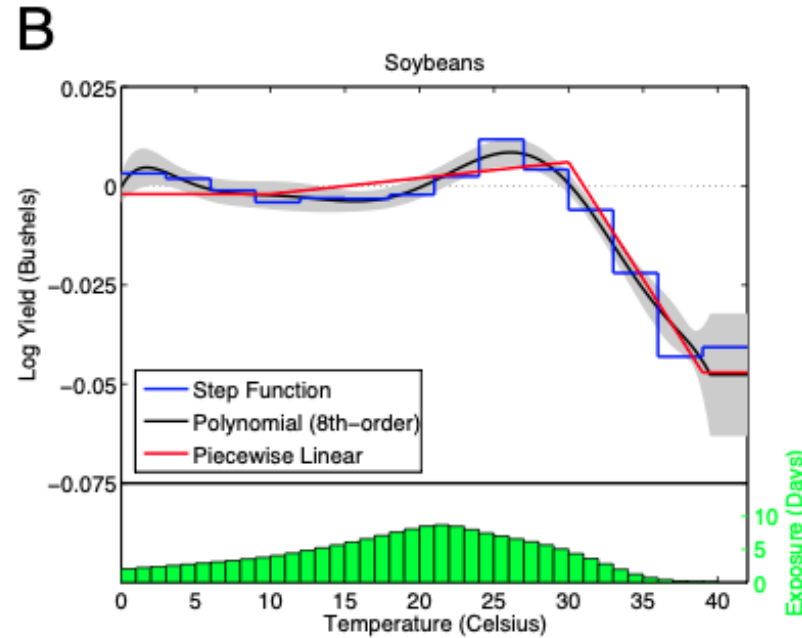
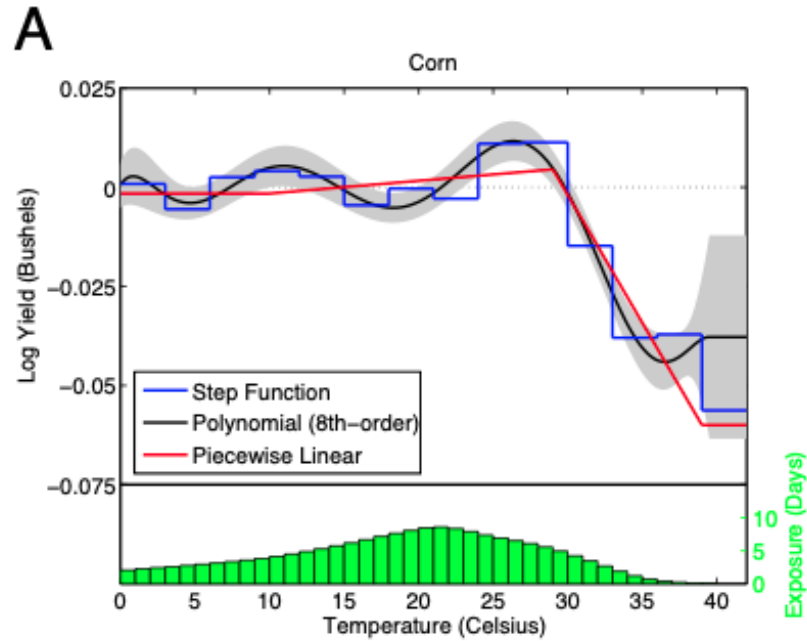
Hot temperatures reduce Chinese manufacturing productivity



Hot temperatures reduce Chinese manufacturing productivity



Hot temperatures reduce US crop yields



Days above 30°C
decrease crop yields
dramatically

One 35°C day (95°F)
decreases yields by 4%
for several staple crops

Does temperature affect mortality?

Mortality impacts of environmental change are one of the most critical to understand

What does it mean to place a value on life?

The EPA does not place a dollar value on individual lives. Rather, when conducting a benefit-cost analysis of new environmental policies, the Agency uses estimates of how much people are willing to pay for small reductions in their risks of dying from adverse health conditions that may be caused by environmental pollution.

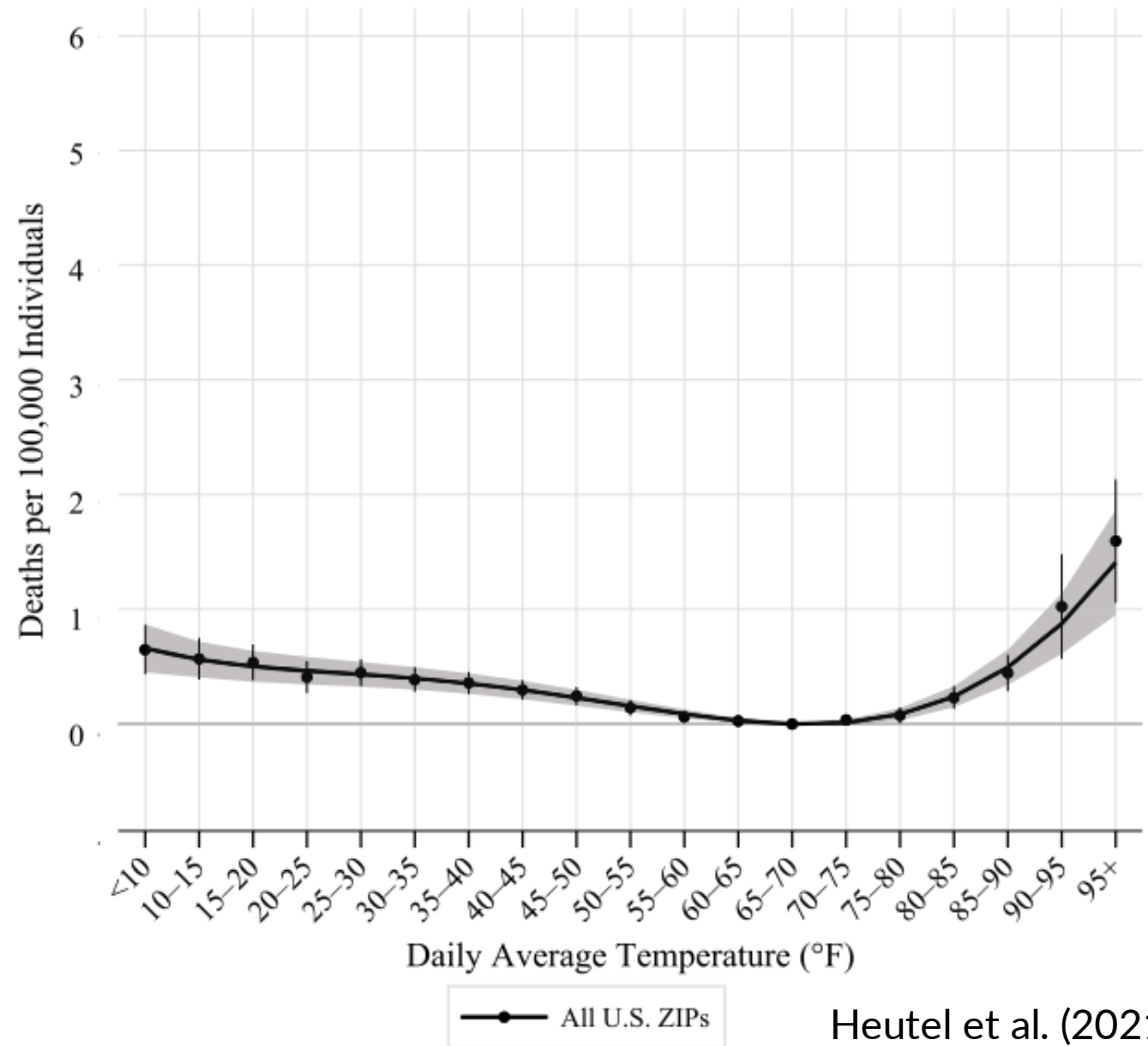
What value of statistical life does EPA use?

EPA recommends that the central estimate of \$7.4 million (\$2006) updated to the year of the analysis, be used in all benefits analyses that seek to quantify mortality risk reduction benefits regardless of the age, income, or other population characteristics of the affected

The effect of heat on mortality is mixed

In the US:

- Extreme heat increases mortality rates
- Extreme cold also increases mortality rates (but to a lesser extent)



