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Temperature Shocks and Human Mortality in the Philippines

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Abstract

With the advent of climate change, informed policymaking and rational climate policies for mitigation and adaptation responses are imperative. The present study contributes to the body of knowledge about climate change impacts, particularly on human health in one of the most vulnerable countries, the Philippines. Using complete records of all deaths and historical climate data from 2005 to 2011, it investigates temperature and annual mortality relationships across various subgroups of the population, as well as by causes of death. After controlling for different socio-economic indicators, our fixed-effect analysis reveals that temperature is a significant determinant of all-cause mortality, with the most prominent effect on the elderly (75 years old and above). Women suffer disproportionately, too, exhibiting stronger temperature-mortality associations than men. Cause-specific mortalities show varied responses to temperature increases. However, heart disease and malnutrition mortalities have a highly positive dependence on temperature. Thus, the study illustrates the impacts of temperature and weather variability among vulnerable groups and the prevalence of some causes of death. This study offers valuable insights to enhance social preparedness for climate change.

Keywords: temperature shocks, mortality, climate change, fixed-effect model, Philippines

1. Introduction

This paper aims to assess the temperature-mortality relationships in the Philippines, a developing country threatened by climate change. Using a regional panel dataset that captures all death registries and annual meteorological files from 2005 to 2011, the study showed how a one-degree Celsius temperature anomaly could affect the Philippine population in terms of mortality outcomes.

Scientific evidence on the climate change phenomenon is mounting. It is projected that the global average temperature will rise by 1.8 to 4.0 °C by the end of this century, alongside greater weather variability. It could translate into adverse impacts on broad socio-economic aspects, like economic activity (Dell et al., 2008), labor productivity (Kjellstrom et al., 2009), agriculture (Adams et al., 1989; Olesen and Bindi, 2002), tourism (Amelung et al., 2007), and international trade (Jones and Olken, 2010), as extreme heat or cold can affect human behavior and efficiency.

The health implications of climate change are a growing concern too. The World Health Organization (WHO) estimates that some 150,000 lives lost annually can be blamed on climate change since the turn of the millennium. Intensified by global warming, non-infectious and infectious health problems could increase, thereby endangering human welfare (Patz et al., 2005). The rising temperature anomaly could also bring excessive mortality. Exactly how temperature is etiologically linked to mortality can be understood in light of two interrelated mechanisms (Burgess et al., 2014). In the direct mechanism, physical exposure to weather conditions affects an individual's heat regulation system, and extremities in temperature can put human physiologies under great medical emergencies such as increased heart rate, heat exhaustion, or hypothermia. In the indirect mechanism, temperature and weather variabilities can aggravate existing diseases, generate unfavorable conditions in which sicknesses develop, or even set off income shocks that could likely diminish an individual's quality of life and probability of survival.

Consequently, studies that observe climate-health relationships and potential future outcomes in mortality are beginning to attract attention. The impact of extreme temperatures on death is one aspect that many researchers assess empirically.

Deschenes and Greenstone (2011) estimated the health-related welfare impacts of climate change in the United States. Using fixed-effect estimation on comprehensive panel data of mortality and temperature variations covering the entire USA for 35 years, a statistically significant relationship was found between mortality and daily occurrences of extreme temperatures were positively associated with higher mortality risks. In addition, the results showed that infants and the elderly suffered the worst from rising temperature and that across states, varied magnitudes of responses were observed.

Temperature shocks and mortality in India's rural and urban populations have also been studied by Burgess et al. (2014). Using district-level panel data from 1957 to 2000 and a similar approach to Deschenes and Greenstone (2011), the study found that hot-day weather yielded an unequal effect on urban and rural deaths. When confronted with a one-standard deviation increase in temperature, rural populations faced higher susceptibility to mortality, with a 7.3% increase compared to a 2.8% rise in their urban counterparts. Moreover, there was a significant reduction in rural dwellers' income and agricultural production following a temperature rise. It could explain why their mortality rates displayed more sensitivity to weather shocks. Therefore, they showed the vast impacts of abnormally hot weather, not just on human health but also on agricultural productivity.

