

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

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Statistical Modelling

Proceedings of the
14th International Workshop on
Statistical Modelling



Graz, Austria, July 19-23, 1999

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(EDITORS)



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
8x8 km grid	1465	14.9	10.3	d.l.	120.7
districts	96	14.4	10.1	3.1	53.7

d.l. detection limit

2. Study period: 1980 - 1993

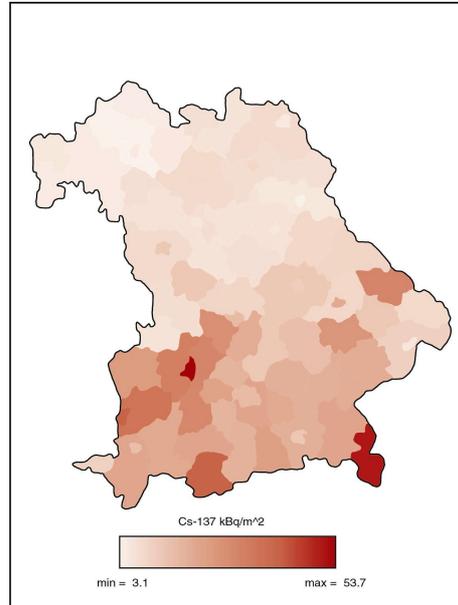
3. Outcome variable:

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=SB/TB

Independent variables (optional): ¹³⁷Cs, ([¹³⁷Cs]^{3.5}), time, (time²)

Optional covariables: dummy coding for 1987 (v₈₇) and 1988 (v₈₈), dummy coding for districts, interactions: time*location

There are many possible approaches for modeling the association between the cesium deposition 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.

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) with a 95% confidence interval of [0.34, 1.26]. Restricting consideration to 1987 alone, yields practically the same estimate, however, with somewhat reduced precision. This estimate of 0.80%/(1kBq/m²) entails a theoretical increase of approximately 50% 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 = 37.2 kBq/m²), the stillbirth proportion increased by about 45% above the expected level in 1987 (57 observed against 39.4 expected cases, p = 0.0157). No significant effect was seen in the ten districts with the lowest contamination.

Table 2. 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

Log odds of model	Parameter estimate	p-value	95% confidence limits
lt+Cs*v ₈₇	7.6E-3	0.0028	[2.6E-3, 1.3E-2]
lt+Cs*v ₈₇ +0.5*Cs*v ₈₈	8.0E-3	0.0007	[3.4E-3, 1.3E-2]
lt+Cs ^{3.5} *v ₈₇	7.5E-7	0.0001	[3.8E-7, 1.1E-6]
lt+Cs ^{3.5} *v ₈₇ +0.5*Cs ^{3.5} *v ₈₈	7.7E-7	0.0001	[3.9E-7, 1.1E-6]

Abbreviations: Cs, Cs-137; lt, sum of 96 linear trends employing spatial dummy coding for all 96 districts of Bavaria.; v_x temporal dummy coding for years x=(19)87 and x=(19)88 respectively

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.

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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

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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 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.

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 is 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 in Europe was very variable. Ukraine, Belarus, as well as parts of Russia and Scandinavia were highly contaminated by radioactive fallout (Bossey et al., 1996).

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 each of which official perinatal death proportions by the Bavarian Statistical Office and regional measurements of the radioactive cesium (Cs-137) for 1986 are available (BStMLU

Part of Germany	n	Mean	Median	Min	Max
FRG-(GDR+Bavaria)	894	4.7	3.5	d.l.	57.0
GDR	1089	3.2	2.2	d.l.	47.0
Bavaria	1465	14.9	10.3	d.l.	120.7
Bavaria (districts)	96	14.4	10.1	3.1	53.7

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

und BStMELF, 1987).

We analyzed the association of stillbirths and perinatal mortality with deposited Cs-137 on the district level in Bavaria using linear logistic regression. In these joint regression analyses we allowed for linear logistic trends for each of the 96 districts to account for as much as possible variation of the dependent variable due to differences between the districts. This allows for a maximum power in the estimation of the corresponding cesium parameter. According to Grosche et al. (1997), there was an increase of stillbirths in Bavaria during the first 2 years following the accident. Hence, we also included the year 1988 in the analysis utilizing a relative weight of 0.5 for the cesium parameter in this year. This weight approximately corresponds to the relation of the excess stillbirth proportions in Bavaria in 1987 and 1988. Körblein and Küchenhoff (1997) found a nonlinear dependency of the perinatal death proportion on the calculated cesium concentrations in women's bodies. The estimated exponent of the cesium variable is 3.5. Therefore, we additionally computed logistic regressions utilizing this exponent of the cesium variable.

2 Result

The 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) with a 95% confidence interval of [0.34, 1.26]. Restricting consideration to 1987 alone yields practically the same estimate, however, with somewhat reduced precision. This estimate of 0.80%/(1kBq/m²) entails a theoretical increase of approximately 50% 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 = 37.2 kBq/m²), the stillbirth proportion increased by about 45% above the expected level in 1987 (57 observed against 39.4 expected

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lt+Cs ¹ v ₈₇	7.6E-3	0.0028	[2.6E-3, 1.3E-2]
lt+Cs ¹ v ₈₇ +0.5*Cs ¹ v ₈₈	8.0E-3	0.0007	[3.4E-3, 1.3E-2]
lt+Cs ^{3.5} v ₈₇	7.5E-7	< 0.0001	[3.8E-7, 1.1E-6]
lt+Cs ^{3.5} v ₈₇ +0.5*Cs ^{3.5} v ₈₈	7.7E-7	< 0.0001	[3.9E-7, 1.1E-6]

lt: sum of 96 linear trends employing spatial dummy coding for 96 districts.
v_x: temporal dummy coding for years x=(19)87 and (19)88, respectively.

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; the individual trend functions for the districts are taken into account as covariables.

cases, $p = 0.0157$). No significant effect was seen in the ten districts with the lowest contamination. The perinatal death proportion in Bavaria in 1987 as well as in 1988 is not significantly related to the cesium fallout from the Chernobyl accident. Only if we utilize Körblein and Küchenhoff's (1997) result and regress perinatal death proportions on Cs^{3.5} rather than on Cs¹, we get significance. With this modification, a highly significant association is obtained for the stillbirth proportion (see Table 2). Our results should not be mistaken for extrapolations to exposures beyond the observed range of the contamination, as has been done with Körblein and Küchenhoff's finding (Kellerer, 1998).

Two papers presenting the above material as well as thorough analyses of German and European trends in perinatal death and stillbirth proportions are in progress (Scherb et al., 1999a and 1999b).

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 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,

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the findings should be interpreted with caution and further independent evidence should be searched for.

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

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