Spatial-temporal logistic regression of the cesium contamination and the time trends in annual stillbirth proportions on a district level in Bavaria, 1980 to 1993

Hagen Scherb and Eveline Weigelt
GSF-National Research Center for Environment and Health
85764 Neuherberg

Statistical Modelling

Proceedings of the
14th International Workshop on
Statistical Modelling

Graz, Austria, July 19-23, 1999

H. Friedl, A. Berghold, G. Kauermann
(Editors)
SPATIAL-TEMPORAL LOGISTIC REGRESSION OF THE CESIUM CONTAMINATION AND THE TIME TRENDS IN ANNUAL STILLBIRTH PROPORTIONS ON A DISTRICT LEVEL IN BAVARIA, 1980 TO 1993

Hagen Scherb and Eveline Weigelt
Institut für Umweltmedizinische Forschung GmbH
Ingolstädter Landstr. 1, 85764 Neuherberg e-mail: scherb@igf.de

Problem
Statistical association between the cesium deposition following the Chernobyl accident and stillbirths on a district level in Bavaria.

Data
1. Surrogate exposure variable:

| Table 1. 137Cs (kBq/m²) in Bavaria 1986 |
|-----------------|-----------------|-----------------|
| unit            | n | Mean | Median | Min | Max |
| 88 km grid districts | 1465 | 14.9 | 10.3 | d.l | 120.7 |
| d.l detection limit | 96 | 14.4 | 10.1 | 3.1 | 53.7 |

2. Study period: 1980 - 1993
3. Outcome variable:

1,713,147 live births (LB, no event) and 6,261 stillbirths (SB, event) in Bavaria 1980-1993 on a district level; TB=LB+SB

1,344 observations (= 96 districts x 14 years)

Software
EXCEL, PROCEDURE LOGISTIC OF SAS 6.12

Bavaria and 137Cs contamination on a district level

Method
Logistic regression, dummy coding of time and location, as well as corresponding interactions.

Dependent variable: stillbirth proportion (SBp)
SBp=LB/SB

Independent variables (optional): 137Cs, (137Cs)², (time)²

Optional covariates: dummy coding for 1987 (v1987) and 1988 (v1988), dummy coding for districts, interactions: time-location

In this model, the estimation of the individual trend functions for the stillbirth proportion makes use of a logistic regression

V = Logodds/Parameter estimate Pa-value 95% confidence limits

Log odds of model

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Estimate</th>
<th>p-value</th>
<th>95% confidence limits</th>
</tr>
</thead>
<tbody>
<tr>
<td>137Cs</td>
<td>0.0028</td>
<td>0.0002</td>
<td>[2.6E-3, 1.3E-2]</td>
</tr>
<tr>
<td>137Cs²</td>
<td>0.0007</td>
<td>0.0001</td>
<td>[3.8E-7, 1.1E-6]</td>
</tr>
<tr>
<td>137Cs³</td>
<td>0.0001</td>
<td>0.0000</td>
<td>[3.9E-7, 1.1E-6]</td>
</tr>
</tbody>
</table>

Result
A possible result is summarized in Table 2. Assuming that the year 1988 is affected approximately half as much as the year 1987, we found a significant (p = 0.0007) association of the stillbirth proportion with deposited Cs-137 as a surrogate variable for the total individual internal and external exposure. We determined the slope in the corresponding linear logistic regression as 0.80%/1kBq/m² for the total individual internal and external exposure. This result is consistent with the findings of many analyses of the health consequences of the Chernobyl accident in Bavaria and the stillbirth proportion on a district level. One can use purely spatial, purely temporal, and spatial-temporal models. One can assign different (relative) weights to the years 1987 and 1988. One can consider the years 1987 and 1988 separately as well as combined into one dummy variable. One can base the analysis on a global trend for whole of Bavaria, or one can use a different trend for each district, which somewhat violates the usual requirement of parsimony. The most appropriate approach has not yet been identified.