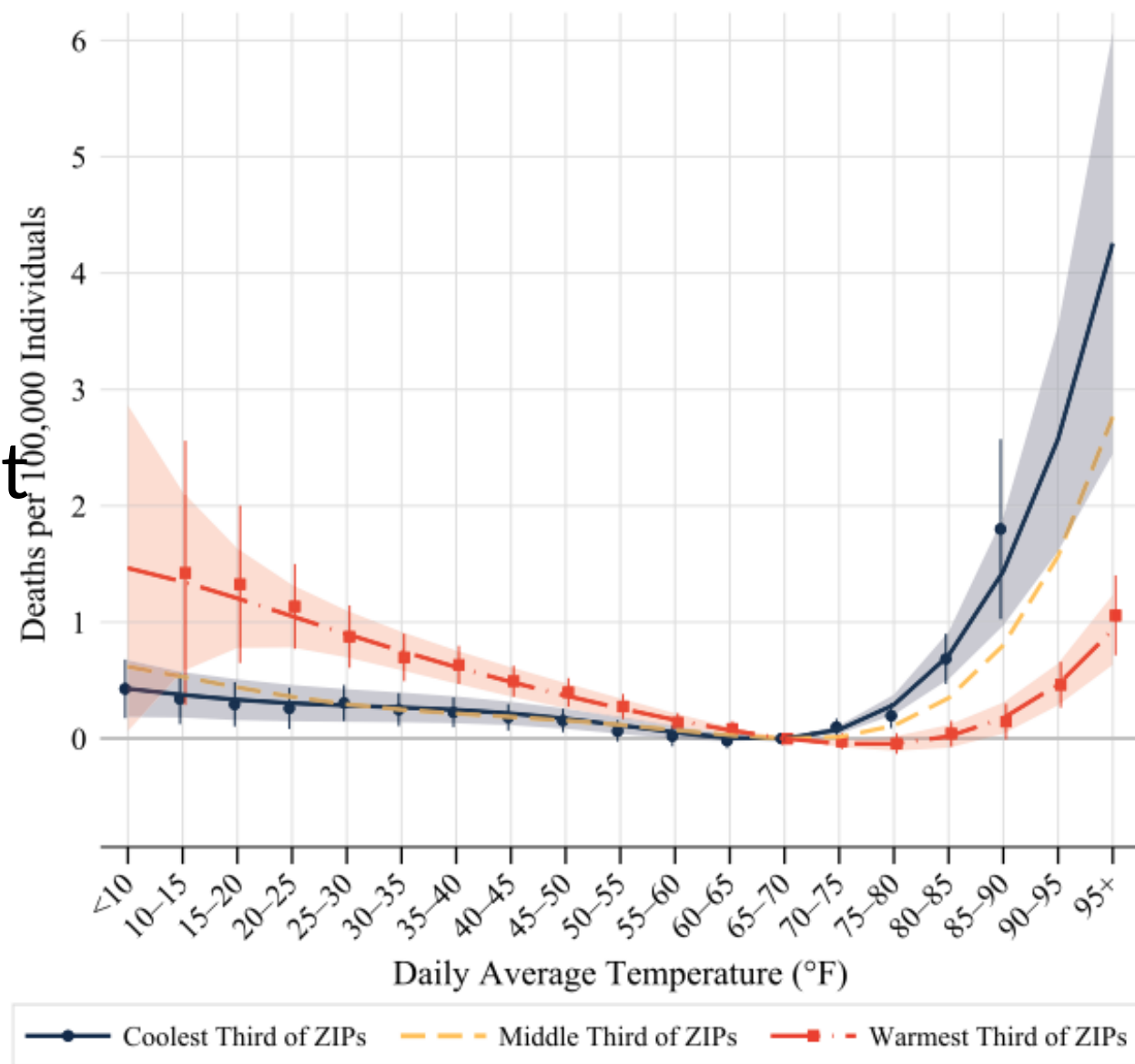
The effect of heat on mortality is mixed

But this masks significant heterogeneity!

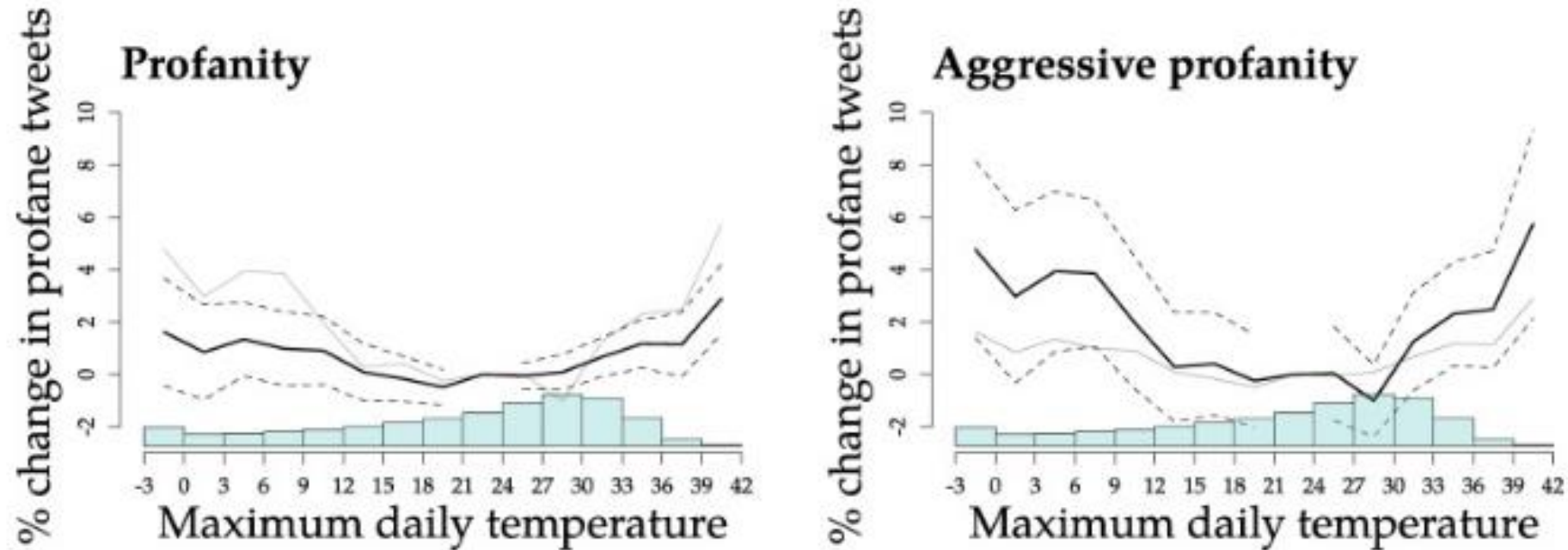
Cold places are susceptible to heat

Hot places are susceptible to cold

Why? Adaptation



Extreme heat has negative mental health consequences



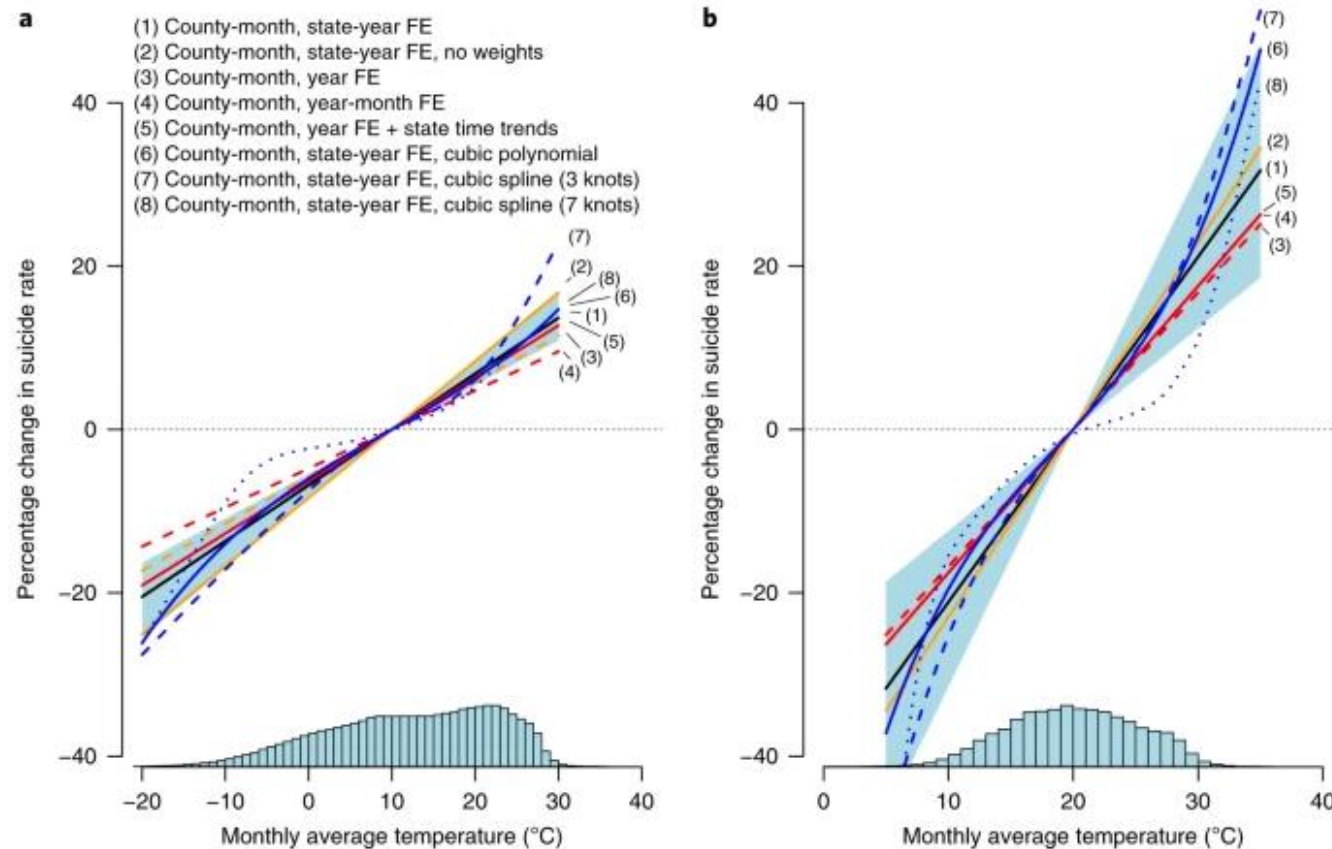
Extreme heat and cold are associated with more profanity and negative sentiment on social media

Extreme heat is associated with suicide rates

Hotter temperatures in the US and Mexico are associated with higher suicide rates

Why?