Other cases of epidemiological evidence that observe temperature-mortality relationships are mostly conducted in Europe, North America, and other high-income countries or cities. For example, Hajat et al. (2014), in a time series regression analysis, documented an elevated risk of heat- and cold-related mortality in the United Kingdom, with the elderly population facing the largest risk. In Sydney, Australia, Vaneckova et al. (2008) collected daily mortality statistics from 1993 to 2001, performed synoptic analysis to relate mortality and combined weather factors and found that the urban population, particularly women and elderly, stood vulnerable to high temperatures. Then, Hales et al. (2000), using Poisson regression treatment on city-level data from 1988 to 1993, reported a one percent increase in all-cause mortality associated with a one-degree Celsius increase in temperature in Christchurch City, New Zealand. While in Kyushu, Japan, Honda et al. (1995), with daily temperature and mortality data spanning 1972 to 1990, identified the significant positive influence of temperature on deaths, most notably on the death burdens from respiratory and circulatory ailments. These studies have consistently reported similar findings of the effects of temperature on human mortality and the vulnerable group being the elderly. Most studies documented as well as the existence of a threshold temperature beyond the comfortable zone, where mortality sharply increases (Armstrong, 2006).

There is, however, scarce evidence on the topic coming from developing countries, especially in those with tropical climate conditions. The work of McMichael et al. (2008) is among the few resources that provide an international assessment of heat and urban mortality relationships by using local data from 12 cities in non-Organisation for Economic Co-operation and Development (OECD) low- and mid-income countries. The need for this kind of regional assessment of vulnerability to health risks is important for two reasons. First, developing countries are ranked among the most vulnerable to climate change because of their high exposure to climate-driven disasters and dependence on the drought-prone agriculture sector. Second, people within these developing countries generally have fewer resources that can be used for life-preserving adaptation strategies such as insurance or air conditioning systems to protect them from thermal stress. This "more vulnerable, less resilient" argument implies that the impact of increasing temperature and weather fluctuations might be more severe in developing countries than those noted in developed ones.

This study then contributes to the knowledge gap of how rising temperatures affect developing countries. Age-specific and gender-specific analyses may help identify high-risk groups that should be protected from the adverse impact of an increasing temperature, given the climate change scenario. Moreover, by disaggregating temperature effects on the prevalence of cause-specific deaths, the study contributes to epidemiological literature in showing how certain diseases might be affected by a temperature shock, thus offering significant policy measures for public health care and strategies in the country.

2. Study area and climate

The Philippines has a tropical and maritime climate, known to be generally warm and humid, and with abundant rainfall. There are two seasons: dry and rainy. The coldest month occurs in January with a mean temperature of 25.5 °C, while the warmest is in May with 28.3 °C (Philippine Atmospheric, Geophysical, and Astronomical Services Administration - PAGASA). This climate feature of the study area sets it apart from other epidemiological studies of this kind, as they are mostly conducted in mid-and high-latitude areas that experience a full breadth of temperature variation in a year.

3. Data and Methodology

3.1 Data Description

Mortality and Population Data. The vital statistics record compiled by the Philippine Statistics Authority (PSA) was used for mortality data. It aggregates registered deaths in the country sourced from individual death certificates filed at the local civil registry. Importantly, each death count in the vital statistics record is supplied with valuable information such as sex, age, residence, and cause and date of death. From 2005 to 2011, about 3.23 million deaths were recorded. The cause of death is classified according to the International Classification of Diseases 10 (ICD-10) for each record. In this study, the analysis only included the following categories: all-cause mortality (ICD-10 code A00-Z99), tuberculosis mortality (A15-A19; B90), diabetes mortality (E10-E14), heart disease mortality (I00-I52), pneumonia mortality (J12-J18), deaths due to malnutrition (E40-E46), malarial deaths (B50-B54), and transport accidents mortality (V00-V99).

