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Temperature, human health, and adaptation: A review of the empirical literature☆

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ABSTRACT

This paper presents a survey of the empirical literature studying the relationship between health outcomes, temperature, and adaptation to temperature extremes. The objectives of the paper are to highlight the many remaining gaps in the empirical literature and to provide guidelines for improving the current Integrated Assessment Model (IAM) literature that seeks to incorporate human health and adaptation in its framework. I begin by presenting the conceptual and methodological issues associated with the measurement of the effect of temperature extremes on health, and the role of adaptation in possibly muting these effects. The main conclusion that emerges from the literature is that despite the wide variety of data sets and settings most studies find that temperature extremes lead to significant reductions in health, generally measured with excess mortality. Regarding the role of adaptation in mitigating the effects of extreme temperature on health, the available knowledge is limited, in part due to the few real-world data sets on adaptation behaviors. Finally, the paper discusses the implications of the currently available evidence for assessments of potential human health impacts of global climate change.

1. Introduction

The changes in the earth's climate that are predicted to result from greenhouse gas emissions are both varied and complex. As a result, the impact margins of climate change are wide and far-reaching. In particular, climate change is likely to affect human health in a number of ways: through its effect on the disease environment, through changes in the prevalence of extreme and destructive weather events, through changes in the average and the variability of temperature, through droughts, etc. Human health is now recognized as one of the most important impact margins of climate change, and thus is a global research priority (Lancet 2009). A vast literature – almost exclusively in public health and epidemiology – has emerged to document the excess morbidity and mortality associated with exposure to extreme temperatures, as well as the associated risk factors. (See International Panel on Climate Change (IPCC), 2007 and National Institutes of Environmental Health Science (NIEHS), 2010 for reviews.)

A critical aspect in assessing the human health threats posed by climate change is the degree to which 'adaptation' is possible. Adaptation, according to the IPCC, is defined as "adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities" (IPCC, 2007). For the rest of this paper, the practical definition of adaptation will refer to the set of actions that are taken in order to reduce the health impacts of exposure to extreme weather events or changes in climate. [1] As such, adaptation measures can include individual or household-level actions as well as community-level actions. Further, some aspects of adaptation will be possible in the short-run and longer-run (e.g., air-conditioning usage, migration) while others will only be possible in the longer-run (e.g., urban space redesign). [2]

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[1] Physical acclimatization could also be considered as a form of adaptation. However, since acclimatization occurs through medium-term changes in human physiology (i.e. increased physiological tolerance to extreme heat) as opposed to behavioral adaptation (such as air-conditioning usage), it does not fall under the scope of this paper. Nevertheless, if physical adaptation increases heat-tolerance in the population, then it will lead to similar effects as behavioral adaptation in the long-run, i.e. reduce the health impacts of exposure to extreme temperatures.

[2] Short-run forms of adaptation are also called defensive or avoidance behavior in environmental economics literature.

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The purpose of this paper is to review the existing empirical literature that specifically examines the determinants and effects of adaptation on human health in response to extreme weather and climate events. In order to narrow the scope of the analysis, I focus exclusively on health impacts and adaptation driven by exposure to extreme temperatures. It is important to note that the set of changes to the global climate system unquestionably goes far beyond rising temperatures (i.e. rising sea-levels, droughts, storms). As such, this review only offers a partial survey of the implications of global climate change on human health and adaptation.[3] However, the increased incidence of extreme temperature events and the prospects of increased heat-related morbidity and mortality are by far the most studied outcomes in empirical research.

I begin by presenting the conceptual and methodological issues associated with the measurement of the effect of temperature extremes on health, and the role of adaptation in possibly muting these effects. To proceed, I derive the implications of a simple version of the Becker–Grossman economic model of health production in the presence of 'adaptation'. The model highlights the tradeoff between health production and costly adaptation. A key implication is that in the extreme, it is possible that individuals can fully adapt such that extreme temperatures would have no detectable effects on measured health outcomes. In this case, an analysis that would only focus on the dose–response relationship between health outcomes and temperature would incorrectly conclude that the human health burden of climate change is negligible. An important finding in the review below is that virtually all studies outside of the economic literature do not explicitly model adaptation and so are subject to such incorrect inference.