One potential reason is economics

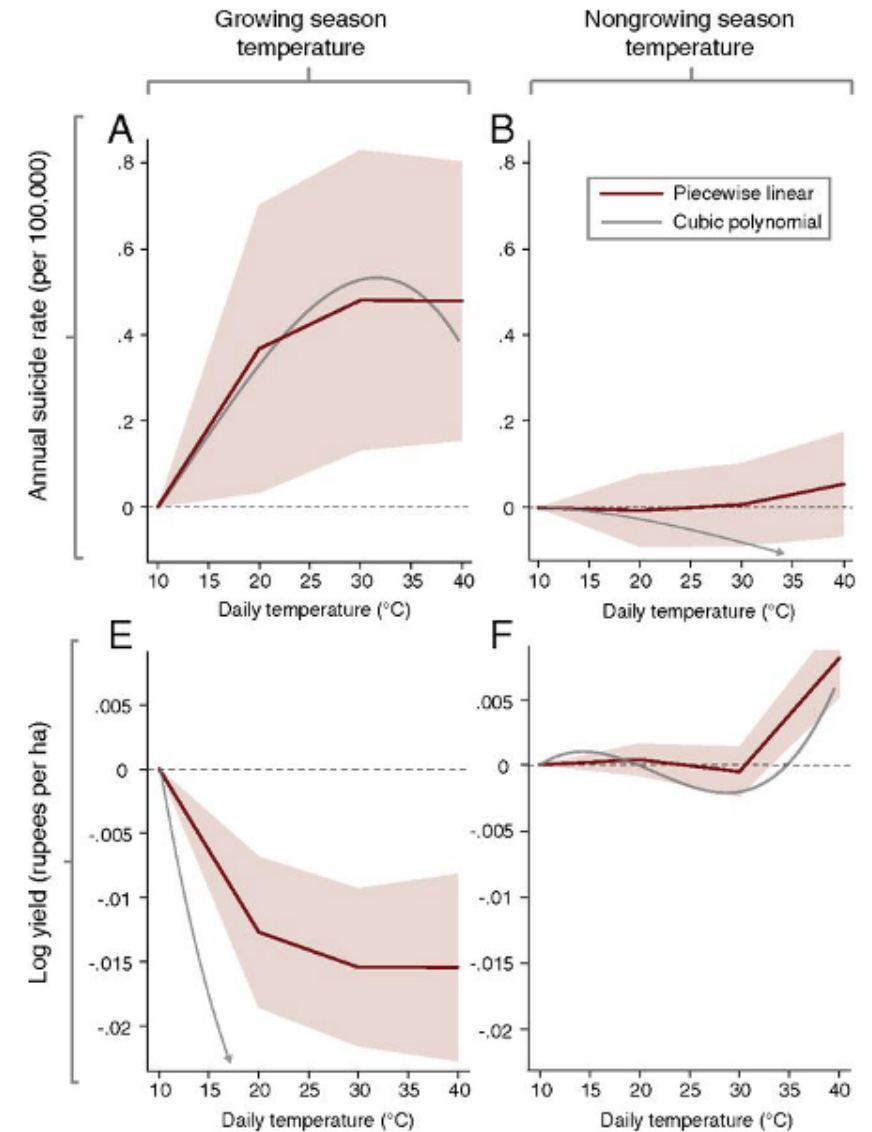


Extreme heat increases suicide only during the growing season

Extreme heat in India during the growing season has massive negative effects on agricultural yields

These same places also have large increases in suicide rates

There is no relationship outside the growing season



Aggregating up to global impacts

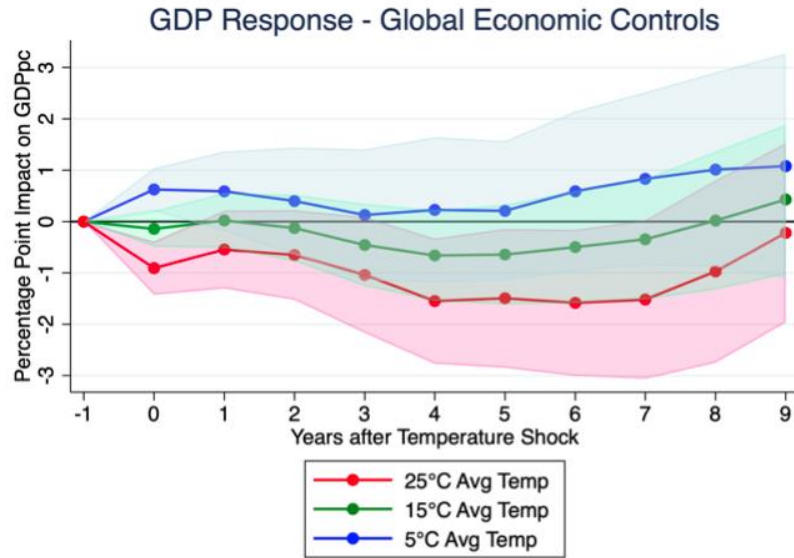
Now let's take a global, aggregate view

How does annual temperature affect country-level or global GDP per capita?

More aggregate outcomes should pick up on some (but not all) of the different micro-level channels

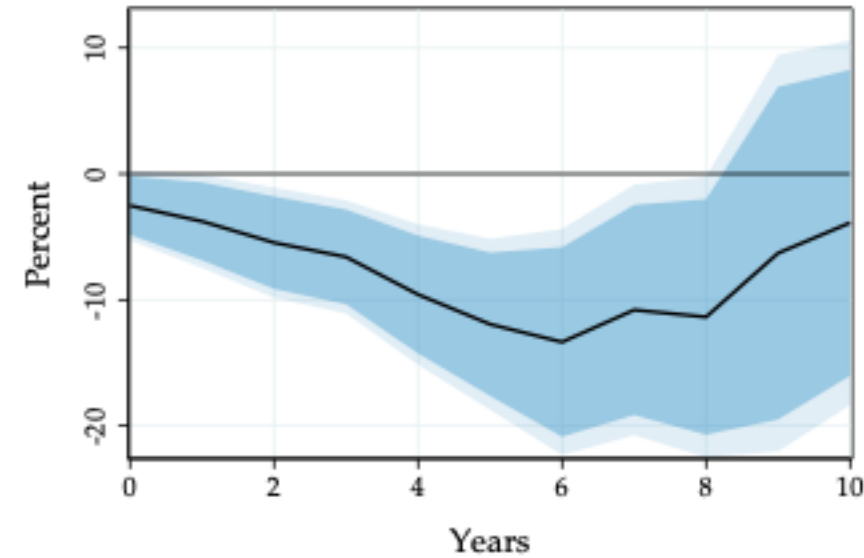
Aggregating up to global impacts: very recent evidence

Nath et al. (2025)



1°C increase in country temperature reduces GDP per capita by up to 2%, persisting for a decade

Bilal and Kanzig (2024)

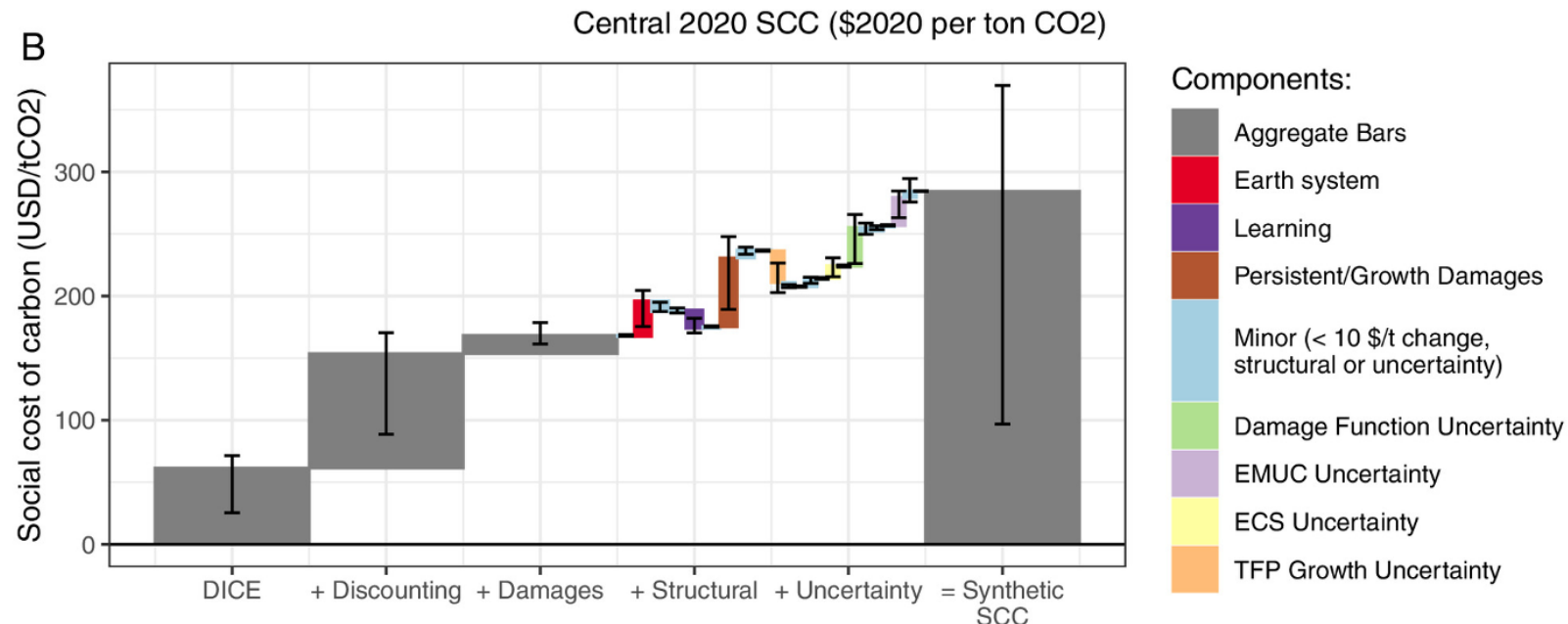


1°C increase in global temperature reduces GDP per capita by up to 10%, persisting for a decade

What does this mean for the cost of CO₂?

