Mortality, Temperature, and Public Adaptation Policy: Evidence from Italy

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Abstract

In 2004, Italy introduced a national program to prevent and tackle heat-related health risks. This initiative includes public awareness campaigns, the establishment of heat-wave warning systems, and the implementation of hospital protocols, among other measures. By leveraging administrative mortality data and a Difference-in-Differences-in-Temperature (DiDiT) approach, this paper shows that, on average, the policy has mitigated the effect of hot temperatures (days above 30 °C) by more than 57%. A key contribution to the policy's success pertains to the behavioural responses triggered by the implementation of the Heat Health Watch Warning Systems (HHWWS). By employing a staggered Difference-in-Differences-in-Temperature (DiDiT) approach, we find that the HHWWS led to a significant reduction in excess mortality (-22%) due to daily average temperatures exceeding 30 °C among treated provinces, compared to both not-yet and never-treated provinces. The effectiveness of the warning system becomes particularly pronounced after the third year of its implementation. Importantly, this mitigating effect remains robust even when considering the penetration of air conditioning. Our findings underscore the crucial role of public adaptation policies in coping with the increasing risk of heat stress.

JEL Classification: Q54, Q58, H510

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1 Introduction

A growing number of evidence has shown the harmful impact of exposure to extreme temperatures on excess mortality across several countries and settings. Climate change has already been identified as one of the prominent threats to health in the coming decades (Lancet, 2009), with the rising frequency, intensity and length of temperature shock episodes triggering the risk of mortality.

The related economic consequences are considerable and recent analyses suggest that mortality due to extreme heat will represent one of the primary contributors of climate change damages (Carleton et al., 2022; Hsiang et al., 2017) and a leading driver of the social cost of carbon (EPA, 2022; Carleton and Greenstone, 2022). Carleton and Greenstone (2022) estimate that, under a high-emissions scenario, climate change will globally increase the average mortality risk by approximately 3.2% of GDP by 2100, net of the inclusion of adaptation benefits and costs. Besides, the distribution of damages is uneven across countries with different underlined climates (Carleton and Greenstone, 2022), rural and urban areas (Burgess et al., 2014) and are particularly pointed towards vulnerable categories. Due to physiological constraints in the ability to regulate body temperature, exposure to heat stress can be remarkably detrimental for individuals with pre-existing health conditions, the elderly and children (Deschenes, 2014; Banerjee and Maharaj, 2020; Heutel et al., 2021). This implies that the consequences of climate change can interact with other structural changes such as the ageing of the population, present in most developed countries including Italy, leading to unprecedentedly high damages.

This paper examines the evolution of the relationship between hot temperatures and mortality in Italy over the last three decades, focusing on the role played by a public adaptation policy in mitigating heat-related deaths. First, we explore the causal impact of temperature on monthly provincial mortality and its trend over time, leveraging reasonably exogenous random weather shocks. By employing mortality data from the Italian National Institute of Statistics (ISTAT) at the province-monthly level from 1992 to 2019, we study the changes over time in the effect of temperature on mortality, benefiting from extensive spatial and temporal disaggregation over a significant number of years. We find that an additional day with a temperature exceeding 30 °C increases by 0.0187 the deaths per 1,000 inhabitants compared to a day with a reference temperature between 10 and 15 °C.

Our findings reveal that although total excess mortality due to heat exposure has increased over time, the impact of extreme hot temperatures has decreased when controlling for the shift in age structure. This implies that the rise in total mortality is explained by a composition effect in the population, while the decreasing trend in the estimated effect of temperature indicates an increased adaptive capacity.

Second, we link this exogenous temperature variation with the implementation of a national program against heat waves, to investigate the policy effectiveness in reducing heat-related excess mortality. The national program for the prevention of heat health effects initiated in 2004 has been implemented by the Department of Civil Protection and the Ministry of Health. The plan envisages various actions targeting both the response of health care system and raising public awareness. Key measures include implementing a national mortality surveillance system, heat health watch warning systems (HHWWS) for the 27 large Italian cities, public information campaigns, targeted health interventions for vulnerable groups, specialized training for social and healthcare services, the establishment of emergency protocols in health centers, and a nationwide helpline offering advice on minimizing health risks during heat waves. We rely on a Difference-in-Differences-in-temperature (DiDiT) approach to identify how the adoption of this plan modified the temperature-mortality relationship. Specifically, we combine temporal variation before and after the policy with plausibly exogenous variation in daily average temperature, while keeping constant potential confounding factors at the monthly and province level that are correlated with the policy and might have modified the temperature-mortality relationship. We so retrieve its causal effect.

We find that the reduced effect of extreme heat on mortality can be largely attributed to the successful national adaptation plan against heat. On average, the policy has mitigated the adverse impact of hot temperatures (days above 30 °C) by approximately 57% compared to the pre-policy period. Moreover, the effectiveness of the plan persists and even slightly increases over time, with the reduction in heat-related mortality rising from 38% in the initial phase (2004-2010) to 46% during the full implementation period (2011-2019) compared to the pre-policy year.

Finally, we examine the role of behavioural responses prompted by the adaptation plan, to which the implementation of the HHWWS has likely made a significant contribution.

This system, deployed in 27 major Italian cities, provides daily risk-level information from May to September and plays a crucial role in raising public awareness. To assess the impact of these warnings on reducing excess mortality caused by extreme heat, we employ a Staggered Difference-in-Differences-in-Temperature (DiDiT) strategy. This approach leverages the gradual inclusion of cities in the system, comparing treated provinces to those not yet treated and those never treated. This variation is then again combined with quasi-exogenous variation in daily average temperature while allowing for time-invariant differences in the temperature-mortality relationship across provinces, and unit-invariant differences in the temperature-mortality relationship over years. We so account for any unobserved changes in the temperature-mortality relationship due to confounders correlated with the policy at the province and yearly level.

Our results suggest that treated provinces experience approximately a 22% reduction in the adverse effects of extreme temperatures, compared to those not yet treated or never treated, relative to the pre-implementation period.

Our paper makes several significant contributions to the study of the impacts of extreme temperatures. First, it directly speaks to the literature on temperature and mortality, providing new causal estimates of heat damage in Italy. While most of the studies show evidence for the United States (Deschenes and Moretti, 2009; Deschênes and Greenstone, 2011; Barreca, 2012; Barreca et al., 2015, 2016; Heutel et al., 2021; Mullins and White, 2020), only a few focused on developing countries (Burgess et al., 2014; Cohen and Dechezleprêtre, 2022; Yu et al., 2019) and Europe (Adélaïde et al., 2022; Masiero et al., 2022). Moreover, Italy faces both a rapidly ageing population and significant exposure to climate change, making it a particularly compelling case study at the intersection of these two challenges.

Second, we provide the analysis of a national heat action plan, which embraces the possibility of exploring the potential of public adaptation in mitigating the impact of extreme temperatures. This represents a substantial novelty. Despite its study has been acknowledged as a priority for the global research agenda for this century (Organization et al., 2009), the role of adaptation in the temperature-mortality relationship remains underexplored in the literature, with only a limited number of studies addressing it (Deschenes, 2014). Some attempts focused on the regional differences in adaptation, exploiting cross-sectional variation (Heutel et al., 2021; Barreca et al., 2015). The most significant contributions relates to residential energy consumption (Deschênes and Greenstone, 2011; Barreca, 2012) and air-conditioning adoption (Barreca et al., 2016). Additionally, a few studies have investigated the role of changes in health care access, provision and organization (Barreca et al., 2016; Mullins and White, 2020; Cohen and Dechezleprêtre, 2022). Finally, geographical mobility (Deschenes and Moretti, 2009) and the allocation of time (Graff Zivin and Neidell, 2014) have been examined as adaptive responses to extreme temperature exposure. To the best of our knowledge, no studies have examined the impact of a national adaptation plan against extreme heat. This presents a remarkable opportunity to gain insights into the role of public adaptation in mitigating mortality from extreme temperatures.

Moreover, our findings shed light on the impact of early warning systems, evaluating their effectiveness in prompting behavioural changes among individuals. Previous work has investigated their role in preventing exposure to pollution (Barwick et al., 2024), and recently few studies focused on the warnings related to heat risk (Rabassa et al., 2021). These studies found a tangible impact in modifying individuals' behaviours, leading to avoidance of outdoor exposure or activities and increased spending on protective products. Our study makes a step forward in this direction by evaluating the benefits of reduced mortality attributable to these behavioral changes.

Finally, we contribute to the literature on the role of the policy environment to mediate or emphasize climate impacts on socio-economic outcomes (Mullins and White, 2020; Cohen and Dechezleprêtre, 2022; Colmer and Doleac, 2023; Pavanello and Zappalà, 2024). In line with this literature, we employ a methodology combining exogenous variation in daily temperatures and a Difference-in-Difference design of a policy intervention. However, differently from these studies, we focus on a policy that directly targets temperature exposure.

The remainder of the paper is organized as follows. Section 2 provides background on the policy. Section 3 presents the data, while Section 3.4 offers key descriptive statistics. Section 4 outlines the empirical strategy and presents the results on the mortality-temperature relationship. Section 5 discusses the empirical approach used to assess the policy's impact and reports the main findings. This is followed by the analysis of behavioural responses to the implementation of the HHWWS in Section 6. Finally, Section 7 concludes with a summary of the main results and an outline of the next steps for the further development of this paper.

2 Background

The Mediterranean area is highly vulnerable to heat waves (Michelozzi et al., 2007) due to a combination of population susceptibility and extreme weather events. During the recent heat wave hitting Europe in the summer of 2022, Italy recorded the highest heat-related mortality rates, with approximately 18,010 deaths (Ballester et al., 2023). In particular, it reported the highest number of deaths among European countries for individuals aged 65–79 and those 80 years and older.

This evidence intersects with the demographic trend that Italy experienced in the last decades, characterised by a substantial ageing process. In Italy, people aged 65 and over were approximately 8% of the total population in 1951. However, in recent years, despite the large mortality caused by COVID-19, this share has more than tripled, reaching approximately 24% by 2023 and pushing the average population age to 46.4 years (Tomassini and Lamura, 2009; ISTAT, 2023). Demographic projections forecast a 35% increase in the proportion of elderly above 80 in the next two decades, raising the total amount to 6 million individuals. Italy is not alone in experiencing this sharp increase in its elderly population; similar trends are observed in other Southern European countries such as Portugal, Spain, and Greece.

Overall, the demographic shift raises many concerns about the increase in health expenditure in these countries and poses a substantial challenge to the sustainability of the national health system (Lopreite and Mauro, 2017). The increased exposure due to climate change, combined with the heightened susceptibility of the population from demographic shifts, will raise overall vulnerability.

2.1 The national plan for preventing the health effects of heat

As a response to the dramatic consequences of the heat wave in 2003, the Department of Civil Protection and the Ministry of Health adopted in 2004 a national plan aimed to prevent the health effects of heat. The plan is organised into multiple actions aimed at reducing excess mortality caused by heat (De'Donato et al., 2018). These measures can be summarised into three main categories: preventive actions, monitoring actions, and response actions.