The rationale behind the selection of these cause-specific death categories is twofold: tuberculosis, diabetes, heart disease, pneumonia, and transport accidents comprise the top ten leading causes of death in the Philippines, according to the Department of Health (DOH), while malnutrition and malaria are amongst those known to be climate-change-attributable diseases. The individual death statistics for all these causes were eventually aggregated into a panel dataset of annual mortality count for the 17 administrative regions of the country.

The PSA census for 2000 and 2010 was consulted for the total population in each region, gender, and age group. For the study, five age groups were considered, namely: Age Group 1, AG-1 (under five years old), Age Group 2, AG-2 (six to 44 years old), Age Group 3, AG-3 (45 to 64 years old), Age Group 4, AG-4 (65 to 74 years old), and lastly, Age Group 5, AG-5 (75 years of age and above). In determining these age group divisions, the researchers balanced the need for separating the old and young populations. Age is a key determinant of health, with the availability of data. An estimate was taken by interpolating an exponential function given annual regional growth percentages for years with no official population count.

The death counts and population data were used to calculate the mortality rates — the outcome variable. Because of the richness of the vital statistics record, age-specific, gender-specific, and cause-specific mortality rates in all 17 regions of the country were generated.

Climate Data. The official weather bureau, PAGASA, provided historical temperature, precipitation, and relative humidity from 2005 to 2011. PAGASA has 58 weather stations that track atmospheric patterns; however, due to limitations on data access, only 17 weather stations representative of each geographical region were used to source data. The obtained annual averages for the climate indicators represent the main independent variables in this study. Other Socio-economic Variables. Following a WHO report that identified inequalities in health outcomes based on this social determinant (Marmot, 2005), some conventional indicators about the state of economy and health that could affect mortality were controlled for the analysis. The regional gross domestic product (GDP) per capita was included in the regression model. Likewise, the total number of hospitals (both public and private) and the total number of community health stations per region were used as proxies to capture the availability of medical services. These were all extracted from the PSA Statistical Yearbook, updated on an annual basis.

3.2 Descriptive Statistics

Table 1 presents the mean and range of annual mortality, climate, and socio-economic variables evaluated from 2005 to 2011.

Table 1. Summary Statistics: Mortality, Climate, and Other Socioeconomic Variables, 2005-2011

Variables	**Mean ± SD**	**Min**	**Max**	***Observation***
Mortality				
All-cause Deaths	5,439.00± 4,656.84	51	21,821	595
Male Deaths	3,167.43 ± 2,717.65	35	14,117	595
Female Deaths	2,271.57 ± 2,162.69	16	10,330	595
Tuberculosis	294.97 ± 334.69	0	1,669	595
Diabetes	248.97 ± 333.16	0	1,753	595
Heart Disease	1,165.28 ± 1,334.46	0	6,230	595
Pneumonia	476.05 ± 583.62	4	3,734	595
Malnutrition	25.32 ± 35.32	0	260	595
Malaria	1.27 ± 3.13	0	36	595
Transport	88.02 ± 131.39	0	808	595
Climate				
Temperature, °C	27.05 ± 2.34	15.5	29.3	575
Rainfall, mm rain	209.02 ± 82.43	67.1	511.5	595
Humidity, %	81.45 ± 4.25	71	90	595
Socioeconomic				
GDP per capita, *Philippine Pesos*	28,419.16± 29,136.13	3,195.90	175,100.30	595
Number of Hospitals	107.36 ± 54.85	19	259	595
Number of Health Stations	1,012.57 ± 523.59	12	2,199	545

There was an annual average of 5,439 deaths (minimum: 51; maximum: 21,821) per age group, per region. Among the diseases surveyed, heart disease claimed the largest number of lives with an average of 1,165 deaths per age group per region (minimum: 0; maximum: 6,230), while malaria had the smallest death toll with one death per age group per region (minimum: 0; maximum: 36).

