Climate Services xxx (2016) xxx–xxx

Contents lists available at ScienceDirect

Climate Services

journal homepage: www.elsevier.com/locate/cliser

# Climate and weather service provision: Economic appraisal of adaptation to health impacts

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A R T I C L E  I N F O

*Article history:*
Received 6 May 2016
Received in revised form 16 September 2016
Accepted 4 October 2016
Available online xxxx

A B S T R A C T

This paper seeks to demonstrate that the value of climate projection information can be used to derive quantitative estimates of both the costs and benefits of information-based measures introduced to reduce climate-related risks. Specifically, information relating to both longer term climate change and weather variability are combined to identify potential resource implications for health service planning when faced with higher frequencies of heatwaves. A range of climate projection-city combinations are explored in order to test the robustness of the economic justification for heatwave warning systems (HWWS) in Europe – London, Madrid and Prague. Our results demonstrate that in most cases the HWWS option can be justified in the current climate – it is therefore a "no/low regret" option. Our results also show that whilst costs increase slightly under climate change scenarios, benefits of HWWS are likely to increase more steeply in European contexts. However, whilst the majority of cost-benefit analysis (CBA) outcomes are found to be positive, (i.e. economic benefits are greater than economic costs), across alternative climate projection-city combinations, in sensitivity analyses it is possible to generate negative results in certain geographical contexts. Indeed, with respect to this climate change risk, this analysis has identified that the analysis of key uncertainties, such as effectiveness of HWWSs and the valuation of health improvements, is critical in strengthening the case for HWWS implementation.



**Practical Implications**

The paper undertakes a quantitative analysis of both the costs and benefits of heatwave warning systems, (HWWSs), in the cities of London, Madrid and Prague from the present day to 2050 – the mid-point in the period, 2035–2064, for which the climate projections exist. These HWWSs currently exist and rely on the local meteorological institutes to provide advance warning of heatwave conditions. We compare the discounted benefits and costs of the HWWSs to derive net present value (NPV) and benefit-cost (B-C) ratio estimates under a baseline (no climate change) and three climate change scenarios. Unlike previous assessments this analysis uses real-world data, combined with current climate scenario and population projections to provide results that can inform strategies to respond to heat-wave conditions. The central results are presented in Table 1. These results show that under the core assumptions adopted the existing HWWSs pass the economic criterion – known as economic efficiency – since they have positive NPV and B-C ratios greater than one.

However, the paper also shows that the effectiveness of the HWWS is not well-established and may vary depending on location. Thus, in sensitivity analysis it is demonstrated that when a low rate of effectiveness is assumed for the London HWWS economic efficiency is no longer guaranteed. One implication for policy makers – at least in London – is therefore to ensure that effectiveness is likely to be reasonably high; this may entail monitoring the performance of HWWS in the near future, as well as ensuring that lessons are learnt from the experience of other cities,

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http://dx.doi.org/10.1016/j.cliser.2016.10.004
2405-8807/

**Table 1**
Cost benefit analysis of heatwave warning systems under baseline and climate change scenarios for the 2035–2064 time period.

| Scenario | London | | Madrid | | Prague | |
|---|---|---|---|---|---|---|
| | NPV | B-C Ratio | NPV | B-C Ratio | NPV | B-C Ratio |
| Baseline | 54,600,000 | 11 | 2,097,700,000 | 913 | 398,700,000 | 308 |
| Cool | 114,400,000 | 21 | 3,297,600,000 | 1375 | 498,700,000 | 385 |
| Median | 124,300,000 | 23 | 3,297,600,000 | 1375 | 498,700,000 | 385 |
| Hot | 154,200,000 | 28 | 4,697,500,000 | 1880 | 598,700,000 | 462 |

particularly those like Paris and New York who are of a similar size to London and who face similar summer weather patterns. Complementary to such monitoring is the impetus that this finding gives to the exploration of other options – such as those presented in Table 6 – that help to reduce the health risks of heatwaves. These include cross-sectoral options that incorporate spatial planning.

