# A Report on "Adapting to Climate Change: The Remarkable Decline in the US Temperature-Mortality Relationship over the Twentieth Century" by Barreca et al. (2016)

Reviewer 2

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> I am wiser than this person; for it is likely that neither of us knows anything fine and good, but he thinks he knows something when he does not know it, whereas I, just as I do not know, do not think I know, either. I seem, then, to be wiser than him in this small way, at least: that what I do not know, I do not think I know, either.
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> Plato, *The Apology of Socrates*, 21d

> To err is human. All human knowledge is fallible and therefore uncertain. It follows that we must distinguish sharply between truth and certainty. That to err is human means not only that we must constantly struggle against error, but also that, even when we have taken the greatest care, we cannot be completely certain that we have not made a mistake.
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> Karl Popper, 'Knowledge and the Shaping of Reality'

# Overview

**Citation:** Barreca, A., Clay, K., Deschenes, O., Greenstone, M., and Shapiro, J. S. (2016). Adapting to Climate Change: The Remarkable Decline in the US Temperature-Mortality Relationship over the Twentieth Century. *Journal of Political Economy*, Vol. 124, No. 1, pp. 105–159.

**Abstract Summary:** This paper examines the temperature-mortality relationship in the US over the twentieth century to document a decline in heat-related mortality and identify the adaptations responsible for this change.

**Key Methodology:** Large-scale empirical analysis using newly digitized state-by-month mortality counts (1900–2004) merged with state-level data on residential electricity, air conditioning, and doctors per capita, employing econometric models with fixed effects and a discrete-continuous model to estimate consumer surplus.

**Research Question:** What explains the decline in the US temperature-mortality relationship over the twentieth century, and what are the welfare consequences of the identified adaptations?

# Summary

## Is It Credible?

This article presents a highly influential economic analysis of climate adaptation, offering a striking narrative about the United States' ability to decouple extreme heat from mortality. The authors utilize a massive dataset of vital statistics to document a "remarkable decline" in the lethality of hot days over the twentieth century, specifically noting that the mortality impact of days exceeding 90°F fell by approximately 85 percent after 1960 (p. 130). The article's most aggressive claim, however, is causal: it asserts that the diffusion of residential air conditioning (AC) "explains essentially the entire decline" in these fatalities (p. 107). Furthermore, the authors estimate the consumer surplus generated by AC to be between $85 and $185 billion in present value as of 1960 (p. 151). While the descriptive finding of reduced mortality is robust, the causal attribution to AC and the specific magnitude of the welfare estimates face significant methodological headwinds that suggest the headline claims may be upper-bound estimates.

The primary credibility challenge lies in the identification strategy used to isolate the effect of air conditioning. The authors rely on an observational design where AC adoption is the key explanatory variable. However, the diffusion of AC was not random; it occurred simultaneously with broad modernization trends, including income growth, improvements in housing stock quality, the shift from outdoor to indoor employment, and medical advances. While the authors employ rigorous state-by-month fixed effects to control for many variables, they acknowledge that "the variation in the modifiers is not experimental" and that unobserved determinants could bias the results (p. 126). The risk here is that the AC variable acts as a proxy for a broader bundle of heat-mitigating technologies and socioeconomic improvements. This concern is amplified by the article's own calculations, which show that

the estimated lives saved by AC (about 18,000 annually) exceed the total net reduction in heat-related fatalities observed in the data (approximately 14,100) (p. 152). When a single mechanism explains more than 100 percent of a phenomenon, it often indicates that the coefficient is capturing the effects of omitted, correlated variables.

Furthermore, the construction of the AC data introduces a layer of uncertainty that the precise econometric estimates might obscure. The analysis relies on state-level AC ownership rates that are only observed in three census years (1960, 1970, and 1980). For the vast majority of the post-1960 period, particularly from 1981 to 2004, the key independent variable is a linear extrapolation rather than observed data (p. 116). This imposes an artificial smoothness on the adoption curve and assumes that the relationship between time and adoption remained constant for decades. When the authors restrict their analysis to years near the census data to mitigate this measurement error, the coefficient for the protective effect of AC shifts significantly, increasing in magnitude by over 60 percent (p. 144). Such sensitivity to model specification suggests that the precise point estimates are somewhat unstable.