What does all of this mean for the **social cost of carbon**: the cost to society from the damage caused by 1 ton of CO₂ emissions

Aggregating all work over the last 20 years suggests: **~\$275/tCO₂**



How do we adapt? Two of many ways

Innovation

If climate change is harming productivity or well-being, we can innovate to make ourselves more resilient

- Crop varieties

Migration

If climate change is harming productivity or well-being, we can move somewhere with a better climate

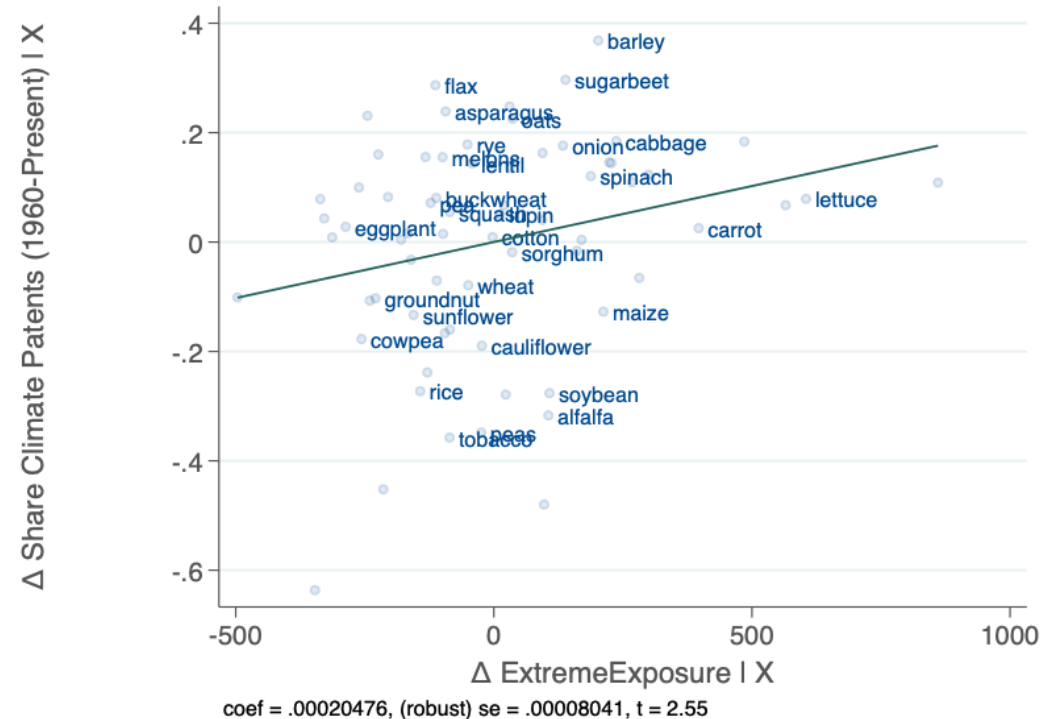
- Migration in Mexico and the US

Innovation in crops

One way to deal with climate change is to develop resilience through innovation

- In agriculture: development of climate-resilient crop varieties

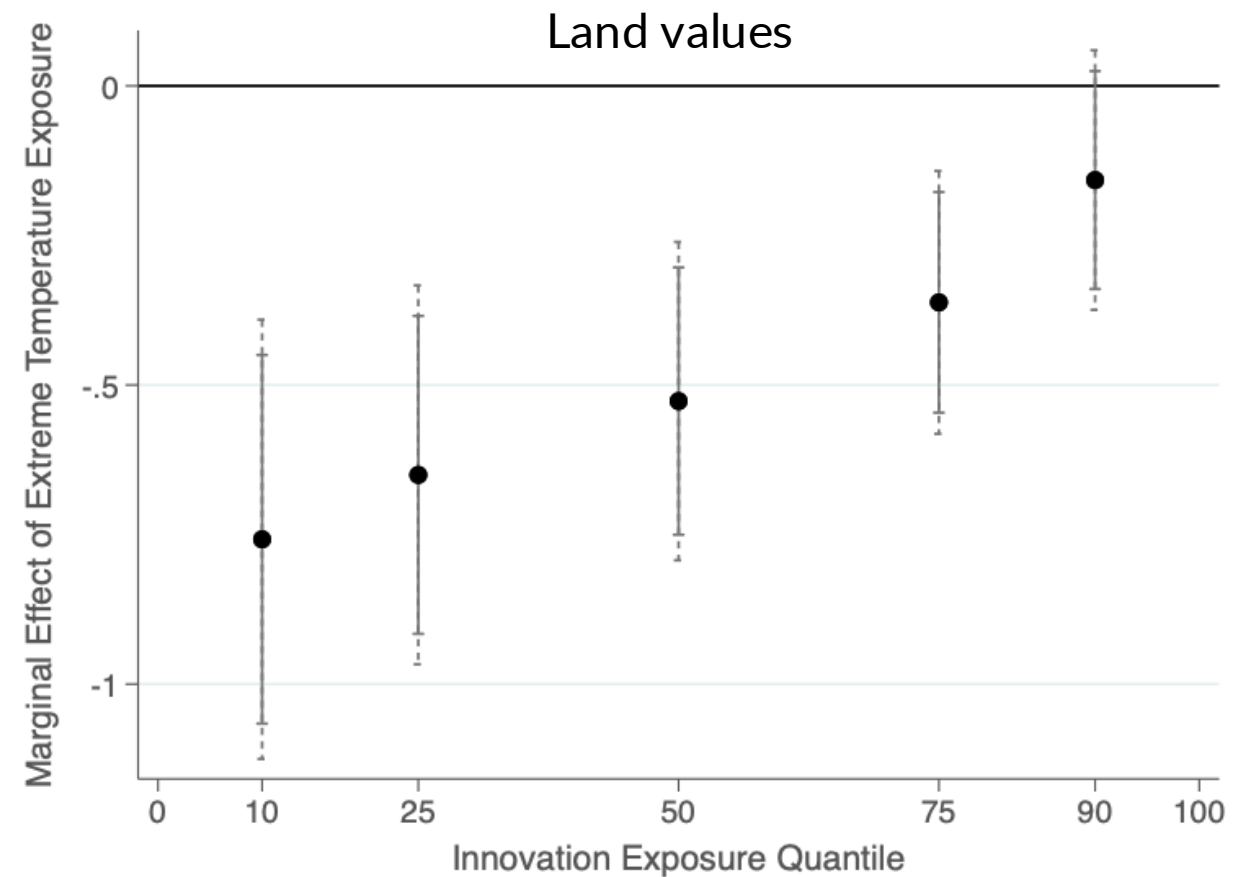
Crops more exposed to extreme and harmful temperatures in the recent past have higher rates of climate-relevant patenting!



Moscana and Sastry (2022)

Innovation in crops

Crops that had more climate innovation in the past are less sensitive to extreme temperature in the future



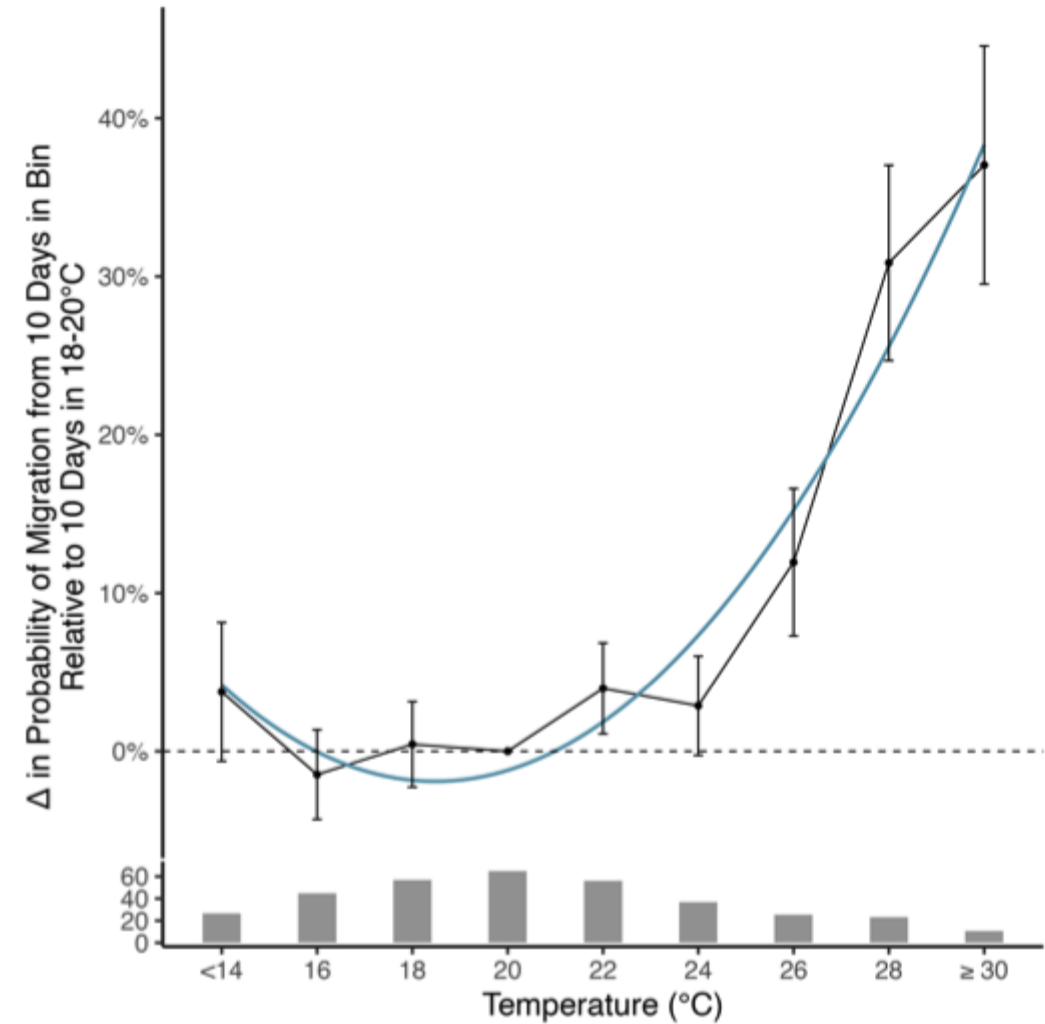
Innovation in response to past climate change increases future climate resilience