In terms of methodological issues, the most salient are the measurement of health, temperature exposure, and adaptation, the research design underlying the study, and its external validity. At the conceptual level, the main limitation of the existing literature is that mortality and hospitalizations are the only health outcomes that have been exclusively studied, and so little is known about the potentially large "lower-level" effects of temperature extremes on chronic conditions and quality of life. A second key drawback is that only a handful of possible adaptations have been analyzed in context by the literature, namely energy consumption (or air-conditioning), geographical mobility, and indoor/outdoor time allocation. Finally, the empirical literature is based on research designs that exploit day-to-day or year-to-year fluctuations in daily temperature distributions. Since daily temperatures are determined independently of health conditional on time and location, these studies have generally reasonable degrees of internal validity. Whether or not these studies are externally valid to make projections of impacts due to permanent climate change is clearly more questionable. At the very least, economic theory suggests that these impacts derived from short-run fluctuations in temperatures are likely to overstate the impacts that would result under permanent climate change.

I then present a review of the literature published in economics journals and working papers, as well as in public health and epidemiology. Unfortunately, the lack of uniformity of the modeling of temperature effects across the wide range of studies makes it virtually impossible to convert the estimates into elasticities or other statistics that can be systematically compared across studies. In particular, the public health studies mostly report the estimates through figures, and do not consistently report point estimates and confidence intervals for the temperature–mortality gradients. My review of these studies is thus based on visual inspection of the relevant figures, and the conclusions stated by the authors.

The main points that emerge from this literature review are that despite the wide variety of data sets and settings most studies find that temperature extremes lead to significant reductions in health, generally measured with excess mortality. There is also some evidence of heterogeneity in the response across subpopulations and geographical areas, although that evidence is not as definitive. There is broad evidence of a dynamic relationship between temperature exposure and health, where heat impacts on mortality are more immediate, and to some extent reflect the influence of harvesting or forward displacement. On the other hand, cold temperature exposure leads to mortality impacts that tend to accumulate over time, indicative of delayed effects.

Regarding the role of adaptation in mitigating the effects of extreme temperature on health, the available knowledge is more limited, in part due to the fewer credible and large scale real-world data on measures of adaptation and associated research design. The best evidence available looks at the relationship between residential energy consumption and extreme temperatures and finds a nonlinear relationship where energy consumption increases significantly at the extremes of the temperature distribution. The response of residential energy consumption to extreme heat is four times as large as the mortality response (Deschenes and Greenstone, 2011). This is consistent with the hypothesis that the more muted mortality–temperature relationship is at least partially due to the self-protection provided by the cooling from increased energy consumption. Further, a recent study by Barreca et al. (2013) confirms and substantiates this finding by documenting that the diffusion of residential AC in the U.S. from the mid-1950s to the present substantially reduced the incidence of heat-related mortality in the U.S.

I conclude with a discussion of the remaining gaps in the empirical literature, the implications of the currently available evidence for assessments of the potential human health impacts of global climate change, and by providing guidelines for improving the current Integrated Assessment Model (IAM) literature that seeks to incorporate human health and adaptation in its framework.

2. Economic framework

This section presents a simple one-period Becker–Grossman health production model that highlights the role of adaptation in the context of the health impact of climate change. The presentation follows from Harrington and Portney (1987) and Deschenes and Greenstone (2011). In particular the model shows the important point that the health-related welfare impact of climate change goes beyond what is suggested by the statistical relationship between climate or weather extremes and health when individuals invest resources in adaptation or self-protection. Indeed, the model shows that the correct measurement of the willingness-to-pay (WTP) to avoid climate change requires knowledge of how temperature affects health outcomes like mortality and how it affects self-protection investments that maintain health. More generally, the correct WTP should consider all the monetized health impacts and the value of all self-protection investments caused by the climatic factors likely to change under global climate change.

To proceed, assume that the representative individual derives utility from consuming a single consumption good, X_C (whose price is normalized to 1), and from health, or more precisely from the survival rate S.[4] This can be represented by the following utility function:

$$U = U[X_C, S]. \qquad (1)$$

The survival rate depends on ambient temperature T and on the consumption of a health-maintaining market good X_H (with price $= p_H$) that increases the probability of survival. Expenditures in X_H have also been labeled 'defensive' or 'averting' expenditures. Specifically, the production function for survival is expressed as follows:

$$S = S(X_H, T). \qquad (2)$$

The consumption of X_H does not directly generate utility, it is only purchased to increase the survival probability and is defined such that

[3] See IPCC (2007) and NIEHS (2010) for broad surveys of the full spectrum of potential health impacts of climate change.

[4] A more complete model would also include leisure. See Harrington and Portney (1987).

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