First, the **preventive actions** encompass a comprehensive set of initiatives designed to inform the population about heat risk and recommend actions to prevent health consequences, thereby raising general awareness. Disseminating advice on heat stress risks and protective behaviours is pursued through the promotion of information campaigns. At a national level, campaigns act via the main mass media, while at the local level through direct communications on local authorities' websites and informative flyers to elderly care centres, public spaces, local pharmacies, health centres, and General Practitioners (GPs). Moreover, a dedicated heat helpline can be reached to receive information on preventive measures and the availability of local services. Some adaptation measures were also implemented, including increased adoption of air-conditioning in health and social centres. Access to these facilities has been extended during heatwaves to provide a refuge from the heat. One key preventive initiative was the realization of the Heat Health Watch Warning System (HHWWS), which issues daily risk levels for major Italian cities during the summer months. This system helps inform the public and local authorities about heatwave occurrences and alerts the healthcare system to put in place prompt response actions.

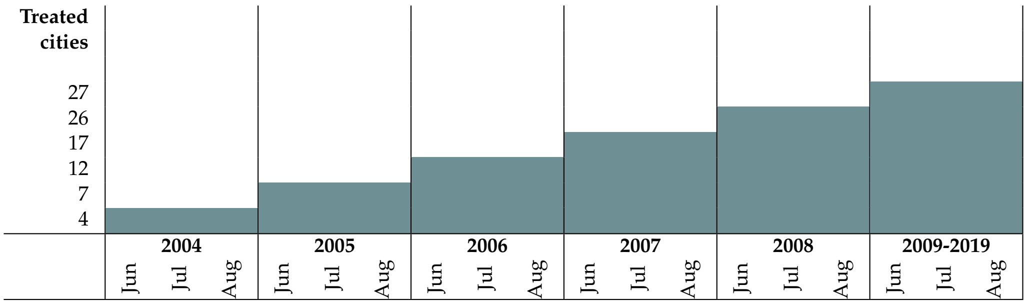
Then, **monitoring actions** were arranged to collect information on the mortality trend and identify the most susceptible individuals and their distribution on the territory. This is possible, first, via the health information providing details on hospitalisation records, drug prescriptions and socio-economic conditions. Then, GPs or social workers are entitled to carry out questionnaires to spot further risky conditions. Trained caregivers operate in the network of community services to monitor the more vulnerable individuals. To this, it adds the action of volunteers and social workers in performing telemonitoring, carrying out phone calls to elderly patients recorded as frail. Finally, GPs raised their surveillance through phone calls and home visits addressed to the most vulnerable patients. This involvement is voluntary and reaches approximately 30% of the GPs. Overall, while the socio-demographic and health characteristics used to classify vulnerable individuals are consistent across Italy, the above-discussed practices vary by region, leading to some degree of heterogeneity in the registries of susceptible individuals.

Finally, **emergency response actions** were designed to strengthen the healthcare system's capacity to deal with prolonged and extreme heat. These measures, activated when the warning signals level 2 or 3, aim to enhance the operational efficiency in hospitals, nursing homes and social structures, through a better organisation of the resources available during heat waves. Key actions include increasing staff in the emergency department or critical wards (intensive care units, geriatrics, etc.), redistributing available beds, rescheduling non-urgent admissions and surgeries, and revising the discharge planning. Additionally, there is an increased supply of medication and water, and at-risk patients are moved to air-conditioned areas. Public places with cooling facilities remain open to protect during peak heat periods. In addition, prior to the state of emergency, educational activities (seminars/workshops, dissemination of thematic guidelines, meetings, etc.) were organised to improve social and health workers' abilities related to heat wave emergencies.

2.2 Heat Health Watch Warning System (HHWWS)

Among the main actions implemented, the National Plan for Preventing the Health Effects of Heat established the launch of the Heat Health Watch Warning System (HHWWS) managed by the Lazio Region Department of Epidemiology. This system introduced daily warnings for the largest Italian cities between May and September. Each city is assigned a daily risk level ranging from 0 to 3, where 0 indicates no risk for the population, 1 indicates conditions that may precede the occurrence of a heatwave, 2 indicates the presence of a risk mainly for highly vulnerable individuals, and 3 indicates a prolonged risk situation for the entire population lasting more than two days. Italy was one of the pioneering countries in Europe to adopt HHWWS following the 2003 heatwave. Unlike other countries relying on fixed temperature thresholds, Italy's city-specific HHWWS incorporates local climate characteristics, adaptation levels and population vulnerabilities. This is achieved through an assignment of the bulletin based on a retrospective analysis of the relationship between mortality and weather conditions (air temperature, dew point temperature, atmospheric pressure, wind speed, and direction) to identify circumstances associated with a significant increase in mortality rates (for more details on the methodology, see Michelozzi et al. (2010)). Moreover, centralized coordination and a robust information network are crucial in the effective spreading of warning bulletins, enhancing heat health prevention strategies (Michelozzi et al., 2010). The daily bulletins are published on the Italian Department of Civil Protection and the Ministry of Health websites. Moreover, local centres are promptly informed of the daily risk level and are responsible for taking action and disseminating information within the territory are expressly notified of the daily risk level.

Table 1: Timeline of the Implementation of the Heat Health Watch Warning System (HH-WWS) in Italian Cities



New Cities Covered by the HHWWS:

2004: Rome, Milan, Turin, Bologna;
2005: Brescia, Genoa, Palermo;
2006: Bari, Catania, Florence, Naples, Venice;
2007: Cagliari, Campobasso, Pescara, Trieste, Verona;
2008: Bolzano, Perugia, Viterbo, Rieti, Civitavecchia, Frosinone, Latina, Reggio Calabria, Messina.
2009: Ancona.

Cities are included in the HHWWS and daily mortality surveillance system based on specific criteria. This includes large cities (>500,000 inhabitants) and medium-large cities (200,000-500,000 inhabitants). Additionally, regional capitals with populations under 200,000 inhabitants are also targeted. Currently, 27 cities are covered by the national HHWWS. In addition, another 7 cities are monitored by a daily mortality surveillance system. Among these, 5 are regional capitals (Aosta, Catanzaro, L'Aquila, Potenza, Trento) and the remaining 2 are cities with populations exceeding 200,000 (Padua, Taranto). The HHWWS was implemented gradually across the 27 cities. Table 1 provides an overview of the cities covered by the HHWWS and the respective entry years into the program. When including also the cities under the surveillance system without HHWWS, the number increases to 34, encompassing all municipalities with over 250,000 inhabitants and reaching 21.3% of the Italian population aged 65 or above.

3 Data

In this section, we first provide an overview of the data employed in this study and their sources. To conduct our analysis, we combine administrative data on the number of deaths at the province-level with high-quality weather information. We also obtain data on age shares, air-conditioning ownership and GDP per capita. We conclude with key descriptive analyses that offer relevant insights into the main characteristics of our data.

3.1 Mortality rates

Data on deaths are supplied by ISTAT, providing nearly 30 years of monthly data at the provincial level. This includes the number of deaths reported to the civil registry offices in the municipality where the event occurred. Additionally, complementary information is available, such as the gender of the deceased individuals and the cause of death. Our main dependent variable is the mortality rate per 1000 people. Mortality rates are computed at the province-monthly level using annual resident population data for the provinces, also sourced from ISTAT. In cases where provinces underwent administrative changes, we aggregate the information at the broader administrative area affected by the variation.

3.2 Weather

We process weather data from the ERA5-Land reanalysis product Muñoz Sabater et al. (2019), which provides hourly temperature and precipitation from 1950 to present at a 0.1° spatial resolution (about 11km). We combine weather data with 15 arc-seconds population CIESIN (2018) to compute the province-level population-weighted daily average temperature and total precipitation.

3.3 Additional data

We enrich our final data set with further information obtained from various sources.

Age-specific population shares. Using population data from ISTAT we also construct province-level population shares for four age groups (0-1, 2-24, 25-64, and ≥ 65) for the years 1992-2019.

Ownership of air-conditioning. We obtain annual information on residential air-conditioning ownership for the period 1997-2019 at the NUTS1 level from ISTAT.[1] This data are obtained aggregating at the most disaggregated level household information from the Italian Household Budget Survey (HBS).

[1] NUTS1 divides Italy in five macro-regions: North-West, North-East, Center, South, and Isles

Income. We gather annual NUTS3[2] data on GDP at costant prices from the ARDECO database of the EUROSTAT for the years 1992-2019. GDP is measured in Million EUR2015. We then divide by population to obtain province-level GDP per capita.

3.4 Descriptive statistics

After data collection and processing, the final dataset includes 104,040 observations across 106 provinces. As shown in Table 2, the average mortality rate in the full sample is 0.826 per 1,000 individuals, with a slight increase observed between the pre-policy and post-policy periods. Similarly, the average temperature rose from 13.70 °C before 2003 to 13.96 °C in the following period. This temperature increase might be one of the drivers of the rise in mortality, along with the growing proportion of older individuals in the population, particularly those aged 25-64 and 65 and older. Conversely, the population among younger age groups experienced a decreasing trend.

Table 2 also provides descriptive statistics for other key control variables, such as GDP per capita and air conditioning penetration. Note that data on air conditioning are only available from 1997 onward, resulting in fewer observations. The average GDP per capita is 60,258.91 (EUR2015 PPP), while the average air conditioning penetration rate is 0.267. Both variables show an upward trend over time, with air conditioning penetration experiencing a particularly sharp increase, nearly tripling between the two periods.

4 The temperature-mortality relationship in Italy

4.1 Empirical framework

We start identifying the causal effect of temperature on mortality by leveraging plausibly exogenous weather shocks at the provincial level, specifically daily fluctuations in temperature relative to the underlying local climate. To achieve this, we define and estimate the baseline relationship between temperature and mortality as follows:

$$Y_{imy} = \alpha + \beta\, f(T)_{imy} + \gamma\, g(P)_{imy} + \mathbf{X}_{imy}\boldsymbol{\lambda} + \mu_{im} + \theta_{r(i)y} + \delta_{my} + \varepsilon_{imy} \tag{1}$$

[2]For Italy NUTS3 corresponds to provinces.

Table 2: Descriptive statistics

	Full Sample			Pre-policy Sample			Post-policy Sample		
	Obs.	Mean	SD	Obs.	Mean	SD	Obs.	Mean	SD
Outcome Variable									
Mortality rate	104040	0.826	0.175	43632	0.813	0.193	60408	0.835	0.160
Climate Variables									
Daily Avg. Temperature	104040	13.653	7.145	43632	13.489	7.089	60408	13.771	7.182
Days Avg. Temp $\geq$ 30 °C	104040	0.0355	0.377	43632	0.028	0.329	60408	0.0408	0.397
Daily Avg. Precipitation	104040	0.686	1.250	43632	1.069	1.321	60408	0.412	1.119
Control Variables									
% Pop. (age: 0-1)	104040	0.903	0.158	43632	0.937	0.189	60408	0.879	0.127
% Pop. (age: 2-24)	104040	24.678	4.591	43632	27.978	4.294	60408	22.316	3.098
% Pop. (age: 25-64)	104040	53.280	2.401	43632	51.995	2.569	60408	54.199	1.773
% Pop. (age: $\geq$ 65)	104040	21.138	3.654	43632	19.090	3.333	60408	22.605	3.132
GDP per capita	104040	60258.910	56547.070	43632	50216.050	47402.170	60408	67447.380	61271.310
Air-conditioning	86364	0.267	0.143	25956	0.100	0.058	60408	0.337	0.105

Notes: Mortality rates are calculated per 1,000 individuals, with all statistics weighted by population size.

where Y_{imy} is the all-age mortality rate in 1,000s of province i in month m and year y; $\mathbf{X}_{imy}$ is a vector of annual province-level shares of population in three age group (0-1, 2-24, and $\geq$ 65) interacted with month dummies;[3] μ_{im}, $\theta_{r(i)y}$, δ_{my} are respectively province-month, region-year and month-year fixed-effects; ε_{imy} is the error term. Standard errors are two-way clustered at the province and month-year level.