For climate variables, temperature averaged at 27.1 °C (minimum: 15.5; maximum: 29.3); precipitation averaged at 209.0 millimeter (minimum: 67.1; maximum: 511.5); and relative humidity averaged at 81.5 percent (minimum: 71; maximum: 90) across regions. These numbers indicate the tropical character of the Philippine climate.

3.3 Economic Framework

This work estimates the regression model shown in Equation 1. It builds on the work of Deschenes and Greenstone (2011), with the addition of humidity and the three other socio-economic variables identified previously. Said modification is not unreasonable, considering that other empirical works control for them too. For example, Li et al. (2014) controlled for humidity, while Larsen (1990) used rank dummies for state incomes in the characterization of temperature-mortality associations in Chinese cities and US states, respectively.

$$MRrta = \beta 0 + \beta 1TEMPrt + \beta 2RAINrt + \beta 3HUMIDrt + \beta nXrt + \alpha a + \delta r \ + \gamma t \ + urta \quad (1)$$

In Equation 1, MRrta represents the outcome variable, the mortality rate for age group **a** in region **r** at year **t**. The main parameter of interest is **β1**, which provides the estimated temperature impact on mortality rates. The estimates for **β2** to **βn (n=6)** refer to the individual effects of rain, humidity, GDP per capita, the total number of hospitals, and the total number of community health stations, respectively, on mortality outcomes.

Included in Equation 1 are some sets of dummy variables that try to capture the effects of unobserved time-invariant parameters. Using panel data, these dummy variables that control for age group, region, and year fixed effects try to minimize the endogeneity problem. The term αa is a set of dummies that absorbs the age group fixed effects, like the overall fitness of the population in each region. Meanwhile, the specification δr controls for region-fixed effects. For example, it is possible that low-income regions are mostly situated in hotter regions, and such regions may have higher mortality rates due to inadequacy in access to education, differences in nutritional diet, or simply due to low income. Then, the correlation between such unobserved regional characteristics and temperature would cause an upward bias in the effects of temperature on mortality rates. Thus, controlling for the region-fixed effects would at least reduce such endogeneity biases arising from regional differences.

Finally, **γt** accounts for year dummies, absorbing the effects of aggregate trends in mortality rates. It could include the impact of a financial shock (e.g., the global financial crisis in 2008) and the passage or reform of a national health bill experienced by all at any given time. Conditional on the unobserved time-invariant age group, region, and year fixed effects, it seems reasonable to assume that the set of climate variables are exogenous because of their inherently unpredictable and random character.

In this study, Equation 1 is estimated for mortality rates corresponding to all-cause mortality and other cause-specific mortalities, including tuberculosis, diabetes, heart disease, pneumonia, malnutrition, malaria, and transport accidents. In some instances, Equation 1 was also fit separately for the five different age groups to see the variation in responses among subpopulations. In all the estimations, cluster-by-region robust standard errors are run to account for probable heteroscedasticity arising from error terms possibly being correlated within regions over time that might consequently render the test statistics invalid.

4. Results and Discussion

4.1 Effects of Temperature on Overall Mortality

The main regression results are summarized in Table 2 (below). Model 1 is the most parsimonious model that does not include regional fixed effects. As can be seen, the coefficient for temperature (TEMP) is positive and statistically significant. However, as described earlier, this might overstate the true effect of temperature on mortality rates due to the correlation between unobservable regional characteristics and temperature. Thus, Model 2, which includes regional dummies, re-estimates the coefficient for TEMP. Indeed, it shows a drastic reduction in the magnitude of the β1 parameter, from 2.757 to 1.191, indicating the biasness of Model 1. According to this result, a one-degree Celsius increase in annual temperature would bring an additional death burden of 1.191 per 10,000 people, significant at a 95% confidence level.

