THE LONDON SCHOOL OF ECONOMICS AND POLITICAL SCIENCE

Grantham Research Institute on Climate Change and the Environment

Mortality Inequality, Temperature, and Public Health Provision: Evidence from Mexico

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(joint with François Cohen)

Will climate change halt the global convergence in life expectancy?

- **Life expectancy + 10 years 1980-2015 globally**, & more so in developing countries
- **Climate change will affect many determinants of health**
  - Water, food supply, public infrastructure, housing, economic growth and conflict.
  - By 2030-2050, climate change could be responsible for 250,000 deaths every year (WHO).
- **Most of the health impacts of climate change will be felt in developing countries**
  - Stronger negative effects (warmer and sensitive to precipitations) and weaker adaptive capacity
  - Climate change may also widen within-country differences between the rich and the poor

The paper

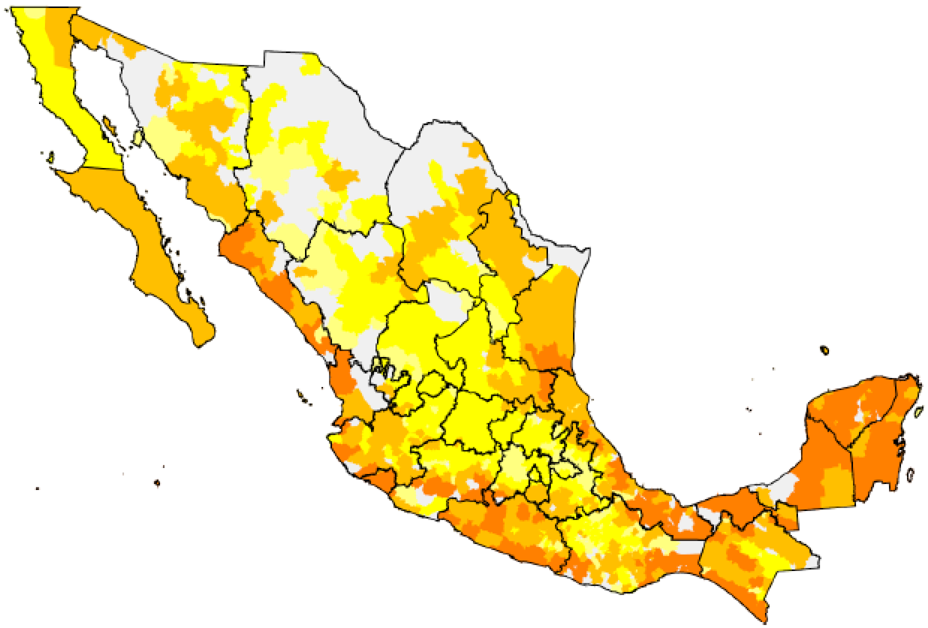
1. **What is the effect of temperatures on mortality in developing countries?**
   - Case study: Mexico. Daily weather & mortality data over 1998-2010
2. **How does weather-related mortality differ according to income level?**
   - Use individual predictions on income levels to measure the correlation between income and weather vulnerability
3. **How can government policies increase resilience to extreme weather?**
   - Analyse whether the development of universal healthcare in Mexico (Seguro Popular) reduced weather vulnerability

Why focus on the temperature – mortality relationship?

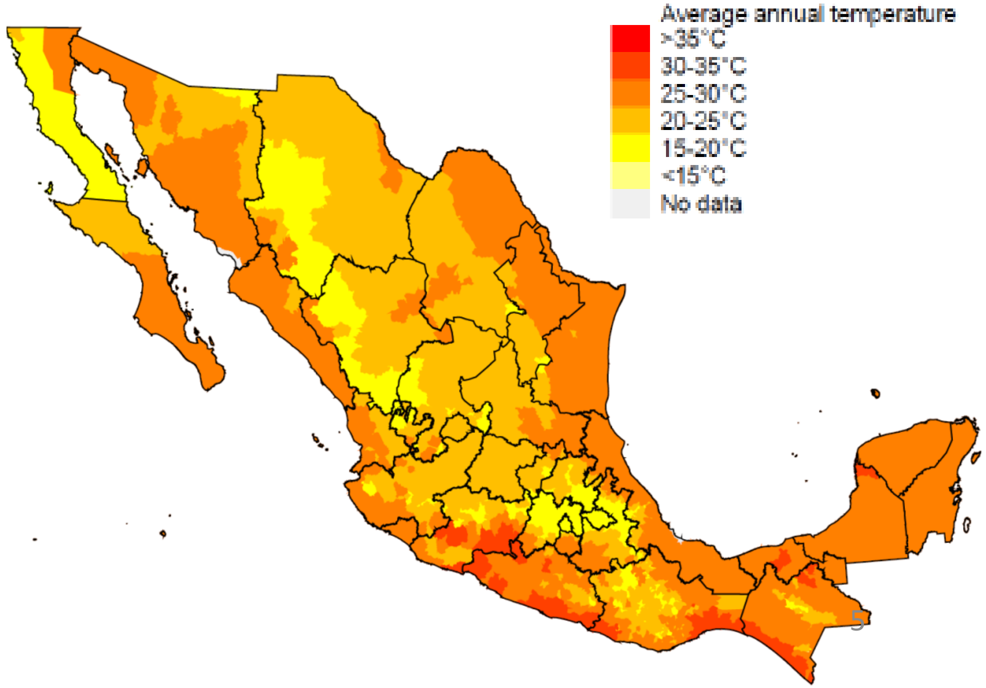
- **Temperature shocks will be the most direct way through which climate change will impact health**
  - Vast epidemiological literature: Impact through cardiovascular and respiratory diseases; affects mostly the elderly (75+)
  - Not only extreme temperatures: comfort zone of 20-25°C
- **Climate change expected to increase mortality**
  - Eg Deschênes and Greenstone (2011); McMichael et al. (2008)
  - But limited evidence on developing countries (Burgess et al. 2014: only paper applying general circulation climatic model)
- **Heterogeneous effects**
  - Moderate effects of extreme cold and heat in US (Deschenes and Greenstone, 2011; Barreca, 2012) but strong effect of heat in India (Burgess et al., 2014), no within-country study

Why look at Mexico?

- **A middle-income country with strong income inequalities**
  - Compare with US (many studies) and India (Burgess et al. 2014)
  - Analyse heterogeneity across income groups
- **Among the hottest countries in the world**
  - Strong impact of climate change