In Equation 1, $f(T)_{imy}$ and $g(P)_{imy}$ are some function of daily average temperature and total precipitation in a province i in month m and year y. In our baseline specification we model temperature non-parametrically using ten 5-degree temperature bins, obtained counting the number of days in a month in each temperature interval. The omitted bin is the interval 10-15 °C.[4] As for precipitation, we model it by the means of a second-order polynomial in all our specification. All regressions are weighted by the average population for the period 1992-2003.

4.2 Results: Declining impact of temperature on mortality over time

Main results. In this section, we present the results based on the baseline specification defined in Equation 1. We estimate the mortality-temperature relationship for three samples:

[3] The excluded age group is 25-64.

[4] We also estimate models (i) including only the extreme cold and hot bins, < -10 °C and $\geq$ 30 °C,[5], (ii) including only the warmer bins ($20-24$°C, $25-29$°C, and $\geq$ 30 °C), (iii) using polynomials up to the third degree, (iv) using maximum daily temperature, and (v) using relative measures of temperature.

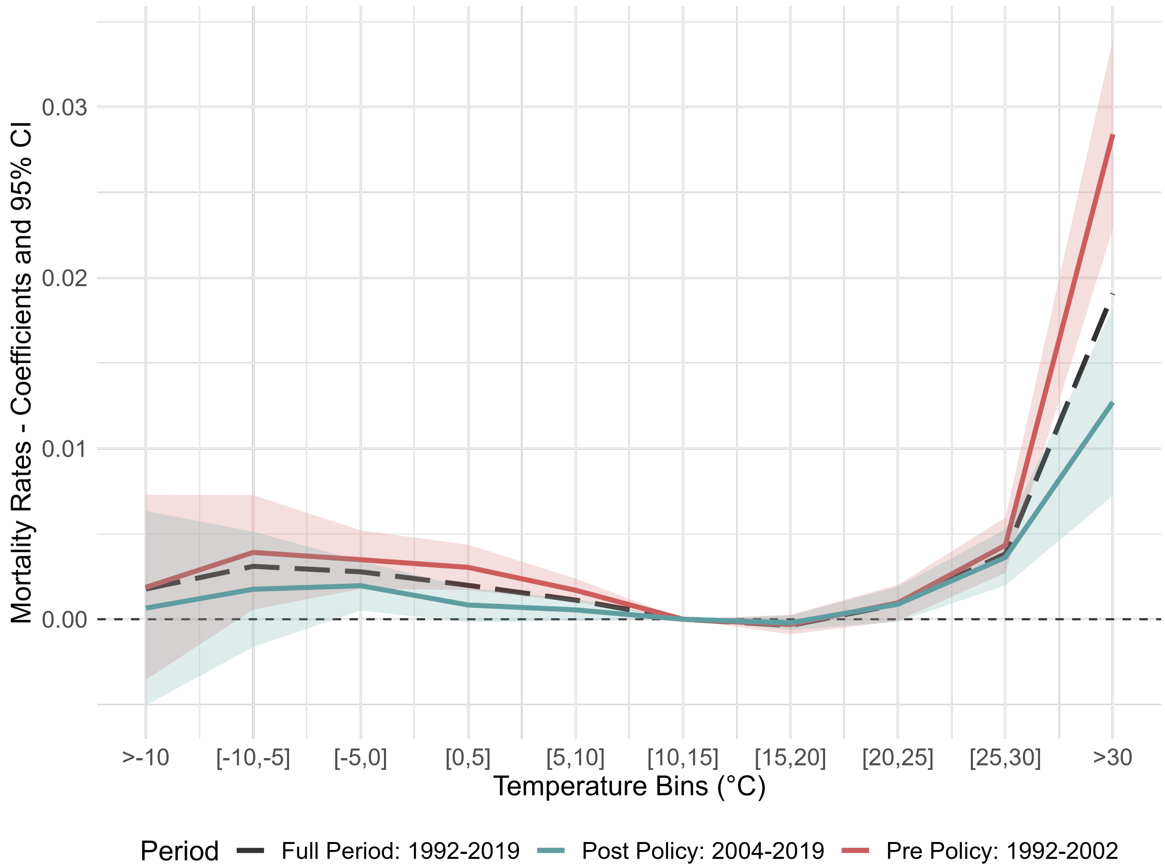


Figure 1: Temperature-mortality estimates for the pre- and post-policy periods

the full, the pre-policy and the post-policy ones. Figure 1 represents the results along the distribution of the bins. Detailed estimates are presented in the related Tables A1 and A2 in Appendix A.

We observe the well-documented U-shaped relationship between temperature and mortality. However, the impact of high temperatures is more consistently robust across specifications and exhibits a larger magnitude compared to that of cold temperatures. Specifically, temperatures exceeding 25 °C have a positive and significant effect on mortality. For each additional day with an average temperature above 30 °C, the mortality rate increases by 0.0189 deaths per 1,000 individuals, which corresponds to an approximate 2% increase. This result remains robust across different specifications.

Table A3 contextualizes the results by comparing the estimates with previous studies on both developed and developing countries. We find that the overall effect for Italy is substantially larger than the estimates reported by Barreca et al. (2016) for the United States and

Burgess et al. (2017) for India. Although Italy has higher air conditioning (AC) penetration rates compared to India, its older population likely drives the higher estimated impact.

The red and blue lines in Figure 1 represent estimates for the pre-policy and post-policy periods, respectively. The results reveal a considerable difference starting at temperatures above 25°C, with the gap widening at temperatures exceeding 30 °C. This indicates a substantial reduction in the impact of high temperatures in the period following 2004.

The temporal evolution depicted in Figure 2 provides a clearer perspective on the trends observed. The red line and corresponding points illustrate the estimates and their 95% confidence intervals for a rolling 7-year window centred on each indicated year. The relationship between temperature and mortality diminishes over time, with a notable decline occurring particularly after the policy implementation. On the bottom part of the same Figure, the vertical bars (light beige) represent the 7-year rolling average of the yearly total number of days with temperatures exceeding 30 °C. A comparison of these two trends reveals that the observed reduction in the relationship between temperature and mortality cannot be attributed to a decrease in exposure to high temperatures.

Robustness checks. To ensure the validity of our baseline results, we conduct several robustness checks by testing the specification with alternative temperature measures. Specifically, Table B1 in Appendix B presents the results for both the full sample and the split sample, using average temperature percentiles as regressors. In addition, Table B2 shows the results for the analogous specification testing for maximum temperature bins. Results are consistent with the baseline specification using absolute average temperature thresholds.

5 The implementation of the national adaptation plan against heat stress

5.1 Empirical framework

Equation 1 establishes the baseline relationship between temperature and mortality, suggesting that temperature's effect on mortality decreased after 2004. Building on this, we now estimate the mitigation effect of the 2004 policy on this adverse effect of temperature.

Conceptually, our empirical approach is to estimate a Difference-in-Difference (DiD) de-

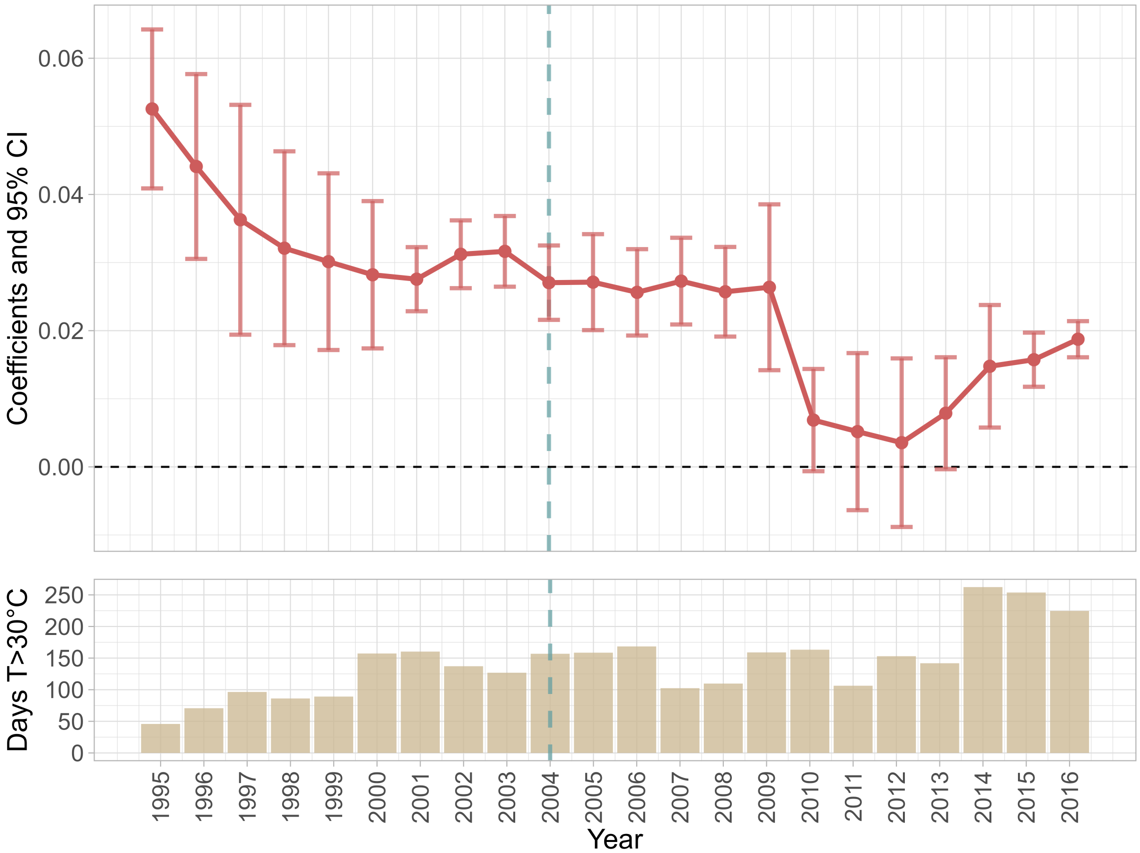


Figure 2: 7-Year rolling sample estimates

sign for the effect of the national program on the temperature-mortality relationship. Since the policy was implemented nationally, our estimates are derived from identifying changes in the temperature-mortality relationship before and after the program's introduction.