Table 2. Climate, Socioeconomic, and Mortality Relationships: All-Cause Deaths

Impact on Annual Mortality Rates per 10,000								
	TEMP	**RAIN**	**HUMID**	**GDP/ CAPITA**	**HOSPITAL**	**HEALTH STATION**	**REGION FE**	**R SQUARED**
All-cause Deaths								
Model 1	**2.757***	-0.108	4.945	4.3e-4	**0.775***	-0.001	No	0.9470
	(1.856)	(0.107)	(3.841)	(0.000)	**(0.340)**	(0.020)		
Model 2	**1.191****	0.015	2.017	**-1.7e-4***	-0.252	0.023	Yes	0.9574
	(0.524)	(0.021)	(1.585)	**(0.000)**	(0.282)	(0.014)		
By Gender, Models 3-4								
Male	0.815	0.035	2.027	**-2.4e-4****	-0.336	0.027	Yes	0.9545
	(0.6617)	(0.024)	(1.898)	**(0.000)**	(0.361)	(0.018)		
Female	**1.469*****	-0.001	1.999	**-1.3e-4***	-0.176	0.020	Yes	0.9547
	(0.454)	(0.018)	(1.339)	**(0.000)**	(0.237)	(0.012)		
By Age Group (AG), Models 5-9								
AG-1	0.079	-0.001	0.427	-2.2e-5	-0.047	0.005	Yes	0.9801
(under 5)	(0.068)	(0.008)	(0.341)	(0.000)	(0.043)	(0.004)		
AG- 2	**0.081*****	-0.001	0.150	-1.1e-5	-0.002	0.001	Yes	0.9762
(6-44)	**(0.022)**	(0.002)	(0.122)	(0.000)	(0.017)	(0.001)		
AG- 3	**0.487****	-0.005	0.340	-4.3e-5	**-0.170***	0.010	Yes	0.9793
(45-64)	**(0.192)**	(0.008)	(0.733)	(.000)	**(0.083)**	(0.007)		
AG- 4	0.985	0.011	0.689	-1.4e-4	-0.518	0.017	Yes	0.9749
(65-74)	(0.725)	(0.028)	(2.172)	(0.000)	(0.337)	(0.020)		
AG- 5	**4.323***	0.073	8.479	-6.5e-4	-0.521	0.084	Yes	0.9705
(over 75)	**(2.276)**	(0.095)	(6.263)	(0.000)	(1.273)	(0.055)		

Notes: All models are run using Equation 1. Cluster-by-region robust standard errors are shown in parenthesis. There are 530 observations for Models 1 to 4, and 106 observations for the age-specific regressions in Models 5 to 9. Entries in bold are statistically significant, with ***** indicating significance at 1% level, **** at 5% level, and * at 10% level.

4.2 Effects of Temperature on Gender-Specific Mortality

Models 1 and 2 aggregate all the deaths; however, the temperature effect might differ depending on gender. Hence, Models 3 and 4 run the regression separately for all male and female deaths, respectively. Although the coefficient for TEMP is positive for both genders, it is women who seem to suffer more from an increase in temperature. In the event of a one-degree increase in temperature, the incidence of female deaths per 10,000 population will rise by 1.469, while male deaths will increase by 0.815. The result for female deaths is strongly significant too, which fails to hold true for male deaths.

This gender-stratified result was also reported in other epidemiological studies of a similar kind, like in four Chinese cities (Li et al., 2014), in Sydney, Australia (Vaneckova et al., 2008), and in Mexico City, Mexico (Bell et al., 2008), wherein women showed a larger risk of succumbing to death accompanying a temperature rise. Only, the result of this study is externally valid to the general Philippine population and is not confined to a handful of cities or regions, as reported by these previous studies. One likely explanation for this may be the physiological differences between the two genders that initiate varied thermoregulatory action. As Druyan et al. (2012) established in a series of medical experiments, women were shown to have weaker heat tolerance.

4.3 Effects of Temperature on Age-Specific Mortality

Models 5 to 9 separately estimate Equation 1 for different age groups to see the heterogeneity in the effects of temperature by age groups. Moving from a younger to an older age category, the temperature coefficients are observed to increase, with the highest impact felt by those aged 75 and above, where a one-degree increase in temperature would raise the incidence of deaths by as much as 4.32 per 10,000 people.