Discussion
Numerous investigations have been carried out on the possible impact of the Chernobyl accident on the prevalence of anomalies at birth and on perinatal mortality. In many cases the studies were aimed at the detection of differences of pregnancy outcome measurements between regions or time periods. Most authors conclude that there is no evidence of a detrimental physical effect on congenital anomalies or other outcomes of pregnancy following the accident. This presentation reports on a statistical spatial-temporal analysis of the Cs-137 contamination on a district level in Bavaria, accounting for the time trends of stillbirth proportions of the districts from 1980 to 1993. We found a significant (p = 0.0007) association of the stillbirth proportion with deposited Cs-137 as a surrogate variable for the total individual internal and external exposure. In addition to this finding we disclosed a marked differential effect in the combined long term stillbirth time trends between western Europe (Belgium, France, Great Britain, Ireland, Iceland, Luxembourg, Portugal, Spain), central Europe (Austria, Denmark, Germany, Italy, Norway, Switzerland), and eastern Europe represented by four countries (Sweden, Poland, Hungary, Greece). In contrast to the western and central European trends, the eastern European trend exhibits an absolute increase of the stillbirth proportion in 1986 as compared with 1985 and an apparent upward shift of the whole trend line from 1986 on. Our results are in contrast to those of many analyses of the health consequences of the Chernobyl accident and contradict the present radiobiological knowledge. As we are dealing with aggregated data, other causes or artifacts may explain the observed effects. Hence, the findings should be interpreted with caution and further independent evidence should be sought.

References

Table 1. Linear logistic regression of stillbirth proportions (SBp) on the mean values of deposited Cs-137 (kBq/m²) in the 96 districts of Bavaria 1980 – 1993; the individual trend functions for the districts are taken into account as covariables

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Estimate</th>
<th>p-value</th>
<th>95% confidence limits</th>
</tr>
</thead>
<tbody>
<tr>
<td>137Cs</td>
<td>0.0028</td>
<td>0.0002</td>
<td>[2.6E-3, 1.3E-2]</td>
</tr>
<tr>
<td>137Cs²</td>
<td>0.0007</td>
<td>0.0001</td>
<td>[3.8E-7, 1.1E-6]</td>
</tr>
<tr>
<td>137Cs³</td>
<td>0.0001</td>
<td>0.0000</td>
<td>[3.9E-7, 1.1E-6]</td>
</tr>
</tbody>
</table>

Abbreviations: Cs, Cs-137; V = sum of 96 linear trends employing spatial dummy coding for all 96 districts of Bavaria; v = temporal dummy coding for years 1987 and 1988 respectively
Spatial-temporal logistic regression of the cesium concentration and the time trends in annual stillbirth proportions on a district level in Bavaria, 1980 to 1993

Hagen Scherb and Evelyne Weigelt

1 GSF-Forschungszentrum für Umwelt und Gesundheit, Institut für Biomathematik und Biotemperatur, Postfach 1479, D-85758 Oberschleißheim, Germany

Abstract: Numerous investigations have been carried out on the possible impact of the Chernobyl accident on the prevalence of anomalies at birth and on perinatal mortality. In many cases the studies were aimed at the detection of differences of pregnancy outcome measurements between regions or time periods. Most authors conclude that there is no evidence of a detrimental physical effect on congenital anomalies or other outcomes of pregnancy following the accident. This note reports on a statistical spatial-temporal analysis of the Cs-137 contamination on a district level in Bavaria accounting for the time trends of the stillbirth proportions in the district from 1980 to 1993. We found a significant (p = 0.0007) association of the stillbirth proportion with deposited Cs-137 as a surrogate variable for the total individual internal and external exposure.

Keywords: Chernobyl accident; cesium contamination; districts in Bavaria; stillbirth proportion; time trend; spatial-temporal analysis.

1 Introduction: Data and Statistical Method

To date, the explosion of the nuclear reactor in Chernobyl, about 160 km northwest of Kiev, on 26 April 1986 was the most serious accident in a nuclear power station. The event led to a release of large quantities of radioactive material over a 10-day period. Depending on atmospheric conditions at the time, the extent of contamination was a variable quantity. Therefore, Bavaria, as well as parts of Russia and Scandinavia were highly contaminated by radioactive fallout (Bossew et al., 1994).

As Bavaria was the most highly contaminated part of Germany, we investigated a possible relationship between the stillbirth and perinatal death proportions and the deposition of Cs-137 on a regional level in Bavaria. Table 1 summarizes the results of Cs-137 measurements in Germany. There are 96 districts (Landkreise) in Bavaria for which official perinatal death proportions by the Bavarian Statistical Office and regional measurements of the radioactive cesium (Cs-137) for 1986 are available (BSAMU and BSEMFL, 1987).