Migration in Mexico

One way to deal with climate change is to move people to places with better climates

- Extreme heat is bad for wages, quality-of-life

Mexican households are 40% more likely to move if there are 10 more days in a year $> 30^{\circ}\text{C}$



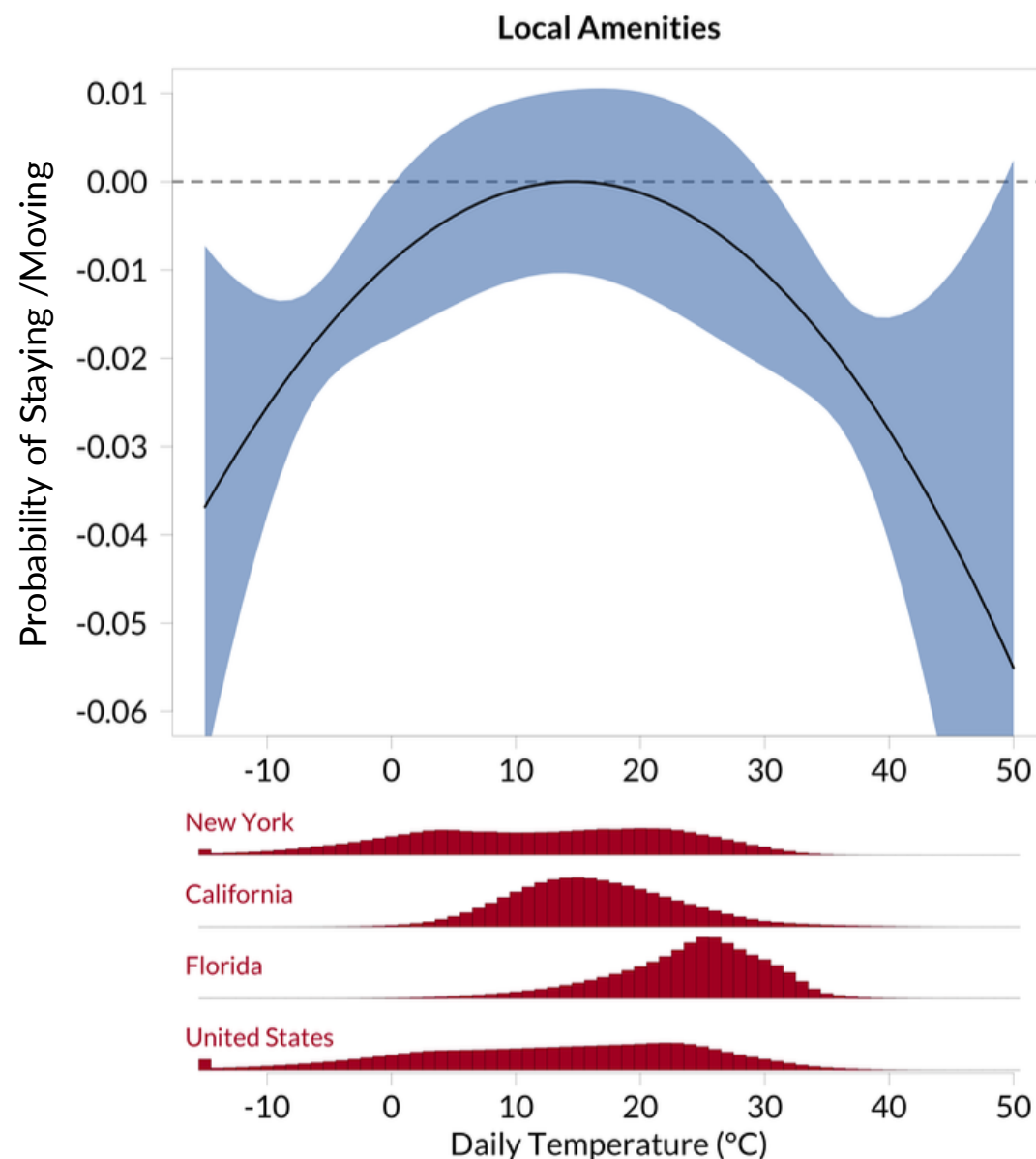
Migration in the US

Why do people move?

Better wages, better amenities

In the US, **holding wages fixed**, people move more when it's extremely cold or hot

Moderate temperatures are a valuable amenity



Policies, markets, and adaptation

Policy tools and markets are critical for managing climate impacts and adaptation

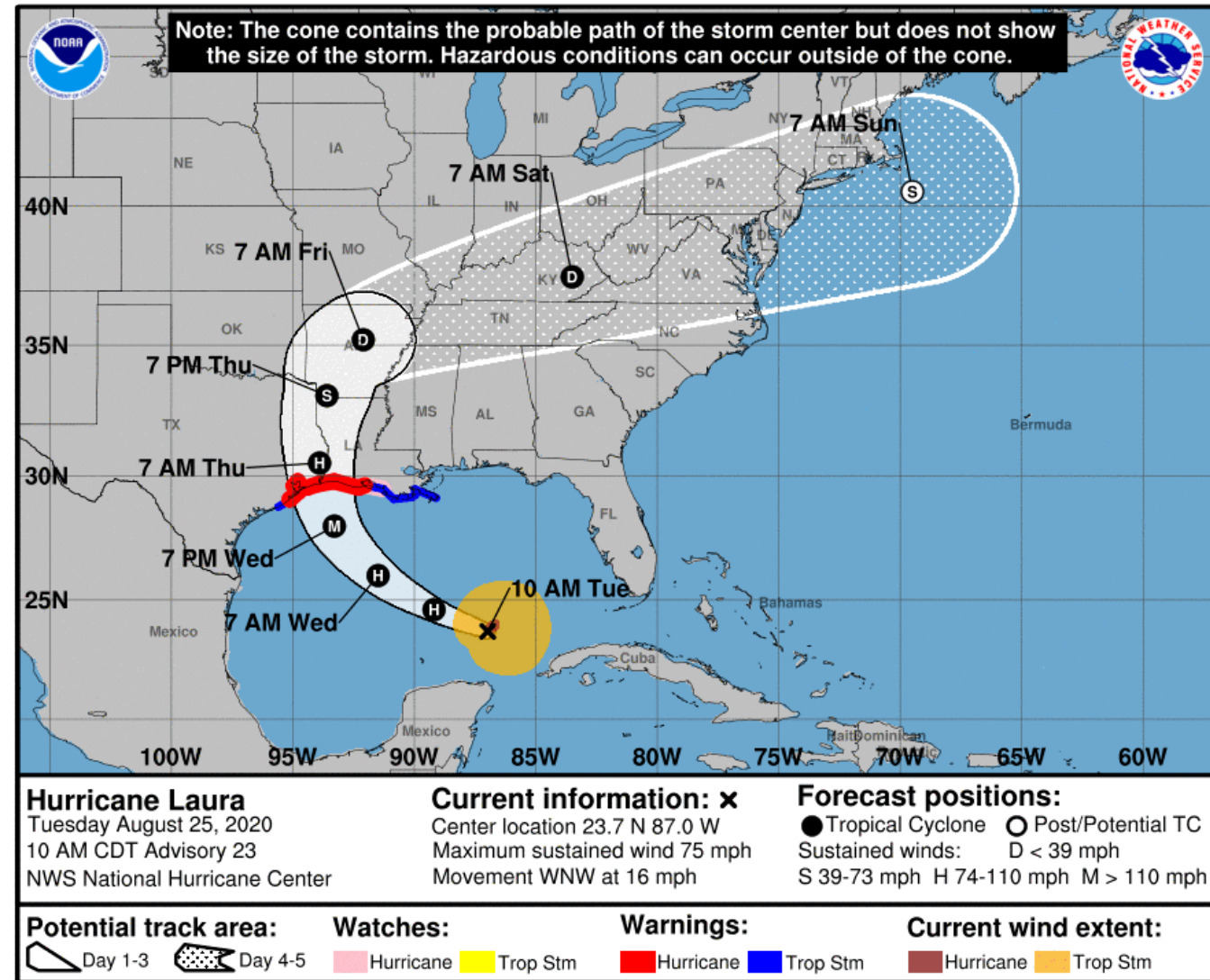
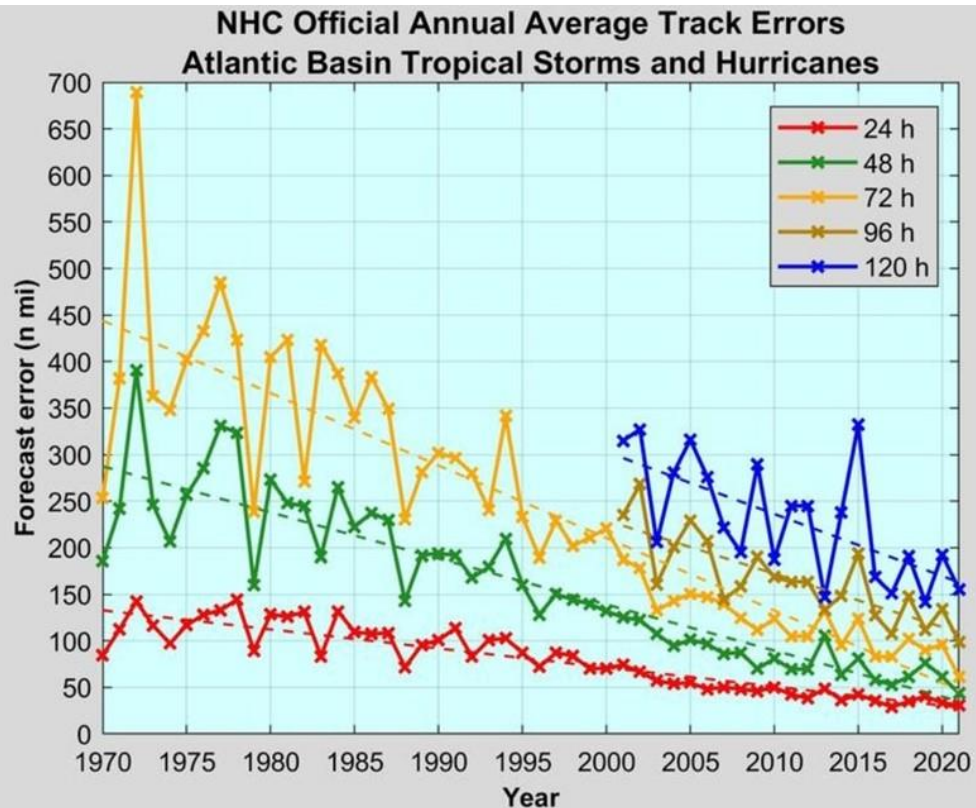
Well-designed policies and well-functioning markets can improve our resilience to climate change, or worsen it if poorly done