The age-differentiated effects of temperature on deaths make sense: because older people generally suffer from the decline of their homeostatic responses and the regulation of their blood pressure, as well as a sedentary lifestyle that induces a loss in the ability to acclimatize to the heat, they are more sensitive to overheating and likelier to experience heat exhaustion (Lundgren et al., 2012). Likewise, the existence of a previous health complication and medication history could exacerbate their response to thermal stress. Significant findings were also documented for temperature-mortality associations among 45- to 64-year-old citizens. It could be linked to their higher chances of being directly exposed to the outdoor environment, considering that this age group predominantly consists of working adults that regularly commute to and from work.

In sum, the results show significant evidence among subgroups: women, people aged 45 to 64, and elderly aged 75 years and above that show higher mortality risks as the annual temperature becomes hotter.

In most cases, other climate variables such as rain and humidity positively impact mortality rates, though they were found to be statistically insignificant. Generally, the socio-economic variables of GDP per capita and the number of hospitals were negatively associated with all-cause and cause-specific death rates. A unit improvement in these socio-economic indicators signifies a general amelioration in a state of well-being that could translate to lower death rates, and the results illustrate exactly the same.

4.4 Effects of Temperature on Cause-Specific Mortality

In Table 3 (below), the mortality outcomes are disaggregated according to their specific causes. The temperature has a significant and positive effect on deaths due to heart disease and malnutrition. Per one-degree increase in temperature, heart disease mortality will claim an additional 1.078 life per 10,000 people, while the deaths due to malnutrition will be 0.064 higher.

It is well reported in various literature that cardiovascular mortalities tend to be very heat-dependent and occur more frequently during extremely hot weather. At high temperatures, blood viscosity and cholesterol levels elevate, potentially increasing the risk for heart attack (Curriero, 2012). When the analysis was re-run to focus on age 65 years and older, the population group where the risks of heart disease are ominously higher, the resulting heat slope becomes even more pronounced. At more than twice as much at 2.58 against the 1.078 deaths per thousand in the age-unadjusted estimate, this shows the elevated risk of elderly people to heart complications that may lead to death.

Regarding the effects of temperature on deaths attributable to malnutrition, hot weather creates a negative impact in agricultural production, limiting the harvest of key grains that could be used for food and accentuating dips in income (Burgess et al., 2014). When these scenarios converge with high levels of malnutrition, the upshot could be lethal. Such might be the mechanism through which high temperature affects death due to malnutrition in the Philippines.

Table 3. Climate, Socioeconomic, and Mortality Relationships: Cause-specific deaths, All age-groups

	Impact on Annual Mortality Rates per 10,000							
	TEMP	**RAIN**	**HUMID**	**GDP/ CAPITA**	**HOSPITAL**	**HEALTH STATION**	**REGION FE**	**R SQUARED**
Tuberculosis	**-0.084***	-0.001	-0.013	-1.7e-5	0.010	-3.7e-5	Yes	0.9087
	(0.048)	(0.002)	(0.112)	(0.000)	(0.014)	(0.001)		
Diabetes	-0.084	-0.001	0.066	**-3.9e-5****	-0.002	-4.6e-4	Yes	0.8395
	(0.052	(0.001)	(0.107)	**(0.000)**	(0.012)	(0.001)		
Heart Disease	**1.078*****	0.014	0.661	**-1.6e-4****	-0.146	0.002	Yes	0.9217
	(0.210)	(0.010)	(0.596)	**(0.000)**	(0.168)	(0.007)		
Pneumonia	**-0.215****	0.002	-0.119	**5.7e-5****	-0.060	4.4e-4	Yes	0.8979
	(0.083)	(.004)	(0.201)	**(0.000)**	(0.050)	(0.002)		
Malnutrition	**0.064****	0.002	0.087	**9.0e-6**	0.020	4.1e-4	Yes	0.7087
	(0.028)	(0.001)	(0.055)	**(0.000)**	(0.014)	(0.000)		
Malaria	0.002	**0.0002****	-0.004	8.3e-8	-0.002	5.2e-5	Yes	0.3628
	(0.003)	**(0.000)**	(0.004)	(0.000)	(0.001)	(0.000)		
Transport	-0.022	-5.2e-4	0.025	**-3.9e-6****	-0.003	1.6e-4	Yes	0.7716
	(0.014)	(0.000)	(0.026)	**(0.000)**	(0.006)	(0.000)		