The first approach is to estimate a simple interaction model, also defined as Difference-in-Temperature (DiT) (Colmer and Doleac, 2023). That is, we modify Equation 1 as it follows:

$$
\begin{aligned}
Y_{imy} = \alpha + \beta f(T)_{imy} + \pi f(T)_{imy} \times D_t + \gamma g(P)_{imy} + \mathbf{X}_{imy}\boldsymbol{\lambda} + \\
\mu_{im} + \theta_{r(i)y} + \delta_{my} + \varepsilon_{imy}
\end{aligned}
\tag{2}
$$

where D_t is a binary indicator equal to 1 after 2004.[6] At this stage, we focus on the upper tail of the temperature distribution. Specifically, we estimate a more parsimonious model that

[6] Notice that the coefficient related to the uninteracted term of D_t would be omitted because of the collinearity with the fixed effects. For this reason, we do not include it in Equation 2

includes only the three highest temperature bins as regressors, as these are most directly affected by the policy introduction. The results remain robust when the full temperature distribution is included.

To make π the causal mitigation effect of the policy the key assumption is that no other unobserved policies or time-invariant and time-varying local factors, which are correlated with the policy itself, also moderate the temperature-mortality relationship. However, it is unlikely that this assumption holds in the DiT setting, as other policies, such as shock to the public health expenditure, might have influenced the effect of temperature on mortality.

To solve the identification problem in the DiT specification, we rely on a Difference-in-Differences-in-Temperature (DiDiT) specification (Colmer and Doleac, 2023; Pavanello and Zappalà, 2024; Mullins and White, 2020). This consists of flexibly modelling temperature over time and space such that the potential confounders are kept fixed over time. To illustrate it, we modify Equation 2 as follows:

$$\begin{aligned} Y_{imy} = \pi f(T)_{imy} \times D_t + \gamma g(P)_{imy} + \mathbf{X}_{imy}\boldsymbol{\lambda} + \\ \eta_i f(T)_{imy} + \phi_m f(T)_{imy} + \mu_{im} + \theta_{r(i)y} + \delta_{my} + \varepsilon_{imy} \end{aligned} \tag{3}$$

where $\eta_i f(T)_{imy}$ and $\phi_m f(T)_{imy}$ indicate that we allow temperature to vary across provinces and month.[7] In this way, we can isolate the causal effect of the policy, while controlling for other potential unobservables that changes the temperature-mortality relationship. In additional regressions, we also let temperature-mortality relationship vary before and after the summer 2003 heatwave. This is because the event has changed public perception of the health risks related to heat stress. Finally, an important drawback of this analysis is that at this stage we are not controlling for regional air-conditioning penetration. The policy included informative campaign measures that aimed at making the population more aware of the risks related to heat stress. This makes air-conditioning a bad control in our regression, since the policy itself likely induced an increase in air-conditioning adoption. For this reason, we are going to interpret our coefficient as a gross effect of the policy, which however do not distinguish for the role of private adaptation. Moreover, to control for potential better adaptation opportunities, such as air-conditioning, we include in $\mathbf{X}$ province-level annual

[7] We also test for allowing temperature effect varying across summers rather than month.

GDP per capita interacted with month indicators.

The identifying assumption is that in the absence of treatment, trends in the temperature-mortality relationship would have not changed. We provide indirect tests of this assumption. Specifically, we estimate binned event studies. Furthermore, notice that the national plan to address the health impacts of heat waves was introduced in 2004, with a more stringent phase starting in 2011. Hence, the binned event study allows to assess the dynamic effects of the policy over time.

5.2 Results: policy effectiveness in reducing heat-related mortality

Initial results. Our results are displayed in Figure 3, and exact point estimates are summarized in Table C1 and Table C2 in Appendix C. In panel (a), we observe the results of the DiDiT estimation. The policy successfully decreases by -0.0137 the deaths per 1,000 individuals, mitigating the 57% of the adverse effects of temperatures exceeding 30 °C compared to the pre-policy period. As shown in Table C1, it also effectively reduced the impact of temperatures between 20-25°C and 25-30 °C by 43% and 39%, respectively.

Dynamic effects. Panels (b) and (c) of Figure 3 present the results of the binned event study, accounting for dynamic effects. Panel (b) compares the pre- and post-policy periods with the year prior to implementation, while panel (c) distinguishes between two post-implementation phases: the initial phase in 2004 and the full implementation phase from 2011 to 2019, estimating their effects separately. Results are detailed in Table C2 in Appendix C.

A key observation from both specifications is the absence of any pre-trend for the hottest temperature bin ($T \geq 30$ °C), while the policy's effect is evident in significantly reducing the temperature's impact. Furthermore, when examining the policy's effectiveness across the two phases of implementation, we observe a stronger impact during the second phase, which aligns with expectations given the more stringent measures introduced during this period. Specifically, we find that the policy resulted in a 38% reduction in the negative impacts of exposure to temperatures above 30 °C, with this mitigating effect increasing to 46% after 2011.

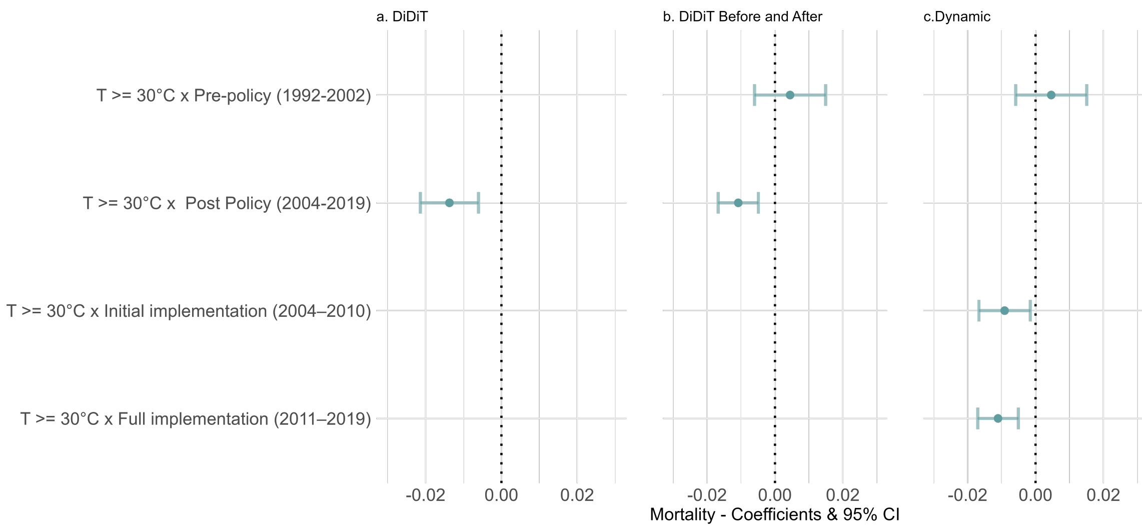


Figure 3: The Dynamic Impact of the 2004 National Plan (DiDiT)

Robustness checks. We explore alternative model specifications by using temperature bins based on percentiles and maximum temperatures. The results using average temperature percentiles as regressors are presented in Appendix D, Table D1, while those using maximum temperature bins are found in Table D2. These robustness checks confirm the consistency and reliability of the policy impact findings across different temperature measures.

6 The role of the Heat Health Watch Warning Systems

Previous section show that the 2004 policy against extreme heat was effective at reducing heat-related mortality. The next step is to understand how the policy was able to reduce such impact. To do, we consider the set of measures included in the policy. First, we estimate the mitigation effect of the introduction of heat wave warning systems in 27 major Italian cities.

6.1 Empirical framework

We start restricting our sample only to the provinces were the province capital is part of the program.[8] These cities have been indeed specifically selected for the program based

[8]Data at the province level are not available for Civitavecchia since it is not a province but a municipality (comune). However, Civitavecchia is part of the province of Rome, and so it is indirectly included in the analysis. We consider Civitavecchia treated at the same time of Rome.

on population figures and weather conditions. To identify the effect of the introduction of the heatwave warning systems, we exploit the staggered roll-out of this measure across province capitals. Our baseline specification is a difference-in-difference-temperature regression (DiDiT) that looks as follows:

$$
\begin{aligned}
Y_{imy} = {} & \beta f(T)_{imy} + \pi f(T)_{imy} \times H_{iy} + \psi H_{iy} + \gamma g(P)_{imy} + \mathbf{X}_{imy}\boldsymbol{\lambda} + \\
& \eta_i f(T)_{imy} + \phi_y f(T)_{imy} + \mathrm{AC}_{ny} \times f(T)_{imy} + \\
& \mu_{im} + \theta_{r(i)y} + \delta_{my} + \varepsilon_{imy}
\end{aligned}
\tag{4}
$$

where our coefficient of interest is π, and H_{iy} is a binary indicator equal to 1 when in province i and year y a heatwave warning system is fully operational. The remaining of the equation is identical to 3. Equation 4 then allows to identify the effect of the policy comparing treated units with not yet treated units. To make π causal, we allow for fixed differences in the effect of temperature across the provinces and years. In addition, we control for the interaction between temperature and NUTS1-level air-conditioning penetration, $\mathrm{AC}_{ny} \times f(T)_{imy}$. In this way, we aim to isolate the effect of the introduction of the heatwave warning systems from private adaptation (i.e. AC). Air conditioning (AC) ownership represents a significant investment due to its relatively high cost and the time required for installation, making it a long-term decision rather than a short-term reaction. This suggests that AC adoption is more likely influenced by broader efforts to raise awareness and educate the public — key components of the overall policy — rather than the immediate response triggered by the heat warning systems. The warnings are, indeed, expected to prompt short-term behavioural changes, such as modifying time spent outdoors and adopting precautionary measures. However, we cannot entirely dismiss the possibility that the introduction of the early warning system indirectly contributed to the rise in AC ownership, a factor that could confound our analysis (often referred to as a "bad control"). It is important to note that when we control for air-conditioning the time span is reduced, and it covers the period 1997-2019.

After having included all these controls, the identifying assumption in Equation 4 is that in the absence of treatment, trends in the temperature-mortality relationship would have been similar in provinces where HHWWS were implemented in different years. We again provide indirect tests of this assumption, estimating binned event studies. This also allows to evaluate the dynamic effects of the HHWWS implementation.

Finally, we provide robustness checks where we include both treated and not treated units. With respect to Equation 4 we substitute the interaction between temperature and province indicators with the interaction between temperature and a treated unit indicator, $\eta_t \times f(T)_{imy}$. This resembles the approach used by Mullins and White (2020). In this case, the identifying assumption is less restricted: in the absence of the treatment, trends in the temperature-mortality relationship would have been similar in counties where HHWWS were implemented in different years or not at all.

Although HHWWS is implemented at the city level, we adopt the province level for treatment assignment due to the spatial disaggregation constraints in our data. This approach also addresses potential spatial spillovers across different areas. To accurately estimate the causal effect of HHWWS, the Stable Unit Treatment Value Assumption (SUTVA) must hold. SUTVA assumes that the treatment has no impact on non-treated units, meaning that the outcomes for non-treated areas are not influenced by the treatment assigned to treated areas. Given the likelihood of heat alerts spreading beyond city boundaries — due to similar weather conditions, population mobility within provinces and sources of information — we cannot fully rule out such spillovers. Therefore, defining treatment at the provincial level helps to mitigate these potential cross-boundary influences.

6.2 Results: the mitigation effect of HHWWS

Initial results. Panel (a) of Figure 4 highlights the key findings on the impact of Heat Health Warning Systems (HHWWS) implementation by comparing provinces that have received the treatment with those that have not yet been treated (but will be in the future). Detailed results are presented in Table E1 in Appendix E. Each column in the table reports estimates from the Difference-in-Differences-in-Temperature (DiDiT) model, which accounts for variations in the temperature-mortality relationship across different years and provinces.