I'll focus on two areas:

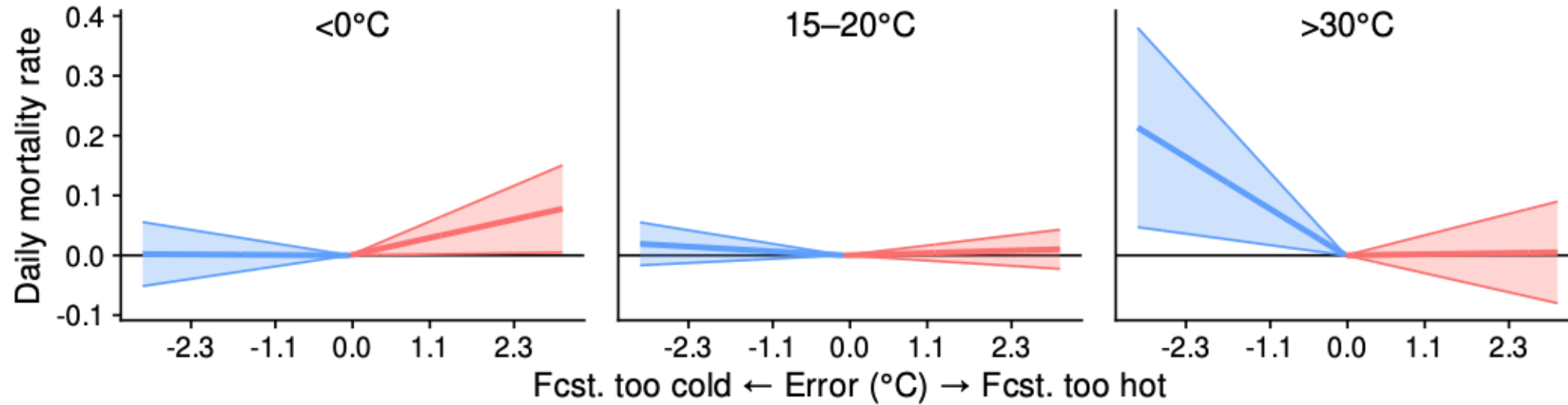
- Forecasting

How can we adapt?

Forecasts provide information so people can take better actions



Temperature forecasts are valuable



Temperature forecasts matter for US county mortality!

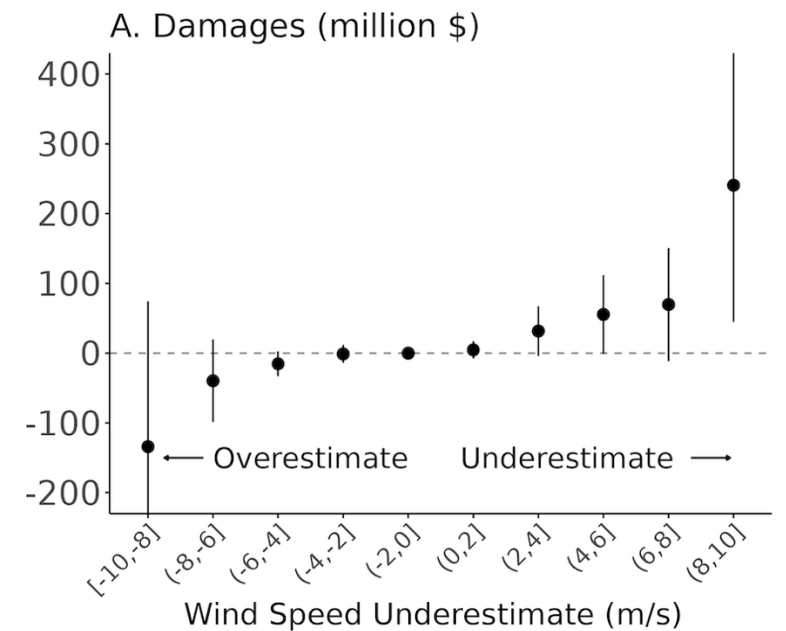
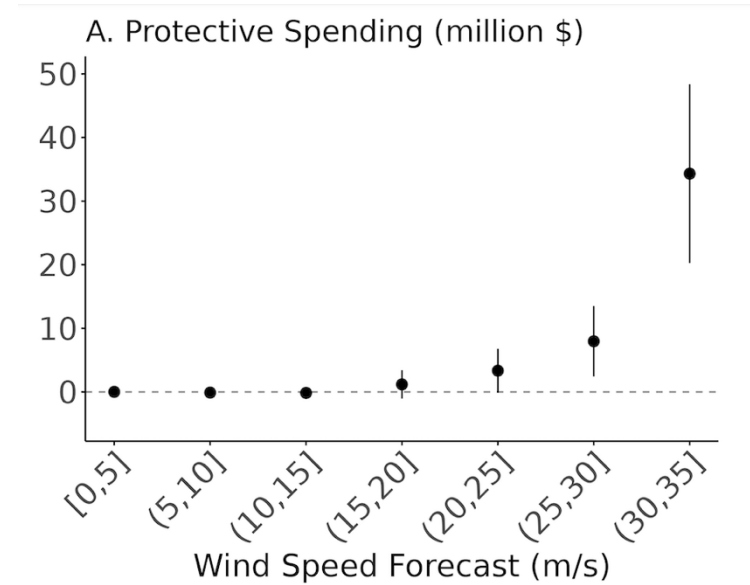
Why? People use this information to stay inside/outside, use air conditioning, etc.

Hurricane forecasts are extremely valuable

US hurricane forecasts drive pre-landfall protective investments by state and federal governments

Precise hurricane forecasts reduce damages by tens of millions of dollars per county

- Underestimate: lots of damage
- Overestimate: too much protection



The role of insurance

Insurance plays a large role in how we deal with climate change

Very salient right now due to increasing numbers of wildfires and floods

Climate impacts and insurance markets are a major issue facing the US



Insurance primer

How does insurance work?

You pay a premium every year for insurance

If you experience a covered loss (e.g. your house is destroyed), the insurer pays you for your loss

Insurance primer

Why does insurance work?

