CEDE

Centro de Estudios sobre Desarrollo Económico

Into the Tropics: Temperature, Mortality, and Access to Health Care in Colombia

Juliana Helo Sarmiento

Documento CEDE

#15

Mayo de 2022

Universidad de los Andes Colombia | Facultad de Economía

Serie Documentos Cede, 2022-15 ISSN 1657-7191 Edición electrónica. Mayo de 2022

infocede@uniandes.edu.co
http://economia.uniandes.edu.co

Impreso en Colombia – Printed in Colombia

CEDE
Centro de Estudios sobre Desarrollo Económico

Documento CEDE

Descripción: los documentos CEDE son producto de las investigaciones realizadas por al menos un profesor de planta de la Facultad de Economía o sus investigadores formalmente asociados.

Universidad de los Andes Colombia | Facultad de Economía

Into the Tropics: Temperature, Mortality, and Access to Health Care in Colombia

Juliana Helo Sarmiento*
Universidad de los Andes
j.helo@uniandes.edu.co

Abstract

This paper analyzes the relationship between temperature, mortality, and adaptation opportunities in a tropical country. Such countries host almost 40% of the world's population, and face inherently different environmental, demographic, and socio-economic conditions than their counterparts in temperate areas. Using detailed data from all Colombian municipalities, I show that even at narrow temperature ranges, which are characteristic of the tropics, anomalously hot or cold days increase mortality. An additional day with mean temperature above 27°C (80.6°F) increases mortality rates by approximately 0.24 deaths per 100,000, equivalent to 0.7% of monthly death rates. Unlike temperate locations, I find that deaths attributed to infectious diseases and respiratory illnesses drive this relationship in the hot part of the distribution, mainly affecting children aged 0-9. These findings uncover new factors and populations at risk, and imply that the average person who dies after a hot temperature shock loses approximately 30 years of life. I also provide evidence that access to health care and quality of services could serve as a mediating factor between temperature and mortality.

JEL classifications: I12, Q50, Q54

Keywords: Weather, Temperature, Mortality

*This paper has benefited greatly from numerous conversations and continuous advise from Javier Birchenall, Kelsey Jack, Olivier Deschenes, Kyle Meng and Kelly Bedard. I thank participants at the UCSB Environmental Lunch Seminar Series and the Environmental Reading Group, especially Danae Hernandez-Cortes, Emily Robertson and Jeffrey Cross, for valuable discussions and suggestions. I would also like to thank Manuel Fernández Sierra, Sahaab Bader, Gonzalo Vazquez-Bare and Jaime Ramirez for additional feedback and support.

En el Trópico: Temperatura, Mortalidad y Acceso al Sistema de Salud en Colombia

Juliana Helo Sarmiento
Universidad de los Andes
j.helo@uniandes.edu.co

Resumen

En este artículo se estudia la relación entre temperatura, mortalidad y oportunidades de adaptación en un país tropical. Estos albergan casi el 40% de la población mundial, y afrontan diferentes condiciones ambientales, demográficas y socioeconómicas que sus contrapartes en la Zona Templada Norte (ZTN). Usando datos detallados de todos los municipios colombianos entre 1993 y 2016, muestro que días inusualmente fríos o calientes aumentan la mortalidad. Un día con temperatura promedio superior a 27°C incrementa las muertes en 0.24 por 100,000 habitantes, equivalente a aproximadamente 0.7% de la tasa mensual. A diferencia de lo que se ha documentado en países en la ZTN, encuentro que las muertes por enfermedades infecciosas y respiratorias son importantes en explicar los resultados en la parte caliente de la distribución de temperatura, y afectan principalmente a niños entre 0 y 9 años. Estos resultados sugieren nuevos factores y poblaciones en riesgo, e implican que en promedio una persona que muere después de un choque de temperatura pierde aproximadamente 30 años de vida. También proporciono evidencia sobre como el acceso al sistema de salud y la calidad de esos servicios pueden ayudar a mitigar la relación entre temperatura y mortalidad.

Códigos JEL: I12, Q50, Q54

Palabras clave: Clima, Temperatura, Mortalidad

1 Introduction

The changing climate has spurred a large literature examining the effects of short-term variations in temperature on a number of economic and health outcomes, including morbidity and mortality.[1] Several papers have documented that instances of extreme heat and cold increases human mortality, resulting in a 'U'-shape relationship between the two over a wide range of temperature with close to zero effect at mild temperatures (Deschênes and Greenstone (2011), Barreca et al. (2016), Burgess et al. (2011), Carleton et al. (2018), Heutel et al. (2017), Cohen and Dechezlepretre (2018)). However, most of this knowledge comes from countries located in temperate latitudes, such as the U.S. or China, where extreme temperatures are observed during winters and summers.[2] Populations in tropical latitudes, on the contrary, are subject to narrow ranges of temperature throughout the year due to the lack of seasonal variation given their closeness to the Equator. Extending the estimates from the temperate region, would suggest close to zero effects in mortality from weather shocks in many tropical places where temperatures remain almost constant at 'mild' levels throughout the year.

This paper documents the relationship between temperature and mortality in a tropical country, provides evidence on the underlying mechanisms, and suggests adaptation opportunities through the access to health services. Understanding how mortality reacts to temperature shocks in such a setting is important because the tropics hosts almost 40% of the world's population and 55% of children under 5 years old, both shares expected to increase to approximately 50% and 60% respectively by 2050 (Edelman et al., 2014). Moreover, populations in these latitudes are expected to bear much of the effects of climate change (Parry et al., 2007). However, the lack of comprehensive datasets in tropical countries has limited our knowledge on how mortality reacts to variations in temperature in these settings, and more so, on the type of technologies and policies that could help mitigate the human health costs associated to climate change.

I use a unique and novel data set that combines monthly Vital Statistics from all Colombian municipalities over the period 1993-2016, with high-resolution meteorological data that produces a balanced panel with close to 300,000 observations. This allows me to exploit monthly variation within municipality and include municipality-by-year,

[1]see Dell et al. (2013) and Deschenes (2014) for a review.
[2]Temperate latitudes are those between latitude 35° and the polar circles.

and month-by-year fixed effects to account for most sources of unobserved heterogeneity. The time span and frequency of data also allows me to control for the possibility of inter-temporal mortality displacement, by including lagged temperature variables and estimating cumulative dynamic effects. I merge this data with administrative records on the percentage of population by municipality covered by some form of health insurance, and the number of legal claims (*tutelas* in Spanish) made to courts by individuals protesting that specific insurers undermine their right to health, which allows me to construct measures of access and quality of health services.

I find that even at narrow temperature ranges, which are characteristic of the tropics, anomalously hot or cold days increase mortality, suggesting that even small variations in mild temperatures can affect human health. Deaths attributed to infectious and respiratory illness mainly explain the effects documented at the hot end of the temperature distribution, affecting children aged 0 to 9 primarily. I provide evidence that access to health care and good quality services are important in mitigating mortality risks associated to temperature. These are novel findings because they uncover new populations and risk factors associated to heat-related mortality. They also shed light on possible adaptation strategies to mitigate the adverse effects of climate change, and the importance of health care provision and good quality services on resilience to temperature shocks. To my knowledge, this is the first paper to assess the importance of quality of health services as a mediating factor between temperature and mortality.

Specifically, I find that an additional day with mean temperature below 17°C (62.6°F) or above 27°C (80.6°F) increases monthly mortality rates by approximately 0.24 and 0.16 deaths per 100,000 respectively, equivalent to 0.62% and 0.43% of monthly death rates. Put another way, a day below 17°C in this setting has a higher effect than what Barreca et al. (2016) find for an additional day below 4°C for the U.S, or what Cohen and Dechezlepretre (2018) find for Mexico for an additional day below 17°C. At 17°C estimates for the U.S. are very close to zero and to 0.2% for Mexico . On the hot part of the temperature distribution, a day above 27°C in my setting has a similar effect to a day between 27-32°C in the U.S. over the period 1931-1959 (0.37%), and much higher to more recent estimates.

These estimates correspond to cumulative dynamic effects of temperature shocks after an exposure window of five months. Including additional lags beyond five months, I find that mortality not only reacts to unusually 'cold' or hot days contemporaneously, but peak after an exposure window of five and seven months respectively. An additional day above 27°C increases mortality by 0.27 deaths per 100,000 after seven months, corresponding to a 0.72% effect. After accounting for the possibility of further delayed effects of hot temperature shocks, mortality increases much more than the estimates for the U.S. or Mexico.

These findings imply that hotter than average days have a longer window of delayed effects than what has been documented thus far. I contribute to the literature that studies how temperature shocks propagate over time. Evidence regarding near-term mortality displacement, also referred to as 'harvesting', and understood as the idea that deaths caused by a contemporaneous weather shock could be compensated by a subsequent fall in mortality over the following days or weeks, is mixed. Deschenes and Moretti (2009) show that in the U.S., harvesting is substantial after heat shocks meaning that effects are close to zero after an exposure window of 30 days. In contrast, Cohen and Dechezlepretre (2018) find that heat effects in Mexico are still significant after 30 days, and Barreca et al. (2016) find that U.S. estimates remain virtually unchanged after two months.

Tropical countries differ in terms of environmental, socio-demographic, and economic conditions, which could trigger differential responses in the temperature-mortality relationship than that from their temperate region counterparts. First, temperature in tropical areas exhibit no seasonality as typically observed in temperate countries, implying that populations are exposed to narrow and constant temperature ranges throughout the year. For the U.S., there is evidence of harmful 'de-adaptation' to infrequent experienced temperatures (Heutel et al., 2017), suggesting that higher mortality risks could arise even at the mild end points of a narrow temperature distribution if those temperatures are not experienced very often.

Second, differences in the underlying causes of death that give rise to the temperature-mortality response function might differ between latitudes. For example, tropical environments are more hospitable to human diseases, given the absence of winter temperatures (Kamarck et al., 1976). These diseases include, among others, those related to respiratory and infectious illness that involve viruses and bacteria. Evidence from the epidemiology literature suggests that higher than average temperature shocks aid in the replication of microbes causing human diseases, and subsequently increasing viral transmission (Council et al., 2001). For example, Hii et al. (2009) show that dengue incidence increased after the occurrence of high temperatures in Singapore. Unlike temperate areas, these factors in tropical climates might pose additional risk to human health after temperature shocks, and explain the differences documented thus far. If this is the case, policies and technologies that could be appropriate for temperate countries to adapt to temperature shocks might not necessarily be cost-effective for tropical areas.

Finally, the literature highlights the importance of income in shaping the relationship between temperature and mortality (Carleton et al. (2018)). Since the tropics tend to host low and middle income countries, differential responses could also be expected. Lower-income populations are also expected to bear much of the effects of temperature shocks, mainly because of their lower adaptive capacity (Cohen and Dechezlepretre, 2018). Understanding adaptation strategies, or technologies that could be readily available and incentivized by public policy, such as access to health care and quality, could be important to understand how we can mediate the adverse effects of temperature shocks.

Having established that mortality reacts to changes in temperature, I investigate whether differences in relevant causes of death and populations at risk give rise to the temperature-mortality response function previously described. I find that mortality effects are unequally distributed across causes of death and age groups. Heat-related mortality is mainly attributed to respiratory and infectious diseases, with an additional day above 27°C increasing specific-cause mortality rates by 2.7% and 2.0% respectively. As for age-groups, children aged zero to nine are at higher risk after the occurrence of hot temperature shocks.

I uncover new populations and risk factors associated to heat-related mortality. Most studies have identified infants (0-1) and the elderly as the main risk groups (White (2017), Cohen and Dechezlepretre (2018),Yu et al. (2019)). I find a broad effect on children, with deaths associated to respiratory and infectious diseases playing a significant role. Respiratory and infectious related deaths include those associated to diseases such as whooping cough, flu, malaria, dengue, zika, tuberculosis, among others. Temperature and extreme climate events have been associated to the proliferation of such viruses and bacteria (e.g. vector, water-borne, etc.), and especially, to tropical diseases that thrive in hot and humid conditions (Gasparrini et al., 2015).

In contrast, the economics literature has identified cardiovascular diseases as the leading cause of heat-related mortality (Deschenes and Moretti (2009), Cohen and Dechezlepretre (2018), Deschenes (2014), Yu et al. (2019)). This is likely due to viruses and bacteria being less prominent in the temperate region (Kamarck et al., 1976). Deaths associated to infectious diseases, for example, are close to zero in the U.S. (Deschenes and Moretti, 2009). These insights are consistent with the finding that hot-temperature shocks have delayed effects and take up to an exposure window of seven months to fully translate into mortality effects. Consistent with the epidemiological finding that proliferation and contagion of infectious and respiratory diseases are influenced by population density, I also find that urban and rich municipalities drive the effects of heat-related mortality.

I further investigate whether the response function evolved over time to shed some light on possible adaptation behaviors. Overall, I find a 55% decline in cold-related mortality over the period 1993-2016, while heat-related mortality increased throughout the period. This is a novel finding since studies in the U.S. have found a decline in heat-related mortality over the course of the 20th century, mainly attributed to the diffusion of residential air conditioning. Access to such technology reduces stress in people's thermoregulatory systems and thus, deaths associated to cardiovascular diseases (Barreca et al., 2016). Using data on access to health care and a measure of quality, constructed using the number of legal claims *(tutelas)* made to courts by individuals protesting that specific insurers undermine their right to health, I explore the role of access and quality of health care as a as a modifier of the response function. Estimates in magnitude are larger for days below 17°C, but effects in the hot end of the temperature distribution are significant, suggesting that access and especially good quality health services could help mitigate the adverse effects of hot temperature days on mortality. I contribute to the literature that documents the importance of access to health care as an adaptation policy to climate change (Mullins and White (2020) and Cohen and Dechezlepretre (2018)).

