11 — The impact of climate change on selected indicators of human health: pharmaceutical sales, doctor visits, and hospitalizations

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– An adverse impact of climate change on hospitalizations is projected, with an increase of about +4%, showing little dependence on the scenario and time period considered.

– Doctor visits and pharmaceutical sales are projected to increase slightly, but statistical uncertainty limits the conclusiveness of results.

11.1. INTRODUCTION

Recent studies indicate that climate change may cause severe adverse health effects, including higher rates of mortality (Deschenes and Greenstone, 2011) and lower birth weights (Deschenes et al., 2009). A rich case study literature links the impact of extreme weather events like heat or cold waves to increases in mortality in Europe (Vandentorren et al., 2004; Conti et al., 2005) and the US (Zanobetti and Schwartz, 2008). Various channels exist through which weather can affect health, e.g., an increased risk of cardiovascular diseases and respiratory health problems (during heat waves), diarrhoeal diseases and malaria (related to natural disasters like floods mainly in developing countries), new patterns of influenza seasons (due to mild or very cold winters), and weather-related effects on mental health (e.g., WHO, 2009; 2012; Ballester et al., 2003; IPCC, 2007b).

This chapter derives empirical relationships between observed temperature and precipitation in Switzerland and selected indicators of human health, and applies these to the CH2011 scenarios to project the impact of climate change. Health indicators include over-the-counter pharmaceutical sales, doctor visits, and hospitalizations. The conjecture is that mild forms of weather-related health impacts may increase the consumption of over-the-counter drugs (which would display in pharmaceutical sales). More serious symptoms eventually require patients to see a doctor (for more effective prescription drugs or further medical treatment). Very severe forms of health impacts, including emergency cases, may lead to an increase in hospitalizations.

‹ Statistics suggests impacts on the health sector with more hospitalizations and sales of registered pharmaceutical products as a result of warming in Switzerland (photo: edia.con).

11.2. METHODS

The analysis is based on four data sets that contain information about human health and observed weather in Switzerland.

Data on over-the-counter **pharmaceutical sales** (in number of units sold) are provided on a monthly basis for the years 2002 to 2012 (129 months) by IMS Health Switzerland (IMS Health, 2012). The information is grouped into sales by pharmacies and sales by drug stores, as well as sales of registered products (authorized by Swissmedic) and non-registered products (health or sanitary products). Pharmacy sales are aggregated to 227 regions, drug store sales are aggregated to 82 regions.

Monthly data on the number of **doctor visits** from 2007 to 2011 (60 months) are obtained from NewIndex AG (NewIndex AG, 2012). The data are aggregated to 577 regions on the 3-digit zip-code classification level, and cover all physicians who are member of one of the Swiss Medical Associations (FHM, KKA, etc). Monthly numbers of **hospitalizations** from 1998 to 2010 (156 months in total) are provided by the Swiss Federal Statistical Office (SFSO, 2012). The data are aggregated to 785 medical regions on the basis of zip-codes.

Weather data include total daily precipitation and mean daily temperature for the period 1998 to 2012 and are available in gridded form at a resolution of about 2 km × 2 km from MeteoSwiss (Frei, 2014). To combine the information the weather data is aggregated on a monthly basis and at the respective spatial resolution of each health indicator. Table 11.1 summarizes the data and shows basic descriptive statistics.

The analysis builds on a statistical model similar to the one estimated by Deschenes et al. (2009) and Deschenes and Greenstone (2011). The model is based on the assumption that each health indicator (as listed in Table 11.1) can be expressed as a function of observed temperature and precipitation. To preserve as much of the daily weather information as possible and to allow for a flexible functional form of the relationship between weather and health, the original weather data is transformed as follows: The distribution of daily temperatures and precipitation is split into seven bins defined by intervals containing a certain fraction of all observations (quantiles):

- Temperature quantiles:
  0–15, 15–30, 30–45, 45–55, 55–70, 70–85, 85–100%

- Precipitation quantiles:
  0–10, 10–25, 25–40, 40–55, 55–70, 70–85, 85–100%

The number of days per month for which a certain region experienced weather conditions falling into any of these bins provides the weather variables included in the model. In other words, the transformed weather variables correspond to histograms of daily temperature and precipitation levels for each month and region. To match the level of aggregation of the health indicators, this transformation is done separately for each of the data sets.