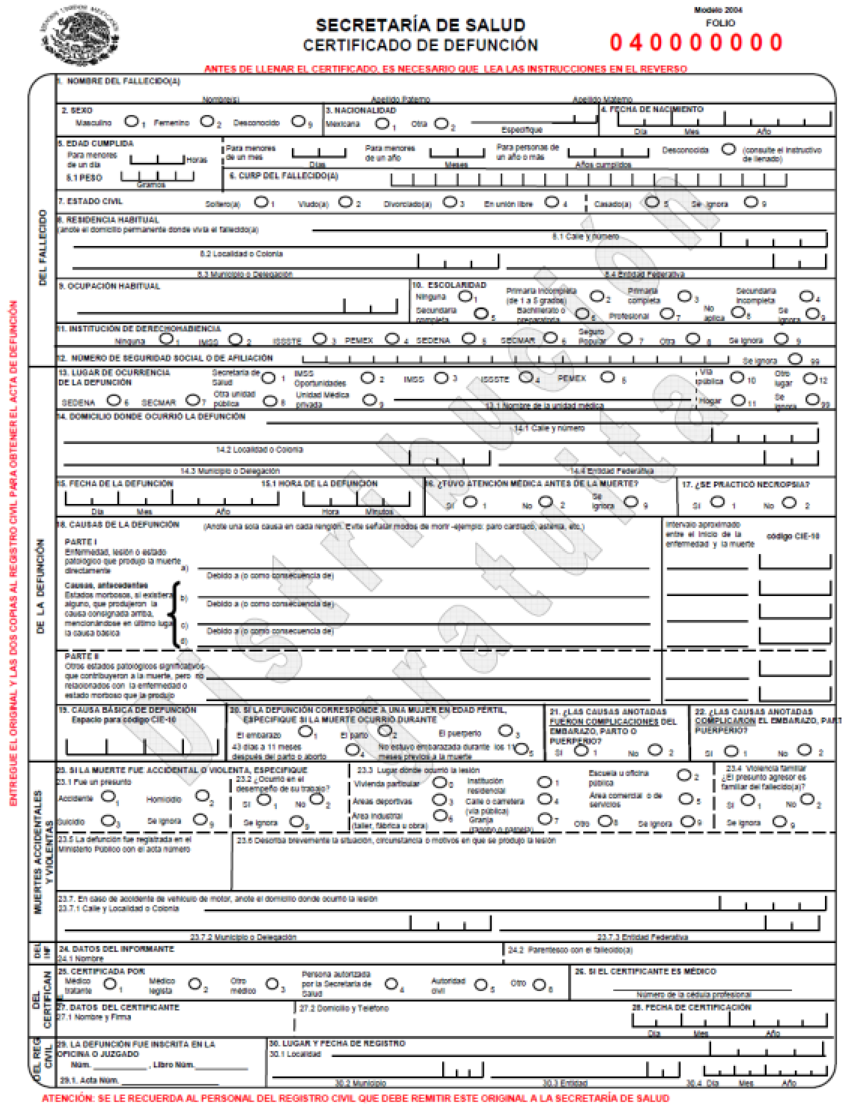
Recent period (1998-2010)



RCP4.5 scenario (GFDL CM3, 2075-2099)

A large dataset covering daily mortality rates and temperature levels

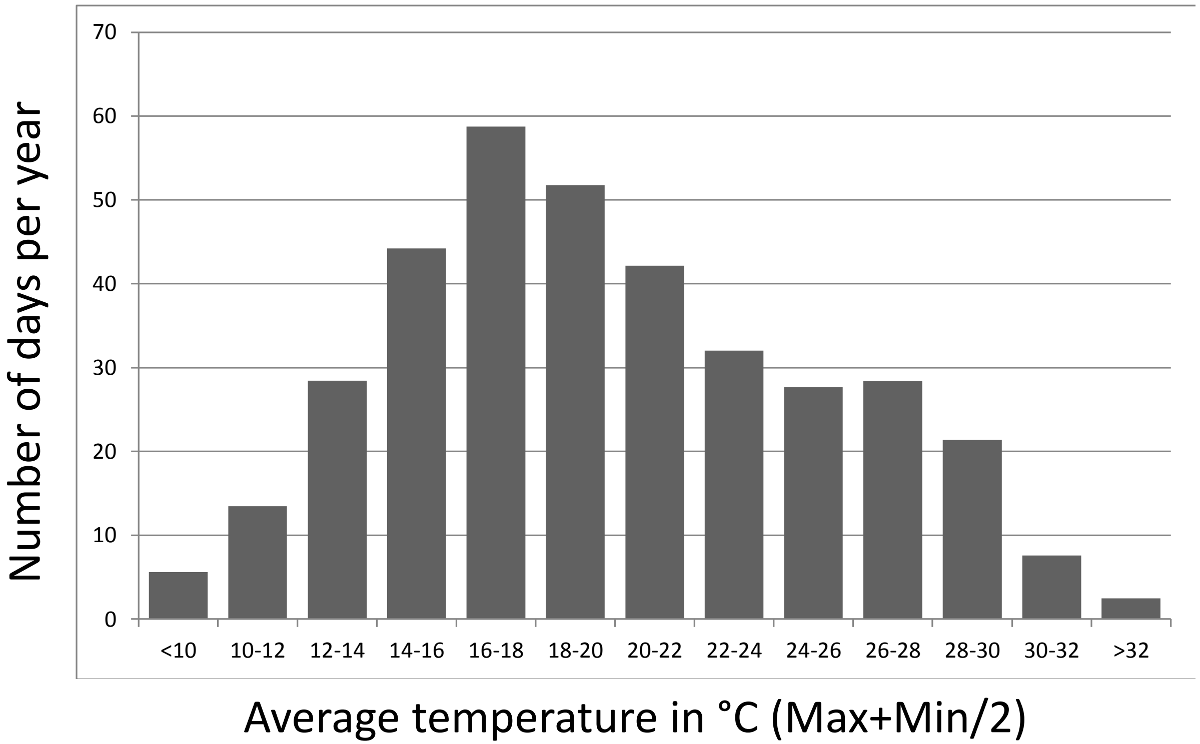
- Individual death certificates for Mexican population (1998-2010), with individual characteristics, cause of death etc
- Daily weather information from more than 5,000 meteorological stations
- More than 9 million daily death rates for 2,100 municipalities



Mortality & temperature: D-stats

		Average daily municipal mortality rate (deaths per 100,000 inhabitants)						
Group	Average population per municipality	All causes	Infectious diseases	Neoplasms	Endocrine, nutritional and metabolic diseases	Circulatory system diseases	Respiratory system diseases	Violent and accidental deaths
Total	44935	1.30	0.049 (3.8%)	0.163 (12.5%)	0.204 (15.7%)	0.295 (22.7%)	0.114 (8.8%)	0.142 (10.9%)

Distribution of daily average temperatures in Mexico 1998-2010



Simplest model: correlate death rates with daily temperatures

- **Fixed effect panel data model**
  - Month-by-year-by-municipality fixed effects: identification from daily variations within a month within a municipality
  - Coefficients weighted by the square root of population in municipality

$$Y_{i,d,m,t} = \sum_{s} \theta_s . B_{s,i,d,m,t} + \sigma . P_{i,d,m,t} + \mu_{i,m,t} + \varepsilon_{i,d,m,t}$$

Mortality rate in municipality *i*, on day *d* of month *m* in year *t*, in deaths per 100,000 inhab.

Vector of dummies indicating the **temperature bin *s*** to which day *d* in month *m* and year *t* belonged in municipality *I* (12 bins)