The paper is structured as follows. Section 2 describes the data sources, the main characteristics of temperature and mortality in Colombia and summary statistics that inform the empirical strategy. Section 3 outlines the econometric models used to estimate the temperature-mortality response function. Section 4 discusses the main results from fitting baseline regressions, heterogeneous findings, the evolution of the relationship throughout the years in the sample, and the role of access and quality of health services as a mediating factor on the temperature-mortality response function. Section 5 concludes and discusses policy implications of the findings.

2 Data and Descriptive Trends

This section describes the data used in the analysis, and characterizes the temperature distribution and mortality profile in Colombia over the period 1993-2016. Key differences with countries in the temperate region are also highlighted.

Weather Data: Temperature and rainfall data are drawn from the European Centre for Medium-Range Weather Forecasts (ECMWF), which uses forecast models and data assimilation systems to produce climate reanalysis data in the ERA-Interim product.[3] ERA-Interim data is available on a $0.125° \times 0.125°$ quadrilateral grid daily since January 1979.[4] Daily average temperature and daily total precipitation are the main variables used in the analysis. Daily average temperature corresponds to the average of four readings per day reported at different times during the day.[5] I aggregate daily grid-level data at the municipality level by taking an area-weighted average of the weather variable of interest in each municipality.[6] Weights are defined by the area of each grid that belongs to a particular municipality.[7] I use daily weather data to construct a balanced panel consisting of 301,656 municipality-monthly observations for the period 1993-2016.

Figure 1 depicts a discrete version of the annual temperature distributions in Colombia and the U.S. Daily average temperatures over the year are classified over ten temperature categories or bins in increments of 5.5°C. The lowest temperature category includes everything less than -12°C and the highest everything above 32°C. The height of the bars correspond to the average number of days in the year in each temperature bin that the average person in each country experiences. Observations are weighted by population. The figure reveals the main difference between temperate and tropical countries in terms of temperature. Populations in Colombia are exposed to a much narrower temperature range over the year, as the distribution is mainly concentrated in four out of the ten categories (13°C-32°C). This difference arises because of the lack of seasonality in temperature, which is explained by Colombia's closeness to the Equator.

[3] The data can be downloaded from http://apps.ecmwf.int/datasets/data/interim-full-daily/levtype=sfc/

[4] This corresponds to grids of approximately 16km×16km

[5] Daily total precipitation is the sum of all the readings per day.

[6] Municipalities are the smallest administrative area, grouped in Departments, where the latter can be though of as States in the United States. There are currently 1,222 municipalities, each one led by an elected mayor and administered by a municipal council.

[7] Shapefiles for Colombian municipalities are superposed over the grid weather data file extracted from ERA-Interim that contains Colombia, to aggregate at the municipality level

Given the narrower temperature range in Colombia, the empirical analysis considers finer temperature categories to guarantee enough variation within municipalities to identify effects on mortality (i.e. 2°C temperature categories). Panel (a) in figure 2 shows the monthly distribution of daily mean temperature grouped across seven temperature bins.[8] These bins represent daily temperatures of less than 17°C, higher than 27°C and five 2°C wide bins in between. The average number of days in a month in the modal bin 17-19°C is 9.1. Most of the distribution is concentrated around this bin, and only a few days are observed in the extreme bins: 1.8 per month in the less than 17°C and 2 in the greater than 27°C bin. The empirical analysis considers this discrete version of the monthly distribution of temperature. The key feature in tropical countries is that the monthly distribution in temperature is very similar across the twelve months in the year. Panel (b) in figure 2 plots monthly distributions in different months of the year, and indicates that there are no differences between them. For the entire country average temperature in all twelve months ranges from only 20.7°C to 21.1°C.

Panels (c) and (d) in figure 2 present another key feature common to tropical countries: temperature depends on elevation. As countries get closer to the Equator, differences in temperature across municipalities are determined by elevation, with average temperature declining as altitude increases. To highlight the elevation-temperature gradient, I group municipalities in two elevation groups: high and low altitude. The former corresponds to those located more than 1000 meters above sea-level and the latter, to those below this threshold.[9] In municipalities closer to sea level, average daily temperatures below 21°C are not observed, whereas average temperatures above 25°C are rare in mountainous/high-altitude areas. Approximately 75% of Colombian municipalities and population is located in the mountainous/high altitude region.

Panels (e) and (f) in figure 2 plots the annual temperature distribution over two time periods: 1993-2005 and 2006-2016, separately for high and low level municipalities[10] Exposure to hotter days increased in both regions, with the number of days in temperature bin > 27°C almost doubling between the two time periods in lower elevation municipalities. The number of days in the coldest temperature bin, <17°C, declined by a factor higher than two in mountainous areas.

[8] This is a discrete version of the continuous distributions of temperature

[9] This is a typical classification of mountainous areas

[10] These time periods are chosen to have an approximate equal number of years in the two subsamples

Mortality Data: Mortality data are taken from Vital Statistics produced by the National Statistics Department of Colombia (DANE). Individual death records, including age, gender, cause of death, municipality of occurrence and type of insurance, are available for the period 1993-2016. I aggregate death records at the monthly-municipality level and combine with population data from DANE to construct age-adjusted monthly mortality rates per 100,000 inhabitants.[11] Age-adjusted mortality rates refer to a weighted average of crude death rates. Weights are determined by the 2005 population distribution in Colombia. Following the literature, I use this adjusted rates to allow for comparisons across municipalities and over time. I also construct specific-cause death rates using the causes of death reported by DANE, and guidelines from the International Statistical Classification of Diseases and Related Health Problems by the World Health Organization (ICD-10 WHO).

Table 1 summarizes all-cause and cause-specific annual mortality rates by age group, as well as the contribution of each cause of death to total mortality. The average annual mortality rate for the period 1993-2016 is 457.3 deaths for every 100,000 inhabitants, with the highest rates for children under 5 and the elderly.[12] As has been documented in different contexts (e.g., Deschenes and Moretti (2009)), cardiovascular disease is the leading cause of death, especially in people over 40. Infectious and respiratory diseases explain almost 25% and 14% of deaths in children aged 0 to 4 and 5 to 9 respectively.

External causes of death (accidents, homicides and suicides) also explain most deaths particularly for younger people. Accidents are the leading cause of death for children aged 5 to 9 with a share of 33.8%, and an approximate of 20% for teenagers and young adults. Homicides explain most of deaths in age groups 10 to 40, reflecting the armed and political conflict in the country. Annual mortality rates for these groups are higher than what have been reported elsewhere.[13]

Comparing these shares with data from Deschenes and Moretti (2009) for the U.S.,

[11] Population counts in each municipality come from the series produced by DANE based on census records and projections.

[12] For comparison purposes this is a monthly mortality rate of 38.21 and approximately daily mortality of 1.26 deaths per 100,000. This number appears consistent with Mexican data, which Cohen and Dechezlepretre (2018) document as 1.3 for the period 1998-2010

[13] An annual mortality rate of 116.8 in age group 10-19 implies a daily rate of approximately 0.31 deaths per 100,000. Cohen and Dechezlepretre (2018) report a daily rate of 0.15 for this same group in Mexico.

reveals important differences in the mortality profiles for both countries. Figure 3 plots the share of total deaths attributed to five causes of death for Colombia and the U.S. Even though cardiovascular diseases are the leading cause of death both in Colombia and the U.S., the share for the entire population is much smaller than that in the U.S. While the total share in Colombia is 28.4%, in the U.S. it accounts for almost 50%. Causes of death that have previously been linked to small changes in temperature, such as infectious diseases that include vector borne like dengue, malaria, zika, or yellow fever, appear to have an important role in explaining deaths in Colombia. Almost 3.5% of deaths in Colombia are attributed to infectious diseases, while they only account for 1% in the U.S. The differences for age group 0-9 are more dramatic, with a share of 10.2% and 6.23% for children 0 to 4 and 5-9 respectively in Colombia, and 2.6% and 3.8% for age 0 and 1-9 in the U.S. Finally, the other category, which contains external causes of deaths that have also been shown to react to temperature, almost doubles the share in the U.S (Burke et al., 2015). These differences in the mortality profile could give rise to differences in the temperature-mortality relationship from that observed in the temperate region.

Institutional Background and Data on Access to Health Care and Quality of Service: Colombia undertook an ambitious health reform in 1993 to address, among other problems, low coverage levels and inequalities in access to health services. As of 1992, approximately 25% of the population had health insurance, and only one out of six individuals in the poorest quintile seek medical treatment (Pinto (2008), Escobar (2005)). The reform established mandatory health insurance, so that all individuals could access a pre-established package of basic health services regardless of their economic means. In transitioning to universal coverage, the system was and is currently divided into two regimes that have a common structure but differ in target populations: (i) the contributory regime (henceforth CR), and (ii) the subsidized regime (henceforth SR). Formal and self-employed workers above a pre-determined minimum income must enroll in CR. Both employer and employee pay for the worker's stipulated premium.

SR targets low-income individuals with no formal work, and eligibility is means tested using an index based on household's socioeconomic characteristics (SISBEN - Beneficiary Identification System). The law mandates that those individuals with the lowest SISBEN scores, as well as vulnerable groups like children under five and pregnant women are prioritized. Individuals make no insurance contributions, but have access to the basic benefits package (known as POS), which includes primary and preventive care services, some inpatient, and emergency care, essential procedures and medication (see Gaviria et al. (2006), Giuffrida et al. (2009), and Pinto (2008) for a more detailed description of the system). I use administrative data from the Ministry of Health and Protection for the period 1998 to 2016 on the share of population per municipality enrolled in the subsidized regime (SR) of the health system to measure healthcare access of vulnerable populations. Affiliation to SR between 1995 to 2016 rose from almost 12% to approximately 50% of the population.

By 2016, more than 95% of the population was covered by some form of health insurance (see figure A1 in Appendix). In either regime, SB or CS, individuals enroll with a health insurance of choice, and the insurer is responsible for guaranteeing enrollees access through their independently contacted network of providers (e.g. hospitals, clinics, laboratories, etc). Insurers cannot deny enrollment in the basis of income, demographics or pre-existing conditions. However, there are incentives to limit utilization of medical services given the pay-structure insurers face (see Bhalotra and Fernández Sierra (2021) for detailed explanation on this issue). In response to these restrictions and delayed authorization of procedures, medicines, exams, surgeries, and treatments by insurers, individuals have used judicial claims available to them under Colombian law, particularly the *tutela* writ. This legal claim, which may be used in any instance were a fundamental right such as health access is undermined, is an expedite procedure that is resolved within 10 days once any judge within the local jurisdiction receives the case, is costless, and need only contain the basic facts. Given its simplicity, the number of *tutelas* filed to courts invoking the violation of any fundamental right, increased from 0.3 to 12.7 per 1,000 inhabitants between 1992 and 2016, with those related to the right of health accounting for 20 to 40% of them (Bhalotra and Fernández Sierra, 2021).

To explore the role of quality of healthcare as a mediating factor between temperature and mortality, I use data on the number of legal claims (*tutelas*) made to courts by individuals protesting that specific insurers undermine their right to health. Using data from 2010, provided by the ombudsman's and available from Bhalotra and Fernández Sierra (2021), I construct a quality measure by insurer using the distribution of *tutelas* rate by insurer. I also construct insurer-specific death rates using enrollment data from the Ministry of Health and Protection, which is available for each municipality over the period 2010-2016.

3 Empirical Strategy

This section presents the models used to estimate the temperature-mortality response function, as well as the factors that could attenuate this relationship. Exploiting the granularity of the data, I estimate contemporaneous and cumulative dynamic effects of temperature shocks.

3.1 Contemporaneous Effect

I estimate fixed-effects linear regressions to quantify the contemporaneous effect of weather on all and specific-cause mortality in any given month and location. Specifically, I fit variants of the following specification:

$$\begin{aligned} DR_{imy} = \sum_{j=1}^{T} \beta_j BinTemp_{jimy} + \gamma_1 LOWP_{imy} + \gamma_2 HIGHP_{imy} \\ + \sum_{k}^{6} \alpha_k BinHumid_{kimy} + \eta_{iy} + \nu_{my} + \varepsilon_{imy} \end{aligned} \tag{3.1}$$

where DR_{imy} is the age-adjusted death rate in municipality i, month m, and year y. Temperature variables are constructed using a discrete version of the monthly distribution, which allows to capture a flexible non-linear relationship with mortality following Deschênes and Greenstone (2011). As such, the variables $BinTemp_{jimy}$ denote the number of days in municipality i in month m in year y in which the average daily temperature is in the j^{th} bin of the seven 2°C bin described in Figure 2. Since the number of days in a month is constant and the temperature variables add up to this constant, temperature bin 23-25°C (73.4-77°F) is excluded from estimation and used as the reference category. This means that the coefficient of interest β_j on the variable temperature bin j, is interpreted as the effect on mortality from exchanging a day in the reference bin to a day in temperature bin j.

All of the specifications control for precipitation. The variables $LOWP_{imy}$ and $HIGHP_{imy}$, capture unusually low or high amounts of rainfall in a municipality i in month-year my. Specifically, $LOWP_{imy}$ is an indicator variable that measures whether realized precipitation in municipality i in month-year my is below the $25th$ percentile of historical monthly distribution of that municipality. In contrast, $HIGHP_{imy}$ measures if the realization is above the $75th$ percentile.