A second important finding from a policy perspective is that the preventative resource costs – as well as the resource health treatment costs avoided – implied by the operation of the HWWS rise as the frequency of heatwaves in the three cities increases under future climate change. However, the three climate scenarios indicate that the uncertainty surrounding these estimates is significant. A policy implication of this is that in order to better inform health service resource planning, it would make sense to continue to invest in climate services that were able to reduce the range of uncertainty over time.

## 1. Introduction

An increase of heat-related mortality and morbidity is identified as being a potentially significant consequence of climate change in Europe (Menne and Ebi, 2006; Confalonieri et al., 2007; Smith et al., 2014). This is of particular concern to people living in large urban areas because the high population density in these areas – combined with the fact that heat exposure may be exacerbated by the urban heat island effect – is likely to result in sizeable public health challenges (Patz et al., 2005). The need to respond to such climate change risks has highlighted the essential role of information provision (Fankhauser et al., 1999). Specifically, knowledge about expected timing and extent of risks, derived from climate projections, can be used to inform design and implementation of adaptation actions that reduce the impact of heat on human health.

This paper identifies the roles that climate and weather services play in responding to risks resulting from climate variability and change before undertaking an economic appraisal of heat warning systems based on weather service provision. The appraisal is of existing heat warning systems in three major European cities under climate change projections for the period 2035–2064. The paper therefore builds upon the literature on the economic appraisal of heat warning systems (Ebi et al., 2004) which is limited to considering current climate risks, and the growing literature of ex-post evaluation of the effectiveness of such warning systems (Toloo et al., 2013). Bringing these together in a future-orientated economic appraisal allows us to make initial estimates of the resource implications of adaptation to climate change, as well as the economic justification for committing these resources in budgetary planning.

The public health context is chosen since private individuals are likely to have imperfect knowledge of the health risks of high ambient temperatures, indicating that this is an area where there is a role for public policy intervention. The paper investigates mortality and morbidity associated with high temperatures. Regarding morbidity, the study focused on respiratory hospital admissions in the elderly population. The rationale for this choice is that the elderly have consistently been shown to be particularly vulnerable to high temperatures, and demographic projections have identified that this segment of the population is going to grow significantly in Europe throughout this century. Respiratory illness is understood to be the dominant risk associated with high temperatures for this age group.

Section 2 describes the steps that constitute the method adopted in this paper. Section 3 then presents the results of the economic appraisal of the heat warning system, before concluding thoughts are given in Section 4.

## 2. Methods

The methodology consisted in several steps. First, we estimated the impact of heat on mortality and morbidity in three European cities with large populations, selected as representative of three geographic/climatological sub-regions, defined as Mediterranean Europe, North-Western Europe and Eastern Europe. Respectively, these cities are Madrid, Spain (6.5 million population in 2014), London, UK (8.6 m) and Prague, Czech Republic (1.2 m). We then identified potential adaptation options that could be implemented to reduce these impacts. In order to demonstrate the potential for economic appraisal of adaptation options, we focused on a specific option – heat-health warning systems – whose existing features are described in the relevant geographical locations. This option is then evaluated against an economic efficiency criterion across alternative locations. The heat health warning system in each of the three selected cities was evaluated separately.

The analysis was undertaken over the fifty-year period to 2064, matching the lifetime assumed for adaptation options considered. This time period coincides with the period – 2035–2064, which has been assessed as the period when 2 °C of warming globally, relative to pre-industrial, will occur under the RCP4.5 stabilization scenario (Vautard et al., 2014) based on a multi-model ensemble analysis. Beyond this period, climate projections diverge significantly between scenarios, depending on the underlying assumptions regarding the variables such as socio-economics, population, technology, etc. that drive future emissions and radiative forcing.

(1) Identification of heat-health climate risks

A principal health risk from climate change identified in Europe is the risk of mortality and morbidity associated with higher ambient temperature. The epidemiological literature, (e.g. Hajat et al., 2005; Johnson et al., 2005; Carson et al., 2006; Kovats et al., 2004; Hajat et al., 2007; Kovats and Hajat 2008), reports a strong correlation between current temperature and mortality, with the temperature-mortality relationship characterized by a U, V or J shaped curve, the bottom of which indicates the level of temperature where the mortality incidence is minimum (threshold).

In the literature, this temperature-mortality curve is frequently described by two key parameters: the threshold value and the slope above the threshold, usually expressed in terms of change