Controls: precipitation, humidity

Fixed effect at municipality – month – year level

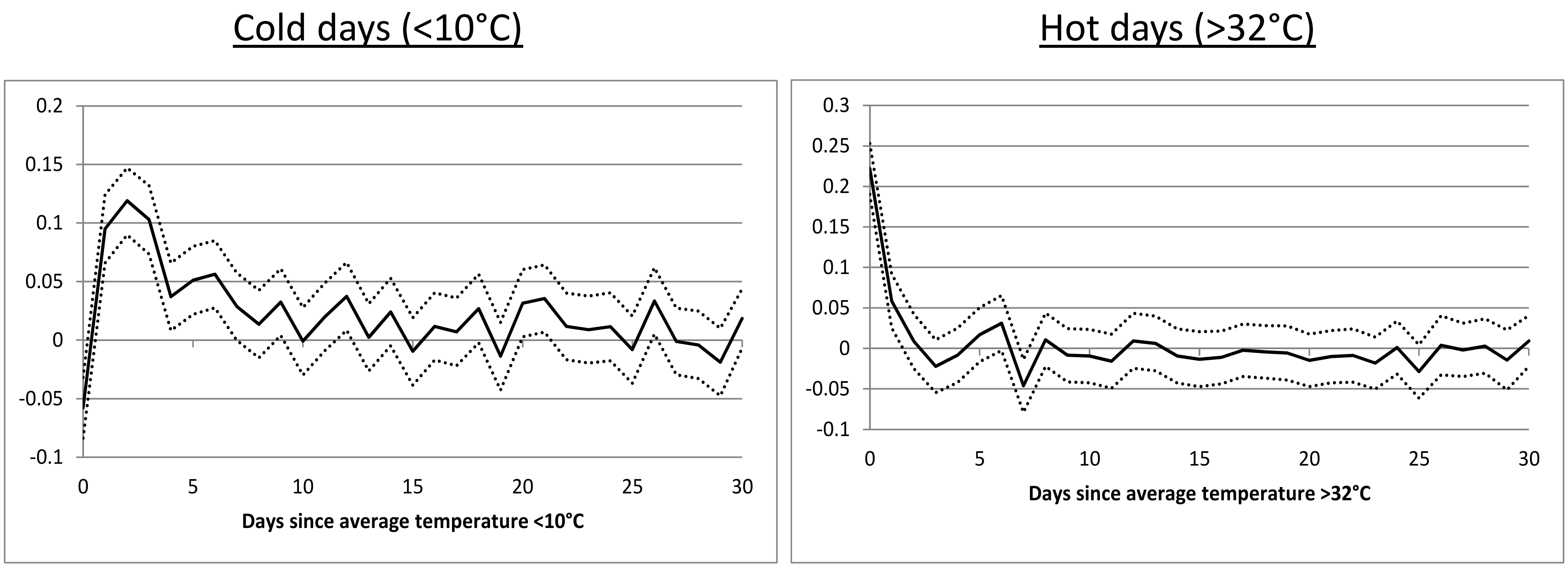
Accounting for delayed impacts: distributed lag model

- **Distributed lag model with temperature bins**
  - Same fixed effects and weights
  - Distributed lags for all temperature bins over 30 days (as recommended in Deschenes and Moretti, 2009)

$$Y_{i,d,m,t} = \sum_{k=0}^{K=30} \sum_{s} \theta_{s,-k} . B_{s,i,d-k,m,t} + \sigma . P_{i,d,m,t} + \mu_{i,m,t} + \varepsilon_{i,d,m,t}$$

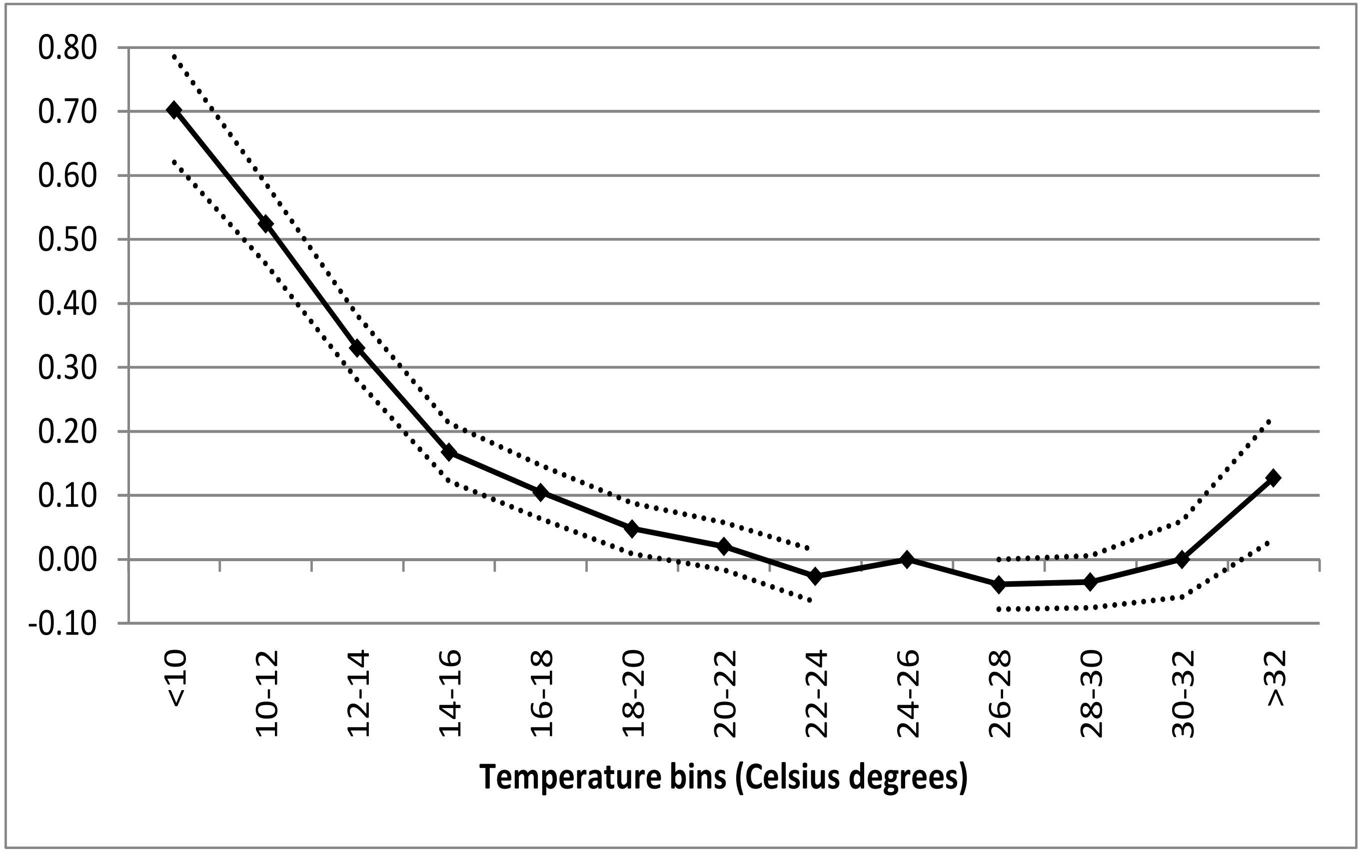
30 lags for each day *k* for each temperature bin s (30x12=360 coefficients)