Finally, the welfare calculations, while innovative, rely on strong structural assumptions. The consumer surplus estimate is derived from a model calibrated on a single cross-section of data from 1980, which is then applied to a 45-year period (p. 147). This assumes that consumer preferences and demand elasticities remained static over half a century of rapid cultural and technological change. Additionally, the authors explicitly note that their calculation "does not account for the capital costs of AC" (p. 151). Therefore, the headline figure of $85–$185 billion represents a gross benefit rather than a net welfare gain. While the article successfully establishes that the US has adapted to heat, the assertion that AC is the sole driver likely oversimplifies a complex modernization process.

## The Bottom Line

The article provides convincing descriptive evidence that heat-related mortality in the US plummeted during the 20th century. However, the claim that residential air conditioning explains the *entirety* of this decline is likely an overstatement driven by the difficulty of disentangling AC adoption from concurrent improvements in housing, healthcare, and wealth. Readers should view the welfare estimates as gross benefits rather than net gains, and regard the specific causal magnitudes as upper-bound estimates of AC's protective role.

# Potential Issues

**Causal identification concerns regarding the effect of air conditioning:** The article's central claim that residential air conditioning (AC) is the primary driver of the decline in heat-related mortality rests on an observational research design where the key variable, AC adoption, is not experimentally assigned. The decision to adopt AC is correlated with numerous unobserved factors that could independently reduce mortality, such as rising income, improvements in housing quality, a structural shift from outdoor to indoor employment, and the growth of other heat-adaptation technologies like non-residential AC in workplaces and public spaces. The authors acknowledge this challenge, stating that "the variation in the modifiers is not experimental... so it is natural to question whether the estimated... coefficients are likely to be unbiased" (p. 126). They employ a rigorous econometric model with state-by-month and year-by-month fixed effects, as well as state-specific time trends, to control for many unobserved confounders. However, whether this extensive set of controls is sufficient to fully isolate the causal effect of residential AC from all other concurrent and correlated aspects of modernization remains a debatable and fundamental limitation of the study's design.

**Data construction for the key independent variable:** The article's main explanatory variable, the state-level share of households with AC, is constructed using extensive data imputation, which may introduce systematic measurement error. The underlying data exist for only three years (1960, 1970, and 1980). The authors use linear interpolation to create annual estimates between these census years and, more significantly, use linear extrapolation based on the 1970–1980 trend for the entire 1981–2004 period (p. 116). This means that for more than half of the post-1960 analysis period, the key variable is not observed data but a mathematical projection. This method imposes an artificially smooth trend on a variable that likely followed a non-linear S-shaped adoption curve and was responsive to economic conditions. The

authors acknowledge this as a potential source of measurement error and conduct a robustness check using only data from years close to the censuses (p. 144, Table 8). Nonetheless, the heavy reliance on imputation for the main analysis represents a significant data limitation.

**Quantitative estimates of lives saved:** The article's own calculations show that the point estimate for the effect of AC is larger than the total phenomenon it is meant to explain. The analysis finds that had pre-1960 mortality rates prevailed, there would have been "about 20,000" annual heat-related fatalities in the 1960–2004 period, compared to the "roughly 5,900" that actually occurred, implying a total reduction of approximately 14,100 deaths per year (p. 152). However, the article then calculates that the diffusion of AC alone "reduced premature fatalities by about 18,000 annually" (p. 152). This estimate for the effect of a single mechanism (AC) is nearly 30% larger than the total observed reduction. The authors address this by noting that "In light of the sampling errors, it is apparent that we cannot reject that the widespread adoption of residential air conditioning explains the entire reduction" (p. 152). While it is statistically plausible for the confidence intervals to overlap, a point estimate that over-explains the outcome to this degree may suggest that the model's coefficient for AC is biased upwards, potentially capturing the effects of other unmeasured, co-occurring adaptations.

**Assumptions in the consumer surplus calculation:** The article's third major finding, an estimate of the consumer surplus from AC, is derived from a structural model that relies on strong and untestable assumptions. The analysis uses a discrete-continuous choice model based on a single cross-section of household data from the 1980 US Census (p. 117). The model's identification depends on specific functional form assumptions and on exclusion restrictions—the assumption that certain variables (e.g., interactions of price and climate) affect the choice to own AC but not the amount of electricity consumed conditional on ownership (p. 147). The validity of these restrictions is not empirically tested. Furthermore, using parameters estimated from

1980 to calculate welfare effects over a 45-year period (1960–2004) implicitly assumes that consumer preferences, demand elasticities, and technology quality remained constant, which is a significant simplification.

