Not just hot air?
The Effects of Weather on Mortality in Germany

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Outline

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Objectives of Paper

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1. To analyse the impact of environmental shocks on mortality by cause.
2. To implement a competing risks model which allows for
   - Unobserved heterogeneity
   - Correlation between risks
   - Changes in population at risk
   - Short- and long-term effects of events
3. To gauge the possible long-term impact of different events in economic terms.

Motivation

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The 2003 European heat wave was the hottest summer on record in Europe since at least 1540. France was hit especially hard. The heat wave led to health crises in several countries and combined with drought to create a crop shortfall in Southern Europe. More than 40,000 Europeans died as a result of the heat wave

Source: Wikipedia

From an economic and societal point of view, a reported death toll of 40,000 is not very informative.

The possibility of a **harvesting effect** – i.e. short-term changes in the timing of death needs to be taken into account.

Besides, an analysis by specific death causes requires allowing for changes in population at risk, **unobserved heterogeneity** etc.

It is the aim of this paper to deal with these methodological issues.

We seek to estimate the impact of the 2003 heat wave in Germany on **different death causes** in **different age groups**.

Motivation 2

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- Ongoing climate change leads to changing environmental conditions of human beings
- According to meteorological scientists; two types of shift in the distribution of temperatures:
  1. Rising average temperatures (Global Warming)
     - In the last 100 years the world's average temperature has risen by 0.74 °C
     - In Germany an average increase of 1.1 °C
  2. Higher probability of more frequent and intense **extreme heat events**
     - The quantity of hot days in Germany has doubled since the 1950s.
- Trend is predicted to proceed in both cases

Literature

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From medical research: extreme temperatures lead to elevated thermal stress on human bodies.

In economics, several studies on impact in high-income countries (Rey et al, 2007; Deschenes & Moretti, 2009).

Typical results:

- Heat events lead to immediately rising mortality rates
- Population groups in weak health status are more affected

Special issues:

1. The **Harvesting Hypothesis**
   - Heat induced increase in mortality is only contemporary, long run net effect tends to zero
2. The **Urban Heat Island Hypothesis**
   - Stronger thermal stress in metropolitan areas due to higher temperatures during the night

Our Data

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Daily data on deaths by death cause (ICD10) from Federal Statistical Office of Germany.

Date of birth and death, cause and county of residence (*Kreis*, $N = 380$).

We focus on the age group $65 - 74$ and the year 2003 to begin with.

Weather data provided by the German Weather Service from 1,045 weather stations: temperature, cloud coverage, precipitation etc.

Weather data interpolated to county centroids using distance weights (50 km radius).

Descriptive Statistics

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Table: Descriptive Statistics, Mortality

Variable	Obs	Mean	Std. Dev.	Min	Max
All					
All Causes	96,476	10.537	6.382	0.886	83.368
Neoplasm	50,102	7.347	4.594	0.331	62.526
Other Heart Diseases	39,956	6.942	4.408	0.331	52.854
All other Causes	49,898	7.437	4.717	0.626	52.854
Males					
All Causes	73,646	18.921	11.956	1.400	168.539
Neoplasm	34,049	14.453	9.436	0.732	109.649
Other Heart Diseases	28,576	14.056	9.237	0.732	112.655
All other Causes	34,224	14.600	9.524	0.732	115.674
Females					
All Causes	50,668	13.746	8.551	0.604	116.505
Neoplasm	22,908	11.483	7.383	0.604	77.670
Other Heart Diseases	15,483	11.093	7.251	0.6045	93.502
All other Causes	22,702	11.526	7.565	0.604	92.593

Mortality per 100,000 inhabitants. *Neoplasm* includes mortality caused by ICD10 keys C00 to D48, *Other Heart Diseases* includes keys from I20 to I52 and *All Other Causes* describes mortality by every cause except Neoplasm and Other Heart Diseases.

Seasonal pattern, 65–74 mortality

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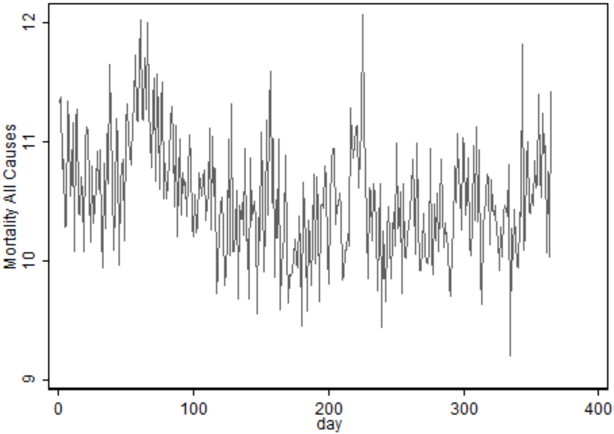

A competing risks framework

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In our estimates, we rely on a piecewise constant hazard function with unobserved heterogeneity:

$$\theta_{kj}^{t}(\mathbf{x},\mathbf{z}) = \exp\left(\alpha_k^t + \beta_{zk}\mathbf{z} + \sum_{s=0}^{m}\gamma_{ks}x_{1,t-s} + \delta_k\mathbf{x}_{-1,t} + \epsilon_{kj}\right) \tag{1}$$

where

- t denotes a day, k a particular death cause.
- $\mathbf{x}$ is a set of time-varying covariates, $\mathbf{z}$ are constant characteristics (e.g. sex).
- x_{1t} is a dummy indicating that a heat wave (mean temp $> 30\,^{\circ}$C) occurred in the county of residence at time t.
- ϵ_{kj} captures unobserved heterogeneity, with associated probability p_{kj}.