Heat strikes immediately while cold has a lagged effect



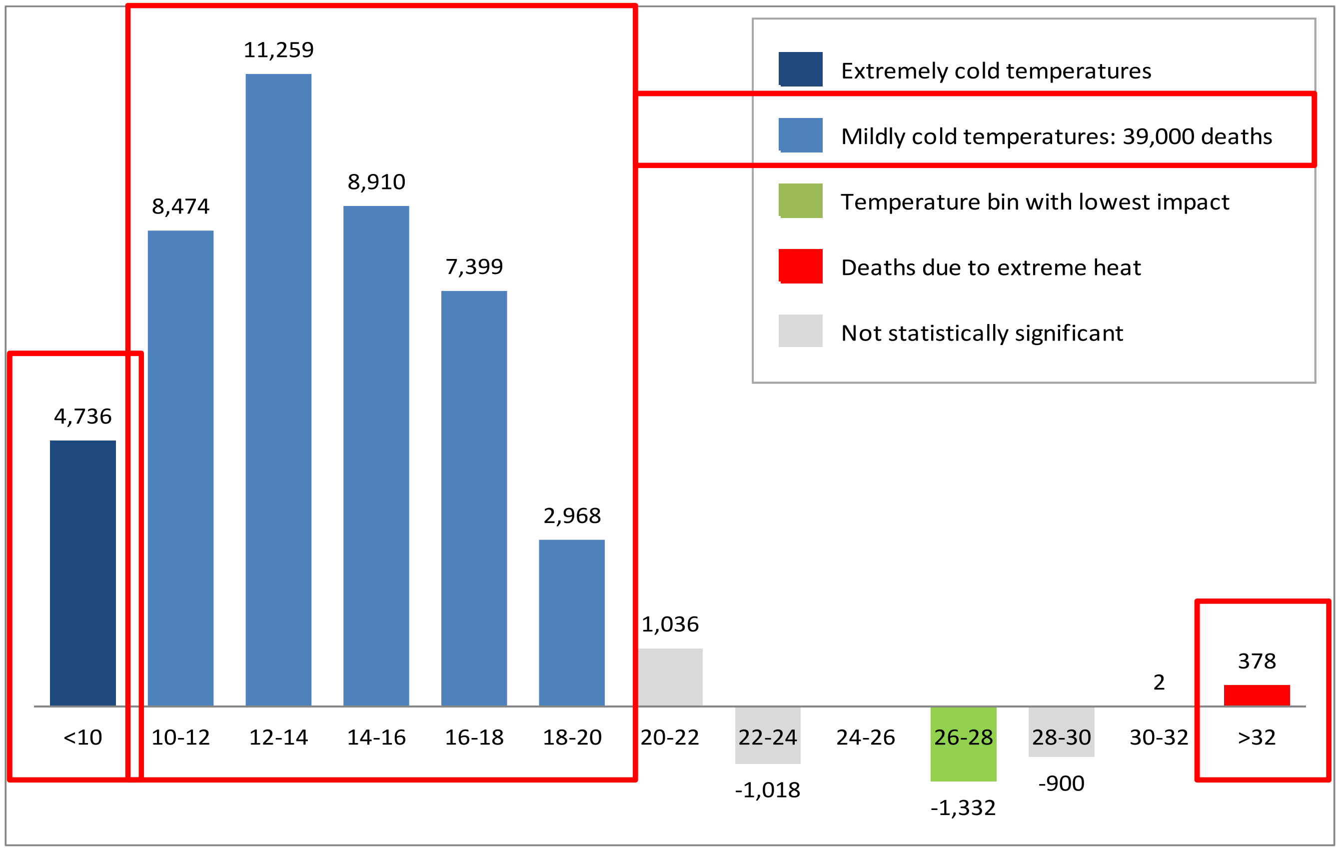
Impact on mortality for each day following the event
(in deaths per 100,000 inhabitants)

Strong impact of cold when delayed effects are accounted for



Extra mortality associated with different temperature levels
(cumulative impact over 31 days in deaths per 100,000 inhabitants)

88% of deaths during mild cold

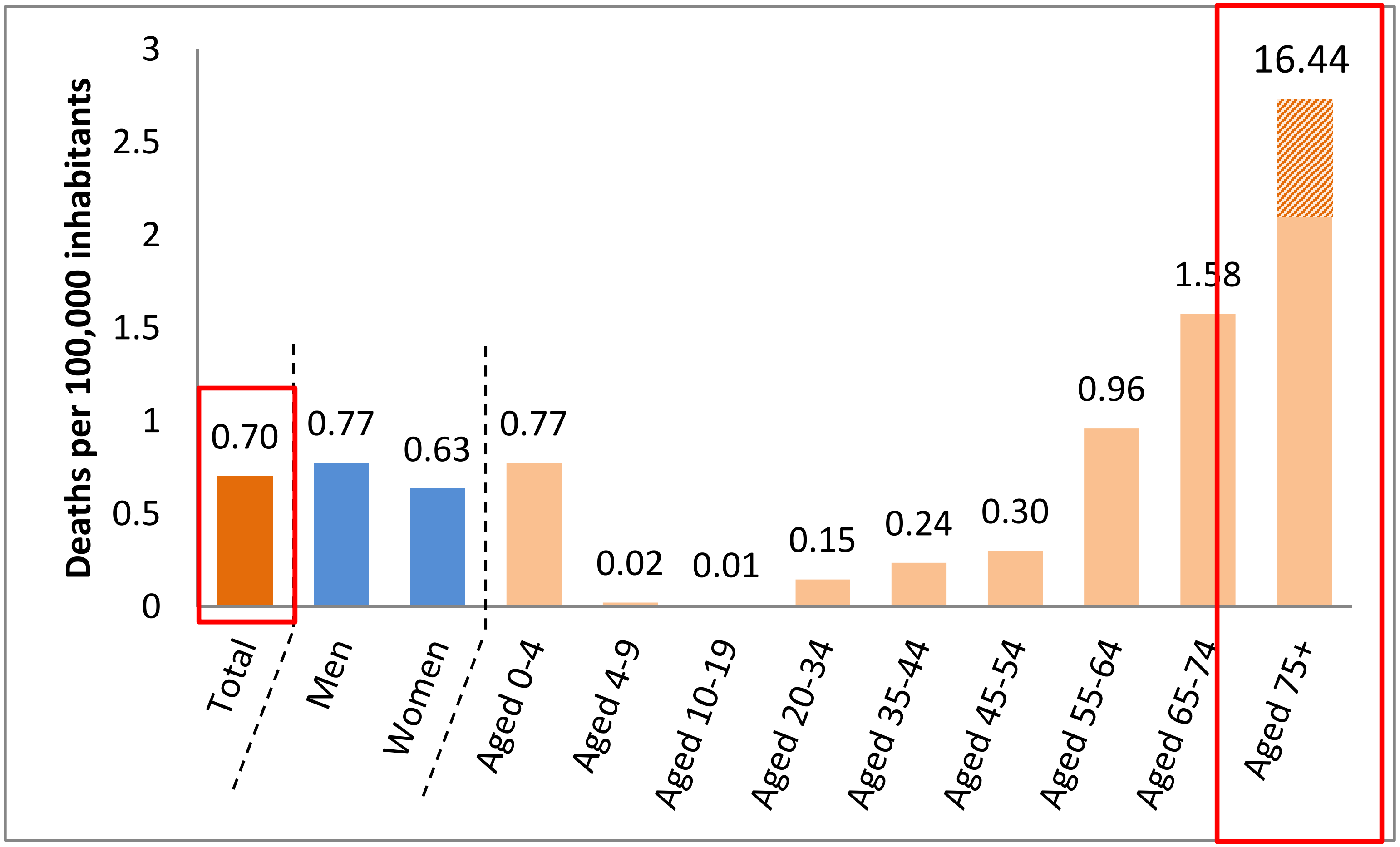


Total is 41,900
7.4% of deaths
in Mexico

≠ Deschenes and Moretti (2009): 0.8% of deaths are temperature-related in the US

Estimated deaths by temperature bins across Mexico
(in deaths per year)

The elderly (75+) are particularly hit: eg day below 10°C



Estimated cumulative impacts over 31 days for a day below 10°C (Deaths per 100,000 inhabitants)

Deschenes and Moretti (2009) also found that the elderly were the most vulnerable in the US

A strong longevity impact on children

Table 8: Years of life lost estimates by age group and temperature level

Age group	<10°C	10-20°C	>32°C
0-4	35,872*	212,115*	-456
5-9	1,040	-25,734	-144
10-19	898	50,675*	2,073
20-34	12,443*	-19,639	1,050
35-44	8,767*	20,167	2,117
45-54	6,282*	87,130	863
55-64	9,461*	60,652	13
65-74	6,413*	48,452	60
75+	23,766*	232,044*	908

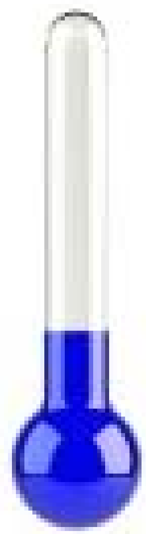
Note: These are estimates of the total number of years of life lost for each age category. They are obtained from multiplying the estimated number of deaths of table 7 with the remaining life expectancy of each age group, as provided by the life table of 2010 for Mexico which is accessible from the Global Health Observatory data repository. An asterisk (*) denotes statistically significant results at 5%.