Finally, a rich set of regional and time fixed-effects is included in the model to control for unobserved heterogeneity in space and time. More specifically, binary variables are included that indicate each of the regions, quarters, month of the year, and interactions with cantonal indicators to filter out as much of the seasonal and regional differences as possible. As a consequence, the estimates identify the effects of temperature and precipitation on health that are unrelated to regional and seasonal differences and common cantonal trends over time.

Future health impacts of climate change are projected based on the estimates of the relationship between observed weather and human health, using the DAILY-GRIDDED dataset (Chapter 3). The number of prospective days in each precipitation and temperature bin is calculated for the three periods (2035, 2060, and 2085) and the three greenhouse gas scenarios (A1B, A2, and RCP3PD) covered by CH2011 (Chapter 3). The statistical models for each of the six health indicators are applied to the climate change scenarios under a ceteris paribus assumption, i.e., assuming that all relevant background factors remain unchanged.

11.3. RESULTS

First, the observed relationship between **weather and the selected indicators of human health** is discussed, as this constitutes the basis for the projections of the impact of

Table 11.1: Summary statistics of the input data: Mean, standard deviation (Std. Dev.), minimum (Min), maximum (Max) and number of observations (Obs.). For human health indicators, monthly counts are listed. Sales are given for registered (R) and non-registered (NR) products.

	Mean	Std.Dev.	Min.	Max.	Obs.
Weather data (1998–2012, Source: MeteoSwiss)					
Precipitation	3.42	7.61	0	279.1	17'249'157
Temperature	8.46	7.88	–26.1	30.1	17'249'157
Pharmaceutical sales (2002–2012, Source: IMS Health Switzerland)					
Sales in pharmacies (R)	22'694	15'656	2'591	200'880	29'283
Sales in pharmacies (NR)	1'131	1'139	11	34'127	29'278
Sales in drug stores (R)	12'913	8'631	304	75'092	10'577
Sales in drug stores (NR)	1'450	1'213	25	69'469	10'576
Doctor visits (2007–2011, Source: Newindex AG)					
Number of patients	5'885	8'142	1	101'683	34'597
Hospitalizations (1998–2010, Source: Swiss Federal Statistical Office)					
Number of patients	170.5	152.9	1	4'970	100'236

climate change. In the following, the effects of weather are expressed in terms of percentage changes in the different health indicators induced by an additional day with temperature or precipitation in a certain quantile. All discussed effects are significant on the 5% level except where stated otherwise.

The results for over-the-counter pharmaceutical sales show modest empirical evidence for weather-related effects. While the effect of precipitation on pharmaceutical sales is small and insignificant throughout, high temperatures are found to have a positive effect on the sales of registered products in pharmacies, with an increase of about +0.5% in sales per additional warm day above the median temperature. This effect is not due to seasonal patterns, as seasonality is controlled for in the statistical analysis (section 11.2). The effect is also net of the possibly opposing effects of additional warm days in winter and in summer.

Given the observed average in registered sales in pharmacies of 22'694 units per month and region (Table 11.1), a +0.5% increase in sales corresponds to about 113 additional units sold per month and region for an additional day in the high temperature bins. For Switzerland this amounts to about 25'800 additional units, assuming homogeneous temperatures across the country.

Doctor visits increase both with additional cold days (+0.45%) and, somewhat less, with additional warm days (+0.3%). This corresponds to an increase of about +0.6 (+0.9) doctor visits on average per region and month and additional cold (warm) day, which adds up to about 346 (519) more doctor visits in Switzerland per month (577 regions times 0.6 or 0.9). The effect of precipitation on doctor visits is small and statistically insignificant.

