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Analysis

Adaptation to Climate Variability: Evidence for German Households

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ABSTRACT

Using panel data originating from two household surveys conducted in 2012 and 2014, we investigate German households' adaptation behavior in response to indoor heat stress during summer months. Providing detailed information of household characteristics, behavior and technical equipment, our database allows us to estimate a random effects probit model on households' vulnerability and adaptive capacity. The estimates indicate that even moderate increases in temperatures are sufficient to trigger investments in adaptation measures: While the propensity to adapt is heterogeneous across socio-economic groups, an increase of one degree Celsius in average summer temperature is associated with a rise of 2.3 percentage points in adaptation probability.

1. Introduction

Rising temperatures are among the key problems pertaining to climate change. Heat stress increases morbidity and mortality (Hajat and Kosatky, 2010; Patz et al., 2005), and negatively affects physical and mental performance (Heal and Park, 2013). In this respect, future consequences of climate change may indeed be serious: Zacharias and Koppe (2015), for instance, predict that heat burden in Germany may more than double by the end of the century.

Fortunately, adaptation has the potential to considerably lower the predicted negative impacts. According to Barreca et al. (2016), for example, the decline in heat-related death rates by more than 75% in the US over the 20th century can almost completely be explained by the dissemination of residential air conditioning. Given the potentially dramatic consequences of increasing heat stress, successful adaptation is needed (Kovats and Kristie, 2006; Zacharias et al., 2014), especially for groups with high vulnerability (e.g. the elderly). However, the ability to adapt crucially depends on households' adaptive capacity, which is typically low for low-income households (Khare et al., 2015). Furthermore, summer heat is generally perceived as positive, which may prevent people from tackling related issues (Lefevre et al., 2015).

Empirical analysis of adaption behavior is scarce, and it remains unclear whether people respond to temperature changes and, if so, what the driving forces are (Berrang-Ford et al., 2011; Ford et al., 2011). While the bulk of existing studies analyzing private adaptation behavior focuses on adaptation in climate-sensitive industries, such as the agricultural sector (Leclère et al., 2013; Olesen et al., 2011; Antle et al., 2004), impacts on private households are potentially even more devastating. This research gap is also highlighted by Germany's official Adaptation Plan (Bundesregierung, 2008). Against the background of more than 3000 fatalities in Germany solely due to the 2003 heat wave, this plan calls for empirical research as a basis for appropriate adaptation policies, particularly for groups with a high vulnerability and low adaptive capacity.

Reliable insights in adaptive behavior are also relevant for choosing the right level of mitigation effort: Neglecting or underestimating the benefits of adaptation may lead to an overestimation of the negative impacts of climate change (Hasson et al., 2010). Hence, it is important to know the degree of individual adaption. Yet, in the absence of better evidence, adaptation usually enters impact assessments via arbitrarily designed scenarios (Hajat et al., 2014; Moss et al., 2010; Zacharias et al., 2014).

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Using panel data originating from two household surveys conducted in 2012 and 2014, we contribute to the literature by empirically investigating the adaptive behavior of German households towards high summer temperatures. In this way, we focus on the factors that stimulate or impede adaptation. Taking account of numerous household characteristics that affect households' vulnerability and adaptive capacity, we estimate a random effects probit model. Relying on cross-sectional variation, our identification strategy rests upon the assumption that the observed adaptation to spatial variation in summer temperatures is a valid proxy for long-term adaptation to climate change. As a central result, we find that a 1 °C increase in average summer temperature is associated with a rise of 2.3 percentage points in adaptation probability. According to the observed average adaptation rate in the population of about 20%, this estimate corresponds to an increase in adaptation probability by more than 10% per 1 °C.

In Section 2, we present the database and define the variables of interest. The empirical methodology is described in Section 3, followed by the discussion of our results in Section 4 and some robustness checks in Section 5. The last section closes with a brief summary and conclusions.

2. Data

The analysis mainly builds on extensive data from two household surveys, conducted in the fall of 2012 and the summer of 2014.[1] To gather the information on adaptation behavior, we collaborated with the professional survey institute *forsa*, which maintains a steadily updated household panel that is representative for the German population older than 14.[2] In total, our sample encompasses 9690 observations. While 3698 households participated in both surveys, 1161 households participated only in the 2012 survey and 1133 solely in the 2014 survey.