Some specifications include humidity variables, constructed using a discrete version of the monthly distribution of specific humidity. $BinHumid_{imy}$ denotes the number of days in municipality i in month m in year y in which the average daily specific humidity is in the k^{th} bin of one of the seven 2 g/kg humidity bins. Humidity bin $< 8\ g/kg$ is excluded from estimation and used as the reference category.[14] The coefficient α_k on humidity bin j is interpreted as the effect on mortality from exchanging a day in the reference bin to a day in bin k.

η_{iy} denotes a full set of municipality-by-year fixed-effects, and ν_{my} month-by-year fixed effects. Municipality-by-year fixed-effects absorb all unobserved municipality-specific determinants of mortality. This municipality-specific flexible time trend captures factors like health conditions that are specific to the municipality in the give year, or availability and quality of health services in each municipality. Month-by-year fixed effects account for time-varying differences in mortality rates that are common across all municipalities, as well as the seasonal patterns in death rates. The last term of equation (3.1), ε_{imy} is a stochastic error term.

By conditioning on this structure of fixed-effects, identification of the parameters of interest, β_j's, comes from municipality-specific deviations in weather from municipality averages after controlling for precipitation, humidity, time-trends specific for each municipality and seasonality common to the whole country that can vary over time. The empirical validity of this specification relies on the identifying assumption that conditional on the fixed effects structure, weather variables are not correlated with the idiosyncratic error term. Due to the randomness of weather variations, the assumption is reasonable and widely made in the literature. Variations in weather are likely orthogonal to unobserved determinants of mortality.

Standard errors are clustered at the municipality level to account for correlation within municipality over time. Weather is highly localized given Colombia's rugged geog-

[14]Specific humidity is defined as the mass of water vapor per kilogram of moist air. The total mass of moist air is the sum of dry air, water vapor, cloud liquid, cloud ice, rain and falling snow (ERA5)

raphy and heterogeneity in causes of death, provide additional reasons to cluster standard errors at the municipality level.

The lack of seasonality and spatial distribution of temperature within this context implies that the effect of exposure to 'colder' temperatures on mortality is identified by municipalities in higher elevations, while the effect of hotter temperatures is driven by those closer to sea-level. To explore the existence of heterogeneous responses at narrower temperature ranges, I also estimate equation 3.1 separately for two elevation groups; those above 1000 meters referred to as 'high altitude' and those below 1000 meters referred to as 'low altitude' municipalities. To that end, the temperature bins for the mountainous area range from below 17°C to 25°C. The 'hottest' two bins are grouped in one given that temperatures above 27°C are rarely observed at higher elevations. For municipalities located closer to sea-level, temperature bins are defined between below 23°C and 27°C. In both cases, temperature bin 23-25°C (73.4-77°F) is excluded from estimation for comparison purposes.

3.2 Dynamic Effect

The relationship between temperature shocks and mortality is likely to be dynamic, as weather shocks could either have lasting effects or anticipate deaths that would have occurred a few days or months later had the event not occurred (Deschenes and Moretti, 2009). The latter is usually referred to as mortality displacement or harvesting. To investigate this possibility, I fit the following specification:

$$DR_{imy} = \sum_{j=1}^{T}\sum_{l=0}^{L}\beta_{jl}BinTemp_{ji(my-l)} + \sum_{l=0}^{L}\gamma_l f(Prec_{ki(my-l)}) + \sum_{k=1}^{6}\sum_{l=0}^{L}\alpha_{kl}BinHumid_{ki(my-l)} + \eta_{iy} + \nu_{my} + \varepsilon_{imy} \quad (3.2)$$

This model allows the effect of weather variables up to L months in the past to affect mortality rates in the current month. To that end, the contemporaneous effect of temperature bin j is β_{j0}, while the dynamic causal effect comes from summing all of the coefficients on temperature bin j: $\sum_{l=0}^{L}\beta_{jl}$. If temperature or weather shocks lead to mortality displacement, an immediate increase in mortality (i.e. $\beta_{j0} > 0$) should be followed by a compensatory fall in subsequent months. On the contrary, weather shocks might have delayed effects on mortality if estimates accumulate over time. For example, β_{j0} could be positive or zero, and subsequently followed by positive coefficients on the lagged variables, such that $\sum_{l=0}^{L} \beta_{jl} > \beta_{j0}$.

3.3 Access and Quality of Health Care as a Modifier

I now describe the augmented models used to quantify the effect of access to health care and its quality as modifiers of the temperature mortality relationship. To determine the effect of access to health care, I include interactions of temperature variables with municipality-by-year shares of population covered by SR. Specifically, I estimate:

$$\begin{aligned} DR_{imy} = \sum_{j=1}^{T} \beta_j BinTemp_{jimy} + \sum_{j=1}^{T} \delta_j BinTemp_{jimy} \times Share_{iy} + \phi Share_{iy} \\ + \gamma_1 LOWP_{imy} + \gamma_2 HIGHP_{imy} + \eta_i + \nu_{my} + \varepsilon_{eimy} \end{aligned} \tag{3.3}$$

where DR_{imy}, $BinTemp_{jimy}$, $LOWP_{imy}$ and $HIGHP_{imy}$ are defined as before. $Share_{iy}$ measures the percentage of people in each municipality affiliated to the SR per year. The specification includes a full set of municipality (η_i) and month-by-year (ν_{my}) fixed effects, as well as a linear time trend at the municipality-year level. Temperature bin 23-25°C is again excluded from estimation. This means that the coefficient on the interaction between share of population covered by SR and temperature bin j (δ_j), measures whether the effect on mortality of an additional day in a given temperature bin is affected by access to health care, relative to the effect of access on mortality impacts of a day in the 23-25°C range.

The threat to identification could come from unobserved determinants of mortality that covary with temperature realizations at a given range, and the expansion of the health system in each municipality. Though unlikely, I control for the interaction between temperature variables and a linear time trend. This allows for the temperature-mortality relationship to vary over time for reasons unrelated to access to health care. The interacted specification focuses on the impacts of access to health care on weather-related vulnerability, controlling for the impact of access to health care on all-cause and specific mortality.

Mortality data allows for the construction of death rates specific to each insurer between 2010 and 2016. To explore the role of quality of health care in attenuating the effect of temperature on mortality, I fit the following specification:

$$
\begin{aligned}
DR_{eimy} = \sum_{j=1}^{T} \beta_j BinTemp_{jimy} + \sum_{j=1}^{T} \delta_j BinTemp_{jimy} \times BadQuality_e \\
+ \gamma_1 LOWP_{imy} + \gamma_2 HIGHP_{imy} + \psi_e + \eta_{iy} + \nu_{my} + \varepsilon_{eimy} \quad (3.4)
\end{aligned}
$$

where DR_{eimy} is the death rate by insurer e in municipality i in month m and year y. $BadQuality_e$ is an indicator variable per insurer that measures whether the complaints per 1000 inhabitants fell above the 75_{th} or the 90_{th} percentile of the distribution of complaints rate at baseline year 2010. This specification also controls for insurer's fixed effects, as well as municipality-by-year and month-by-year. As with the specification for access to health care, I control for the interaction between temperature variables and a linear year trend.

The parameters of interest, δ_j, compare the average change in mortality rates after the exposure of an additional day in temperature bin j relative to a day in the reference category for low quality insurers with the average change in the high quality group of insurers. A positive coefficient indicates that temperature vulnerability is highest for individuals covered with low quality insurance.

4 Findings

4.1 All-Cause Mortality and Temperature

Table 2 presents estimates of the temperature mortality-relationship from fitting equations 3.1 and 3.2 using different exposure windows up to nine months (i.e. using 1 lag up to 8 lags). All coefficients associated to temperature bins measure the estimated impact of exchanging one day in temperature bin j with respect to the reference bin 23-25°C. Results reveal that mortality risks are highest at the endpoints of the narrow temperature distribution observed in Colombia. Exchanging a day in the reference bin 23-25°C for a single day below 17°C leads to a contemporaneous increase of 0.17 deaths per 100,000. This impact corresponds to 0.4% if compared to the mean monthly mortality rate of 37.58 per 100,000. The effect becomes smaller for temperatures closer to the reference bin, but still important and significant at conventional levels. Contemporaneously, the effect of an additional day above 27°C is smaller than the effect of additional days in the 'colder' temperatures, with an estimated impact of 0.06 deaths per 100,000 (0.16%).

To provide a better understanding of the magnitudes of these effects, I link estimates in column (1) in table 2 to the average distribution of monthly temperature presented in panel (a) in figure 2. Days below 17°C cause the death of approximately 144 people each month (95 percent confidence interval is 82.1-206.2), which represents 0.8% of the average monthly deaths in Colombia in 2016.[15] Though the point estimate for temperature bin 17-19°C is smaller, an additional 487 deaths each month are associated to this temperature range because days within this category are much more frequent (95 percent confidence interval is 211.8-762). Together, these 631 'cold'-related deaths represent approximately 3.4% of the average monthly deaths in 2016. Temperatures above 25°C account for 137 additional deaths a month (0.7%). Though somewhat smaller than the effect of 'cold'-temperature shocks, days above this temperature are becoming more frequent. Performing the analysis with the average temperature distribution over the period 2006-2019, where we already see a shift in the distribution towards hotter days, 'cold'-related deaths decline to 447 while deaths in the hot end of the distribution increase to 157.

[15] This calculation considers Colombia's 2016 population of 48,180,000, 0.17 deaths per 100,000, and 1.73 days below 17°C.

Estimates at all temperature bins become larger when considering dynamic effects. The third column in table 2, and figure 4 display cumulative dynamic effects using four lags, which correspond to an exposure window of five months. The effect of an additional day below 17°C accumulates up to 0.24 deaths per 100,000 (0.64%) (i.e. $\sum_{l=0}^{4} \beta_{jl} > \beta_{j0}$), while an additional day between 25-27°C and above 27°C translates into 0.06 and 0.16 (0.43%) additional deaths respectively. The effects of days above 25°C imply the death of approximately 243 people per month (1.3%), considering the average distribution of temperature throughout the period 1993-2016.

Columns 5 and 7 in table 2 present results for longer exposure windows, seven and nine months respectively. The effect of an additional day above 27°C continues to accumulate after five months, up to 0.25 deaths per 100,000 (0.62%) after seven months, and persists at this level even after nine months of exposure. This indicates that hot temperature shocks take time to fully translate into mortality effects. In contrast, the effects of colder temperature shocks vanish almost completely after an exposure window of seven months returning to zero. After this point in time, the relationship becomes increasing throughout the temperature distribution.

For reference, these estimates are close in magnitude or even higher to what the literature has found for extreme temperatures in settings with wider ranges of temperature and more variability. Figure 5 places the cumulative dynamic effect for five months in the context of findings in the literature. The most comparable in terms of methods and socio-economic characteristics are Barreca et al. (2016) and Cohen and Dechezlepretre (2018). The former estimates the mortality response function for the U.S. for two time periods, 1960-2004 and 1931-1960 using an exposure window of two months. The latter correspond to Mexico 1998-2010 after an exposure window of one month, which is a more comparable setting in terms of development. The figure reveals that the effects of additional days above 27°C accumulate to a higher level than what is reported in U.S. and Mexico (0.67% v.s. 0%, 0.12% and 0.37%).

Table 2 also shows that, as temperature, humidity is an important determinant of mortality. Mortality increases throughout the humidity distribution. For example, an additional day with more than $18g/kg$ of specific humidity increases mortality by 0.147 deaths per 100,000 (0.4% of the average monthly mortality rate.) relative to a day with specific humidity below $8g/kg$. Columns (2), (4), (6) and (8) show that point estimates for temperature coefficients fall after controlling for humidity, especially in the hot end of the distribution. However, the patterns described above still hold. After an exposure window of 7 months, an additional day above 27°C increases mortality by 0.156 deaths per 100,000 (0.42% of average monthly mortality rate). This magnitude is still economically significantly and higher to what have been documented in the US and Mexico for those temperature bins. No discernible differences are observed for temperatures below 23°C when including humidity controls.

Panels (a) and (b) in figure 6 report estimates separately for mountainous and lower elevation areas respectively. For both high and low elevation municipalities, mortality risk is highest at the extremes of their corresponding temperature distributions. However, the effect of additional days below 21°C for sea-level municipalities (i.e. 'cold' days for municipalities that are hot on average) is imprecisely estimated due to the low frequency of these events, and the small percent of the sample (25%) that resides in these areas. Estimating the temperature-mortality response function separately for elevation groups reveals that populations at higher elevations are more vulnerable to additional days with average temperature above 25°C than those in lower elevation municipalities (0.82% vs. 0.14% not significant). The difference is statistically significant with a p-value of 0.053 for the F-test. Days above 25°C imply high mortality risk for mountainous populations, while for sea-level municipalities it is highest at 27°C (0.84% after an exposure window of nine months). This suggests that populations are harmfully 'de-adapted' to infrequent experienced temperatures even if they are considered 'mild' or comfortable temperatures, supporting what Heutel et al. (2017) find for the U.S (detailed results available in tables A1 and A2 in the Appendix).