In Panel (a) of Figure 4, we observe no significant effect of HHWWS in reducing mortality from temperatures exceeding 30 °C in treated cities, compared to those not yet treated. However, as indicated in columns (1) and (2) of Table E1, we do detect a significant effect of HHWWS at lower temperature ranges, specifically between 20–25 °C and 25–30 °C.

It is important to emphasise that these results reflect average effects and do not capture

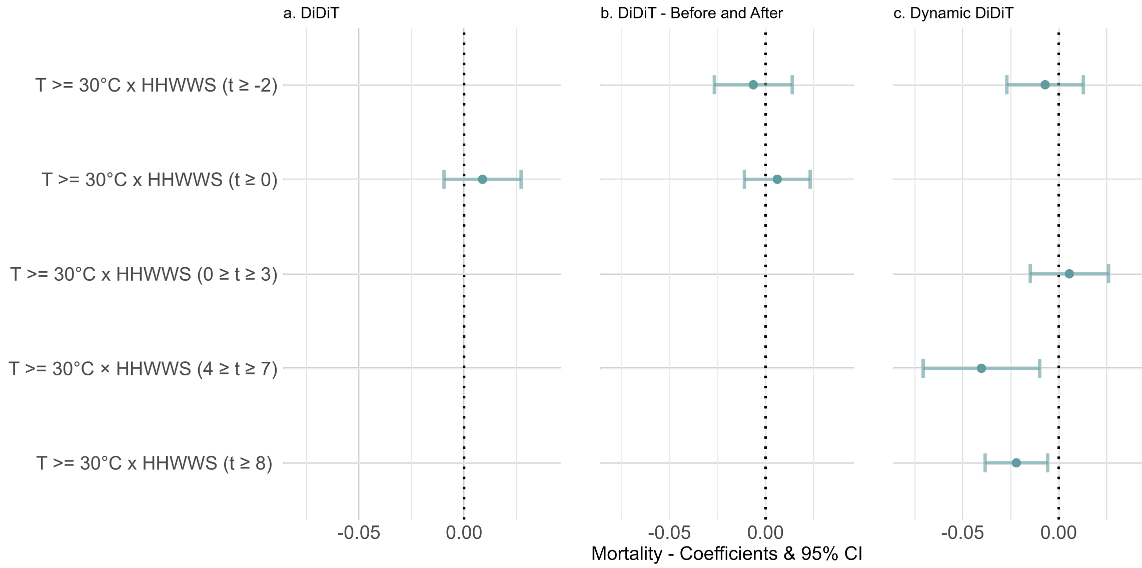


Figure 4: The Dynamic Impact of the HHWWS (DiDiT) - Treated VS Not-yet Treated Provinces

potential variations in the policy's impact over time. The subsequent analysis will explore the dynamic nature of the policy's effectiveness, offering a more detailed understanding of its evolving impact.

Dynamic effects. The dynamic effects of HHWWS (Heat Health Warning Systems) implementation are illustrated in Panels (b) and (c) of Figure 4, with detailed results provided in columns (3) to (6) of Table E1 in Appendix E. Panel (b) compares the year immediately preceding the implementation of HHWWS to both the pre-implementation and post-implementation periods. In this comparison, while no statistically significant effects of HHWWS are observed in reducing the adverse impact of temperatures above 30 °C, we do observe a mediating effect for temperatures in the range of 25–30 °C.

In Panel (c), we extend the analysis by comparing the year before HHWWS implementation to the pre-implementation period, this time using a binned post-implementation period divided into three intervals: $0 \leq t \leq 3$, $4 \leq t \leq 7$, and $t \geq 8$ years. When analyzing the evolution of HHWWS implementation, we find a statistically significant reduction in mortality rates associated with temperatures above 30 °C. Notably, this effect emerges only after a delay, becoming significant from the third year after implementation. Specifically, between the 4th and 7th years post-implementation, HHWWS reduces mortality from exposure to temperatures above 30 °C by approximately 104% compared to the pre-implementation period.

This effect remains significant in the long term, corresponding to a 57% mediating effect.

Including non-treated cities. Up to this point, we have assessed the impact of Heat Health Warning Systems (HHWWS) by comparing provinces that have been treated with those that have not yet implemented the system. To further strengthen the validity of our results, we conduct a robustness check that includes both not-yet-treated and never-treated provinces. This expanded approach allows us to compare treated provinces against both these groups. The results are derived from estimates of the Difference-in-Differences-in-Temperature (DiDiT) model, which accounts for variations in the temperature-mortality relationship across different years, as well as differences between treated and untreated provinces.

Figure 5 illustrates these findings, which are detailed in Table E2 in Appendix E. As in previous analyses, panel (a) shows the comparison between the pre and post-treatment periods. In this case, we observe a significant effect of the HHWWS in mitigating the negative impact of temperatures exceeding 30 °C in treated provinces, compared to those that were not yet or never treated. This translates to an approximate 22% reduction in the adverse effects relative to the period before the warning system was implemented. Additionally, the HHWWS shows a significant mediating effect on temperatures in the 20-25 °C, confirming the findings from the comparison with the not-yet-treated provinces.

The dynamic model results, presented in columns (3) to (4) of Table E2, compare the pre and post-early warning system implementation with the year before its introduction. These results highlight the effectiveness of the HHWWS in mitigating the adverse effects of temperatures across all temperature bins above 20°C. As shown in Figure 5 panel (c), the full dynamics reveal that the system's impact becomes significant after the third year of implementation, achieving a 70% reduction in the effect of temperatures exceeding 30 °C compared to the pre-treatment period. Although this effect decreases to a 24% reduction in later years, it remains persistent. These findings confirm that similar to the comparison with not-yet-treated provinces, the impact of the warning system materializes with a certain delay. Overall, we find that the effectiveness of the HHWWS remains robust when comparing treated units not only with those yet to be treated but also with never-treated units. In fact, this comparison allows for an even clearer identification of the early warning system's impact.

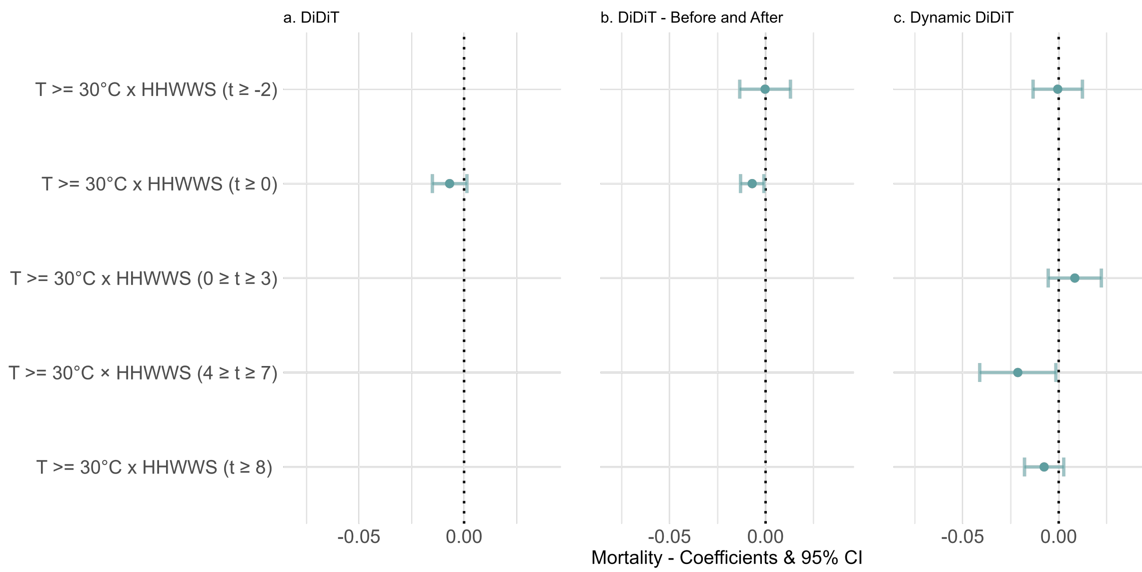


Figure 5: The Dynamic Impact of the HHWWS (DiDiT) - Treated VS Not-yet and Never-Treated Provinces

7 Discussion and conclusions

The main contribution of this paper is to assess the effectiveness of Italy's national heat prevention plan, implemented in 2004, in reducing heat-related mortality. Using provincial-level administrative data spanning from 1992 to 2019 with monthly frequency, we apply a Difference-in-Difference-in-Temperature (DiDiT) approach to estimate the causal impact of the policy on the temperature-mortality relationship.

Our baseline analysis reveals that temperature has a significant impact on mortality, and the effect is not negligible compared to other developed and developing countries. Specifically, we find that each additional day with temperatures exceeding 30 °C results in an average increase of 0.0189 deaths by 1,000 inhabitants. This substantial effect can largely be attributed to Italy's ageing population, a key factor contributing to the country's vulnerability to climate change. To address these health risks, a national heat adaptation plan was introduced in 2004. Our findings indicate that the plan successfully reduced excess mortality caused by temperatures over 30 °C by more than 57% and its effect has been persistent over time.

To understand the drivers behind this reduction, we focus on the role of the Heat Health Watch Warning System (HHWWS). This warning system, implemented in different phases across 27 Italian cities, was designed to trigger avoidance behavioural responses among the public. Our results show that provinces with HHWWS experienced a significant reduction in the mortality impact of temperatures exceeding 30 °C, starting from the third year of implementation, with the effect lasting over time. In particular, treated provinces experienced a 22% reduction in the adverse effect of temperatures above 30 °C compared to the not-yet and never-treated provinces following the implementation of the system.

This paper makes a novel contribution by demonstrating how public policies aimed at heat adaptation can significantly mitigate the health impacts of climate change, thereby preventing societal well-being. We plan to extend this research by exploring additional mechanisms through which the policy may have mediated the severe consequences of heat. First, we intend to evaluate the role of healthcare improvements, using data on emergency department visits, in driving the policy's effectiveness. Additionally, we will further investigate how the policy might have fuelled private adaptation, particularly through the increased penetration of air conditioning, which we have already accounted for. Moreover, we aim to assess the impact of the policy on individuals' perceptions of climate change and related health risks. Finally, we will complement HHWWS analysis with descriptive studies on how the policy shaped avoidance behaviours in more detail, including a closer look at individuals' time use patterns.