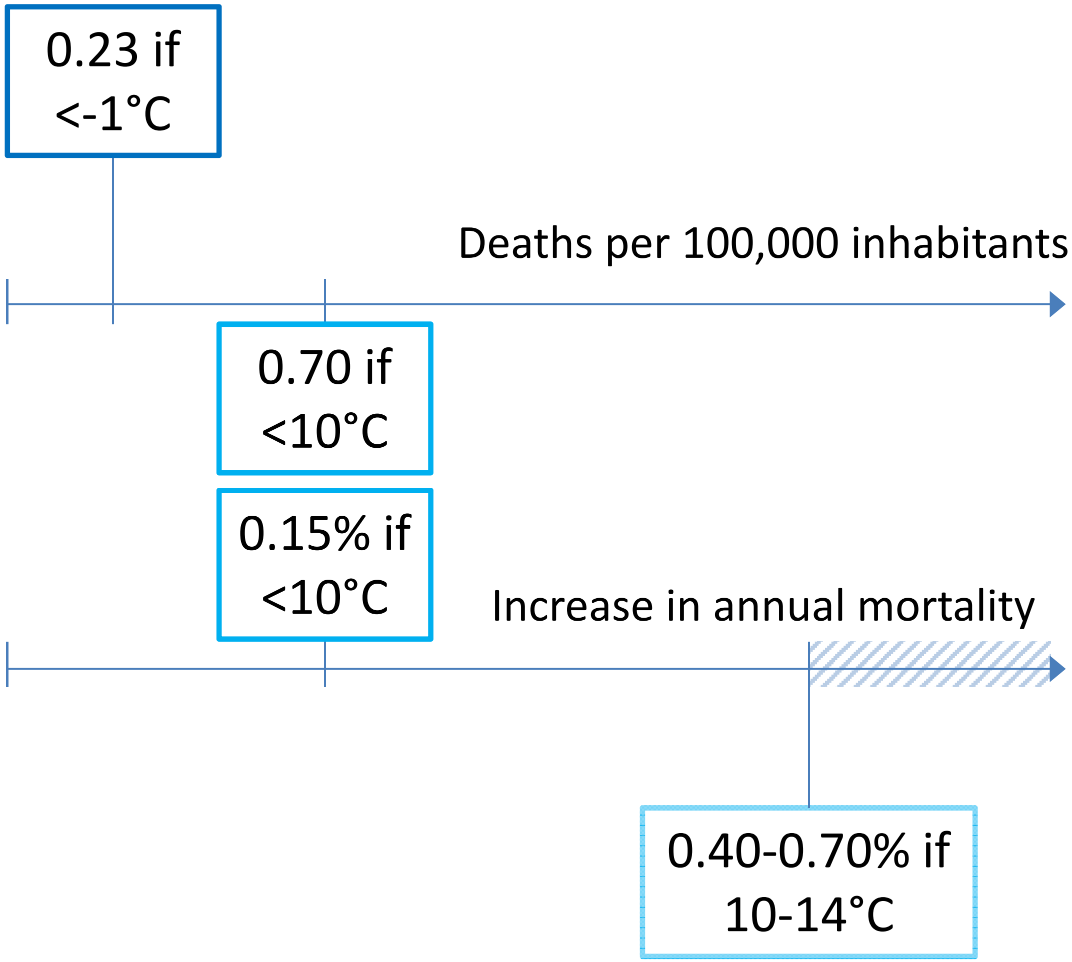
In the US, Deschenes and Moretti (2009) find an impact on the elderly but not on children:

- Higher proportion of children in the Mexican population.
- Stronger effect of low temperatures on infant mortality in Mexico.

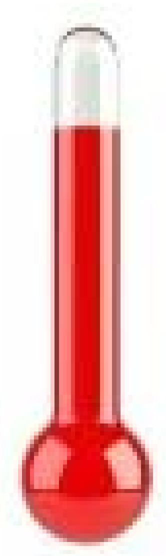
Burguess et al. (2014) also find a strong impact of temperatures on children.

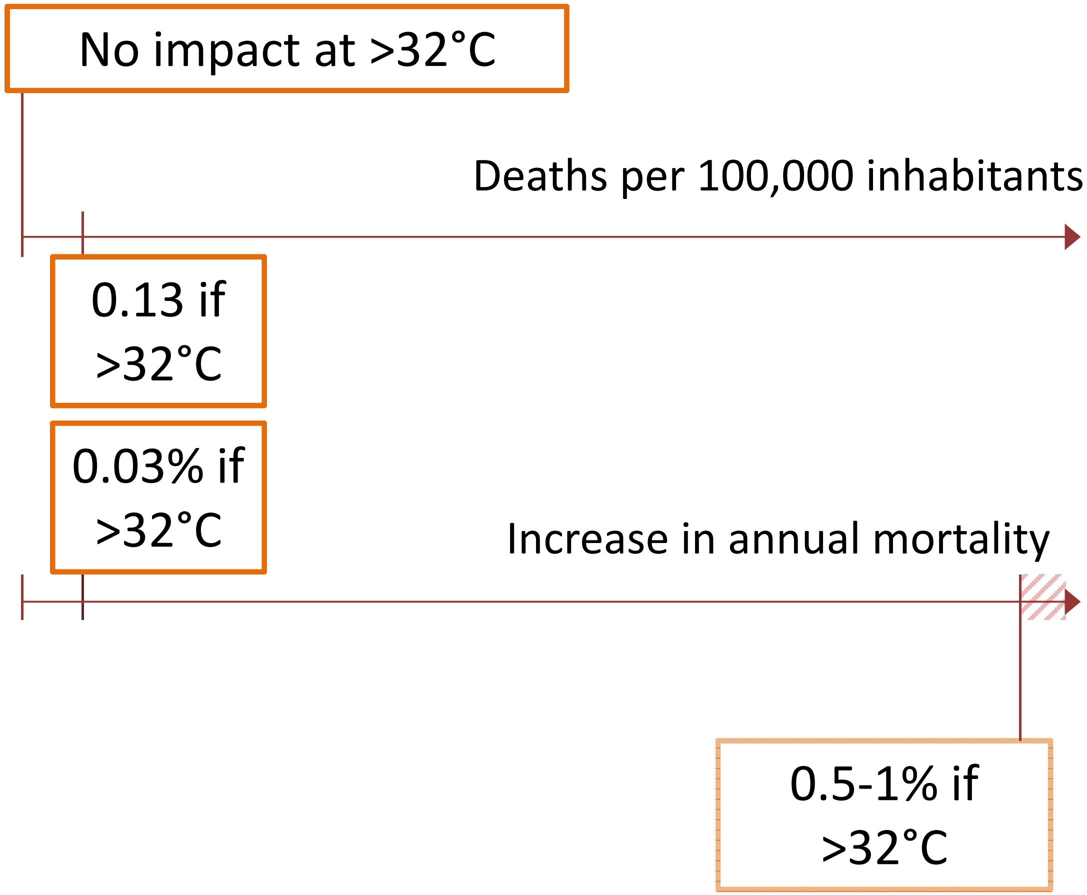
Impact of cold in Mexico ranges between the US and India