4.2 Specific-Cause Mortality and Temperature

To explore the potential mechanisms through which the temperature-mortality relationship arises, this section estimates equations 3.1 and 3.2 for seven specific causes of death that explain almost 80% of total mortality. Results reveal that heat-related mortality is largely explained by increases in deaths due to infectious and respiratory illness. Figure 7 plots the contemporaneous and dynamic responses of specific-cause mortality to temperature. Panel (a) indicates that deaths attributed to infectious diseases do not react immediately to temperature shocks, with an almost flat relationship at the contemporaneous level. However, as time goes by, the relationship monotonically increases in temperature. An additional day in temperature bin <17°C decreases mortality by 0.021 deaths per 100,000, which correspond to a 2.0% effect of the average monthly mortality rate due to infectious diseases. This finding coincides with the idea that hot temperature shocks contribute to the proliferation and breeding of vector, water and air-borne diseases with subsequent contagion to populations. Panel (c) also shows that mortality rates attributed to respiratory illness after hot temperature shocks, react only after an exposure window of several months. An additional day in temperature bin >27°C increases mortality by 0.075 deaths per 100,000 (2.7%). As with infectious diseases, the relationship between temperature and mortality becomes monotonically increasing over the temperature range observed.

The leading causes of cold-related mortality are cardiovascular and respiratory illness, as shown in panels (b) and (c) in figure 7 respectively. Contemporaneously, both react to 'cold' temperature shocks, with an additional day below 17°C increasing mortality by approximately 0.1 (0.9%) and 0.06 (1.7%). These two causes of deaths have been linked to weather shocks in the medical literature and also documented by Deschenes and Moretti (2009). However, 'cold' temperatures at which cardiovascular and respiratory related deaths react in Colombia are much higher than those in the U.S. (e.g. 17°C). This supports the idea and recent evidence from Mexico that even mild days, either hot or cold, can impact human health (Cohen and Dechezlepretre, 2018).

Dynamic effects associated to cardiovascular diseases remain almost stable at the contemporaneous levels, however, the temperature-mortality due to respiratory illness relationship becomes increasing throughout the temperature distribution. Attenuation of effects at the cold-end of the distribution documented in the previous section is likely related to how temperature shocks propagate over different causes of death. The initial positive effects at temperature below 17°C are counteracted by the fall in deaths associated to infectious and respiratory diseases at later points in time.

Panels (e) and (f) present estimates for external causes of death: homicides, and accidents. Contemporaneously both increase in temperature as has been documented in other contexts by Burke et al. (2015). An additional day below 17°C decreases homicide-related mortality by 0.024 (-0.56%), whereas an additional day above 27°C increases it by 0.015 deaths per 100,000 (0.34%). Unlike the estimates of health-related mortality described previously, homicides only react contemporaneously and not after a longer exposure window. As for accidents, an additional day in temperature bin >27°C increases mortality rates by 0.01 per 100,000, which correspond to an effect of 0.4% compared to average death rate for accidents-related deaths. These results suggest that warmer conditions might encourage individuals to engage in outdoor activities such as swimming and driving, increasing the likelihood of accidents. Deschenes and Moretti (2009), for example, find that cold days reduce male teenagers mortality through a fall in motor-vehicle accidents in the U.S.). This finding is reassuring in the sense that there is no reason to suspect that a temperature shock should affect accidents beyond the day of occurrence.

Out of the seven causes of death analyzed, two exhibit no reaction to temperature shocks: deaths attributed to suicide and those caused by neoplasms. Panel (d) in figure 7 shows the contemporaneous and dynamic effects for deaths associated to neoplasms. Both exhibit an almost flat relationship with temperature, serving as a placebo test.

Table 3 presents estimates of the temperature - specific cause mortality relationship with and without controls for humidity. Including humidity in the baseline specification leads to a fall in the temperature coefficients at the hot end of the distribution, particularly for deaths associated to infectious and respiratory illness (columns (4) and (6)). But as previously documented for all cause mortality, point estimates on the effect of hot temperature days remain statistically and economically significant. For respiratory illness, where humidity has the biggest effects (column (4)), the point estimate on the >27°C temperature bin falls from 0.075 to 0.044 deaths per 100,000, which relative to the average monthly death rate translates into a 1.2% effect. Temperature coefficients remain almost unchanged for temperature bins below 23°C, and for deaths related to cardiovascular disease and homicides throughout the distribution.

4.3 All-Cause by Age Group Mortality and Temperature

Results reported so far describe the relationship between temperature and mortality for the population as a whole, but these effects are likely to be unequally distributed across age groups. Table 4 examines heterogeneous effects by age-groups to identify populations at risk. In the interest of making the estimates accessible, the table only reports percentage effects for the corresponding extremes of the temperature distribution, and for different age groups. For comparison purposes within groups, I report cumulative dynamic effects for each temperature category divides by mean monthly mortality rates for each age group. Full regression results are available in table A3 in the Appendix.

Examination of age-specific estimates reveal differences in populations at risk based on whether they are exposed to cold or hot temperature shocks. Children aged 0-9 are at risk after hot-temperature shocks, and the elderly to a lesser extent. Deaths attributed to infectious diseases for children, and respiratory illness for the elderly mainly explain these results (tables A4 and A5 in the Appendix present dynamic effects of temperature on specific cause mortality for two age groups: 0-4 and 80+). Consistent with what Deschenes and Moretti (2009), Yu et al. (2019), and Cohen and Dechezlepretre (2018) find for the U.S, China and Mexico respectively, excess mortality caused by 'cold' temperature shocks increases with age. However, the same patterns are documented at much milder temperatures than what is observed in these three other countries. Cardiovascular and respiratory illness are the leading causes of temperature-related deaths for the age group 80 and older, especially in the cold end of the distribution.

These findings imply that hot-temperature shocks have a higher impact on children, with important effects on life expectancy. In table 5, I calculate implied annual deaths and years of life lost (YLL) per death after the occurrence of hot temperature days. Using life expectancy estimates from the Colombian Life Tables 2000-2005 produced by DANE, cumulative dynamic effects per age group of an additional day above 27°C (table A3 in the Appendix), and following Deschenes and Moretti (2009), I find that approximately 1,777 deaths per year are attributed to hot temperature, which correspond to 0.8% of annual deaths (based on average annual death rate over the period 1993-2016).[16] For children aged 0-4 implied annual deaths are 353, while this number increases to 578 for people older than 80. The average person who dies because of exposure to hot temperature lose approximately 30 years of potential life. This is approximately three times higher to what Deschenes and Moretti (2009) document for the US after the occurrence of cold temperature shocks. The fact that children bear much of the negative effects of hot temperature shocks, explain this difference. With the caveat that this calculation depends on the assumption that people who died because of a temperature shock would have lived until their average life expectancy, this finding suggest important reductions in expected lifetime, and sheds light on the importance of targeting policies aimed at reducing weather-related mortality in younger populations as Cohen and Dechezlepretre (2018) suggest.

[16]This estimate assumes uniform distribution of population across municipalities

4.4 The Potential Role of Income and Adaptation Opportunities

This section further characterizes heterogeneous responses in the temperature-mortality relationship which could shed light on adaptation opportunities. I perform two different types of analyses. The first splits the sample by urban and rural classification, and into rich and poor municipalities. I find that urban and rich municipalities drive the effects of heat-related mortality. The second investigates whether the response function has evolved over time. Overall, I find a 75% decline in cold-related mortality over the period 1993-2016, while heat-related mortality becomes significant only towards the second half of the sample period.

I first classify municipalities by urban, sub-urban and rural category. The Colombian Government defines these categories based on municipality size, population density and access to public services. Urban, for instance, includes the largest cities in Colombia like Bogota, Medellin, and Barranquilla. The rural category are municipalities with populations below 25,000 inhabitants, which account for approximately 20% of the population. Columns (1) and (2) in table 6 report estimates only for urban and rural municipalities, and show that effects in the hot part of the distribution are mainly driven by urban municipalities. These findings are consistent with the association between infectious and respiratory illness and hot temperature shocks, which in turn corroborates results from the epidemiological literature that link proliferation and contagion of these diseases to population density.

Similar patterns emerge when classifying the sample by income. I divide the sample by three income subgroups based on the multidimensional poverty index (MPI) constructed by the Colombian Government using census data from 2005: 25% poorest municipalities, 25% richest municipalities and the remaining 50% of municipalities in between. Columns (3) and (4) in table 6 present results only for rich and poor municipalities, and show that effects on the hot part of the distribution (i.e. temperature above 25°C) are driven by the richest municipalities. The null hypotheses for equality in the coefficient across groups for temperatures above ≥ 25°C are rejected at levels below 4%.

Next, I explore the evolution of the mortality-temperature response function. Columns (5) and (6) in table 6 report coefficients on temperature variables from two different time periods: 1993-2005 and 2006-2016 respectively. Two interesting findings emerge from the analysis. First, cold-related mortality declined more than 75% between these two time periods. Second, heat-related mortality increased throughout the period. Specifically, the effect of an additional day between 25-27°C increased from 0.054 deaths per 100,000 inhabitants during the period 1993-2005 to 0.122 per 100,000 in the more recent years, while the point estimate from temperature bin >27°C jumped from 0.054 to 0.217 deaths per 100,000.

These results suggest that broad health policies that were undertaken at the beginning of the 1990s, improvements in access to services or growth experienced in Colombia during the sample time period, for example, might have played a role in explaining the decline of effects in the 'cold' end of the distribution.[17] The next subsection formally explores if access to health care contributed to the decline in the mortality effects of 'cold' days.

4.5 Access to Health Care and Quality as a Modifier of the Temperature-Mortality Relationship

Table 7 presents results from fitting several versions of equation 3.3. Access to the subsidized health regime is associated with a decrease in mortality throughout the temperature distribution, especially in 'cold' temperature bins. Estimates suggest that a 1 percentage point increase in access to health reduces the mortality effect of below 17°C days by 0.22 per 100,000 inhabitants, approximately 62% of the effect of an additional day below 17°C in the period 1993-2005 ($\approx$ 0.358 in table 6). Applying these estimates to the historical distribution of temperature, the possibility of accessing the health system saved approximately 92 lives a month in the $< 17°C$ temperature bin (95% confidence interval is 79.6 - 104.5). Though estimates at the hotter part of the distribution have the expected sign, they are not statistically significant at conventional levels. Results are robust to several specifications, including different exposure windows (number of lags

[17]Colombia experienced significant growth over the years in the sample, for example, GDP per capita increased from $ 4,000 to $7,700 (Constant 2010 US$) between 1993-2016, and living conditions improved. According to the 2018 household livings standards survey (Encuesta de Calidad de Vida, 2018), 97.7% had access to electricity, and 93.5% had some sort of access to health services. Air conditioning penetration is 4.7% in the entire country, and close to 15% regions located at sea-level. Access to a fan is much higher, with 37.7% for the entire country and 89.5% for municipalities close to sea-level. Finally, close to 86% of households cook with natural and propane gas.

included in the model), and inclusion of temperature-year linear trends.

By 2010, almost 94% of the Colombian population was covered by some form of insurance, either subsided or private. This can be exploited to explore the role of quality of health services as a mediating factor between temperature and mortality. Fitting equation 3.4, I find that high-quality health services appear to attenuate temperature-related mortality. Table 8 shows that, under different specifications and two quality measures, namely 75th and 90th percentile of the rate of complaints distribution, weather-related mortality at the end points of the temperature distribution is higher for those covered by low-quality insurance. Point estimates are bigger in magnitude for days below 17°C, ranging from 0.7 to 1.1 additional deaths per 100,000, or 1.7% higher for those with access to low-quality health care. Linking these estimates to the historical distribution of temperature, implies an additional 339 deaths a month attribute to access bad-quality health insurance. Effects at the hot end of the temperature distribution range from 0.1 to 0.2 deaths per 100,000, or 0.5% higher. Though somewhat smaller, these estimates suggest that access and especially good quality health services could help mitigate the adverse effects of hot temperature days on mortality.

5 Conclusion

This paper advances our understanding of heat-related mortality by focusing on populations that face inherently different environmental, economic and demographic conditions than their counterparts in temperate areas. I document that short-term variations in temperature, even at narrower temperature ranges, have significant effects on mortality rates. Using a unique data set from a tropical developing country, I find that hot temperature shocks not only increase mortality rates contemporaneously, but take time to fully translate into mortality effects. Applying estimates to the historical distribution of temperature in Colombia, I find that variations in temperature translates into 1,013 additional deaths, representing 5.6% of monthly deaths in the country.

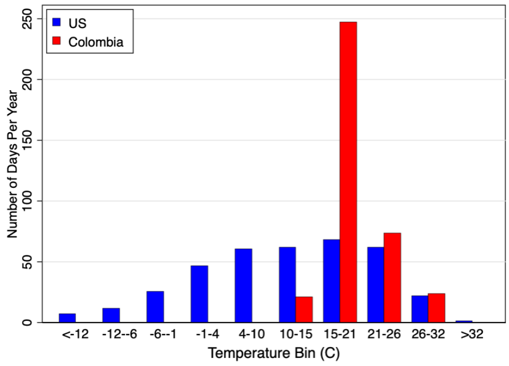
I identify new risk factors after the occurrence of hot temperature shocks. I show that causes of death such as infectious or respiratory illness, which have been shown to react to even small changes in temperature, mainly explain the underlying temperature-mortality response function in the hot part of the distribution. Children aged zero to nine are primarily affected by hot temperature shocks, contrasting findings in temperate areas (e.g. U.S. , Mexico and China) where cardiovascular diseases affecting the elderly drive heat-related mortality. These results suggest that preventive measures to protect vulnerable populations, especially children should be effective in reducing the adverse effects of climate change.