Table 1: Measurements of Cs-137 (kBq/m²) in Germany following the Chernobyl accident.

<table>
<thead>
<tr>
<th>Part of Germany</th>
<th>n</th>
<th>Mean</th>
<th>Median</th>
<th>Min</th>
<th>Max</th>
</tr>
</thead>
<tbody>
<tr>
<td>FRG (GDR + Bavaria)</td>
<td>894</td>
<td>4.7</td>
<td>3.5</td>
<td>0.3</td>
<td>57.0</td>
</tr>
<tr>
<td>GDR</td>
<td>1089</td>
<td>3.2</td>
<td>2.2</td>
<td>0.3</td>
<td>47.0</td>
</tr>
<tr>
<td>Bavaria</td>
<td>1405</td>
<td>4.9</td>
<td>3.0</td>
<td>0.3</td>
<td>20.7</td>
</tr>
</tbody>
</table>

Table 2: Spatial-temporal logistic regression of stillbirth proportions on the mean values of deposited Cs-137 (kBq/m²) in the 96 districts of Bavaria 1980-1993.

<table>
<thead>
<tr>
<th>Parameter estimate</th>
<th>p-value</th>
<th>95% confidence limits</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\text{R} + \text{Cs}_{137}$</td>
<td>7.64 &lt; 0.0001</td>
<td>[3.82, 11.46]</td>
</tr>
<tr>
<td>$\text{R} + \text{Cs}<em>{137} + \text{0.05 Cs}</em>{137}$</td>
<td>8.03 &lt; 0.0001</td>
<td>[3.82, 11.46]</td>
</tr>
<tr>
<td>$\text{R} + \text{Cs}<em>{137} + \text{0.01 Cs}</em>{137}$</td>
<td>7.41 &lt; 0.0001</td>
<td>[3.82, 11.46]</td>
</tr>
<tr>
<td>$\text{R} + \text{Cs}<em>{137} + \text{0.005 Cs}</em>{137}$</td>
<td>7.15 &lt; 0.0001</td>
<td>[3.82, 11.46]</td>
</tr>
</tbody>
</table>

Table 2: Spatial-temporal logistic regression of stillbirth proportions on the mean values of deposited Cs-137 (kBq/m²) in the 96 districts of Bavaria 1980-1993.

2 Result

The result is summarized in Table 2. Assuming that the year 1986 is affected approximately half as much as the year 1987, we found a significant (p = 0.0007) association of cesium contamination with the deposited Cs-137 as a surrogate variable for the total individual internal and external exposure. We determined the slope in the corresponding linear logistic regression as 0.0067(kBq/m²) with a 95% confidence interval of [0.04, 0.10]. Restricting consideration to 1987 alone yields practically the same estimate, however, with somewhat reduced precision. This estimate of 0.067(kBq/m²) entails a theoretical increase of approximately 5% in the stillbirth proportion with the Cs-137 deposition of 50 kBq/m² under the specific conditions of the contamination in Bavaria. Taking the ten most highly affected districts (mean = 32.2 kBq/m²), the stillbirth proportion increased by about 45% above the expected level in 1987 (57 observed against 39.4 expected.

3 Discussion

Analyzing the association of stillbirth proportions with the Cs-137 deposition on a district level in Bavaria discloses a significant relationship. In addition to this finding we disclosed a marked differential effect in the combined long term stillbirth time trends between western Europe (Belgium, France, Great Britain, Ireland, Iceland, Luxembourg, Portugal, Spain), central Europe (Austria, Denmark, Germany, Italy, Norway, Switzerland), and eastern Europe represented by four countries (Sweden, Poland, Hungary, Greece). In contrast to the western and central European trends, the eastern European trend exhibits an absolute increase of the stillbirth proportion in 1986 as compared with 1985 and an apparent upward shift of the whole time trend line from 1886 on. Our results are in contrast to those of many analyses of the health consequences of the Chernobyl accident and contradict the present radiobiological knowledge. As we are dealing with aggregated data, other causes or artifacts may explain the observed effects. Hence, the findings should be interpreted with caution and further independent evidence should be searched for.

Acknowledgements: We thank A. Kürlein for many helpful discussions. We also thank H. Webb, H. Kole, and H.R. Lederle for bringing the elevated stillbirth proportions in Bavaria to the attention of the GSF and the Bavarian government.

References