Individuals don't like risk, they are willing to pay to avoid it

Big insurers can take on this risk at a price if

- Individual risks aren't systematically correlated (health, auto)
- They can charge policyholders their expected loss every year (the *actuarially fair price*)

Insurance primer

We have problems with the insurance market working properly if:

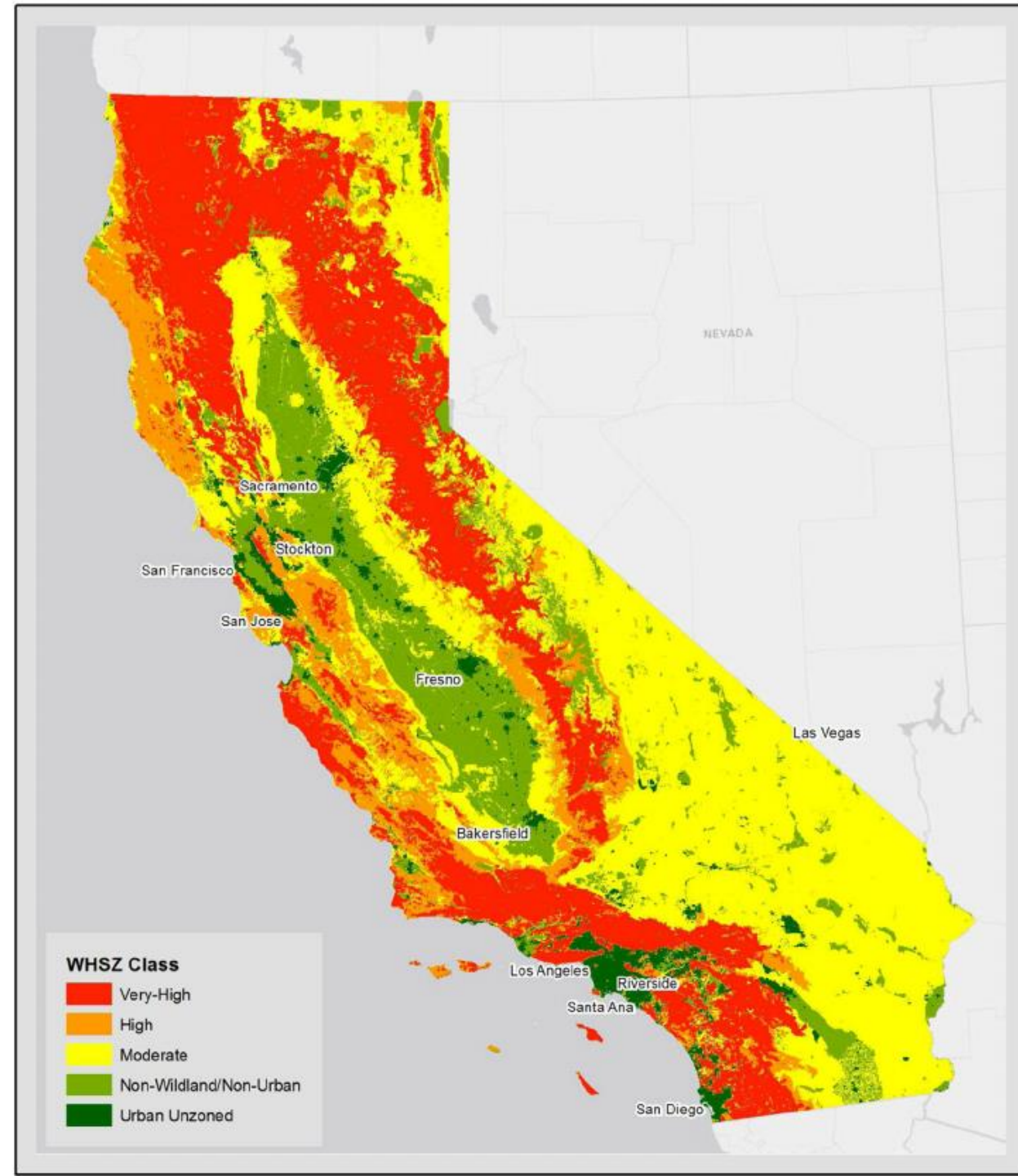
- Risks are systematically correlated
 - Years of **big** losses
- There are barriers preventing insurers from charging actuarially fair prices
 - Insurers will be **unprofitable** and stop insuring

Wildfire risks

Wildfire risk is heavily spatially correlated

If your house burns down, your neighbor's probably did too

Losses from wildfires can be large and hard to diversify



Correlated risk makes profits very risky

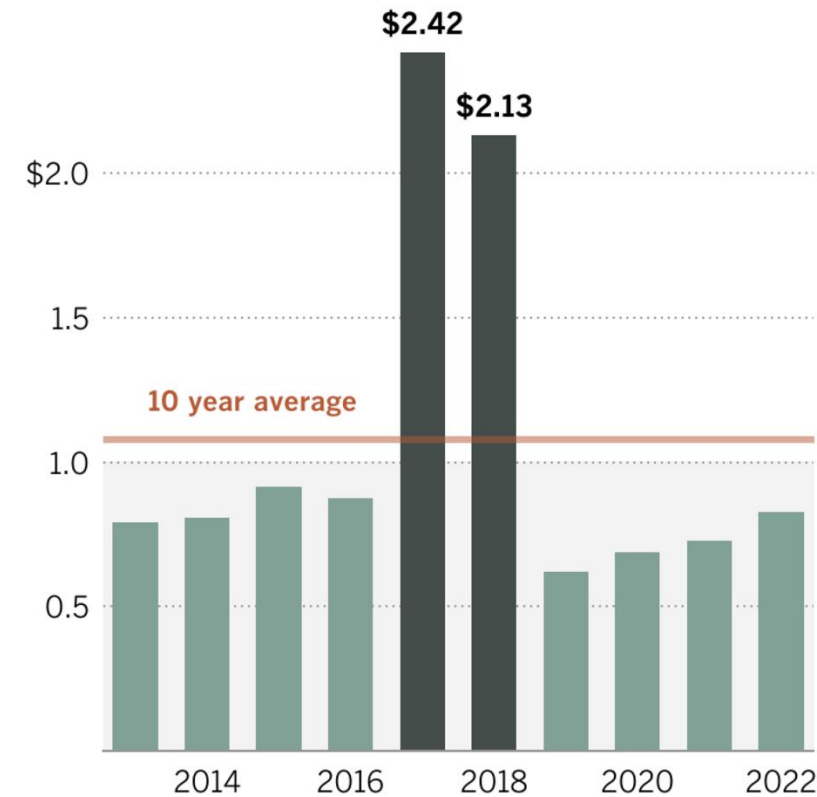
Wildfire risk is heavily spatially correlated

If your house burns down, your neighbor's probably did too

Losses from wildfires can be large and hard to diversify

Despite profits most years, wildfire losses in 2017 and 2018 have been difficult to overcome

In most years, California insurers were profitable. For every dollar of premiums, insurers paid out less. But two extreme wildfire years brought the average up to \$1.08 resulting in a 10-year loss.



Regulating prices can unravel markets

Well-intentioned regulations underprice risk with negative consequences

[Insurance News Overview](#) / [Press Releases](#) / [2025 Press Releases](#) / Commissioner Lara expands moratorium to protect more wildfire survivors from nonrenewals

Commissioner Lara expands moratorium to protect more wildfire survivors from nonrenewals

News: 2025 Press Release

For Release: February 25, 2025

Media Calls Only: 916-492-3566

Email Inquiries: cdipress@insurance.ca.gov

Commissioner Lara expands moratorium to protect more wildfire survivors from nonrenewals

Mandatory one-year moratorium preventing homeowners insurance cancellations and non-renewals now also covers those affected by the Hughes Fire

BUSINESS

POLITICS Published January 9, 2025 4:01pm EST

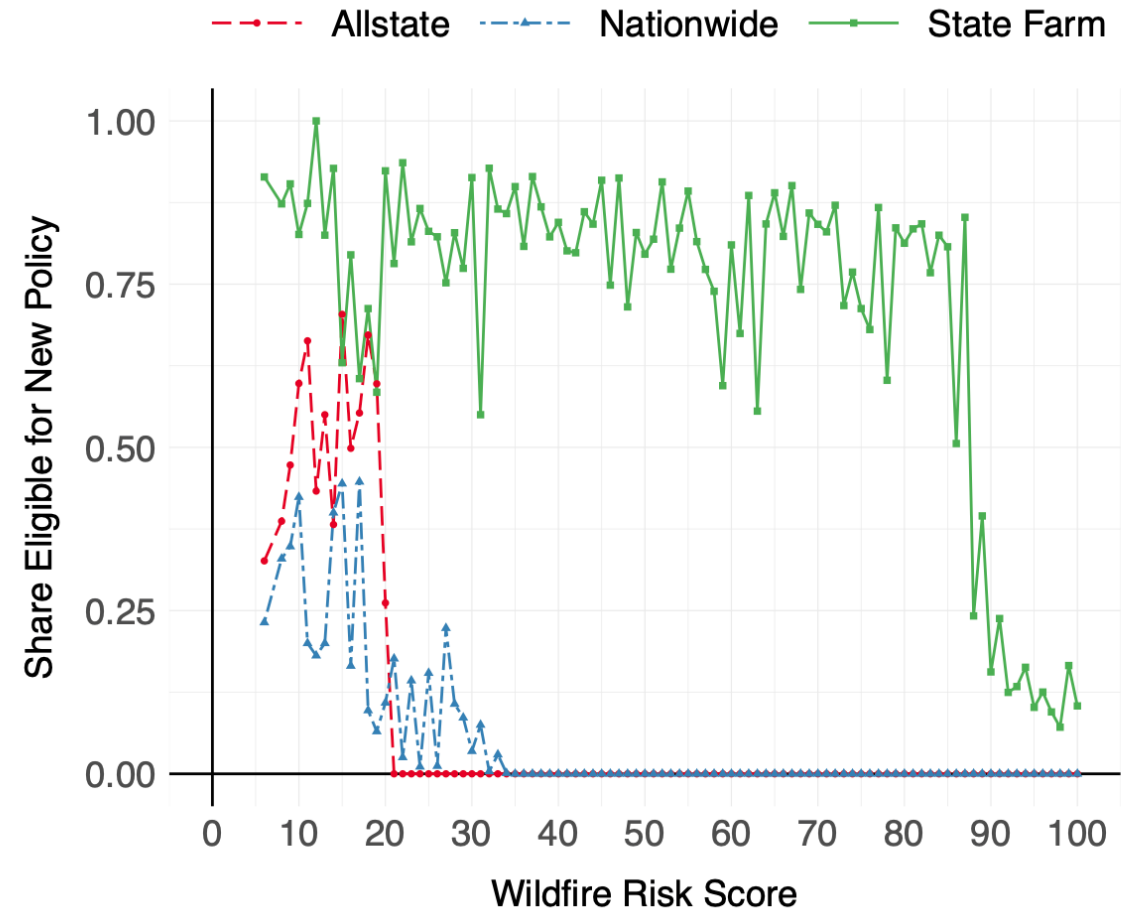
California fires: Insurance companies dropping coverage and fleeing the state due to decades-old law