I also document a decline in 'cold'-related mortality over the period 1993-2016. The empirical results point to access and quality of health services as determinant in this decline. As access to health care expanded after the 1993 reform, estimates linked to the historical distribution of temperature suggest that approximately 92 lives a month were saved after the occurrence of unusually 'cold' days ($< 17°C$) and 676 lives after an additional day between 17-19°C. Though such decline on the hot end of distribution was not observed, access to good quality health services can successfully reduce vulnerability to temperature changes. Under these circumstances, there is a role for public policy to mediate the adverse effects of temperature shocks. Universal health insurance could be effective and a readily available policy, but the quality of those services matter.

However, more research is required to assess and design policies aimed at mitigating heat related mortality. The findings in this paper suggest that appropriate technologies to overcome the effects of hot temperature shocks that have been successful in temperate areas might not necessarily be cost-effective in tropical areas, or should be tailored to the specific needs and vulnerabilities of populations in these areas. For example, adoption of air conditioning has been highly effective in the U.S. or China to mitigate the effects of hot temperature shocks, given that such technology helps stabilize body temperature and diminish the risk of cardiovascular accidents (Barreca et al. (2016), Yu et al. (2019)). In the verge of increasing temperatures, in places like Colombia, policies should also consider that respiratory, infectious diseases and external causes of death, affecting populations in urban and rich municipalities, mainly give rise to the temperature-mortality relationship.

Figures

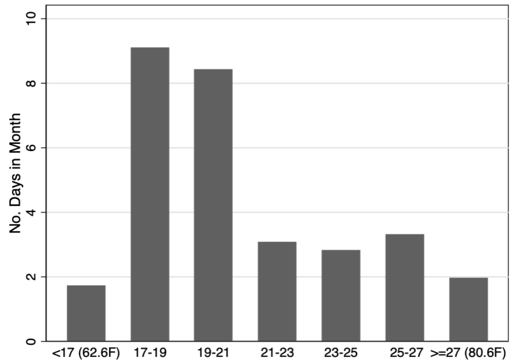
Figure 1: Comparison of population-weighted annual distribution of temperature (°C) between U.S. and Colombia



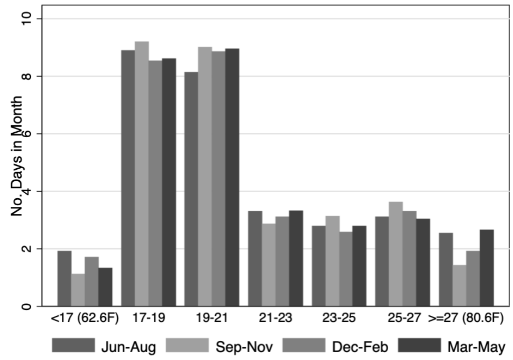
Notes: Historical (1993-2016) annual temperature distribution in Colombia as compared to the U.S. distribution for the period 1900-2004 (Barreca et al. (2016)), across ten temperature bins measured in Celcius (C). Observations are weighted by total population in the municipality in the respective year, so that the bars represent the number of days per year/month in each bin that an average person experiences.

Figure 2: Population-weighted distributions of daily average temperature (in °C) for the period 1993-2016

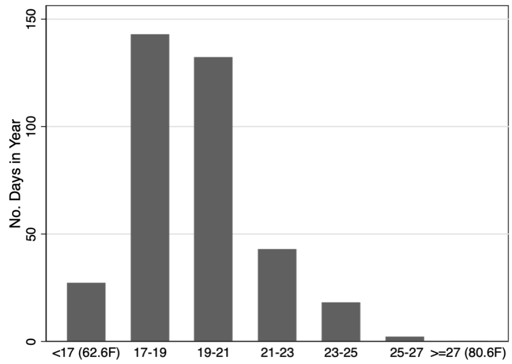
(a) Monthly Distribution



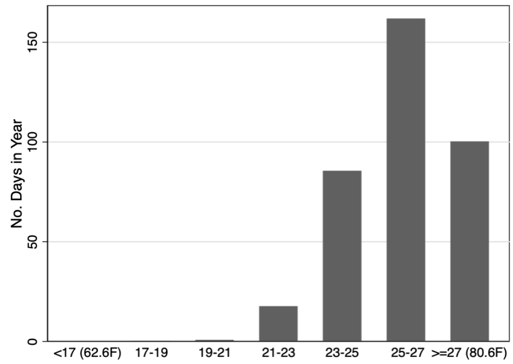
(b) Monthly Distribution



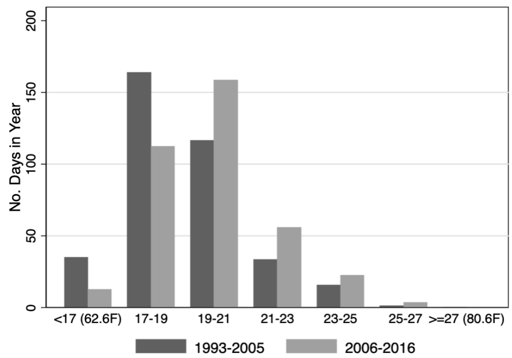
(c) High-Altitude Annual Distribution



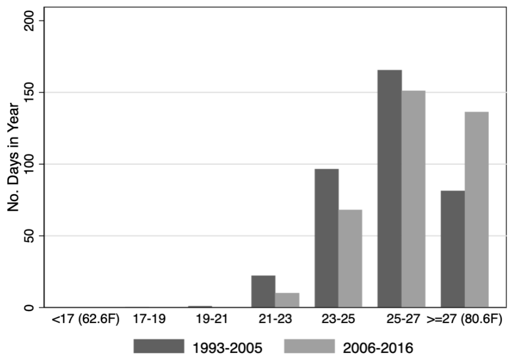
(d) Low-Altitude Annual Distribution



(e) High-Altitude Distribution Over Time

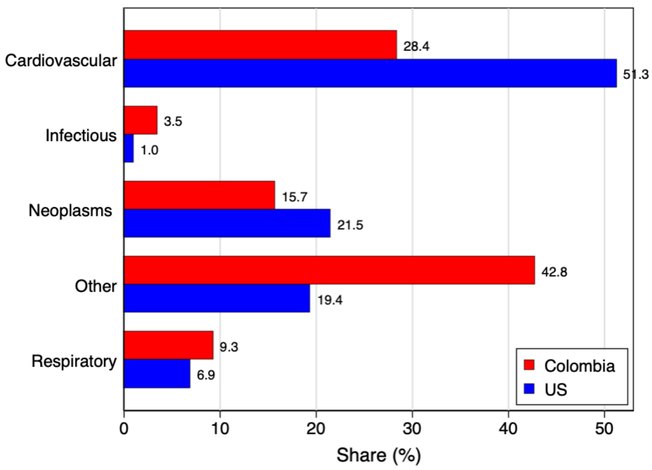


(f) Low-Altitude Distribution Over Time



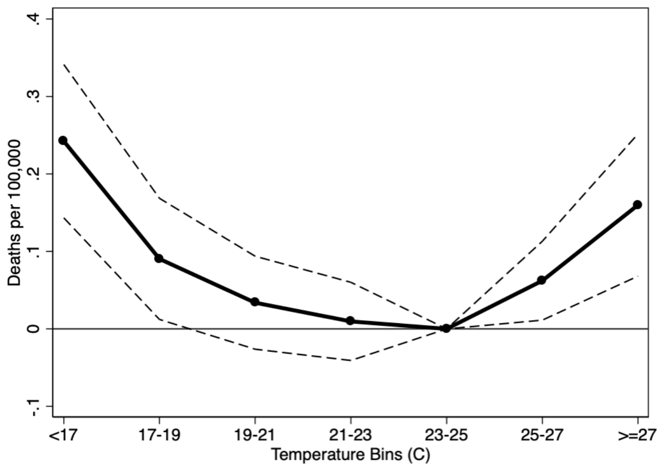
Notes: Panel (a) shows the monthly temperature distribution in Colombia. Panel (b) shows Colombian daily mean temperature distribution separately for different months across seven 2°C temperature bins. Panels (c) and (d) show the annual temperature distribution for high altitude (above 1000 meters) and low altitude respectively. Panels (e) and (f) show annual temperature distribution by elevation over two time periods: 1993-2005 and 2006-2016. Observations are weighted by total population in the municipality in the respective year, so that the bars represent the number of days per year/month in each bin that an average person experiences.

Figure 3: Mortality rates: comparison between Colombia and U.S.



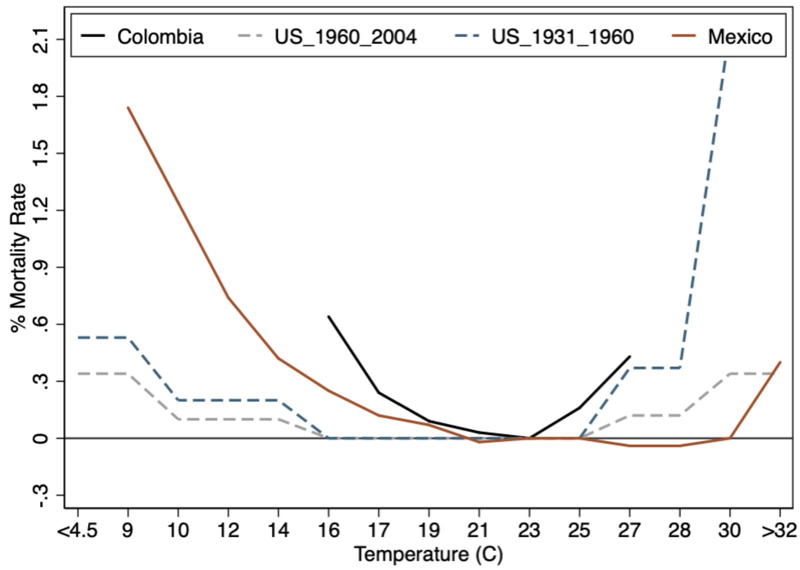
Notes: U.S. mortality data from Deschenes and Moretti (2009). Colombian data grouped in five categories for comparison purposes.

Figure 4: Impact of temperature monthly all-cause mortality (in deaths per 100,000)



Notes: Dynamic cumulative effects for each temperature bin plotted in the figure. Reference temperature bin 23-25°C. Cumulative effects are calculated based on 4 lags that correspond to a temperature exposure window of 5 months. Cumulative estimates using municipality-year and month-year fixed effects. 90% confidence intervals constructed with standard errors clustered at the municipality level. All regressions are weighted by population and control for precipitation.

Figure 5: Impact of temperature on monthly mortality compared to findings in the literature

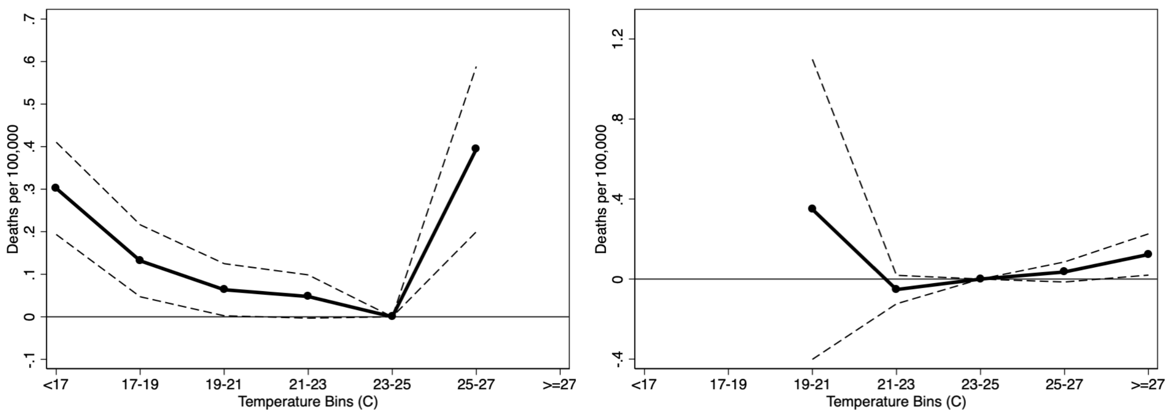


Notes: U.S estimates from Barreca et al. (2016) using cumulative dynamic effects with an exposure window of two months. Mexico estimates from Cohen and Dechezlepretre (2018) with cumulative effects after one month. Estimates for Colombia correspond to cumulative dynamic effect for five months.