Impact of heat is small and significantly lower than in India

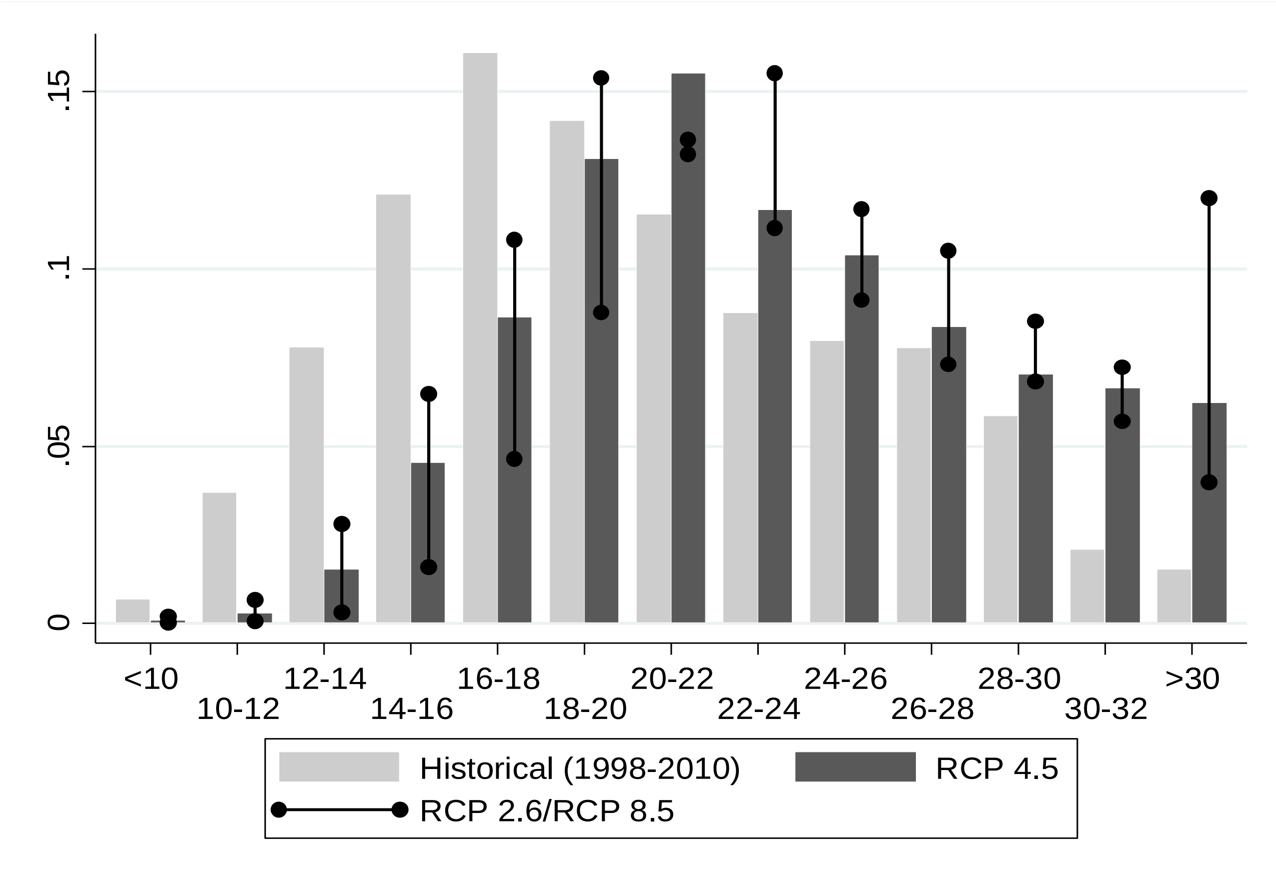




Results robust to wide range of sensitivity tests

- Minimal and maximal temperatures vs. average
- Consecutive hot and cold days
- Account for humidity (evaporation) and precipitation
- Use temperature bins relative to the local average
- Separate estimates for 4 climate regions
- Weekdays vs. weekends
- Less temperature bins like in Deschenes and Moretti (2009)
- 60 lags instead of 30 lags for the bins
- Use of different fixed effects

Estimating impacts from future temperatures



Population-weighted frequency of days falling within each temperature bin (in °C) for historical data and 3 climate change scenarios based on GFDL CM3 model output (2075-2099)

Climate change reduces deaths from 55-80% even without adaptation!

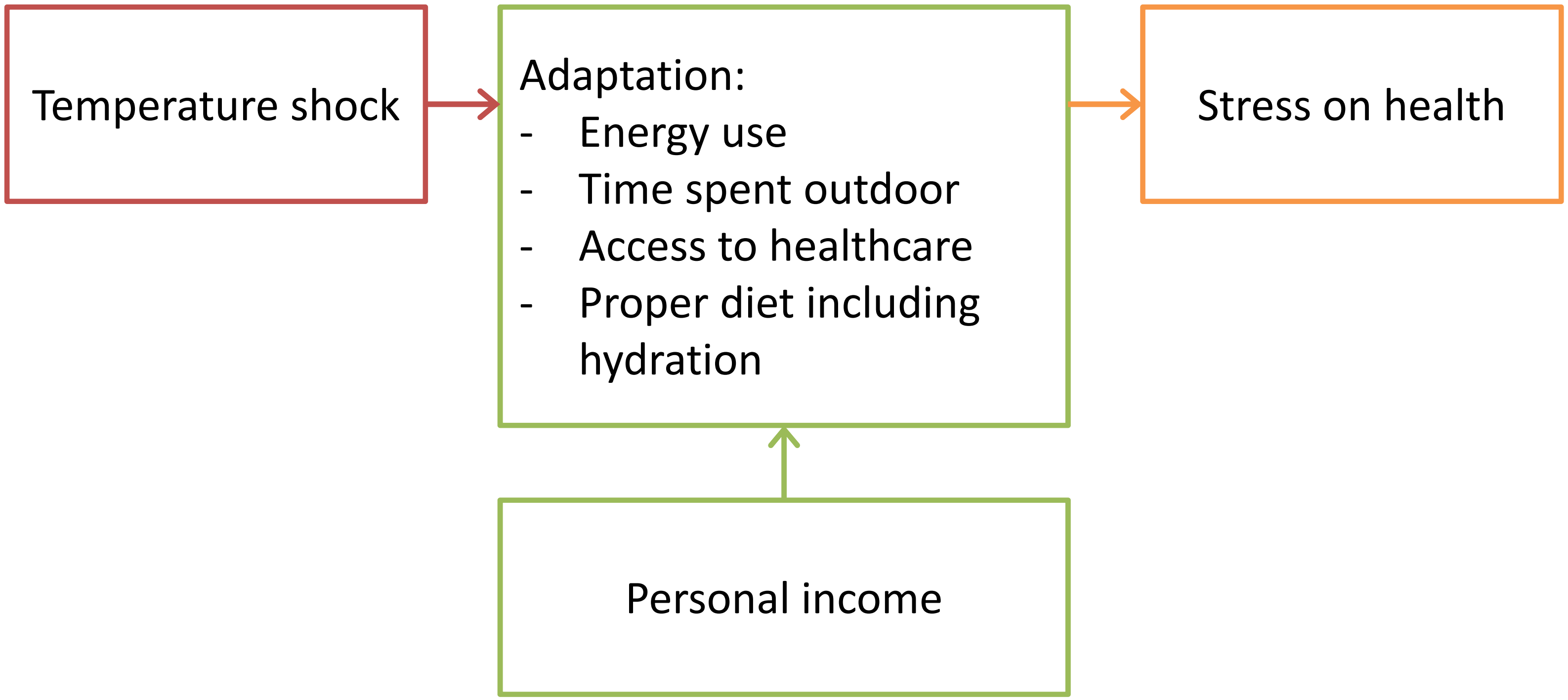
Impact of temperatures on annual deaths in several climate scenarios

Number of deaths	Estimates	Compared to historical temperatures
Historical	41,335 (27,299; 55,370)	
GFDL CM3:		
RCP2.6	18,152 (5,898; 30,405)	-23,183 (-26,410; -19,956)
RCP4.5	12,842 (1,177; 24,506)	-28,493 (-33,196; -23,790)
RCP8.5	7,513 (-4,000; 19,026)	-33,821 (-41,629; -26,014)

Notes: the 95% confidence interval in brackets only take into account the uncertainty of the impact of temperature bins on mortality. It does not take into account the uncertainty of climate models in the magnitude of daily temperatures.