Notes: All models are run using Equation 1. Cluster-robust standard errors are shown in parenthesis. There are 530 observations for all the models. Entries in bold are statistically significant, with ******* indicating significance at 1% level, ****** at 5% level, and * at 10% level.

However, we observe that tuberculosis, diabetes, pneumonia, and transport mortalities are negatively associated with temperature. These findings suggest that they dampen the full impact of temperature on all-cause mortality found in Table 2. This negative association is a novel result that other literature has not identified previously. The case for mortality due to pneumonia and temperature association was negative and significant. This reporting is analogous to the empirical evidence provided by Braga et al. (2002), who determined the small effects of cold temperatures on pneumonia deaths in eight US cities.

Cause-specific analyses, therefore, show the varied effects that temperature has on different causes of deaths—some death causes will occur less frequently. In contrast, others will be more prevalent given a temperature shock.

5. Conclusion and Recommendations

This research aimed to determine the effects of temperature changes on the overall annual mortality and gender-specific, age-specific, and cause-specific death rates in the Philippines. Strong evidence was found on the alarmingly high impact of temperature on human mortality, particularly all-cause mortality, heart disease mortality, malnutrition mortality, women, the elderly, and working adults. In the face of climate change, where temperature increase is very likely, a one-degree increase in annual temperature could claim 1.19 lives per 10,000 people. Among subgroups, women will suffer from 1.469 more deaths, elderly with 4.323 more deaths, and working adults with 0.487 more deaths per 10,000 population. Incidents of deaths due to heart diseases and malnutrition are also predicted to increase by 1.078 and 0.064 per thousand, respectively, given a one-degree ascent in temperature.

Future researchers may benefit by studying to which extent a temperature shock causes changes in income and spending and how it affects one's survivability. Furthermore, some researches noted "harvesting," or the accumulation impact of temperature on mortality. This research does not elucidate these effects, as it would require daily meteorological data that were not available to the researchers. Another caveat to be noted is the reliance of the analysis on annual temperature data, which prevents the researchers from successfully capturing the impact of extremely hot individual days (i.e., >34 °C) that are increasingly becoming usual in recent times. Finally, air pollution, a confounding, time-variant variable and a significant contributor to human morbidity and mortality (Li et al., 2014), was not controlled for in this work.

If air pollution positively correlates with temperature and mortality, the estimates are likely overestimated. On the other hand, the empirical model fails to include the impacts of temperature on morbidity and other medical burdens that do not lead to death. Hence, in this essence, there is an underestimation of the full health impacts of climate change.

Nonetheless, several broader implications could be drawn from this work. The findings point to some insights on adaptation strategies that could be considered for policy action. First, it is crucial to enhance the technical capabilities of PAGASA for better and more accurate forecasting. That way, an early warning system can be issued to the general public so that people can adequately prepare to respond to climatic strains like heat waves. Institutionalized information dissemination about heat watching and proper preventive measures in various media platforms should also be considered. Next, vulnerable population groups should be targeted for particular care.

Additionally, government intervention to introduce efficient heat-control measures for buildings and infrastructure should be explored to reduce exposure to high heat, especially in the urban setup. The health sector's capacity should also be improved to prevent and deal with the diseases identified herein. These are only some of the government actions that can strengthen the community's resilience to climate change. Ultimately, the need for concerted public policies and coordinated adaptive capacity programs will be crucial in facing the impacts of changing temperature, rain patterns, and climate on the Philippine population.

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