Hospitalizations react to changes in both tails of the temperature distribution. For the very low temperatures, the effect is negative with about –0.5%. For high temperatures (above the 70% quantile) the effect is positive with about +0.5%. Thus, one additional day at high temperatures leads to an increase of about 0.85 admissions per medical region and month, or about 677 admissions for Switzerland (785 regions). The effect of precipitation on hospitalizations is weakly positive with about +0.2% for an additional day with precipitation levels in all but the highest bins.

Second, based on the above estimated relationships, projections of the **impact of climate change on the selected indicators of human health** are derived. For registered products in pharmacies, an increase in sales of about +2% is projected, with some variation depending on the scenario and time period (Figure 11.1a). The sales of registered products in drug stores are not affected by climate change according to the CH2011 scenarios (Figure 11.1c). The sales of non-registered products (Figures 11.1b and 11.1d) increase slightly, but with rather large confidence intervals which do not preclude the possibility of no impact at all.

The number of doctor visits is projected to slightly increase with about +0.5%, but the effect is only marginally significant or statistically insignificant at the 5% level (Figure 11.1e). Projections for the number of doctor visits are very similar across the different scenarios and follow similar patterns over time.

Among the selected health indicators analyzed in this chapter, the largest projected impact of climate change is that on hospital admissions (Figure 11.1f). As a result of the positive correlation between high temperatures and hospitalizations and the projected increase in temperatures for all greenhouse gas scenarios, hospitalizations increase by about +4%, with little dependence on the scenario and time period considered.

11.4. IMPLICATIONS

The results of the analysis indicate an adverse impact of climate change on human health as captured by the assessed indicators. A pronounced effect on the number of hospitalizations is found, which may be related to additional emergency cases due to extreme weather events. The projection does not, however, fully capture the impact of extreme weather due to the limited representation of extremes in the CH2011 climate scenarios (Chapters 2 and 3). A slight increase in the sales of registered pharmaceuticals and doctor visits is projected, possibly related to health problems that are non-emergency cases and treatable by a doctor or with specific medication (e.g., cases of general malaise).

The projections calculated above rest on the assumption that the relationship between weather and health remains stable, with the possibility of extrapolating to climate, and climate change. This assumption rules out adaptation in physiology, weather-related behavior, and other relevant socio-economic factors, which would likely reduce the long-term impact of climate change. As a consequence, the present estimates must be interpreted as an upper bound in this respect. On the other hand, changes in climate may introduce novel hazards not observed previously (e.g., new diseases), which in turn would reinforce the estimates of the adverse health impact of climate change.

From a data and modeling perspective, it should be noted that temperatures are relatively homogeneous across Switzerland (with small variations within and between cantons and climatic zones). Some within-variation in temperatures is needed such that common trends and seasonality patterns can be plausibly ruled out in the estimated relationships, and this condition is still fulfilled in our data. Precipitation, on the other hand, shows substantial regional heterogeneity. As a consequence, estimates for the latter likely reflect variations in local weather conditions and local responses in human health. For the extrapolation of the results from a regional to a country-wide impact this implies that estimates based on temperature tend to be more reliable (and have less statistical noise) than estimates based on precipitation. Future analyses should further disentangle these two sources to allow for more detailed projections of the impact of climate change.

Finally, since many climate change projections postulate an increase in extreme weather events, identifying the effects of weather on human health in the tails of the weather distribution is an important aspect. The model used here is flexible in this regard, with the inclusion of bins that stretch over all quantiles. A distinction between the different features of climate change scenarios (e.g., cold vs. heat waves) would be a valuable extension for future research to gain further insights into the impact of climate change on health.