**Sensitivity of the main coefficient to model specification:** The magnitude of the estimated protective effect of AC shows considerable sensitivity to alternative model specifications, which may suggest that the baseline point estimates are not stable. First, in a robustness check that mitigates measurement error from data interpolation by using only years near the censuses, the point estimate for the effect of AC on >90°F days increases in magnitude by over 60% (from -0.0212 to -0.0343), though with a much larger standard error (Table 8, p. 144). Second, when year-by-temperature trends are added to control for unobserved secular changes, the coefficient's magnitude increases by 77% (to -0.0376). The authors interpret this latter finding as evidence their baseline estimate is conservative (p. 145). While this interpretation is plausible, the degree of fluctuation across specifications indicates that the precise magnitude of AC's effect is sensitive to modeling choices.

**Omission of capital costs in consumer surplus calculation:** The article's estimate of the consumer surplus from AC, valued at "$85 to $185 billion" in present value (p. 106), is a measure of the gross benefit from use and does not account for the capital costs of purchasing and installing the AC units. A complete welfare analysis would subtract these adoption costs from the benefits to arrive at a net surplus. The authors explicitly acknowledge this limitation, stating that "the consumer surplus calculation does not account for the capital costs of AC" (p. 151). While this transparency is commendable, it means the headline welfare figure should be interpreted as a gross benefit rather than the net value to consumers.

**Limitations of data aggregation and proxies:** The analysis is constrained by the nature of historical data, leading to potential biases from aggregation and the use of imperfect proxies. First, the use of state-by-month data masks significant local variation in both temperature exposure and adaptation, as a single value must rep-

resent diverse areas within large states (p. 113). This aggregation may introduce an ecological fallacy, where state-level correlations do not accurately reflect individual-level relationships. Second, the article finds no effect for its "access to health care" variable, which is proxied by "doctors per capita." The authors acknowledge this is an "imperfect prox[y]" that is likely a noisy measure of true healthcare access and quality (p. 110). While the authors mitigate these issues where possible (e.g., with population-weighted weather data), they remain inherent limitations.

**Scope of the conclusion on future adaptation:** The article concludes that AC "has positioned the United States to be well adapted to the high-temperature-related mortality impacts of climate change" (p. 154). This forward-looking statement may be overly optimistic as it does not address a key vulnerability for the US: the dependence of AC on a stable electrical grid. Extreme heat waves, which are projected to become more common, are a primary cause of grid stress and blackouts, creating a scenario where the main adaptation mechanism could fail precisely when it is most needed. The authors do mention grid reliability as a constraint on AC's effectiveness in developing countries like India (p. 155), but they do not apply this important caveat to their conclusion about future resilience in the United States.

**Minor presentation and transparency issues:** Several minor issues related to presentation and transparency exist in the article. First, the text on page 140 claims that the positive interaction between electricity adoption and >90°F days in the pre-1960 period is "statistically insignificant by conventional criteria," which directly contradicts the corresponding result in Table 6, which is marked as statistically significant at the $p < 0.05$ level (p. 139). This appears to be a clerical error in the text. Second, the article relies on newly digitized historical data, but the specific quality control procedures for the digitization process are not documented (p. 114).

# Future Research

**Quasi-experimental identification of cooling technologies:** Future work should move beyond state-level trends and exploit exogenous variation in the adoption of cooling technologies to better isolate their causal impact. Research could utilize discontinuities in electrical grid expansion, specific housing policy changes that subsidized cooling in certain regions, or utility-level variation in energy pricing that affected AC adoption rates independent of general economic growth. This would help disentangle the specific effect of mechanical cooling from the broader "bundle" of wealth and modernization.

**Net welfare analysis including externalities:** To provide a more realistic accounting of the value of adaptation technologies, future studies should calculate the net welfare effects by incorporating the full costs of adoption. This includes the capital costs of equipment purchase and installation, which were omitted in this article, as well as the negative externalities associated with increased energy consumption, such as local pollution and greenhouse gas emissions. A comprehensive model would weigh the mortality and comfort benefits against these financial and environmental costs.

**Decomposition of the housing effect:** Given the correlation between AC adoption and general housing quality, future research should attempt to decompose the "indoor environment" effect. Research could investigate the distinct roles of thermal insulation, window quality, and passive cooling design versus active mechanical air conditioning. Understanding whether "passive" improvements in housing stock contributed significantly to the mortality decline would have major implications for adaptation strategies in developing nations with limited energy infrastructure.

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