Figure 6: Impact of temperature on monthly mortality by elevation (in deaths per 100,000)

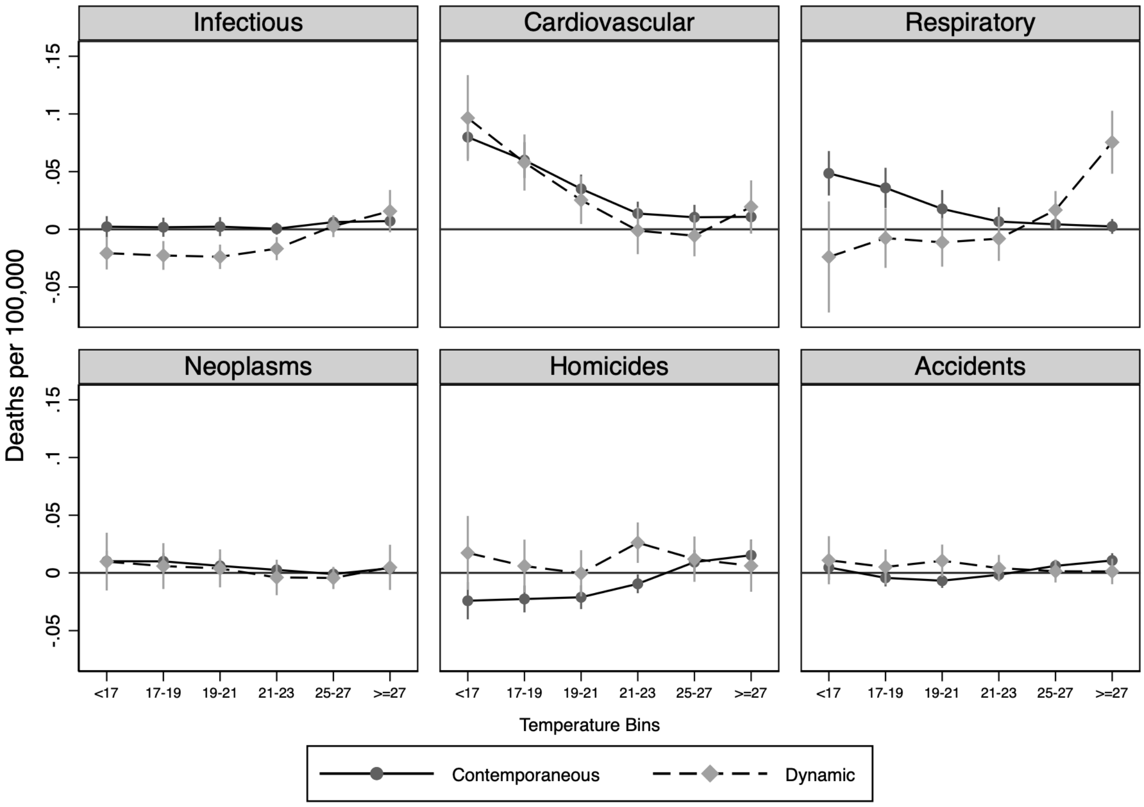
(a) High Altitude Municipalities

(b) Low Altitude Municipalities



Notes: Dynamic cumulative effects for each temperature bin plotted in the figures. Reference temperature bin 23-25°C. Cumulative effects after an exposure window of 5 months. Estimates using municipality-year and month-year fixed effects. 90% confidence intervals constructed with standard errors clustered at the municipality level. All regressions are weighted by population and control for precipitation.

Figure 7: Impact of temperature on cause-specific mortality (in deaths per 100,000)



Notes: Each panel shows contemporaneous (solid line) and dynamic cumulative effects (dashed line) for each temperature bin plotted by specific causes of death. Reference temperature bin 23-25°C. Estimates using municipality-year and month-year fixed effects. 95% confidence intervals constructed with standard errors clustered at the municipality level. All regressions are weighted by population and control for precipitation shocks.

Tables

Table 1: Annual mortality rate per 100,000 inhabitants and share of specific cause of death by age group

	Age Group										
	All	0-4	5-9	10-19	20-29	30-39	40-49	50-59	60-69	70-79	80+
Infectious Diseases	3.64	10.20	6.23	2.43	4.27	6.58	5.48	3.48	2.42	1.98	1.75
Neoplasms	15.71	1.93	13.79	5.27	4.89	11.33	21.21	25.95	24.66	20.05	12.48
Endocrine and Nutritional	4.35	4.38	2.37	0.89	0.85	1.59	3.18	5.11	5.95	5.72	5.17
Cardiovascular Diseases	28.40	1.37	4.35	3.17	3.85	9.52	21.29	31.58	37.58	41.89	44.39
Respiratory Diseases	9.28	12.50	6.80	2.38	1.76	2.56	4.04	6.21	9.00	12.04	15.80
Other Diseases	18.31	61.38	23.15	11.08	9.17	11.60	13.72	14.62	14.71	15.13	16.55
Accidentes	7.68	7.60	33.75	21.96	19.75	16.81	11.53	6.53	3.75	2.56	2.29
Homicides	11.67	0.65	8.65	48.49	51.93	37.66	17.98	5.72	1.56	0.44	1.46
Suicides	0.96	0.00	0.92	4.35	3.53	2.35	1.56	0.80	0.37	0.17	0.10
Death Rate $\times$ 100,000	457.3	357.4	33.0	116.8	209.2	217.8	301.3	601.1	1339.4	3052.6	9099.5

Notes: Specific cause of death classified according to ICD-10 WHO. The last row of the table corresponds to the annual crude death rate per 100,000 for the whole country weighted by population. All other entries correspond to shares of specific cause of death for all sample and by age group. The sample includes 1,033 municipalities from 1993 to 2016.

Table 2: Impact of temperature on monthly all-cause mortality

	Contemp.		Cum 5		Cum 7		Cum 9	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Base Temperature: $\in$ [23C,25C) [73F,77F)								
Temperature < 17	0.173***	0.162***	0.242***	0.224***	0.020	0.036	-0.032	0.017
	(0.038)	(0.037)	(0.060)	(0.063)	(0.079)	(0.074)	(0.142)	(0.106)
Temperature $\in$ [17,19)	0.111***	0.099**	0.090*	0.074	-0.006	-0.036	-0.041	-0.050
	(0.032)	(0.032)	(0.048)	(0.047)	(0.050)	(0.056)	(0.107)	(0.087)
Temperature $\in$ [19,21)	0.053*	0.051*	0.034	0.030	-0.017	-0.036	0.026	-0.017
	(0.029)	(0.030)	(0.036)	(0.039)	(0.038)	(0.045)	(0.077)	(0.063)
Temperature $\in$ [21,23)	0.020	0.017	0.010	0.011	-0.022	-0.032	0.038	0.004
	(0.021)	(0.022)	(0.031)	(0.031)	(0.034)	(0.037)	(0.055)	(0.047)
Temperature $\in$ [25,27)	0.050**	0.039**	0.059*	0.053*	0.058	0.052	0.068	0.088
	(0.016)	(0.017)	(0.031)	(0.029)	(0.038)	(0.038)	(0.053)	(0.057)
Temperature $\geq$ 27	0.061**	0.038**	0.158**	0.106**	0.248***	0.156**	0.233**	0.182**
	(0.020)	(0.019)	(0.056)	(0.036)	(0.068)	(0.051)	(0.082)	(0.082)
Base Humidity: < 8 g/kg								
Humidity $\in$ [8,10)]		0.114***		0.114***		0.232***		0.221***
		(0.008)		(0.030)		(0.040)		(0.058)
Humidity $\in$ [10,12)]		0.103***		0.170***		0.306***		0.253***
		(0.013)		(0.038)		(0.050)		(0.076)
Humidity $\in$ [12,14)]		0.107***		0.174***		0.322***		0.286**
		(0.014)		(0.040)		(0.049)		(0.092)
Humidity $\in$ [14,16)]		0.113***		0.164***		0.264***		0.225**
		(0.025)		(0.047)		(0.057)		(0.102)
Humidity $\in$ [16,18)]		0.088***		0.094**		0.180**		0.034
		(0.026)		(0.046)		(0.065)		(0.137)
Humidity $\geq$ 18]		0.147***		0.171***		0.198**		-0.044
		(0.040)		(0.048)		(0.068)		(0.156)
25th Precipitation Pctile	-0.115	-0.077	-0.342	-0.333	-0.139	-0.046	-0.175	-0.258
	(0.094)	(0.084)	(0.230)	(0.227)	(0.310)	(0.305)	(0.376)	(0.386)
75th Precipitation Pctile	0.027	-0.001	0.423**	0.345*	0.917***	0.807***	1.219***	1.117***
	(0.093)	(0.092)	(0.195)	(0.191)	(0.223)	(0.215)	(0.274)	(0.295)
Observations	300,504	300,504	300,436	300,436	300,402	300,402	300,368	300,368
Mean Mortality Rate	37.59							
SD Mortality Rate	19.74							
Municipality $\times$ Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year $\times$ Month FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Notes: Estimates in each column come from separate regression. Dependent variable is monthly mortality rate per 100,000 inhabitants. Column Contemp. present estimates using no lags. Cum X estimates the dynamic model using (X-1) lags, meaning results correspond to cumulative dynamic effects after an exposure window of X months. X corresponds to 5, 7 or 9. Specifications control for precipitation, specific humidity, municipality-year and month-year fixed effects. Standard errors clustered at the municipality level reported in parenthesis. All regressions are weighted by population. ***p-value < 0.001, **p-value < 0.01, *p-value < 0.05.

Table 3: Cumulative dynamic impacts of temperature in monthly specific-cause mortality

	Cardiovascular		Respiratory		Infectious		Homicides	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Base Temperature: $\in$ [23C,25C) [73F,77F)								
Temperature < 17	0.096***	0.099***	-0.024	-0.016	-0.021**	-0.012	-0.024**	-0.025**
	(0.023)	(0.024)	(0.029)	(0.025)	(0.009)	(0.009)	(0.010)	(0.010)
Temperature $\in$ [17,19)	0.058***	0.055**	-0.008	-0.010	-0.023**	-0.017**	-0.023**	-0.024***
	(0.015)	(0.017)	(0.016)	(0.015)	(0.008)	(0.008)	(0.007)	(0.007)
Temperature $\in$ [19,21)	0.025**	0.023	-0.011	-0.012	-0.024***	-0.020**	-0.021***	-0.022***
	(0.013)	(0.015)	(0.013)	(0.012)	(0.006)	(0.007)	(0.006)	(0.006)
Temperature $\in$ [21,23)	-0.001	0.001	-0.008	-0.009	-0.017**	-0.016**	-0.009*	-0.010*
	(0.012)	(0.013)	(0.012)	(0.010)	(0.006)	(0.007)	(0.005)	(0.005)
Temperature $\in$ [25,27)	-0.005	-0.004	0.017*	0.012	0.003	0.002	0.009	0.009
	(0.011)	(0.011)	(0.010)	(0.009)	(0.006)	(0.006)	(0.006)	(0.006)
Temperature ≥ 27	0.019	0.016	0.075***	0.044***	0.016	0.011	0.015*	0.015*
	(0.014)	(0.016)	(0.017)	(0.012)	(0.011)	(0.010)	(0.008)	(0.008)
Base Humidity: < 8 g/kg								
Humidity $\in$ [8,10)]		0.022**		0.042***		0.010***		0.005**
		(0.011)		(0.009)		(0.003)		(0.002)
Humidity $\in$ [10,12)]		0.037**		0.065***		0.009*		0.001
		(0.017)		(0.011)		(0.005)		(0.004)
Humidity $\in$ [12,14)]		0.031		0.064***		0.006		0.002
		(0.019)		(0.013)		(0.005)		(0.005)
Humidity $\in$ [14,16)]		0.011		0.063***		0.007		-0.002
		(0.020)		(0.013)		(0.007)		(0.005)
Humidity $\in$ [16,18)]		0.002		0.054***		0.002		-0.004
		(0.024)		(0.013)		(0.008)		(0.007)
Humidity ≥ 18		-0.007		0.067***		0.003		-0.004
		(0.025)		(0.016)		(0.009)		(0.006)
25th Precipitation Pctile	-0.111	-0.128	0.073	0.101	0.065*	0.066*	0.030	0.028
	(0.112)	(0.108)	(0.093)	(0.099)	(0.038)	(0.038)	(0.032)	(0.032)
75th Precipitation Pctile	0.188**	0.176*	-0.008	-0.032	0.075**	0.058	0.009	0.010
	(0.091)	(0.090)	(0.092)	(0.087)	(0.036)	(0.038)	(0.032)	(0.033)
Observations	300,419	300,419	300,402	300,402	300,385	300,385	300,504	300,504
Mean Mortality Rate	10.93		3.61		1.29		4.38	
SD Mortality Rate	6.91		3.24		1.62		7.03	
Municipality $\times$ Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year $\times$ Month FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Notes: Each column corresponds to a separate regression and a specific-cause of death. For deaths related to cardiovascular, respiratory, and infectious diseases, estimates correspond to cumulative dynamic effects. Homicides correspond to contemporaneous effects. Columns (2), (4), (6), (8) control for specific humidity variables. All specifications control for precipitation, municipality-year and month-year fixed effects. Standard errors clustered at the municipality level reported in parenthesis. All regressions are weighted by population. ***p-value < 0.001, **p-value < 0.01, *p-value < 0.05.

Table 4: Impact of temperature on monthly all-cause mortality by age-group

Age-Group	Dynamic 5 Months		Mean Mortality Rate
	< 17	≥ 27	
0-4	0.26	1.32**	26.05
5-9	0.49	1.17**	2.47
10-19	1.28**	-0.20	8.2
20-29	0.14	0.31	16.96
30-39	0.44	0.76***	17.45
40-49	0.33	0.07	22.98
50-59	0.09	0.14	45.12
60-69	0.20	0.54***	105.12
70-79	0.72***	0.31	249.45
80+	1.22***	0.63**	778.89

Notes: Estimates in each row comes from separate regressions by age group. The entries under each temperature bin are calculated by taking cumulative dynamic effects (point estimates available in table A3 in the Appendix) and dividing them by average monthly mortality rates for each age group. All specifications control for precipitation, municipality-year and month-year fixed effects. Standard errors clustered at the municipality level. ***p-value < 0.001, **p-value < 0.01, *p-value < 0.05 from point estimates in each regression.