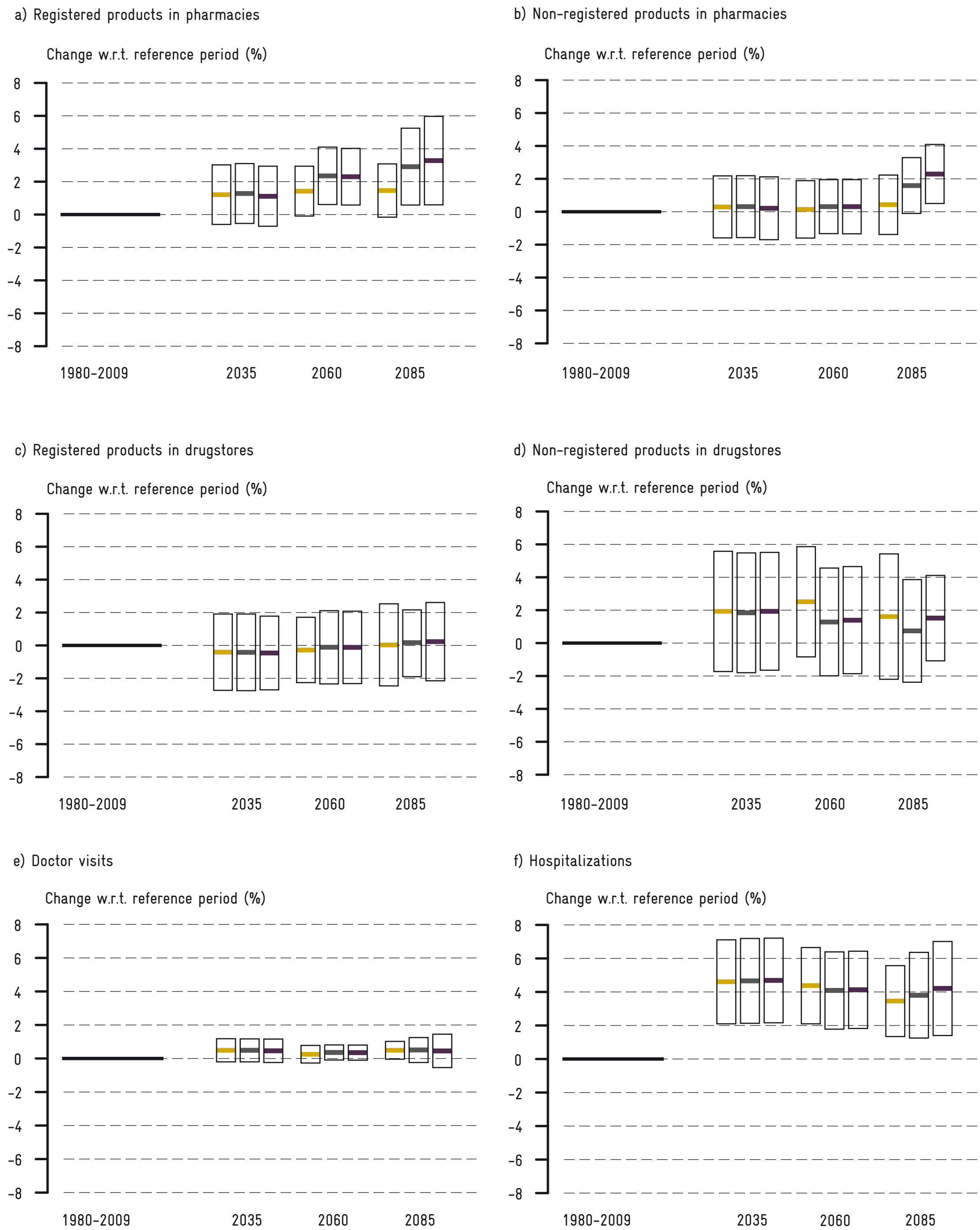

Figure 11.1: Human health indicators under reference (1980–2009) and future climate conditions (2035, 2060, and 2085) as projected for the three greenhouse gas scenarios RCP3PD (yellow), A1B (grey), and A2 (purple). Top: sales in (a) registered and (b) non-registered products in pharmacies. Middle: sales in (c) registered and (d) non-registered products in drug stores. Bottom: (e) number of doctor visits and (f) number of hospitalizations.