Are low-income groups more vulnerable?

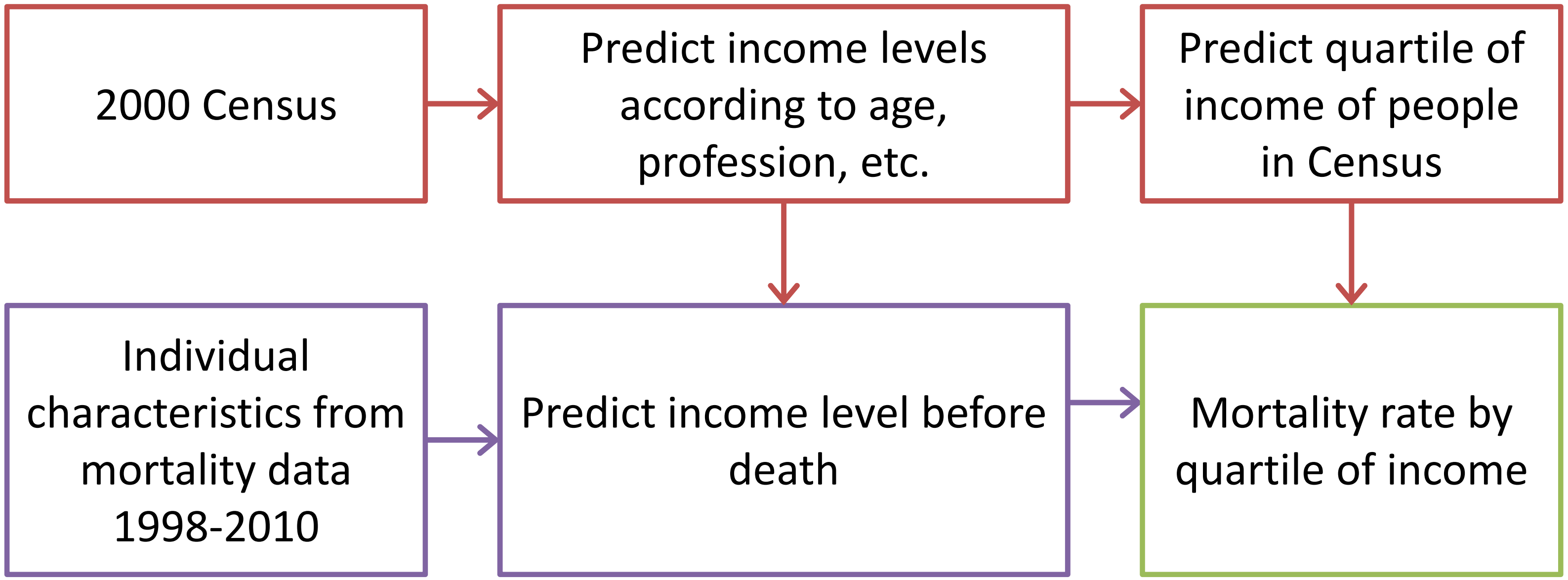
Hypothesis: adaptation minimizes mortality, but depends on incom



We predict personal income at death using information commonly present on death certificates and the Mexican Census data.

We construct mortality rates by income quartiles

- We determine the level of income at death based on socio-economic characteristics:



Good fit to predict personal income from 2000 Census Data

Dependent variable	Log(Personal income)
Age	-0.0089*** (0.0002)
Age squared	0.0001*** (0.00001)
Female	0.0033** (0.0014)
Fixed effects	
Civil status	Yes
Occupation	Yes
Social security affiliation	Yes
Educational level	Yes
Municipality and rural/urban area	Yes
Interactions:	
Civil status x gender	Yes
Occupation x age	Yes
Occupation x age squared	Yes
R2	0.44
Number of observations	8,756,128

<u>Description of fixed effect regression used to predict income levels</u>

Impacts by income quartile correcting for age

Table 14: Impact by income quartile and cause of death of a cold day below 10°C on cumulative 31-day mortality correcting for differences in the pyramid of ages across quartiles

Cause of death	1st quartile	2nd quartile	3rd quartile	4th quartile	1st vs. 4th	First two versus last two
All causes	1.05*** (0.17)	1.12*** (0.13)	0.75*** (0.17)	0.61*** (0.23)	+0.43 (0.28)	+0.36** (0.18)
Respiratory system diseases	0.31*** (0.05)	0.34*** (0.04)	0.10** (0.05)	0.21*** (0.06)	+0.10 (0.08)	+0.17*** (0.05)
Circulatory system diseases	0.31*** (0.08)	0.43*** (0.06)	0.26*** (0.08)	0.18* (0.10)	+0.13 (0.13)	+0.15* (0.08)
Endocrine, nutritional and metabolic diseases	0.21*** (0.07)	0.22*** (0.05)	0.22*** (0.06)	0.19** (0.10)	+0.02 (0.11)	+0.01 (0.07)
Infectious diseases	0.05 (0.03)	0.01 (0.02)	0.01 (0.02	-0.002 (0.02)	0.05 (0.03)	+0.02 (0.02)
Neoplasms	-0.01 (0.06)	-0.05 (0.04)	0.10* (0.06)	0.12 (0.08)	-0.13 (0.09)	-0.14** (0.06)
Accidents and violent deaths	0.04 (0.07)	0.02 (0.06)	-0.01 (0.09)	-0.11 (0.14)	+0.15 (0.15)	+0.09 (0.09)

Note: All the coefficients come from a different regression and correspond to the 31-day long run cumulative effect of a day below 10°C on mortality, for specific quartiles and causes of death. The dependent variable is always the daily mortality rate in deaths per 100,000 inhabitants and all regressions include the daily precipitation level as control. Death counts and population levels have been weighted such that the pyramid of ages are comparable across age groups, taking the 1st quartile of income as a reference. Standard errors in brackets. *, **, ***: statistically significant at 10%, 5% and 1%. Reference day is 24-26 Celsius degrees.

Only the 50% poorest households are vulnerable to mildly cold temperatures

	Excess number of deaths per year		
Temperature level	**<10°C**	**10-20°C**	**Total <20°C**
1st quartile	1,813*** (1,232; 2,393)	11,909*** (4,920; 18,899)	13,722*** (6442; 21001)
2nd quartile	1,437*** (1118; 1757)	21,055*** (14,024; 28,087)	22,492*** (15,284; 29,701)
3rd quartile	731*** (321; 1142)	-1,306 (-10,858; 8,246)	-575 (-10,331; 9,182)
4th quartile	404 (-273; 1081)	1,936 (-8,753; 12,626)	2,340 (-8,676; 13,357)
Entire population	4,385*** (3353; 5418)	33,595*** (16,165; 51,025)	37,980*** (20,050; 55,911)