Table 5: Number of deaths associated with temperatures above 27°C and years of life lost

Age-Group	Life Expectancy (1)	Population (in 100,000) (2)	Cum. Effect of 1 day ≥ 27 (3)	Implied Annual Deaths (4)=(2)*(3)*23.57	Total YLL (5)=(4)*(1)
0-4	73.06	43.4	0.345*	353.22	25806.29
5-9	69.88	44.7	0.029*	30.52	2132.82
10-19	62.60	86.7	-0.016	-32.70	-2046.65
20-29	53.43	70.9	0.052	86.96	4645.95
30-39	44.66	59.9	0.132*	186.46	8327.60
40-49	35.76	51.4	0.017	20.61	736.91
50-59	27.04	33.6	0.064	50.74	1371.74
60-69	18.96	20.8	0.563*	275.57	5224.08
70-79	12.08	12.4	0.778	226.97	2740.66
80+	7.92	5.0	4.901*	578.83	4584.31
Annual deaths attributable to hot temperature (all ages)				1777.17	YLL per death: 30.12

Notes: I estimate annual deaths associated with hot temperature shocks (column 4) by multiplying population in each age group (column 2) by the age-specific estimate of an additional day above ≥ 27°C on mortality (column 3), and the average number of days above this temperature in a year (23.57). The total number of deaths attributable to hot temperature is the sum of all deaths in each age group: 1,777.17. The product of column 4 and life expectancy for each age group (column 1) provides the total years of life lost (YLL) (column 5). I divide the total number of YLL (53,523.71) by the total number of deaths associated to hot temperature to obtain the years of life lost per death. * denotes statistically significant estimates at conventional levels.

Table 6: Impact of temperature on monthly all-cause mortality by urban/rural, rich/poor and time period

	Monthly Mortality Rate per 100,000					
	(Urban)	(Rural)	(Rich)	(Poor)	(1993-2005)	(2006-2016)
Temperature < 17	0.237**	0.295***	0.276**	0.348**	0.358***	0.084
	(0.102)	(0.069)	(0.090)	(0.113)	(0.091)	(0.082)
Temperature $\in$ [17,19)	0.035	0.179***	0.054	0.177**	0.227**	-0.000
	(0.077)	(0.053)	(0.074)	(0.089)	(0.074)	(0.061)
Temperature $\in$ [19,21)	0.002	0.123**	0.007	0.117	0.103	-0.016
	(0.068)	(0.045)	(0.067)	(0.073)	(0.063)	(0.045)
Temperature $\in$ [21,23)	-0.003	0.047	-0.002	0.045	-0.011	-0.010
	(0.055)	(0.033)	(0.057)	(0.032)	(0.037)	(0.040)
Temperature $\in$ [25,27)	0.128**	0.033	0.199**	-0.000	-0.049	0.122**
	(0.063)	(0.024)	(0.078)	(0.031)	(0.033)	(0.043)
Temperature ≥ 27	0.273**	0.015	0.369***	-0.007	0.054	0.217**
	(0.087)	(0.035)	(0.096)	(0.036)	(0.049)	(0.070)
25th Precipitation Pctile	-0.207	-0.124	-0.404	0.028	0.036	-0.535*
	(0.334)	(0.409)	(0.319)	(0.525)	(0.485)	(0.322)
75th Precipitation Pctile	0.646**	0.163	0.604**	-0.371	0.790**	0.394
	(0.274)	(0.317)	(0.271)	(0.413)	(0.330)	(0.291)
Observations	32,256	184,708	77,756	68,348	256,320	137,808
F-Test Bin < 17	0.8581		0.5836		0.0006	
F-Test Bin [17,19)	0.2994		0.5238		0.0023	
F-Test Bin [19,21)	0.2706		0.5298		0.0438	
F-Test Bin [21,23)	0.6356		0.7361		0.5856	
F-Test Bin [25,27)	0.2207		0.0398		0.0099	
F-Test Bin ≥ 27	0.0194		0.0002		0.0434	

Notes: The table shows heterogeneous effects of temperature on mortality by: (i) urban/rural classification, (ii) rich and poor municipalities, and (iii) time periods. For each heterogeneous response one fully interacted regression is estimated, so p-values for F-statistics for the hypothesis of equality of coefficients on each temperature bin are reported at the bottom of the table. All specifications control for precipitation, municipality-year and month-year fixed effects interacted with each category. Standard errors clustered at the municipality level reported in parenthesis. All regressions are weighted by population. ***p-value < 0.001, **p-value < 0.01, *p-value < 0.05.

Table 7: Access to health care as a modifier of the temperature-mortality relationship

	Interaction Temperature and Share Population with Access to Subsidized Regime					
	(Cont)	(Cum 2)	(Cum 2)	(Log Cum 2)	(Cum 3)	(Cum 5)
Base Temperature: $\in$ [23C,25C) [73F,77F)						
Temperature $<$ 17 $\times$ Share	-0.237**	-0.221*	-0.326**	-0.015**	-0.175	-0.157
	(0.109)	(0.117)	(0.119)	(0.005)	(0.128)	(0.144)
Temperature $\in$ [17,19) $\times$ Share	-0.277**	-0.308**	-0.321**	-0.011**	-0.306**	-0.337**
	(0.120)	(0.128)	(0.128)	(0.004)	(0.135)	(0.141)
Temperature $\in$ [19,21) $\times$ Share	-0.173	-0.197	-0.214	-0.009**	-0.202	-0.218
	(0.124)	(0.128)	(0.144)	(0.004)	(0.135)	(0.141)
Temperature $\in$ [21,23) $\times$ Share	-0.097	-0.078	-0.182	-0.007*	-0.083	-0.140
	(0.097)	(0.114)	(0.127)	(0.004)	(0.128)	(0.147)
Temperature $\in$ [25,27) $\times$ Share	-0.089	-0.097	-0.076	-0.003	-0.083	-0.103
	(0.079)	(0.091)	(0.096)	(0.003)	(0.102)	(0.120)
Temperature $\geq$ 27 $\times$ Share	-0.010	-0.005	-0.089	-0.005	-0.031	-0.044
	(0.095)	(0.107)	(0.142)	(0.005)	(0.115)	(0.130)
Observations	236,892	235,853	235,853	195,362	234,814	232,736
Mean Mortality Rate	37.77					
SD Mortality Rate	20.19					
Municipality	Yes	Yes	Yes	Yes	Yes	Yes
Municipality $\times$ Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Year $\times$ Month FE	Yes	Yes	Yes	Yes	Yes	Yes
Temperature $\times$ Year Trends	No	No	Yes	Yes	No	No

Notes: Each column corresponds to a separate regression. Except in column (Log Cum 2) the dependent variable is monthly mortality rate per 100,000 inhabitants. In column (Log Cum 2) the dependent variable is log monthly mortality rate. Cumulative dynamic effects are reported in columns (Cum X), and (Log Cum 2),where X = 2, 3, 5. The table reports coefficients for the interaction between each temperature bin and share of population with access to SR health service. Standard errors clustered at the municipality level reported in parenthesis. All regressions control for precipitation, a rich set of fixed effects and are weighted by population. ***p-value $<$ 0.001, **p-value $<$ 0.01, *p-value $<$ 0.05

Table 8: Insurer quality as a modifier of the temperature-mortality relationship

	(Cont)	(Cum 2)	(Log Cum 2)	(Cum 5)
A: 75th Percentile				
Temperature < 17 × Quality	1.016	1.186	0.017**	1.651
	(0.790)	(0.910)	(0.006)	(1.204)
Temperature $\in$ [17,19) × Quality	0.236	0.269	0.009**	0.321
	(0.348)	(0.424)	(0.003)	(0.602)
Temperature $\in$ [19,21) × Quality	0.057	0.093	0.004	0.064
	(0.097)	(0.117)	(0.002)	(0.192)
Temperature $\in$ [21,23) × Quality	0.035	0.104	0.004	0.295*
	(0.072)	(0.087)	(0.003)	(0.174)
Temperature $\in$ [25,27) × Quality	0.016	0.041	0.005	0.025
	(0.154)	(0.190)	(0.003)	(0.294)
Temperature ≥ 27 × Quality	0.090	0.142	0.005*	0.232
	(0.140)	(0.145)	(0.003)	(0.154)
B: 90th Percentile				
Temperature < 17 × Quality	0.692**	0.815**	0.016***	1.148**
	(0.259)	(0.315)	(0.004)	(0.520)
Temperature $\in$ [17,19) × Quality	-0.011	-0.012	0.003	-0.050
	(0.146)	(0.170)	(0.002)	(0.230)
Temperature $\in$ [19,21) × Quality	-0.044	-0.023	0.004	0.040
	(0.113)	(0.120)	(0.003)	(0.141)
Temperature $\in$ [21,23) × Quality	-0.240	-0.292	0.006*	-0.496
	(0.181)	(0.209)	(0.004)	(0.307)
Temperature $\in$ [25,27) × Quality	-0.027	0.010	0.004	0.085
	(0.065)	(0.071)	(0.003)	(0.082)
Temperature ≥ 27 × Quality	0.106	0.162**	0.003**	0.212**
	(0.080)	(0.082)	(0.001)	(0.092)
Observations	93,417	70,937	70,937	48,917
Mean Mortality Rate	37.73			39.05
SD Mortality Rate	218.44			228.08
Insurer	Yes	Yes	Yes	Yes
Municipality × Year FE	Yes	Yes	Yes	Yes
Year × Month FE	Yes	Yes	Yes	Yes
Temperature × Year Trends		Yes	Yes	

Notes: Each column corresponds to a separate regression. The dependent variable is monthly mortality rate and log monthly mortality rate for column Log Cum 2. Temperature exposure windows varies from a period of 1 month (column Cont), two months (columns (Cum 2) and (Log Cum Month), and five months (Cum 5). In panel (A) quality is measured using a variable that equals 1 if municipalities have complaints above the 75th percentile of the complaints distribution and 0 otherwise. Panel B uses the 90th percentile threshold. All regressions control for precipitation and insurer fixed effects. Standard errors clustered at the municipality level reported in parenthesis. All regressions are weighted by population. ***p-value < 0.001, **p-value < 0.01, *p-value < 0.05.

References

Barreca, A., Clay, K., Deschenes, O., Greenstone, M. and Shapiro, J. S. (2016). Adapting to climate change: The remarkable decline in the us temperature-mortality relationship over the twentieth century. *Journal of Political Economy* 124: 105–159.

Bhalotra, S. and Fernández Sierra, M. (2021). The right to health and the health effects of denials. *Documento CEDE* .

Burgess, R., Deschenes, O., Donaldson, D. and Greenstone, M. (2011). Weather and death in india. *Cambridge, United States: Massachusetts Institute of Technology, Department of Economics. Manuscript* 19.

Burke, M., Hsiang, S. M. and Miguel, E. (2015). Climate and conflict. *Annu. Rev. Econ.* 7: 577–617.

Carleton, T., Delgado, M., Greenstone, M., Houser, T., Hsiang, S., Hultgren, A., Jina, A., Kopp, R. E., McCusker, K., Nath, I. et al. (2018). Valuing the global mortality consequences of climate change accounting for adaptation costs and benefits .

Cohen, F. and Dechezlepretre, A. (2018). Mortality, temperature, and public health provision: Evidence from mexico. *Working Paper* .

Council, N. R. et al. (2001). *Under the weather: climate, ecosystems, and infectious disease*. National Academies Press.

Dell, M., Jones, B. F. and Olken, B. A. (2013). What do we learn from the weather? The new climate-economy literature. Tech. rep., National Bureau of Economic Research.

Deschenes, O. (2014). Temperature, human health, and adaptation: A review of the empirical literature. *Energy Economics* 46: 606–619.

Deschênes, O. and Greenstone, M. (2011). Climate change, mortality, and adaptation: Evidence from annual fluctuations in weather in the us. *American Economic Journal: Applied Economics* 3: 152–85.

Deschenes, O. and Moretti, E. (2009). Extreme weather events, mortality, and migration. *The Review of Economics and Statistics* 91: 659–681.

Edelman, A., Gelding, A., Konovalov, E., McComiskie, R., Penny, A., Roberts, N., Templeman, S., Trewin, D., Ziembicki, M., Trewin, B. et al. (2014). State of the tropics 2014 report .

Escobar, M. L. (2005). Health sector reform in colombia. *Development Outreach* 7: 6–9.

Gasparrini, A., Guo, Y., Hashizume, M., Lavigne, E., Zanobetti, A., Schwartz, J., Tobias, A., Tong, S., Rocklöv, J., Forsberg, B. et al. (2015). Mortality risk attributable to high and low ambient temperature: a multicountry observational study. *The Lancet* 386: 369–375.

Gaviria, A., Medina, C., Mejía, C., McKenzie, D. and Soares, R. R. (2006). Assessing health reform in colombia: From theory to practice [with comments]. *Economia* 7: 29–72.

Giuffrida, A., Flórez, C. E., Giedion, Ú., Cueto, E., López, J. G., Glassman, A., Castaño, R. A., Pinto, D. M., Pardo, R., Tono, T. M. et al. (2009). *From few to many: ten years of health insurance expansion in Colombia*. Inter-American Development Bank.

Heutel, G., Miller, N. H. and Molitor, D. (2017). Adaptation and the mortality effects of temperature across US climate regions. Tech. rep., National Bureau of Economic Research.

Hii, Y. L., Rocklöv, J., Ng, N., Tang, C. S., Pang, F. Y. and Sauerborn, R. (2009). Climate variability and increase in intensity and magnitude of dengue incidence in singapore. *Global Health Action* 2: 2036, doi:10.3402/gha.v2i0.2036.

Kamarck, A. M. et al. (1976). The tropics and economic development; a provocative inquiry into the poverty of nations .

Mullins, J. T. and White, C. (2020). Can access to health care mitigate the effects of temperature on mortality? *Journal of Public Economics* 191: 104259.