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Appendices

A Additional results - Baseline

Table A1: The baseline temperature and mortality relationship

	Mortality rate (in 1,000s)				
	(1)	(2)	(3)	(4)	(5)
$T_{AVG} < -10$ °C	0.00742*	0.00955**	0.00230	0.00198	0.00191
	(0.004)	(0.004)	(0.002)	(0.002)	(0.002)
$T_{AVG} \in [-10, -5)$ °C	0.00824***	0.0104***	0.00258***	0.00244***	0.00244***
	(0.003)	(0.003)	(0.001)	(0.001)	(0.001)
$T_{AVG} \in [-5, 0)$ °C	0.00619***	0.00803***	0.00271***	0.00262***	0.00246***
	(0.002)	(0.002)	(0.001)	(0.001)	(0.001)
$T_{AVG} \in [0, 5)$ °C	0.00404***	0.00537***	0.00201***	0.00190***	0.00187***
	(0.001)	(0.001)	(0.000)	(0.000)	(0.000)
$T_{AVG} \in [5, 10)$ °C	0.00176***	0.00253***	0.00102***	0.00106***	0.00103***
	(0.001)	(0.000)	(0.000)	(0.000)	(0.000)
$T_{AVG} \in [15, 20)$ °C	-0.000964**	-0.000954***	-0.000339**	-0.000430***	-0.000382**
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
$T_{AVG} \in [20, 25)$ °C	0.000297	-0.000449	0.000944***	0.000838**	0.000888**
	(0.001)	(0.001)	(0.000)	(0.000)	(0.000)
$T_{AVG} \in [25, 30)$ °C	0.00668***	0.00458***	0.00387***	0.00374***	0.00387***
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
$T_{AVG} \geq 30$ °C	0.0247***	0.0196***	0.0190***	0.0188***	0.0185***
	(0.003)	(0.004)	(0.003)	(0.003)	(0.003)
Precipitation controls	Yes	Yes	Yes	Yes	Yes
Province-Month FE	Yes	Yes	Yes	Yes	Yes
Region-Year FE	No	Yes	Yes	Yes	Yes
Month-Year FE	No	No	Yes	Yes	Yes
Pop. share × Month	No	No	No	Yes	Yes
Log income × Month	No	No	No	No	Yes
Mean Outcome	0.827	0.827	0.827	0.827	0.827
Observations	34680	34680	34680	34680	34680

Notes: The dependent variable is the number of deaths per 1,000 people (mortality rate). The estimated period is 1992-2019. The reference category for temperature is bin 10-15 °C. Standard errors are two-way clustered at the province and month-year level. * ($p < 0.10$), ** ($p < 0.05$), *** ($p < 0.01$). All regressions are weighted by province population.

Table A2: The baseline temperature and mortality relationship

	Mortality rate (in 1,000s)							
	Pre-Policy: 1992-2002				Post-Policy: 2004-2019			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
$T_{AVG} < -10$ °C	0.00753*	0.00851*	0.00179	0.00170	0.00726	0.00982*	0.00136	0.00136
	(0.004)	(0.004)	(0.002)	(0.002)	(0.005)	(0.005)	(0.002)	(0.002)
$T_{AVG} \in [-10, -5)$ °C	0.00972***	0.0113***	0.00310**	0.00348***	0.00737*	0.00974**	0.00145	0.00120
	(0.003)	(0.003)	(0.001)	(0.001)	(0.004)	(0.004)	(0.001)	(0.001)
$T_{AVG} \in [-5, 0)$ °C	0.00804***	0.00893***	0.00333***	0.00340***	0.00558*	0.00773***	0.00206***	0.00193***
	(0.002)	(0.002)	(0.001)	(0.001)	(0.003)	(0.003)	(0.001)	(0.001)
$T_{AVG} \in [0, 5)$ °C	0.00600***	0.00643***	0.00288***	0.00283***	0.00297**	0.00458***	0.00113**	0.000970*
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
$T_{AVG} \in [5, 10)$ °C	0.00296***	0.00322***	0.00157***	0.00159***	0.00121*	0.00200***	0.000552	0.000570*
	(0.001)	(0.001)	(0.000)	(0.000)	(0.001)	(0.001)	(0.000)	(0.000)
$T_{AVG} \in [15, 20)$ °C	-0.00145***	-0.00148**	-0.000341	-0.000367	-0.000395	-0.000691*	-0.000254	-0.000288
	(0.001)	(0.001)	(0.000)	(0.000)	(0.001)	(0.000)	(0.000)	(0.000)
$T_{AVG} \in [20, 25)$ °C	-0.000181	-0.000667	0.000919	0.000925	0.00136*	-0.000434	0.000991*	0.000869*
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
$T_{AVG} \in [25, 30)$ °C	0.00751***	0.00647***	0.00456***	0.00422***	0.00647***	0.00338***	0.00364***	0.00363***
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
$T_{AVG} \geq 30$ °C	0.0335***	0.0301***	0.0302***	0.0268***	0.0205***	0.0147***	0.0131***	0.0130***
	(0.006)	(0.002)	(0.002)	(0.004)	(0.003)	(0.002)	(0.003)	(0.003)
Precipitation controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Province-Month FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Region-Year FE	No	Yes	Yes	Yes	No	Yes	Yes	Yes
Month-Year FE	No	No	Yes	Yes	No	No	Yes	Yes
Covariates × Month	No	No	No	Yes	No	No	No	Yes
Mean Outcome	0.814	0.814	0.814	0.814	0.837	0.837	0.837	0.837
Observations	14544	14544	14544	14544	20136	20136	20136	20136

Notes: The dependent variable is the number of deaths per 1,000 people (mortality rate). The estimated period is 1992-2019. The reference category for temperature is bin 10-15 °C. Covariates include the share of population by age groups interacted with the month indicator. Standard errors are two-way clustered at the province and month-year level. * ($p < 0.10$), ** ($p < 0.05$), *** ($p < 0.01$). All regressions are weighted by province population.

Table A3: Comparison of the mortality-temperature relationship estimates

Country	Period	Temp. Bin (°C)	Estimates	Life Expect.	AC Penetr.
United States (Barreca et al., 2016)	1960–2004	T > 32.2	0.0034	70-77	12-87%
India (Burgess et al., 2017)	1957-2000	T > 35	0.0074	45-63	0-7%
Italy (our study)	1992-2019	T > 30	0.021	81-83	10-40%

Notes: Estimates refer to the logarithmic transformation of mortality rates

B Robustness - Baseline

Tables B1 presents the results of estimating Equation 1 using average temperature percentiles as regressors. This table offers a robustness check of our main findings by exploiting relative temperature measures, with percentiles calculated based on the local (province-specific) temperature distribution. Table B2 presents the results for an additional robustness check by testing the baseline specification with the average maximum temperature bins as regressors.

Table B1: The baseline temperature and mortality relationship - Temperature percentiles

	Mortality rate (in 1,000s)					
	Pre-Policy: 1992-2002			Post-Policy: 2004-2019		
	(1)	(2)	(3)	(4)	(5)	(6)
$T_{AVG} < 5^{th}$ perc	0.00340***	0.00313***	0.00471***	0.00462***	0.00222***	0.00220***
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
$T_{AVG} 5^{th} - 10^{th}$ perc	0.00238***	0.00231***	0.00273***	0.00273***	0.00161***	0.00162***
	(0.000)	(0.000)	(0.001)	(0.001)	(0.000)	(0.000)
$T_{AVG} 10^{th} - 15^{th}$ perc	0.00150***	0.00123**	0.00254***	0.00235***	0.000396	0.000369
	(0.000)	(0.000)	(0.001)	(0.001)	(0.000)	(0.000)
$T_{AVG} 15^{th} - 20^{th}$ perc	0.00163***	0.00143***	0.00153**	0.00127**	0.00174***	0.00169***
	(0.000)	(0.000)	(0.001)	(0.001)	(0.000)	(0.000)
$T_{AVG} 25^{th} - 30^{th}$ perc	0.000579	0.000610*	0.000851	0.000902	0.000574	0.000549
	(0.000)	(0.000)	(0.001)	(0.001)	(0.001)	(0.001)
$T_{AVG} 30^{th} - 35^{th}$ perc	-0.0000860	-0.000209	0.000536	0.000493	-0.000364	-0.000348
	(0.000)	(0.000)	(0.001)	(0.001)	(0.000)	(0.000)
$T_{AVG} 70^{th} - 75^{th}$ perc	-0.000102	-0.000207	-0.000336	-0.000625*	0.000571	0.000591*
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
$T_{AVG} 75^{th} - 80^{th}$ perc	-0.000292	-0.000239	0.000148	0.000312	-0.000325	-0.000301
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
$T_{AVG} 80^{th} - 85^{th}$ perc	0.0000973	0.0000222	-0.0000950	-0.000450	0.000538	0.000491
	(0.000)	(0.000)	(0.001)	(0.001)	(0.000)	(0.000)
$T_{AVG} 85^{th} - 90^{th}$ perc	0.000554	0.000745*	0.000783	0.000953*	0.00109**	0.00111**
	(0.000)	(0.000)	(0.001)	(0.001)	(0.001)	(0.001)
$T_{AVG} 90^{th} - 95^{th}$ perc	0.00141***	0.00137***	0.00246***	0.00243***	0.00140**	0.00135**
	(0.000)	(0.000)	(0.001)	(0.001)	(0.001)	(0.001)
$T_{AVG} \geq 95^{th}$ perc	0.00600***	0.00602***	0.00737***	0.00727***	0.00547***	0.00543***
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Precipitation controls	Yes	Yes	Yes	Yes	Yes	Yes
Province-Month FE	Yes	Yes	Yes	Yes	Yes	Yes
Region-Year FE	No	Yes	Yes	Yes	Yes	Yes
Month-Year FE	No	No	Yes	Yes	Yes	Yes
Pop. share × Month	Yes	Yes	Yes	Yes	Yes	Yes
Log Income × Month	No	Yes	No	Yes	No	Yes
Mean Outcome	0.814	0.814	0.814	0.837	0.837	0.837
Observations	34680	34680	14544	14544	20136	20136

Notes: The dependent variable is the number of deaths per 1,000 people (mortality rate). The estimated period is 1992-2019 in columns 1-2, 1992-2002 in columns 3-4, and in 2004-2019 in columns 5-6. The reference category for temperature is bin 12-27 °C. Standard errors are two-way clustered at the province and month-year level. * ($p < 0.10$), ** ($p < 0.05$), *** ($p < 0.01$). All regressions are weighted by province population.