Using a state-of-the-art tool, *forsa* allows respondents to fill out the questionnaire using either the internet or, if access is unavailable, a television. Households retrieve and return questionnaires from home and can interrupt and continue the survey at any time. Based on visually supported questionnaires, households provide in-depth information on their attitudes towards climate change, technical endowment of their building, and their housing situation.[3] This data is complete with a large set of regularly updated household specific socio-economic and demographic characteristics, which are available from *forsa*'s household selection procedure. The survey aims at interviewing the head of the household, defined as the person reporting to be responsible for the household's decisions. As a result, there are more males than females in our sample. Table A.1 (in the Appendix) displays the average of household income and household size as well as the regional distribution of households in the estimation sample (Column 1) and compares it to the full survey (Column 2) and the German census (Column 3). With respect to these characteristics, a high degree of representativeness of the sample is confirmed. Unfortunately, we cannot underpin the representativeness for individual characteristics, as no official information is available on household heads.

To measure adaptation, we analyze information on measures with which households attempt to ameliorate the negative effects of high temperatures. Adaptation measures include ventilators, reflective films and anti-sun glass in the windows, air conditioners, and green roofs. We define a binary indicator of adaptation, taking on the value of one if a household has implemented at least one these measures and zero otherwise. The composition of the index is shown in Table A.3 in the Appendix. Eighteen percent of the sample households had implemented some of these adaptation measures in 2012, a segment that increased to 25% in 2014.

Drawing on adaptation literature (Adger et al., 2003; Brooks et al., 2005; Smit and Wandel, 2006; Osberghaus, 2015), we exploit information on the most important socio-economic factors of vulnerability and adaptive capacity. Specifically, as control variables, we include gender, employment status, years of education, age and body weight of household heads, households' net income, and a range of housing characteristics (Table 1). A full correlation matrix can be found in Table A.2 in the Appendix.

Using information on population figures from the Federal Statistical Office (DESTATIS), we derive an indicator of urban areas, defined as those areas where population density is higher than 500 inhabitants per km^2.

Additionally, we use data from Germany's national meteorological service *Deutscher Wetterdienst* (DWD). The data includes information on the daily average temperature for all days between January 1, 2008, and December 31, 2013, as well as the exact coordinates of each of the 485 weather stations in the database.

To measure heat stress, we calculate the local average summer temperature, defined as the moving average of daily temperatures in June, July and August of the last 4 years. To obtain average summer temperatures for each of the 8270 German postcode regions, we identify the coordinates of the geographic centroid of each area and calculate the distance to each weather station. The squared inverse of these distances are used as weights for the spatial interpolation of the temperatures:

$$temp_i = \sum_{j=1}^{3} \frac{temp_j * \frac{1}{distance_{ij}^2}}{\sum_{j=1}^{3} \frac{1}{distance_{ij}^2}},$$

where the temperature in zip code region i is calculated as the average of the measured temperatures of the nearest three weather stations $j = 1$–3, weighted by the inverse of their squared *distance* to the postcode region's centroid.

The weather stations that are evenly distributed across Germany document the fact that there are substantial regional differences in summer temperature. (Fig. 1). The coastal areas in the north, for

Table 1
Descriptive statistics.

	Mean	Standard deviation	Minimum	Maximum
Adaptation indicator	0.22	–	0	1
Summer temperature (in °C)	17.76	0.89	9.93	19.99
Income (in 1000€)	2.93	1.35	0.25	5.75
Female	0.30	–	0	1
Employment	0.67	–	0	1
Years of education	12.63	3.88	8	18
Age under 30	0.07	–	0	1
Age over 60	0.30	–	0	1
Body weight (in kg)	83.15	16.99	39.00	220.00
Household size	2.21	1.09	1	20
House	0.47	–	0	1
Attic	0.14	–	0	1
Ownership	0.57	–	0	1
Urban area	0.38	–	0	1
Number of observations	9690			

Information on income is provided in equidistant categories. To derive a continuous variable, this information is recoded according to the category means.

[1] The establishment of the household panel on adaptation to climate change and energy consumption is a part of the project *Evaluating Climate Mitigation and Adaptation Policies (Eval-MAP)*, www.rwi-essen.de/eval-map.

[2] Supporting information on the panel is available at http://www.forsa.com/.

[3] For further information on the questionnaire, in German, see Osberghaus and Philippi (2015).