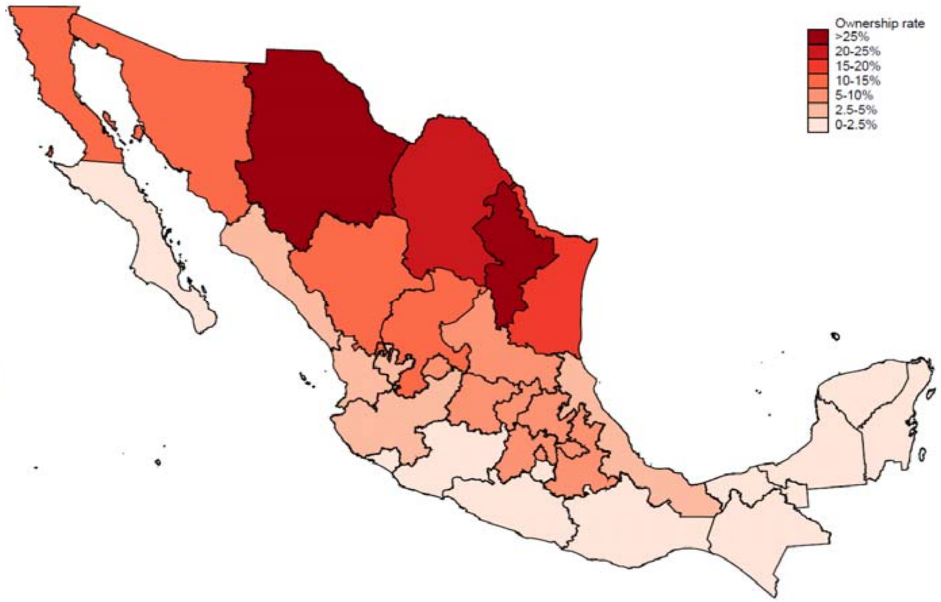
Estimated number of deaths per year imputable to cold by quartile

Many possible mechanisms.
Ex: Heaters equipment

Ownership rate of heaters and heating systems in 1st and 4th income quartiles:

1st quartile

4th quartile



Source: Encuesta Nacional de Ingreso y Gasto de Hogares (2004, 2005, 2006)

Another possible mechanism: low access to healthcare

In the 2000 Census, 83% of people from the 1st quartile of income had no health insurance, either public or private.

We aim to test the importance of this factor using the progressive extension of universal healthcare in Mexico through the Seguro Popular (2004).

→ Possibility of public intervention to reduce weather related vulnerability.

The Seguro Popular

- **An extension of universal healthcare:**
  - Targeting a list of diseases, including the treatment of the most common death causes (e.g. diabetes).
  - Fully free for low-income groups
  - Progressive roll-out in Mexican municipalities
  - From 2004 to 2010, around 10 million additional people enrolled in the system every year.
  - Complemented by a special fund to help out families affected by costly, chronical diseases (cancers of children and HIV).

We use 2SLS to assess the impact of universal healthcare on mortality

- **First stage: we look at the impact of universal healthcare on medical assistance before death:**

$$\textit{First stage:} \quad M_{i,d,m,t} = m_1 E_{i,d,m,t} + m_2 C_{i,d,m,t} + F_{i,m,t} + v_{i,d,m,t}$$

$M_{i,d,m,t}$: Share of people that died in municipality *i*, on day *d* of month *m* in year *t* and received medical assistance before death (%).

$E_{i,d,m,t}$: Share of people dying from covered diseases if municipality is enrolled in the Seguro Popular: ***eligibility***

$C_{i,d,m,t}$: Share of people dying from covered diseases: ***potentially covered cases***

- **Municipality by month by year fixed effects:**
  - Only look at short run effects.
  - A shock on death causes should impact medical assistance differently in municipalities that are part (or not) of the scheme.

Eligibility is our instrument

$$\textit{Second stage:} \quad Y_{i,d,m,t} = m_3 M_{i,d,m,t} + m_4 C_{i,\mathrm{d},m,t} + \mu_{i,m,t} + \varepsilon_{i,d,m,t}$$

Mortality | Medical assistance before death | Potentially covered cases

- **Exclusion criterion:**
  - The fixed effects control for the average monthly vulnerability.
  - Monthly distribution of death causes is « random ».
  - Short term peaks in vulnerability caused by changes in causes of death are controlled for.
  - Control var. is valid if no reverse causality: death causes impact mortality, but mortality does not impact death causes.

Medical assistance before death reduces mortality

	(1)	**(2)**	(3)	(4)	(5)
Independent variables	OLS	**2SLS**	2SLS	2SLS	OLS
First stage results: Medical assistance (%)					
Potentially covered cases (%)	-	**0.08*** (0.003)**	0.05*** (0.003)	0.08*** (0.003)	
Eligible to the schemes (%)	-	**0.03*** (0.004)**	0.03*** (0.004)	0.03*** (0.004)	
Temperature <10° C (cumulative effect)	-	**-**		-0.001 (0.001)	
Stock-Yogo weak identification test (Kleibergen-Paap rk Wald F statistic: passed)	-	**75.4**	94.7	75.3	
Second stage results: Daily mortality (per 100,000)					
Medical assistance (%)	-0.12*** (0.003)	**-0.71** (0.31)**	-0.63** (0.28)	-0.69** (0.31)	
Potentially covered cases (%)	-0.03*** (0.003)	**0.03 (0.03)**	0.02 (0.02)	0.03 (0.03)	-0.02*** (0.009)
Temperature <10° C (cumulative effect)	-	**-**	-	0.65*** (0.05)	-
Eligible to the schemes (%)	-	**-**	-	-	-0.02** (0.009)
Sociodemographic controls (†)	No	**No**	Yes	No	No

Does access to healthcare reduce climate vulnerability?

- **2SLS results by season:**

Table 18: The impact of medical assistance before death on reducing mortality, according to the period of death

Independent variables	Dec. – Feb.	Mar. - May	Jun. – Aug.	Sep. – Nov.
Medical assistance (%)	-3.32***	0.63	-0.60	-0.11
	(1.25)	(0.68)	(0.48)	(0.54)
Potentially covered cases (%)	0.29**	-0.12*	0.02	0.04
	(0.13)	(0.07)	(0.05)	(0.05)
Stock-Yogo weak identification test (Kleibergen-Paap rk Wald F statistic: passed)	12.4	15.7	28.9	19.3

Note: The table reports IV results obtained from fixed effect regressions with by municipality by month by year fixed effects. The dependent variable is daily mortality rate (per 100,000 inhabitants) at the municipality level. The regression includes municipality-by-year-by-month fixed effects. The instrument corresponds to the share of deceased people that were eligible to the schemes. One, two and three stars respectively mean statistically significant at 10%, 5% and 1%.

- **We also use a reduced form approach to look at climate vulnerability:**
  - Impact of medical assistance interacted with the temperature lags.
  - 2SLS not possible because as many interactions with medical assistance as temperature lags.
  - Reduced form approach: we interact eligibility to the schemes with temperature lags.

Healthcare access before death reduces vulnerability to cold

Independent variables	(1)	(2)
Potentially covered cases (%)	-0.02**	-0.05***
	(0.01)	(0.01)
Eligible to the schemes (%)	-0.02**	0.004
	(0.01)	(0.01)
Temperature <10° C (cumulative effect):	0.64***	-
	(0.05)	
x Potentially covered cases (%)	0.14	-
	(0.10)	
x Eligible to the schemes (%)	-0.23**	-
	(0.12)	
Temperature <20° C (cumulative effect):	-	0.16***
		(0.01)
x Potentially covered cases (%)	-	0.06***
		(0.02)
x Eligible to the schemes (%)	-	-0.04**
		(0.02)

The schemes reduce mortality caused by unusual cold days (<10°C) by 30%, and by 17% for midly cold days (<20°C)

Conclusions

1. Temperatures kill even in a relatively rich developing country
   - Around 40,000 deaths per year in Mexico: 8% of annual deaths
   - Mostly due to mildly cold temperatures
2. The poor are much more vulnerable
   - 35% more vulnerable when correcting for age
   - Cold only kills people below median income
3. Universal health coverage reduces weather vulnerability among the poor

Thanks!