Table B2: The baseline temperature and mortality relationship - Maximum temperature

	Mortality rate (in 1,000s)					
	Pre-Policy: 1992-2002			Post-Policy: 2004-2019		
	(1)	(2)	(3)	(4)	(5)	(6)
$T_{MAX} < 0$ °C	0.00294***	0.00304***	0.00312**	0.00274*	0.00245**	0.00254**
	(0.001)	(0.001)	(0.002)	(0.002)	(0.001)	(0.001)
$T_{MAX} \in [0,3)$ °C	0.00202***	0.00208***	0.00299***	0.00343***	0.00124	0.00122
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
$T_{MAX} \in [3,6)$ °C	0.00172***	0.00180***	0.00161*	0.00148	0.00167***	0.00169***
	(0.000)	(0.001)	(0.001)	(0.001)	(0.001)	(0.000)
$T_{MAX} \in [6,9)$ °C	0.00140***	0.00148***	0.00214***	0.00221***	0.000717	0.000711
	(0.000)	(0.000)	(0.001)	(0.001)	(0.000)	(0.000)
$T_{MAX} \in [9,12)$ °C	0.000669**	0.000727**	0.000535	0.000605	0.000754**	0.000785**
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
$T_{MAX} \in [27,30)$ °C	0.00159***	0.00150***	0.00215***	0.00211***	0.00128***	0.00126***
	(0.000)	(0.000)	(0.001)	(0.001)	(0.000)	(0.000)
$T_{MAX} \in [30,33)$ °C	0.00313***	0.00311***	0.00428***	0.00426***	0.00258***	0.00262***
	(0.000)	(0.000)	(0.001)	(0.001)	(0.000)	(0.001)
$T_{MAX} \in [33,36)$ °C	0.00591***	0.00580***	0.00669***	0.00679***	0.00533***	0.00535***
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
$T_{MAX} \in [36,39)$ °C	0.0161***	0.0156***	0.0213***	0.0182***	0.0116***	0.0116***
	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)
$T_{MAX} \geq 39$ °C	0.0280***	0.0282***	0.0329***	0.0384***	0.0275***	0.0269***
	(0.005)	(0.006)	(0.009)	(0.013)	(0.004)	(0.004)
Precipitation controls	Yes	Yes	Yes	Yes	Yes	Yes
Province-Month FE	Yes	Yes	Yes	Yes	Yes	Yes
Region-Year FE	No	Yes	Yes	Yes	Yes	Yes
Month-Year FE	No	No	Yes	Yes	Yes	Yes
Pop. share × Month	Yes	Yes	Yes	Yes	Yes	Yes
Log Income × Month	No	Yes	No	Yes	No	Yes
Mean Outcome	0.814	0.814	0.814	0.837	0.837	0.837
Observations	34680	34680	14544	14544	20136	20136

Notes: The dependent variable is the number of deaths per 1,000 people (mortality rate). The estimated period is 1992-2019 in columns 1-2, 1992-2002 in columns 3-4, and in 2004-2019 in columns 5-6. The reference category for temperature is bin 12-27 °C. Standard errors are two-way clustered at the province and month-year level. * ($p < 0.10$), ** ($p < 0.05$), *** ($p < 0.01$). All regressions are weighted by province population.

C Additional results - Policy

Table C1: Mortality-temperature relationship and the impact of the 2004 national plan

	Mortality rate (in 1,000s)			
	Baseline	**Policy**		
		DiT	DiDiT	DiDiT
	(1)	(2)	(3)	(4)
$T_{AVG} \in [20, 25)$ °C	0.00135***	0.00175***		
	(0.000)	(0.000)		
$T_{AVG} \in [25, 30)$ °C	0.00437***	0.00555***		
	(0.001)	(0.001)		
$T_{AVG} \geq 30$ °C	0.0190***	0.0268***		
	(0.003)	(0.003)		
$T_{AVG} \in [20, 25)$ °C × Post (2004-2019)		-0.000737**	-0.000612*	-0.000620*
		(0.000)	(0.000)	(0.000)
$T_{AVG} \in [25, 30)$ °C × Post (2004-2019)		-0.00200***	-0.00191***	-0.00191***
		(0.001)	(0.001)	(0.001)
$T_{AVG} \geq 30$°C × Post (2004-2019)		-0.0123***	-0.0131***	-0.0137***
		(0.004)	(0.004)	(0.004)
Precipitation controls	Yes	Yes	Yes	Yes
Province-Month FE	Yes	Yes	Yes	Yes
Region-Year FE	Yes	Yes	Yes	Yes
Month-Year FE	Yes	Yes	Yes	Yes
Covariates × Month	Yes	Yes	Yes	Yes
Bins × Summer	No	No	Yes	No
Bins × Month	No	No	No	Yes
Bins × Province	No	No	Yes	Yes
Mean Outcome	0.827	0.827	0.827	0.827
Observations	34680	34680	34680	34680

Notes: The dependent variable is the number of deaths per 1,000 people (mortality rate). The estimated period is 1992-2019. The reference category for temperature is bin < 20 °C. Covariates include the share of population by age groups and province-level GDP per capita interacted with the month indicator. Standard errors are two-way clustered at the province and month-year level. * ($p < 0.10$), ** ($p < 0.05$), *** ($p < 0.01$). All regressions are weighted by province population.

Table C2: Mortality-temperature relationship and the impact of the 2004 national plan - Binned event study

	Mortality rate (in 1,000s)					
	DiT	DiDiT	DiDiT	DiT	DiDiT	DiDiT
	(1)	(2)	(3)	(4)	(5)	(6)
$T_{AVG} \in [25, 30)$°C × Pre (1992-2002)	0.000471	0.00116**	0.00128**	0.000473	0.00117**	0.00129**
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
$T_{AVG} \in [20, 25)$°C × Pre (1992-2002)	0.00208***	0.00104	0.00120*	0.00208***	0.00103	0.00118*
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
$T_{AVG} \geq 30$°C × Pre (1992-2002)	0.0101*	0.00533	0.00445	0.0101*	0.00567	0.00462
	(0.005)	(0.006)	(0.005)	(0.005)	(0.006)	(0.005)
$T_{AVG} \in [25, 30)$°C × Post (2004-2019)	-0.000298	0.000450	0.000557			
	(0.001)	(0.001)	(0.001)			
$T_{AVG} \in [20, 25)$°C × Post (2004-2019)	-0.000180	-0.000961	-0.000815			
	(0.001)	(0.001)	(0.001)			
$T_{AVG} \geq 30$°C × Post (2004-2019)	-0.00832***	-0.00982***	-0.0108***			
	(0.003)	(0.003)	(0.003)			
$T_{AVG} \in [25, 30)$°C × Initial Implementation (2004-2010)				0.0000438	0.000754	0.000862
				(0.001)	(0.001)	(0.001)
$T_{AVG} \in [20, 25)$°C × Initial Implementation (2004-2010)				-0.000204	-0.00112*	-0.000986
				(0.001)	(0.001)	(0.001)
$T_{AVG} \geq 30$°C × Initial Implementation (2004-2010)				-0.00207	-0.00672**	-0.00911**
				(0.004)	(0.003)	(0.004)
$T_{AVG} \in [25, 30)$°C × Full Implementation (2011-2019)				-0.000557	0.000244	0.000352
				(0.001)	(0.001)	(0.001)
$T_{AVG} \in [20, 25)$°C × Full Implementation (2011-2019)				-0.000271	-0.000907	-0.000741
				(0.001)	(0.001)	(0.001)
$T_{AVG} \geq 30$°C × Full Implementation (2011-2019)				-0.00981***	-0.0103***	-0.0110***
				(0.003)	(0.003)	(0.003)
Precipitation controls	Yes	Yes	Yes	Yes	Yes	Yes
Province-Month FE	Yes	Yes	Yes	Yes	Yes	Yes
Region-Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Month-Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Covariates × Month	Yes	Yes	Yes	Yes	Yes	Yes
Bins × Summer	No	Yes	No	No	Yes	No
Bins × Month	No	No	Yes	No	No	Yes
Bins × Province	No	Yes	Yes	No	Yes	Yes
Mean Outcome	0.827	0.827	0.827	0.827	0.827	0.827
Observations	34680	34680	34680	34680	34680	34680

Notes: The dependent variable is the number of deaths per 1,000 people (mortality rate). The estimated period is 1992-2019. The reference category for temperature is bin < 20 °C. Covariates include the share of population by age groups and province-level GDP per capita interacted with the month indicator. Standard errors are two-way clustered at the province and month-year level. * ($p < 0.10$), ** ($p < 0.05$), *** ($p < 0.01$). All regressions are weighted by province population.

D Robustness - Policy

Table D1 provides a robustness check for the policy results, estimating Equations 2 and 3 using average temperature percentiles as regressors. This approach offers additional validation by incorporating relative temperature measures based on local (province-specific) distributions. Similarly, Table D2 presents analogous results, this time using maximum temperature bins as the temperature variables. In both cases, the findings remain robust.

Table D1: Mortality-temperature relationship and the impact of the 2004 national plan - Temperature percentiles

	Mortality rate (in 1,000s)				
	Baseline	**Policy**			
		DiT	DiDiT	Dynamic DiT	Dynamic DiDiT
$T_{AVG}85^{th}-90^{th}$ perc	0.000846***	0.000936***		0.00232	
	(0.000)	(0.000)		(0.002)	
$T_{AVG}90^{th}-95^{th}$ perc	0.00145***	0.00232***		0.000254	
	(0.000)	(0.001)		(0.006)	
$T_{AVG}\geq 95^{th}$ perc	0.00611***	0.00760***		0.00857***	
	(0.001)	(0.001)		(0.003)	
$T_{AVG}85^{th}-90^{th}$ perc $\times$ Pre (1992-2002)				-0.00152	0.00182
				(0.002)	(0.002)
$T_{AVG}90^{th}-95^{th}$ perc $\times$ Pre (1992-2002)				0.00221	0.000925
				(0.006)	(0.005)
$T_{AVG}\geq 95^{th}$ perc $\times$ Pre (1992-2002)				-0.00126	-0.00230
				(0.003)	(0.003)
$T_{AVG}85^{th}-90^{th}$ perc $\times$ Post Policy (2004-2019)		-0.000228	0.0000901		
		(0.000)	(0.000)		
$T_{AVG}90^{th}-95^{th}$ perc $\times$ Post Policy (2004-2019)		-0.00139*	-0.00100		
		(0.001)	(0.001)		
$T_{AVG}\geq 95^{th}$ perc $\times$ Post Policy (2004-2019)		-0.00236***	-0.00274***		
		(0.001)	(0.001)		
$T_{AVG}85^{th}-90^{th}$ perc $\times$ Initial Implementation (2004-2010)				-0.00121	0.00248
				(0.002)	(0.002)
$T_{AVG}90^{th}-95^{th}$ perc $\times$ Initial Implementation (2004-2010)				0.00152	0.00103
				(0.006)	(0.005)
$T_{AVG}\geq 95^{th}$ perc $\times$ Initial Implementation (2004-2010)				-0.00331	-0.00445*
				(0.003)	(0.002)
$T_{AVG}85^{th}-90^{th}$ perc $\times$ Full Implementation (2011-2019)				-0.00177	0.00159
				(0.002)	(0.002)
$T_{AVG}90^{th}-95^{th}$ perc $\times$ Full Implementation (2011-2019)				0.000249	-0.000774
				(0.006)	(0.005)
$T_{AVG}\geq 95^{th}$ perc $\times$ Full Implementation (2011-2019)				-0.00326	-0.00478*
				(0.003)	(0.003)
Precipitation controls	Yes	Yes	Yes	Yes	Yes
Province-Month FE	Yes	Yes	Yes	Yes	Yes
Region-Year FE	Yes	Yes	Yes	Yes	Yes
Month-Year FE	Yes	Yes	Yes	Yes	Yes
Covariates $\times$ Month	Yes	Yes	Yes	Yes	Yes
Bins $\times$ Month	No	No	Yes	No	Yes
Bins $\times$ Province	No	No	Yes	No	Yes
Mean Outcome	0.857	0.857	0.857	0.857	0.857
Observations	34320	34320	34320	34320	34320

Notes: The dependent variable is the number of deaths per 1,000 people (mortality rate). The estimated period is 1992-2019. The reference category for temperature is bin < 20 °C. Covariates include the share of population by age groups interacted with the month indicator. Standard errors are clustered at the province and month-year level. * ($p < 0.10$), ** ($p < 0.05$), *** ($p < 0.01$). All regressions are weighted by province population.