Probability of Death Cause

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For our analysis, the main interest lies in $F_k\left(t|\mathbf{x},\mathbf{z}\right)$: the probability of having exited due to cause k by time t (suppressing unobserved heterogeneity):

$$F_k\left(t|\mathbf{x},\mathbf{z}\right) = \sum_{h=1}^{t} \int_{h-1}^{h} \theta_k^h\left(\mathbf{x},\mathbf{z}\right) S\left(u|\mathbf{x},\mathbf{z}\right) \mathrm{d}u = \sum_{h=1}^{t} P_k\left(h \mid \mathbf{x},\mathbf{z}\right) \qquad (2)$$

where

$$P_k\left(h \mid \mathbf{x},\mathbf{z}\right) \equiv \pi_k^h\left(\mathbf{x},\mathbf{z}\right)\left[S\left(h-1|\mathbf{x},\mathbf{z}\right) - S\left(h|\mathbf{x},\mathbf{z}\right)\right] \qquad (3)$$

is the probability of exiting at time h due to cause k and

$$\pi_k^h\left(\mathbf{x},\mathbf{z}\right) \equiv \frac{\theta_k^h\left(\mathbf{x},\mathbf{z}\right)}{\sum_{j=1}^{K}\theta_j^h\left(\mathbf{x},\mathbf{z}\right)}. \qquad (4)$$

is the relative hazard rate for cause k.

The Impact of a Heat Wave

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In order to gague the impact of a heat wave, we calculate a counterfactual.

Hence, we use the alternative exit probability $\hat{F}_k\left(t|\mathbf{x}', \mathbf{z}\right)$...

...where $\mathbf{x}'$ is the set covariates with the heat wave dummy set to zero in all periods.

We use parameter estimates to calculate $\hat{F}_k\left(t|\mathbf{x}', \mathbf{z}\right)$ and $\hat{F}_k\left(t|\mathbf{x}, \mathbf{z}\right)$, and define the 'Impact of the 2003 Heat Wave' as

$$LTE_k \equiv \hat{F}_k\left(365 \mid \mathbf{x}, \mathbf{z}\right) - \hat{F}_k\left(365 \mid \mathbf{x}', \mathbf{z}\right) \quad (5)$$

Alternatively, we may multiply it by the initial population to get the number of additional deaths.

Estimation

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The competing risks model was estimated using maximum likelihood.
Unobserved heterogeneity captured by eight different nodes:

- For each death cause, we allow for a separate intercept term ϵ_k.
- All eight possible combinations allowed.
- Each ϵ_k associated with a probability: $p_1, p_{21}, p_{22}, p_{311}, p_{312}, p_{321}, p_{322}$.
- The hypotheses of uncorrelated risks corresponds to
  - $p_{21} = p_{22}$
  - $p_{311} = p_{312}$ or $p_{321} = p_{322}$.

Standard errors for implied death counts were derived using the Delta method.

Parameter Estimates

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Table: Parameter Estimates, Ages 65–74

Variable	Neoplasm		Cardiovascular		Other	
	Par.	**p val**	**Par.**	**p val.**	**Par**	**p val.**
Cloud Coverage	-0.01	0.39	0.00	0.64	0.00	0.84
Precipitation	0.00	0.49	0.01	0.11	0.00	0.37
Heat	-0.10	0.37	-0.30	0.03	0.09	0.39
L1.Heat	0.08	0.48	0.26	0.06	0.17	0.12
L2.Heat	0.14	0.21	0.27	0.05	0.07	0.55
L3.Heat	-0.03	0.77	-0.15	0.31	-0.01	0.93
L4.Heat	0.04	0.69	0.06	0.65	-0.01	0.90
L5.Heat	-0.02	0.86	0.06	0.66	0.04	0.69
L6.Heat	-0.07	0.53	-0.20	0.17	0.08	0.46
L7.Heat	0.03	0.76	0.09	0.51	-0.05	0.65
Epsilon	-3.33	0.00	-3.40	0.00	-1.83	0.00
p1	0.87	0.00	0.81	0.00	0.65	0.00
p2	0.86	0.00	0.83	0.00		
p3			0.62	0.00		
p4			0.68	0.00		

Constant, month dummies and time trend suppressed.

Impact of the 2003 Heat Wave

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Next, we estimate the long-term effect of the heat wave on the three different death causes.

The total population in this age group was **8.2 Million** at the beginning of 2003.

Table: Additional Deaths, Ages 65–74

Death Cause	Number	Standard Error
Neoplasm	77.6	167.1
Cardiovascular	420.8	159.0
Other	88.9	123.4

Number of additional deaths compared with baseline.

Clearly, we only observe a significant effect for cardiovascular disease; an effect which is approximately 5 cases per 100,000.

Summary and Conclusions

- Using a competing risk framework, we find that the 2003 heat wave had a significant impact on death related to cardiovascular disease in Germany.
- For the other two death causes considered, we find no effect.
- This is different from the oldest old, for which also other death causes are significantly affected (cf. Karlsson & Schmitt, 2011).
- Unobserved heterogeneity is of considerable importance, but unclear whether risks are correlated.
- Most of the effect concentrated in the first few days following a heat event.