It's not just State Farm. Allstate no longer sells new home insurance policies in California

Having good risk information matters

State farm is willing to offer insurance to much higher-risk households than other insurers

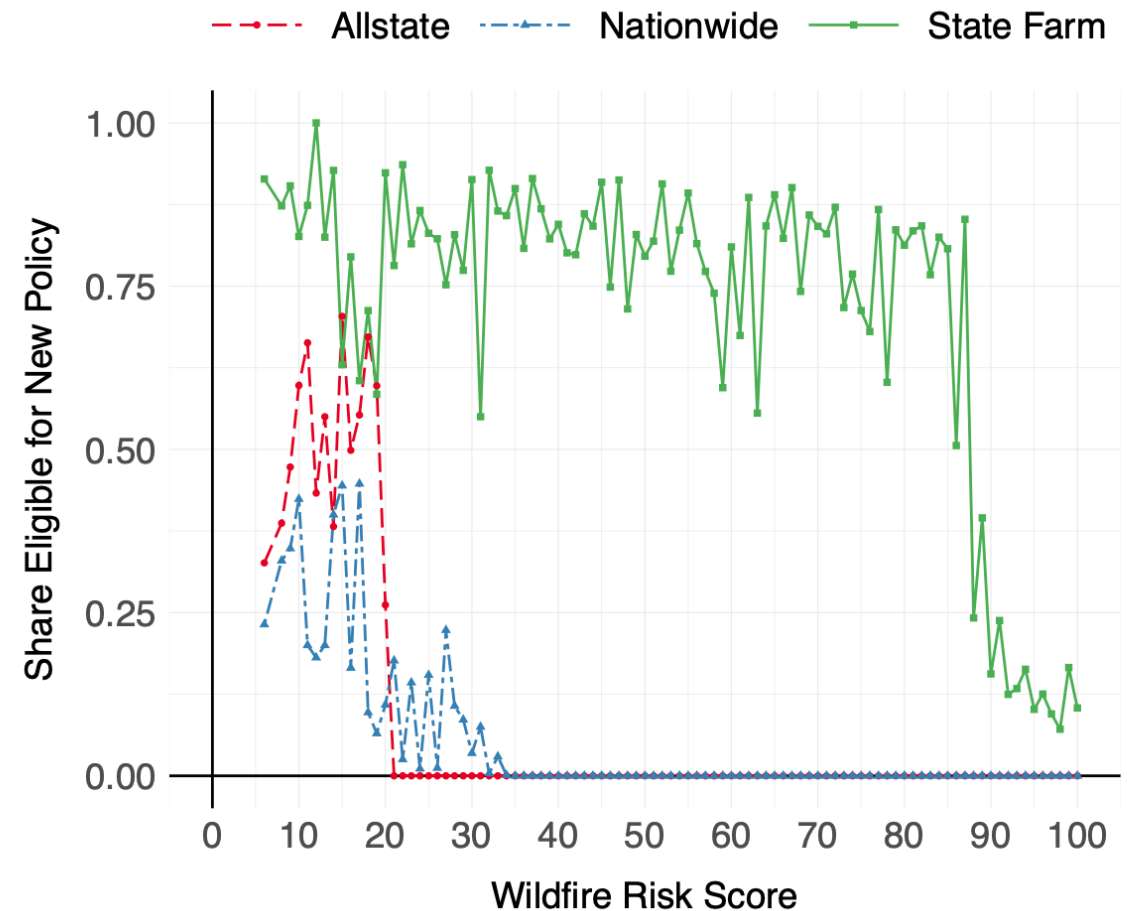
Why?



Having good risk information matters

State Farm has the best wildfire risk model in CA: better risk information

Allstate and nationwide must worry about **adverse selection**: high-risk homeowners choose their plans because they underestimate the risk



Forecasts and insurance are intertwined

Both are about providing the right information so people can adapt

Forecasts: this is what's going to happen this year

- Direct information provision

Insurance: this is the expected loss you're going to incur this year

- Provides information through the price system (like other goods in the economy)

Natural capital

Nature provides critical infrastructure to help protect us against climate hazards

In 2024 I helped lead the federal government's development of
Natural Capital Accounts

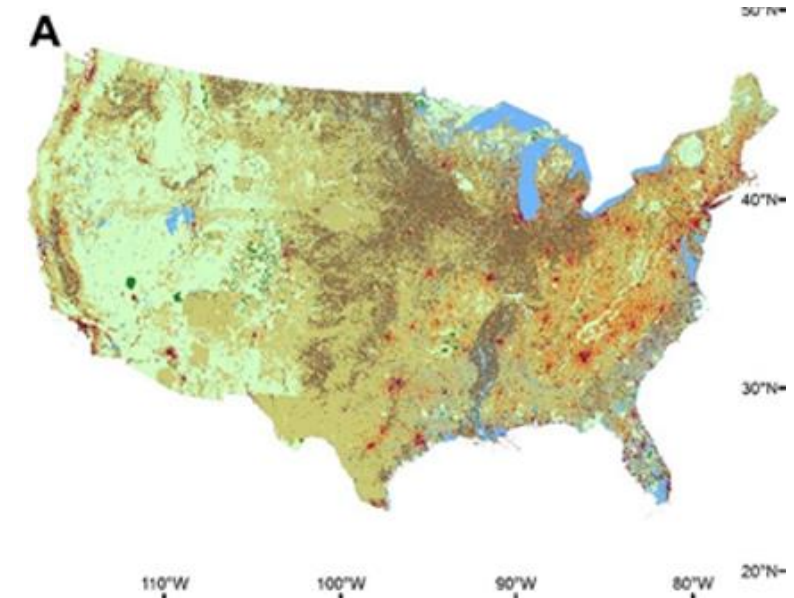
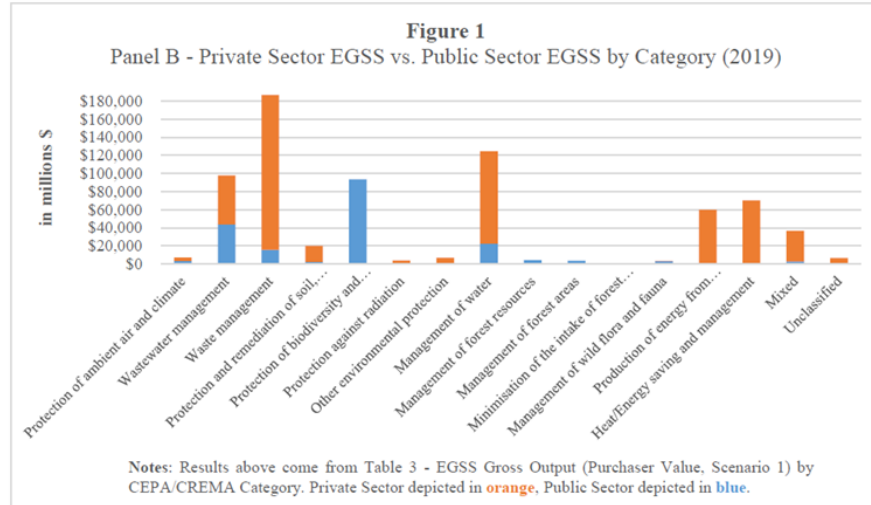


Putting nature on the nation's balance sheet

I. The Need for a System of Statistics for Environmental-Economic Decisions

“The *nation behaves well if it treats the natural resources as assets* which it must turn over to the next generation increased, and not impaired, in value; and behaves badly if it leaves the land poorer to those who come after it. That is all I mean by the phrase, Conservation of natural resources. Use them; but use them so that as far as possible our children will be richer, and not poorer, because we have lived.”

— THEODORE ROOSEVELT, SPEECH TO THE COLORADO LIVESTOCK ASSOCIATION
IN DENVER ON AUGUST 29, 1910



In January 2023, the White House released the first-ever [U.S. National Strategy to Develop Statistics for Environmental-Economic Decisions](#) (National Strategy). It creates a system to account for our natural assets—including the minerals that power our tech economy, the ocean and rivers that support our fishing industry, and the forests that clean our air. The Statistics for Environmental-Economic Decisions (SEED) will quantify the economic value of this natural capital, providing critical data to help us monitor changes in the condition and economic value of land, water, air, and other natural assets.

Putting nature on the nation's balance sheet

The Natural Capital Accounts are about understanding the value of the nature and resources we have in the US and properly accounting for it along side standard economic metrics like GDP

Nature is an asset: it provides value

- Mangroves protect against hurricanes
- Wetlands act as firebreaks
- Forests protect against flooding
- Urban trees reduce ambient air temperature

Quantifying nature leads to better decisions

Knowing the value and location of our natural assets will help us adapt and protect against climate impacts

If the natural capital accounts tell us protective natural capital is deteriorating, we can divert other resources to make up for it

- If a mangrove forest has been destroyed, we can allocate more emergency funds for a temporary levee
- Loss of wetlands tells us to invest more in firebreaks

What can the government do?

Provide public goods: provide information so people can make better decisions

- Improve existing forecasts
- Provide and incentivize better public risk modeling

Ensure markets function well

- Market prices should reflect true risk
- Federal government can potentially act as reinsurer of last resort

Facilitate adaptation for those who don't have the resources