Table D2: Mortality-temperature relationship and the impact of the 2004 national plan - Maximum temperatures

	Mortality rate (in 1,000s)				
	Baseline	**Policy**			
		DiT	DiDiT	Dynamic DiT	Dynamic DiDiT
$T_{MAX} \in [30, 33)$ °C	0.00238***	0.00386***		0.00212**	
	(0.000)	(0.000)		(0.001)	
$T_{MAX} \in [33, 36)$ °C	0.00448***	0.00474***		0.00210	
	(0.001)	(0.001)		(0.002)	
$T_{MAX} \geq 36$ °C	0.0146***	0.0194***		0.0195***	
	(0.002)	(0.002)		(0.002)	
$T_{MAX} \in [33, 36)$°C × Pre (1992-2002)				0.00182	0.00143
				(0.001)	(0.001)
$T_{MAX} \in [30, 33)$°C × Pre (1992-2002)				0.00409**	0.00164
				(0.002)	(0.001)
$T_{MAX} \geq 36$°C × Pre (1992-2002)				-0.000329	-0.00335
				(0.003)	(0.004)
$T_{MAX} \in [33, 36)$°C × Post (2004-2019)		-0.00237***	-0.00232***		
		(0.001)	(0.001)		
$T_{MAX} \in [30, 33)$°C × Post (2004-2019)		-0.000210	-0.000526		
		(0.001)	(0.001)		
$T_{MAX} \geq 36$°C × Post (2004-2019)		-0.00756***	-0.00671**		
		(0.002)	(0.003)		
$T_{MAX} \in [33, 36)$°C × Initial Implementation (2004-2010)				-0.000410	-0.000851
				(0.001)	(0.001)
$T_{MAX} \in [30, 33)$°C × Initial Implementation (2004-2010)				0.00229	0.000104
				(0.002)	(0.001)
$T_{MAX} \geq 36$°C × Initial Implementation (2004-2010)				-0.00742***	-0.0100***
				(0.002)	(0.003)
$T_{MAX} \in [33, 36)$°C × Full Implementation (2011-2019)				-0.000734	-0.00103
				(0.001)	(0.001)
$T_{MAX} \in [30, 33)$°C × Full Implementation (2011-2019)				0.00265	0.000813
				(0.002)	(0.001)
$T_{MAX} \geq 36$°C × Full Implementation (2011-2019)				-0.00749***	-0.00826**
				(0.002)	(0.004)
Precipitation controls	Yes	Yes	Yes	Yes	Yes
Province-Month FE	Yes	Yes	Yes	Yes	Yes
Region-Year FE	Yes	Yes	Yes	Yes	Yes
Month-Year FE	Yes	Yes	Yes	Yes	Yes
Pop. share × Month	Yes	Yes	Yes	Yes	Yes
Log Income × Month	Yes	Yes	Yes	Yes	Yes
Bins × Month	No	No	Yes	No	Yes
Bins × Province	No	No	Yes	No	Yes
Mean Outcome	0.857	0.857	0.857	0.857	0.857
Observations	34320	34320	34320	34320	34320

Notes: The dependent variable is the number of deaths per 1,000 people (mortality rate). The estimated period is 1992-2019. The reference category for temperature is bin < 20 °C. Covariates include the share of population by age groups interacted with the month indicator. Standard errors are clustered at the province and month-year level. * ($p < 0.10$), ** ($p < 0.05$), *** ($p < 0.01$). All regressions are weighted by province population.

E Additional results - HHWWS

Table E1: The mitigation effect of heat-wave warning systems - Not-yet Treated

	Mortality rate (in 1,000s)					
	Post		**Before and After**		**Dynamic**	
	DiDiT (1)	DiDiT (2)	DiDiT (3)	DiDiT (4)	DiDiT (5)	DiDiT (6)
$T_{AVG} \in [20, 25)$°C × HHWWS (t ≤ -2)			0.000122	0.0000431	0.000113	0.0000501
			(0.000)	(0.000)	(0.000)	(0.000)
$T_{AVG} \in [25, 30)$°C × HHWWS (t ≤ -2)			-0.000378	-0.000223	-0.000256	-0.000161
			(0.001)	(0.001)	(0.001)	(0.001)
$T_{AVG} \geq 30$°C × HHWWS (t ≥ -2)			-0.00335	-0.00639	-0.00426	-0.00707
			(0.010)	(0.010)	(0.009)	(0.010)
$T_{AVG} \in [20, 25)$°C × HHWWS (t ≥ 0)	-0.000695*	-0.000644*	-0.000633	-0.000615		
	(0.000)	(0.000)	(0.000)	(0.000)		
$T_{AVG} \in [25, 30)$°C × HHWWS (t ≥ 0)	-0.000831*	-0.00105**	-0.000946*	-0.00112**		
	(0.000)	(0.000)	(0.001)	(0.001)		
$T_{AVG} \geq 30$°C × HHWWS (t ≥ 0)	0.00681	0.00880	0.00476	0.00609		
	(0.009)	(0.009)	(0.008)	(0.008)		
$T_{AVG} \in [20, 25)$°C × HHWWS (0 ≥ t ≥ 3)					-0.000623	-0.000611
					(0.001)	(0.000)
$T_{AVG} \in [25, 30)$°C × HHWWS (0 ≥ t ≥ 3)					-0.00103**	-0.00118**
					(0.000)	(0.000)
$T_{AVG} \geq 30$°C × HHWWS (0 ≥ t ≥ 3)					0.00457	0.00556
					(0.009)	(0.010)
$T_{AVG} \in [20, 25)$°C × HHWWS (4 ≥ t ≥ 7)					-0.000738	-0.000850
					(0.001)	(0.001)
$T_{AVG} \in [25, 30)$°C × HHWWS (4 ≥ t ≥ 7)					-0.000959	-0.000685
					(0.001)	(0.001)
$T_{AVG} \geq 30$°C × HHWWS (4 ≥ t ≥ 7)					-0.0391***	-0.0402**
					(0.013)	(0.015)
$T_{AVG} \in [20, 25)$°C × HHWWS (t ≥ 8)					-0.000658	-0.000849
					(0.001)	(0.001)
$T_{AVG} \in [25, 30)$°C × HHWWS (t ≥ 8)					-0.00182**	-0.00133
					(0.001)	(0.001)
$T_{AVG} \geq 30$°C × HHWWS (t ≥ 8)					-0.0178**	-0.0220**
					(0.007)	(0.008)
Precipitation controls	Yes	Yes	Yes	Yes	Yes	Yes
Province-Month FE	Yes	Yes	Yes	Yes	Yes	Yes
Region-Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Month-Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Covariates × Month	Yes	Yes	Yes	Yes	Yes	Yes
Bins × Year	Yes	Yes	Yes	Yes	Yes	Yes
Bins × Province	Yes	Yes	Yes	Yes	Yes	Yes
Bins × AC	No	Yes	No	Yes	No	Yes
Mean Outcome	0.792	0.800	0.792	0.800	0.792	0.800
Observations	8736	7176	8736	7176	8736	7176

Notes: The dependent variable is the number of deaths per 1,000 people (mortality rate). The estimated period is 1992-2019. The reference category for temperature is bin < 20 °C. Covariates include the share of population by age groups and province-level GDP per capita interacted with the month indicator. Standard errors are two-way clustered at the province and month-year level. * ($p < 0.10$), ** ($p < 0.05$), *** ($p < 0.01$). All regressions are weighted by province population.

Table E2: The mitigation effect of heat-wave warning systems - Not-yet and Never Treated

	Mortality rate (in 1,000s)					
	Post		**Before and After**		**Dynamic**	
	DiDiT (1)	DiDiT (2)	DiDiT (3)	DiDiT (4)	DiDiT (5)	DiDiT (6)
$T_{AVG} \in [20, 25)$°C × HHWWS (t ≤ -2)			-0.0000366	-0.000144	-0.0000343	-0.000136
			(0.000)	(0.000)	(0.000)	(0.000)
$T_{AVG} \in [25, 30)$°C × HHWWS (t ≤ -2)			-0.000474	-0.000446	-0.000562*	-0.000535
			(0.000)	(0.000)	(0.000)	(0.000)
$T_{AVG} \geq 30$°C × HHWWS (t ≥ -2)			-0.00577	-0.000250	-0.00556	-0.000504
			(0.008)	(0.007)	(0.008)	(0.006)
$T_{AVG} \in [20, 25)$°C × HHWWS (t ≥ 0)	-0.000723***	-0.000727***	-0.000751**	-0.000850***		
	(0.000)	(0.000)	(0.000)	(0.000)		
$T_{AVG} \in [25, 30)$°C × HHWWS (t ≥ 0)	-0.000771	-0.000457	-0.00118***	-0.000799**		
	(0.001)	(0.000)	(0.000)	(0.000)		
$T_{AVG} \geq 30$°C × HHWWS (t ≥ 0)	-0.0113***	-0.00688	-0.0135***	-0.00697**		
	(0.004)	(0.004)	(0.003)	(0.003)		
$T_{AVG} \in [20, 25)$°C × HHWWS (0 ≥ t ≥ 3)					-0.00109***	-0.00115***
					(0.000)	(0.000)
$T_{AVG} \in [25, 30)$°C × HHWWS (0 ≥ t ≥ 3)					-0.000222	0.0000763
					(0.001)	(0.001)
$T_{AVG} \geq 30$°C × HHWWS (0 ≥ t ≥ 3)					0.00232	0.00839
					(0.008)	(0.007)
$T_{AVG} \in [20, 25)$°C × HHWWS (4 ≥ t ≥ 7)					-0.000758*	-0.000841**
					(0.000)	(0.000)
$T_{AVG} \in [25, 30)$°C × HHWWS (4 ≥ t ≥ 7)					-0.00103*	-0.000662
					(0.001)	(0.000)
$T_{AVG} \geq 30$°C × HHWWS (4 ≥ t ≥ 7)					-0.0316***	-0.0213**
					(0.010)	(0.010)
$T_{AVG} \in [20, 25)$°C × HHWWS (t ≥ 8)					-0.000621	-0.000722*
					(0.000)	(0.000)
$T_{AVG} \in [25, 30)$°C × HHWWS (t ≥ 8)					-0.00174***	-0.00140***
					(0.000)	(0.000)
$T_{AVG} \geq 30$°C × HHWWS (t ≥ 8)					-0.0135***	-0.00760
					(0.004)	(0.005)
Precipitation controls	Yes	Yes	Yes	Yes	Yes	Yes
Province-Month FE	Yes	Yes	Yes	Yes	Yes	Yes
Region-Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Month-Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Covariates × Month	Yes	Yes	Yes	Yes	Yes	Yes
Bins × Year	Yes	Yes	Yes	Yes	Yes	Yes
Bins × Province	Yes	Yes	Yes	Yes	Yes	Yes
Bins × AC	No	Yes	No	Yes	No	Yes
Mean Outcome	0.827	0.831	0.827	0.831	0.827	0.831
Observations	34680	28788	34680	28788	34680	28788

Notes: The dependent variable is the number of deaths per 1,000 people (mortality rate). The estimated period is 1992-2019. The reference category for temperature is bin < 20 °C. Covariates include the share of population by age groups and province-level GDP per capita interacted with the month indicator. Standard errors are two-way clustered at the province and month-year level. * ($p < 0.10$), ** ($p < 0.05$), *** ($p < 0.01$). All regressions are weighted by province population.