Parry, M., Parry, M. L., Canziani, O., Palutikof, J., Linden, P. Van der, Hanson, C. et al. (2007). *Climate change 2007-impacts, adaptation and vulnerability: Working group II contribution to the fourth assessment report of the IPCC*, *4*. Cambridge University Press.

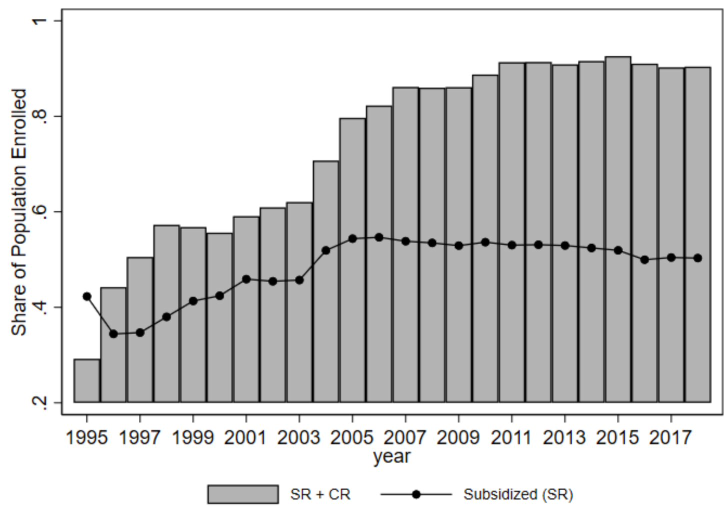
Pinto, D. M. (2008). Colombia: good practices in expanding health care coverage. *Good Practices in Health Financing* : 137.

White, C. (2017). The dynamic relationship between temperature and morbidity. *Journal of the Association of Environmental and Resource Economists* 4: 1155–1198.

Yu, X., Lei, X. and Wang, M. (2019). Temperature effects on mortality and household adaptation: Evidence from china. *Journal of Environmental Economics and Management* 96: 195–212.

Appendix: Additional Figures and Tables

Figure A1: Health system coverage: overall and by regime



Notes: Share of the population covered by either contributory (CR) or subsidized (SR) regime per year depicted in bars. Share of population covered in subsidized regime represented by the solid line.

Table A1: Cumulative dynamic impacts of temperature on all-cause mortality in high elevation municipalities

	Monthly Mortality Rate per 100,000		
	(Contemporaneous)	(Dynamic 5 Months)	(Dynamic 9 Months)
Base Temperature: $\in$ [23C,25C) [73F,77F)			
Temperature < 17	0.162***	0.298***	-0.031
	(0.046)	(0.067)	(0.155)
Temperature $\in$ [19,21)	0.045	0.060	-0.012
	(0.036)	(0.039)	(0.077)
Temperature $\in$ [21,23)	0.024	0.043	0.010
	(0.027)	(0.033)	(0.055)
Temperature ≥ 25	0.130***	0.330**	0.178
	(0.039)	(0.107)	(0.178)
25th Precipitation Pctile	0.008	-0.168	0.313
	(0.100)	(0.303)	(0.473)
75th Precipitation Pctile	0.074	0.576**	1.166***
	(0.102)	(0.246)	(0.320)
Observations	228,960	228,920	228,880
Mortality Rate	40.28		
SD Mortality Rate	18.86		
Municipality FE	Yes	Yes	Yes
Municipality $\times$ Month FE	No	No	No
Municipality $\times$ Year FE	Yes	Yes	Yes
Year $\times$ Month FE	Yes	Yes	Yes

Notes: Each column corresponds to a separate regression. The header indicate the number of lags included in the model. Standard errors clustered at the municipality level reported in parenthesis. All regressions are weighted by population. ***p-value < 0.001, **p-value < 0.01, *p-value < 0.05.

Table A2: Cumulative dynamic impacts of temperature on all-cause mortality in low elevation municipalities

	Monthly Mortality Rate per 100,000		
	(Contemporaneous)	(Dynamic 5 Months)	(Dynamic 9 Months)
Base Temperature: ∈ [23C,25C) [73F,77F)			
Temperature < 23	-0.010	-0.032	0.052
	(0.027)	(0.040)	(0.095)
Temperature ∈ [25,27)	0.044**	0.039	0.084
	(0.017)	(0.031)	(0.064)
Temperature ≥ 27	0.045*	0.125**	0.241**
	(0.025)	(0.063)	(0.119)
25th Precipitation Pctile	-0.298**	-0.752*	-0.574
	(0.133)	(0.396)	(0.726)
75th Precipitation Pctile	-0.068	-0.159	0.827
	(0.153)	(0.375)	(0.568)
Observations	72,696	72,668	72,640
Mortality Rate	28.84		
SD Mortality Rate	20.03		
Municipality FE	Yes	Yes	Yes
Municipality × Month FE	No	No	No
Municipality × Year FE	Yes	Yes	Yes
Year × Month FE	Yes	Yes	Yes

Notes: Each column corresponds to a separate regression. The header indicate the number of lags included in the model. Standard errors clustered at the municipality level reported in parenthesis. All regressions are weighted by population. ***p-value < 0.001, **p-value < 0.01, *p-value < 0.05.

Table A3: Cumulative dynamic impacts of temperature on all-cause mortality by age group

	Monthly Mortality Rate per 100,000									
	(0-4)	(5-9)	(10-19)	(20-29)	(30-39)	(40-49)	(50-59)	(60-69)	(70-79)	(80+)
Base: ∈ [23C,25C) [73F,77F)										
Temperature < 17	0.068	0.012	0.105**	0.024	0.077	0.076	0.039	0.207	1.806***	9.522***
	(0.140)	(0.022)	(0.045)	(0.054)	(0.050)	(0.073)	(0.098)	(0.250)	(0.540)	(1.954)
Temperature ∈ [17,19)	-0.095	-0.025*	0.040	-0.024	0.038	0.007	-0.046	0.068	0.823**	5.517***
	(0.108)	(0.013)	(0.024)	(0.042)	(0.042)	(0.044)	(0.067)	(0.195)	(0.410)	(1.471)
Temperature ∈ [19,21)	-0.079	-0.027**	0.022	-0.006	0.026	-0.028	-0.045	0.051	0.259	3.104**
	(0.089)	(0.011)	(0.020)	(0.038)	(0.035)	(0.039)	(0.059)	(0.167)	(0.313)	(1.271)
Temperature ∈ [21,23)	-0.116*	-0.008	0.014	0.042	0.053	-0.005	-0.028	0.058	-0.021	1.445
	(0.065)	(0.010)	(0.018)	(0.031)	(0.032)	(0.033)	(0.047)	(0.152)	(0.246)	(1.071)
Temperature ∈ [25,27)	0.097*	0.028**	-0.002	0.059*	0.111***	0.018	0.030	0.269*	0.108	1.224
	(0.051)	(0.012)	(0.016)	(0.033)	(0.032)	(0.039)	(0.066)	(0.162)	(0.361)	(0.954)
Temperature ≥ 27	0.345**	0.029**	-0.016	0.052	0.132***	0.017	0.064	0.563***	0.778	4.901**
	(0.122)	(0.012)	(0.017)	(0.041)	(0.039)	(0.041)	(0.089)	(0.169)	(0.538)	(1.706)
25th Precipitation Pctile	-0.314	-0.202**	-0.217	0.044	-0.045	-0.214	-1.529**	0.086	-4.154	2.158
	(0.485)	(0.101)	(0.183)	(0.332)	(0.274)	(0.329)	(0.581)	(1.067)	(2.664)	(6.913)
75th Precipitation Pctile	-0.175	0.137	0.011	0.994***	0.318	0.105	0.539	1.157	-0.347	9.776
	(0.458)	(0.094)	(0.140)	(0.245)	(0.246)	(0.278)	(0.425)	(1.012)	(1.845)	(6.150)
Observations	304,536	304,536	304,536	304,536	304,536	304,536	304,536	304,536	304,416	304,368
Mean Mortality Rate	26.05	2.47	8.20	16.96	17.45	22.98	45.12	105.12	249.45	778.89
SD Mortality Rate	27.95	7.24	13.05	21.76	20.09	23.41	39.46	79.58	169.87	520.39
Municipality × Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year × Month FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Notes: Each column corresponds to a separate regression using four lags in the model. The header indicates the age group. Standard errors clustered at the municipality level reported in parenthesis. All regressions control for precipitation and are weighted by population. . ***p-value < 0.001, **p-value < 0.01, *p-value < 0.05. Ages 40-59 not reported in the interest of space.

Table A4: Cumulative dynamic impacts of temperature on specific-cause mortality for age group 0-4

	Monthly Mortality Rate per 100,000						
	(Infectious)	(Respiratory)	(Cardio)	(Neoplasms)	(Homicides)	(Accidents)	(Suicides)
Base: $\in$ [23C,25C) [73F,77F)							
Temperature $<$ 17	-0.078**	-0.080	0.033**	-0.023**	0.002	0.026	-0.001
	(0.034)	(0.065)	(0.013)	(0.012)	(0.008)	(0.027)	(0.001)
Temperature $\in$ [17,19)	-0.072**	-0.061	0.017*	-0.015*	0.006	0.045**	0.000
	(0.027)	(0.040)	(0.010)	(0.008)	(0.006)	(0.018)	(0.001)
Temperature $\in$ [19,21)	-0.058**	-0.038*	0.017**	-0.006	0.004	0.034**	0.000
	(0.020)	(0.022)	(0.008)	(0.007)	(0.005)	(0.016)	(0.001)
Temperature $\in$ [21,23)	-0.040**	-0.023	0.002	-0.008**	0.002	0.001	0.000
	(0.016)	(0.019)	(0.006)	(0.004)	(0.004)	(0.013)	(0.000)
Temperature $\in$ [25,27)	0.038**	0.050**	-0.006	-0.003	-0.001	-0.021	0.000
	(0.018)	(0.018)	(0.005)	(0.004)	(0.004)	(0.013)	(0.000)
Temperature $\geq$ 27	0.132***	0.095**	-0.005	0.003	0.004	-0.010	0.000
	(0.038)	(0.030)	(0.005)	(0.005)	(0.004)	(0.015)	(0.000)
25th Precipitation Pctile	0.256*	-0.001	0.072	-0.105*	0.005	0.096	-0.001
	(0.148)	(0.188)	(0.061)	(0.062)	(0.039)	(0.163)	(0.004)
75th Precipitation Pctile	0.042	0.108	-0.025	0.046	-0.011	-0.044	-0.001
	(0.113)	(0.154)	(0.051)	(0.052)	(0.036)	(0.119)	(0.002)
Observations	304,536	304,536	304,536	304,536	304,536	304,536	304,536
Mean Mortality Rate							
SD Mortality Rate							
Municipality $\times$ Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year $\times$ Month FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Notes: Each column corresponds to a separate regression using four lags in the model. Standard errors clustered at the municipality level reported in parenthesis. All regressions control for precipitation and are weighted by population. . ***p-value $<$ 0.001, **p-value $<$ 0.01, *p-value $<$ 0.05.

Table A5: Cumulative dynamic impacts of temperature on specific-cause mortality for age group 80+

	Monthly Mortality Rate per 100,000						
	(Infectious)	(Respiratory)	(Cardio)	(Neoplasms)	(Homicides)	(Accidents)	(Suicides)
Base: $\in$ [23C,25C) [73F,77F)							
Temperature < 17	0.122	0.794	3.272**	-0.599	-0.122	0.679**	-0.065
	(0.224)	(0.781)	(1.419)	(0.618)	(0.354)	(0.299)	(0.060)
Temperature $\in$ [17,19)	0.037	0.513	2.127**	-0.527	-0.040	0.366	-0.059
	(0.179)	(0.524)	(1.026)	(0.535)	(0.332)	(0.234)	(0.049)
Temperature $\in$ [19,21)	0.023	0.146	0.797	-0.455	-0.112	0.312	-0.061
	(0.160)	(0.505)	(0.863)	(0.453)	(0.311)	(0.203)	(0.044)
Temperature $\in$ [21,23)	-0.117	0.001	-0.208	-0.328	0.126	0.229	-0.046
	(0.137)	(0.446)	(0.721)	(0.426)	(0.286)	(0.140)	(0.037)
Temperature $\in$ [25,27)	0.001	0.693*	-0.303	0.002	-0.083	0.044	-0.076**
	(0.167)	(0.379)	(0.747)	(0.310)	(0.247)	(0.149)	(0.035)
Temperature ≥ 27	0.235	3.267***	1.801*	0.656*	0.015	0.024	-0.030
	(0.196)	(0.744)	(0.939)	(0.341)	(0.260)	(0.175)	(0.038)
25th Precipitation Pctile	1.809*	2.339	1.236	-3.790	-1.213	-1.443	-0.107
	(1.050)	(4.151)	(6.433)	(2.489)	(1.457)	(1.504)	(0.295)
75th Precipitation Pctile	1.268	-1.202	5.841	2.197	-0.281	1.541	0.136
	(0.952)	(4.112)	(4.747)	(2.342)	(0.994)	(0.964)	(0.196)
Observations	304,368	304,368	304,368	304,368	304,368	304,368	304,368
Mean Mortality Rate							
SD Mortality Rate							
Municipality $\times$ Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year $\times$ Month FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Notes: Each column corresponds to a separate regression using four lags in the model. Standard errors clustered at the municipality level reported in parenthesis. All regressions control for precipitation and are weighted by population. . ***p-value < 0.001, **p-value < 0.01, *p-value < 0.05.